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ENHANCING FIRM INNOVATION PERFORMANCE THROUGH STRATEGIC MANAGEMENT OF NEW PRODUCT DEVELOPMENT

By

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ABSTRACT

ENHANCING FIRM INNOVATION PERFORMANCE THROUGH STRATEGIC MANAGEMENT OF NEW PRODUCT DEVELOPMENT

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This dissertation addresses the important issue of "how not to make things" in new product development (NPD). As increasing competitive pressure forces the firm to greatly reduce costs, improve quality, and shorten development time, making the best use of internal resources and capabilities is not sufficient for NPD program success. Mobilizing resources and capabilities beyond firm boundaries becomes a necessity for the full implementation of new product strategies.

A "barbell-shaped" conceptualization of NPD, in contrast to the traditional "football-shaped" NPD, is proposed for the incorporation of other firms' resources and capabilities in the firm's NPD. "Football-shaped" NPD represents the traditional "do-it-all" paradigm, while "barbell-shaped" NPD allows other firms to "share the burden."

"Barbell-shaped" NPD is based on the integration of internalization theory and the resource-based view of the firm. The two theories stress, from different perspectives, the importance of mobilizing other firms' resources and capabilities in NPD. Internalization theory emphasizes using other firms' resources and capabilities to minimize total NPD costs, to increase speed, and to improve quality. The resource-based view of the firm concentrates on protecting firm core competencies and accessing other firms' valuable resources and capabilities. The two theories converge on the premise of this dissertation: i.e., that the firm should internalize NPD tasks that are closely related to its core

competencies and externalize complex and less important ones to improve NPD efficiency.

Two models are proposed in this dissertation. The first model aims at investigating which tasks should be internalized and which should be given to other firms. The bottom line is that the firm should protect and strengthen its core competencies in NPD. Therefore, it can concentrate on the tasks that affect firm core competencies. Less important and complex tasks, which require resources that are not available internally or capabilities not easily developed internally, can be given to other firms thus accessing their "best-in-world" resources and capabilities.

The second model explores how to enhance NPD capability through interactions with other firms. It illustrates how the firm can enhance NPD capability by acquiring tacit knowledge from strong relationships and novel knowledge from weak relationships and from firms that are unique in relationships.

A large portion of this study is driven by the major concerns of NPD managers. This study provides managerial guidelines on how to use external resources and capabilities to the greatest extent. This dissertation also assists NPD managers in developing a strategy for managing different kinds of relationships. Both strong and weak relationships can be equally valuable for NPD program success. Tacit or uncoded knowledge is likely from strong relationships and novel knowledge is likely from weak relationships or firms that are unique in the relationships.

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This dissertation is also dedicated to my wife Liping, my son Xiaoyu, and my daughter Linda.

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LIST OF ABBREVIATIONS

CFA	CONFIRMATORY FACTOR ANALYSIS
CFI	COMPARATIVE FIT INDEX
IFI	INCREMENTAL FIT INDEX
MCI	MAXIMUM CONDITION INDEX
NFI	NORMED FIT INDEX
NPD	NEW PRODUCT DEVELOPMENT
R&D	RESEARCH AND DEVELOPMENT
RMSEA	ROOT-MEAN-SQUARE ERROR APPROXIMATION
VIF	VARIANCE INFLATION FACTOR

CHAPTER 1

INTRODUCTION

Firms need to learn how not to make things.

—*Venkatesan (1992)*

New product development (NPD) is the set of activities beginning with the perception of a market opportunity and ending in the production, sales, and delivery of a new product (Ulrich and Eppinger 1995; Rogers 1995). Perhaps the most compelling justification for studying NPD is that organizations are less likely to survive without the lifeblood of new products (Montoya-Weiss and Calantone 1994; Rogers 1995; Brown and Eisenhardt 1995). Traditionally, NPD study typically emphasized the best utilization of firm internal resources and capabilities. In recent years, the firm has begun to learn "how not to make things" (Venkatesan 1992, p. 98)—how to give some tasks to other firms which could accomplish them more efficiently, i.e., how to use resources and capabilities beyond firm boundaries (Veugelers and Cassiman 1999).

The Need for Using Other Firms' Resources and Capabilities

The firm is still not clear about how to prevail in NPD (Damanpour 1991b; Montoya-Weiss and Calantone 1994; Rogers 1995; Brown and Eisenhardt 1995; Wind and Mahajan 1997). Fast shifting consumer preferences, high rate of technical obsolescence, short product life cycle, and increasing NPD cost force the firm to greatly reduce cost, improve quality, and shorten development time (Monczka and Trent 1991;

Griffin 1997a, 1997b; Fine 1998). Xerox, for example, is pressed by brutal competition from Japanese competitors and faces a painful choice: either slash its traditional product development cycle, or be overtaken by more nimble competitors (Wysocki, Jr. 1999).

Evidence from a variety of industries shows that making the best use of internal resources and capabilities is not sufficient for NPD success in today's highly competitive environment (Kurokawa 1997; Venkatesan 1992; Millson, Raj, and Wilemon 1996; Hansen 1999; Lowe and Taylor 1998; Monczka, et al. 2000; Krause, Scannell, and Calantone 2000). The firm finds that giving some tasks to other firms is a necessity for the full implementation of new product strategies (Quinn and Hilmer 1994; Goes and Park 1997; Veugelers and Cassiman 1999; Rubenstein 1994). The firm can thus focus its limited resources on important tasks and fulfill them with great quality and high speed. At the same time, this strategy allows other firms to "share the burden" of NPD; other firms' expertise is incorporated into the NPD process (Quinn 1999). The following examples from industry highlight this trend.

- Japanese car companies provide general specifications to suppliers and then expect them to design the parts as the car is being developed, a process called "design-in" (Dutton 1992).
- Chrysler has stopped writing detailed specifications for many parts. Instead, it relies on suppliers to design and build the right parts and to find ways to lower prices. Chrysler and the supplier split the savings (Minahan 1998).
- Whirlpool, McDonnell Douglas, and Boeing have shifted many of their design activities to other firms (Proctor 1999).

- Apple let Sony, the Japanese company specialized in miniaturization, to design the structure of the PowerBook. The PowerBook's size was reduced and the development time was shortened (Magee 1992).

The problem of resource limitations in NPD and the tapping of outside resources has been noted in reviews by Damanpour (1991b), Rogers (1995), Montoya-Weiss and Calantone (1994), and Brown and Eisenhardt (1995). They all recognize that internal resources and capabilities are not sufficient for the full implementation of new product strategy and call for the mobilization of resources outside of the firm. Rogers (1995) noted the necessity to explore inter-firm relationships in R&D. Brown and Eisenhardt (1995) put suppliers and customers in their comprehensive framework of NPD and stress the importance of supply chain partners for new product performance. Montoya-Weiss and Calantone (1994) also noticed the need to explore factors outside of the firm.

Internalization and Externalization of NPD Tasks

In this study, the unit of analysis is the firm's NPD program. At the lowest level of detail, a new product development program is divisible into a number (usually large) of individual tasks that collectively define the new product development program (Yassine and Falkenburg 1999). NPD tasks, therefore, are the basic activities of the NPD program. They are unique and yet related. The accomplishment of a certain NPD task requires employing and allocating specific resources and capabilities. Because the firm is unlikely to possess all of the required resources and capabilities for all the NPD tasks of a NPD program, strategically managing different NPD tasks in a NPD program becomes an important issue.

Internalization of a NPD task means that the firm does the NPD task in-house (Veugelers and Cassiman 1999; Kurokawa 1997; Robertson and Gatignon 1998). If the firm performs a NPD task itself, it is internalizing the task. Externalization, in contrast, refers to the performance, by outside parties, of NPD tasks that would otherwise be performed in-house (Venkatesan 1992). Externalization of an NPD task means that the firm lets other firms perform the task (Quinn 2000). Currently some writers refer to this as an outsourcing (Quinn 2000, 1999; Quinn and Hilmer 1994). The firm may provide specifications of NPD tasks to other firms and allow them to develop the tasks to meet the requirements of a NPD program (externalization of NPD tasks). The firm may absorb knowledge from other firms to enhance its NPD capability and undertake a NPD task relying on its own (the issue of acquiring knowledge from other firms to enhance NPD capability is discussed extensively in Chapter 3).

The distinction between internalization and externalization of NPD tasks lies in who is responsible for the tasks being performed (Venkatesan 1992). Firms may jointly work on a NPD program or part of the program, but are responsible for different tasks. An example of internalization of NPD tasks is Coca-Cola's internal development and manufacture of its secret syrup. Vickers' development of hydraulic systems for Natsteel's NPD program is a case of externalizing NPD tasks.

Tatikonda and Rosenthal (2000) identified two dimensions of a NPD task—importance of the task and complexity of the task. The two dimensions capture the overall execution challenge posed by those tasks to the developing organizations (this will be discussed in detail in Chapter 2). First, if a task is important for the firm's competitive strategies, it tends to be internalized. Second, if a task is so complex that the

firm does not possess the required resources and capabilities, or if a task is so complex that the firm cannot develop it efficiently, externalization of the task is suggested. This is based on the fact that firms are complementary in nature, i.e., one firm's weakness is likely to be another firm's strength (Quinn 2000).

The Research Questions

To identify important problems in NPD, relevant literatures were reviewed and case studies were conducted in several firms. The results indicate that firm NPD strategies are seriously affected by firm resource limitations. These problems can be categorized into three classes.

1. The firm recognized market opportunities, but lacked the requisite capabilities to develop new products. The firm abandoned NPD plans because it was not aware of the importance of using the resources of partner firms such as suppliers, customers, and other firms. Valuable opportunities were missed.
2. The firm recognized the new product opportunity and developed new products internally. But it developed new products poorly because either it did not possess the requisite skills to achieve a high level of quality in certain NPD tasks, or else it did not develop them fast enough and thus missed opportunities. In either case, the firm jeopardized its new product success due to its limited resources and capabilities.
3. The firm recognized the importance of using partner firms' resources and capabilities in NPD but poorly utilized these partner firms. There were two scenarios. First, the firm ignored protection of its core competency, gave

crucial tasks to partner firms, and thus lost its competitive advantage in the long run. Second, the firm did not fully understand how to strengthen its NPD capability in interactions with other firms (similar scenarios can be found in Millson, Raj, and Wilemon 1996).

The literature on externalization in firm NPD is "imprecise" (Brown and Eisenhardt 1995, p. 372). With the firm moving some tasks to partner firms, the literature does not provide sufficient guidance as to what kinds of tasks can be internalized and what kinds of tasks can be externalized. With some NPD tasks being closely related to core competencies, the challenge for both practitioners and academicians is how to protect firm core competencies while incorporating other firms' expertise in NPD. With the firm needing knowledge from outside the firm, the literature is not clear about where and how to get the required knowledge to improve firm NPD capability.

Questions thus arise about which NPD tasks should be developed internally and which tasks should be given to other firms to improve NPD efficiency and effectiveness. Another closely related question would be how to enhance firm NPD capability through interactions with other firms so that the firm can fully implement its new product strategies. These are summarized into three research questions of this dissertation.

1. Which tasks should be developed by the firm itself so that firm core competencies are protected and strengthened and NPD is performed more effectively and efficiently?
2. Which tasks could be given to other firms so that other firms' expertise is incorporated into the NPD process and NPD program performance is improved?

3. How to enhance firm NPD capability by interacting with other firms?

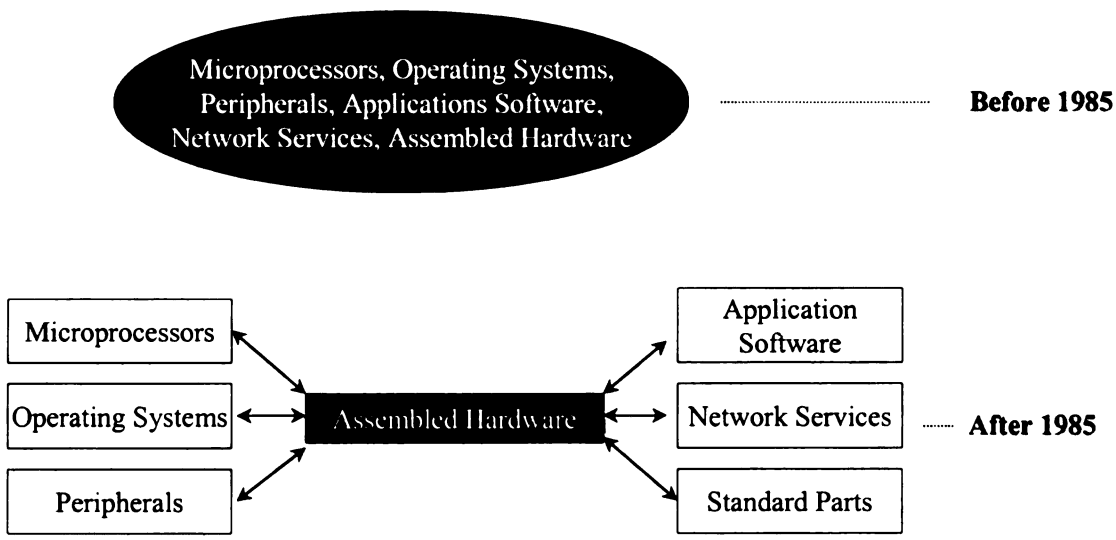
Two studies are conducted to address the above issues. The first study aims at investigating which tasks should be internalized and which should be given to other firms. The second study explores how to enhance NPD capability through interactions with other firms.

Paradigm Shift in NPD

In this dissertation, a "barbell-shaped" conceptualization of NPD, in contrast to the traditional "football-shaped" NPD, is proposed for the incorporation of other firms' resources and capabilities in the firm's NPD. Case studies in the PC, heavy machinery, and steel industries show a paradigm shift from "do it all" to "share the burden" in NPD.

Case Studies in Several Industries

The PC industry. Over the last fifteen years, the firm in the PC industry has experienced a fundamental paradigm shift in NPD. As shown in Figure 1.1, before 1985, the firm was likely to internally develop most of the tasks. After the middle of 1980s, the firm has begun to focus on the development of the key tasks, assembled hardware, and let other firms to perform the other tasks such as microprocessor, operating systems, peripherals, application software, network services, etc., which are not closely related to its core competencies (Fine 1998).

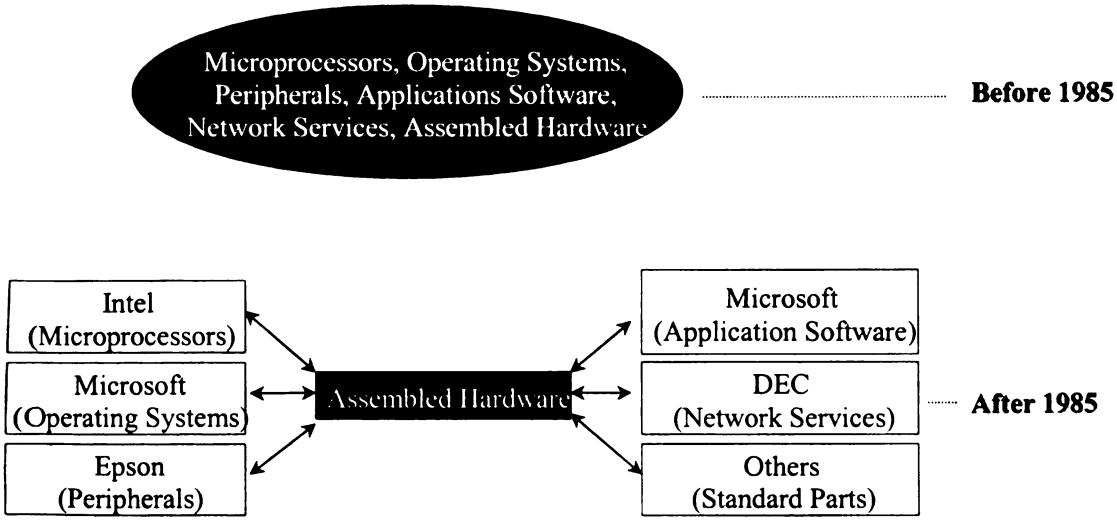


Note: Shaded areas represent internalized tasks

Adopted from Fine (1998)

Figure 1.1: Paradigm Shift of NPD in the PC Industry

Firm A, for example, developed most of the NPD tasks in-house before 1985. After 1985, however, it has begun to focus on the assembled hardware and to externalize application software and operating system to Microsoft, microprocessor to Intel, network services to DEC, peripherals to Epson, etc. (see Figure 1.2). As one highly respected senior R&D vice president stated: "You externalize when other companies can perform the activity better than you." Another said that companies should ask, "What is it we will never be experts at or should not spend time doing?"



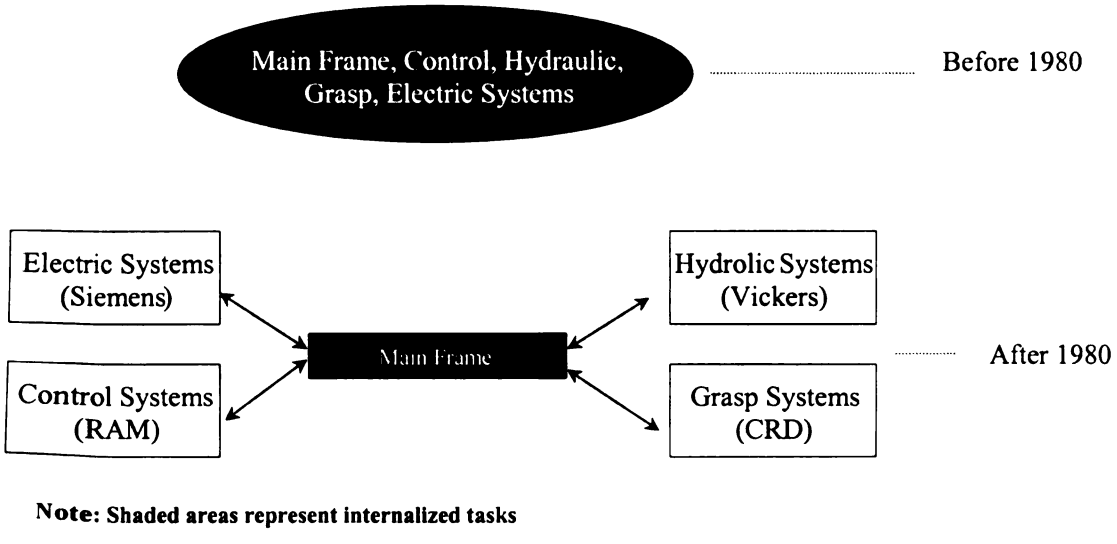
Note: Shaded areas represent internalized tasks

Figure 1.2: Paradigm Shift of NPD — The Firm A Case

The steel industry. Similarly in the steel industry, time-based pressure has forced Firm B to undergo a fundamental change in NPD. Before 1980, Firm B internally designed most NPD tasks. After 1980, it has begun to concentrate on the key technology, the mainframe design, and to let Siemens (the expert firm on electric system) to design the electric system, RAM (a firm that specializes in control) to design control systems, Vickers (a firm experienced at hydraulic system) to design hydraulic systems, and CRD to design grasp systems, thus incorporating other firms' expertise in its own new product development (see Figure 1.3).

Mr. Andrew Wang, Vice President of Engineering, made the following remarks in the interview:

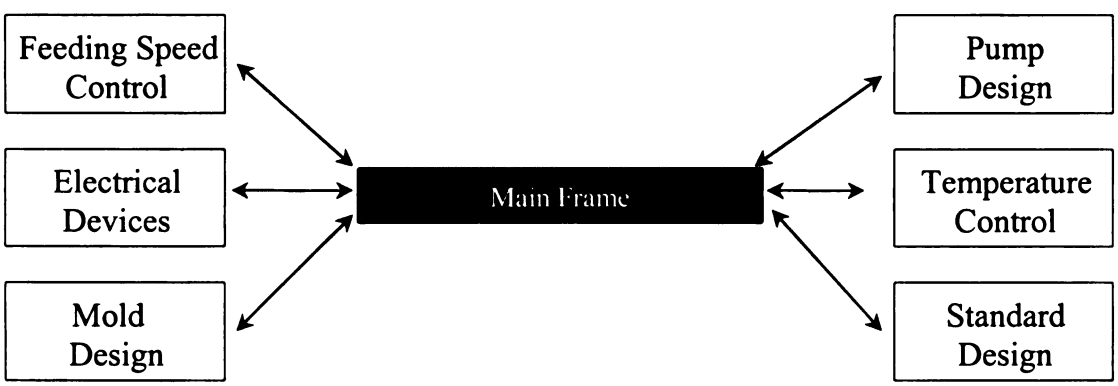
> No one company acting alone can compete successfully with competitors in NPD. Strategically externalizing some of NPD tasks can put a company in a sustainable leadership position. It is the most powerful tool in NPD management.



Note: Shaded areas represent internalized tasks

Figure 1.3: Paradigm Shift of NPD — The Firm B Case

The heavy machinery industry. In the heavy machinery industry, firms like Mannesmann, Kawasaki Heavy Industries, Ltd., and AIDA Corporation have concentrated on the key technology of mainframe and given feeding speed control, pump design, temperature control, and mold design to other firms to speed up new product development (see Figure 1.4). One executive mentioned that externalizing NPD tasks allowed the firm to do more without additional employees or with fewer employees. Even companies with highly developed NPD capabilities have externalized many NPD tasks.



Note: Shaded area represents internalized tasks

Figure 1.4: Paradigm Shift of NPD in Heavy Machinery Industry

Paradigm Shift in NPD

Figure 1.5 provides a metaphorical description of the paradigm shift in NPD. Traditionally, the firm tended to develop most of the tasks internally ("football-shaped" NPD). The "barbell-shaped" NPD allows the firm to give (externalize) some NPD tasks to other firms in order to use outside resources and capabilities to the greatest extent and still keeps its core competencies.

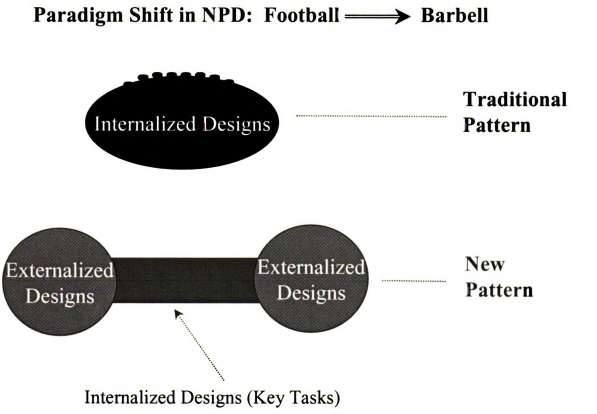


Figure 1.5: Metaphorical Description of the Paradigm Shift in NPD

The "barbell-shaped" NPD allows the firm to focus on critical tasks and externalize the others. The bar of the "barbell" represents the internalized tasks, i.e., tasks

that are performed by the firm itself. The internalized tasks are those that are closely related to the firm's core competencies or those that are critical for customer value creation. The weights of the "barbell" denote the externalized tasks, i.e., tasks that are given to other firms. Those are tasks for which the firm has neither critical strategic needs nor special capabilities.

There are several advantages associated with the "barbell-shaped" NPD. First, the "barbell-shaped" NPD allows the firm to concentrate its "best-in-world" (Quinn 1999, p. 11) resources and capabilities on a few core tasks and thus provide unique and superior value for customers (Quinn 1999; Howells 1999).

Second, this strategy enables the firm to protect and strengthen its core competencies and competitive advantages in the market place. Focusing on the development of core technologies may improve the firm's capability to stay current and provide formidable barriers against present and future competitors (Quinn and Hilmer 1994). Honda, for example, mainly focuses on the design and manufacture of clean, efficient, and small engines and captures a considerable share of the market.

Third, the "barbell-shaped" NPD gives the firm opportunities to use resources that are not available internally or to access capabilities not easily developed internally. Each firm has its own "best-in-world" core competencies. Duplicating them would be prohibitively expensive or even impossible. Giving complicated tasks to other firms is a way of incorporating other firms' expertise into NPD. NPD program performance can thus be greatly enhanced (Prahalad and Hamel 1990; Venkatesan 1992).

Fourth, "barbell-shaped" NPD greatly broadens the windows of opportunities (Quinn 1999; Quinn and Hilmer 1994). Traditionally, many NPD programs are

abandoned or fail and valuable market opportunities are missed because the firm relies mostly on internal NPD capabilities. By incorporating other firms' resources and capabilities, the firm can fully implement NPD strategies and enhance competitive positions. One R&D vice president pointed out that the R&D department often lacks a clear strategic focus because they are preoccupied with operational activities. Externalizing non-strategic NPD tasks permits the R&D department to move away from routine administration toward a more strategic role.

It has to be noted that the "barbell-shaped" NPD not only stresses "giving" tasks to other firms and utilizing outside resources and capabilities beyond the boundaries of the firm, it also emphasizes "taking" knowledge from other firms to strengthen NPD capability, which is another important research issue in this dissertation.

A Theoretical Explanation of the "Barbell-Shaped" NPD

Figure 1.6 presents a conceptual framework of this dissertation to justify the "barbell-shaped' NPD from a theoretical point of view. It links the firm's strategic NPD management to NPD program performance, both directly and indirectly through its influence on firm NPD capability. The direct relationship between strategic NPD management and NPD program performance symbolizes the externalization principle, i.e., to leverage external resources and capabilities. The indirect link between strategic NPD management and NPD program performance indicates the internalization function, i.e., to leverage internal resources and capabilities.

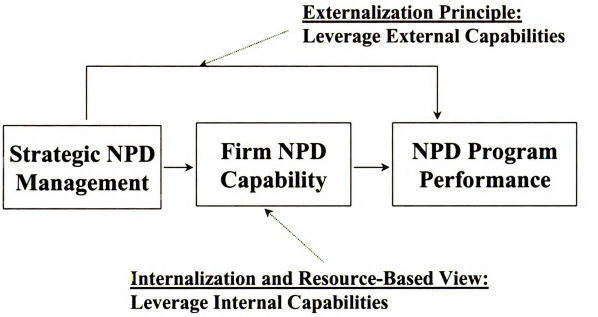


Figure 1.6: Conceptual Framework

The underlying rationale is that firm NPD program performance could be enhanced directly by incorporating other firms' expertise (externalization principle). At the same time, the firm could assemble its limited resources and focus on the development of one or several key technologies, making them the "best-in-world" (internalization principle). The conceptual framework is based on the principles of internalization theory (Buckley and Casson 1976, 1998; Casson 1984, 1994) and the resource-based view of the firm (Wernerfelt 1984; Day and Wensley 1988; Collis 1994). Following are the comparisons of the rationales of internalization theory and the resource-based view of the firm. Table 1.1 is a summary of the two theories.

Table 1.1: Externalization Decision Based on Internalization Theory and Resource-Based View of the Firm

	Internalization Theory	Resource-Based View of the Firm
Logic behind the Strategic NPD Management	Minimizing total NPD costs, increasing speed, and improving quality.	Maximizing NPD program performance by incorporating other firm resources and capabilities.
Logic behind the Externalization Decision in NPD	Using other firm's expertise. Lowering development cost. Letting the firm concentrate on the most successful work. Increasing capacity.	Gaining access to other firm resources and capabilities. Focusing limited resources on key technology and developing "best-in-world" core competencies.
Logic behind the Internalization Decision in NPD	Internalizing NPD tasks is efficient. Important tasks need to be performed internally. The danger of tremendous loss in the future if externalizing certain tasks.	If tasks are critical for firm core competencies, or externalization would transfer firm core competencies, there is less incentive to externalize. Protecting core competencies. Improving market competitive position.
The Logic of Externalizing Complicated Tasks.	If the design of the complex tasks internally is prohibitively costly or impossible, it is better to give that to other firms with more expertise.	Firms exist because of different expertise. Giving complex tasks to other firms is to use the best resources in the world.
Logic of Improving NPD Capability through Knowledge from Other Firms	Knowledge in certain areas is too costly to develop internally.	Getting knowledge in critical areas of NPD from other firms to strengthen core competence.

Rationale of Internalization Theory

Internalization theory comes, in part, from Buckley and Casson (1976) and is further developed by Casson (1984, 1994), Buckley (1983, 1988), and Buckley and Casson (1998). These authors synthesize various critics of the neoclassical model of the firm from the fields of economics, law, and theory of organizations. The main contribution of internalization theory has been to operationalize Coase's (1937) seminal work: he argued that there are conditions under which it is more efficient for the firm to perform certain tasks internally (firm-based solutions) rather than externally (market-based solutions).

Under what conditions would the firm choose each of the two means—internalizing or externalizing—necessary to NPD success? The internalization theory has linked this type of decisions to two types of considerations. The earliest factors addressed in the internalization theory focus on the efficiency of firm activities (Coase 1937; Williamson 1975). Internalization theory proposes that market-based solutions are default options for the firm; but when firm activities are seriously affected by market failure, the firm tends to internalize these activities. The earliest factors addressed in the internalization theory, therefore, focus on the efficiency of the firm's operation. If the firm cannot efficiently accomplish the task, externalization would be considered. Otherwise, internalization would be the choice (Krause, Scannell, and Calantone 2000).

Internalization theory is further advanced by Buckley and Casson (1976, 1998), who have linked firm activities with firm internal factors, such as the firm's core competencies. They argued that efficiency may not be the only consideration that determines the firm strategic choice. The firm internalizes tasks that are critical for NPD

success and externalizes the others. In other words, when firm activities become so important that externalization causes harmful consequences, the firm tends to internalize these activities (Krause, Scannell, and Calantone 2000). In some situations, even if the firm can perform a task efficiently, the firm still considers to strategically externalize it. Thus, the firm can successfully move from one product line to another, or from one market to another market. In the 1980s, Apple internalized most NPD tasks because Apple was the leading firm then and could perform the tasks efficiently. Apple finally lost the dominant position in the market partially because it ignored the strategic side of NPD management.

Internalization theory offers NPD managers a model for rethinking the management of a portfolio of NPD tasks. Time pressure becomes an important concern in NPD (Montoya-Weiss and Calantone 1994; Fine 1998). Internalization suggests that the firm should externalize highly complex NPD tasks (Casson 1982; Rugman1980, 1981; Hennart 1982). This is based on the premise that the firm is unlikely to perform these tasks efficiently. Externalization thus would be the choice (see Chapter 2 for detailed discussion). Examples from industries include IBM's externalization of operating system, Natsteel's externalization of hydraulic system, and Mannesmann's externalization of pump design.

Another strategic consideration for NPD managers is that the firm should internalize NPD tasks that are crucial for firm survival. In NPD, some tasks are very important for the firm. If the firm externalizes these tasks, it is subject to a tremendous loss in the long run. In contrast, if the cost to perform tasks internally is extremely high and these tasks do not affect core competencies, then they could be assigned to other

firms with more expertise. For example, as Toyota builds its core competency in engine parts, it always assigns tasks on transmissions and electrical systems to partners (Fine 1998). How to internalize or externalize NPD tasks is the central theme in Chapter 2.

Rationale of Resource-Based View of the Firm

Wernerfelt (1984), Day and Wensley (1988), Barney (1991), and Prahalad and Hamel (1990) expanded the seminal work of Penrose (1959) and built resource-based theory around the internal competencies of the firm. Firm competitive advantage is rooted inside the firm, in assets that are valuable and inimitable according to the resource-based view of the firm. The firm's survival largely depends on how it builds, develops (or strengthens), and protects its core competencies (Day and Wensley 1988).

Consistent with the principle of internalizing important and critical tasks, the resource-based view of the firm emphasizes the protection of firm core competencies (Penrose 1959; Wernerfield 1984; Barney 1991; Day and Wensley 1988). The firm seeks to perform certain NPD tasks internally because firm specific advantage needs to be protected by its organizational structure. In other words, if NPD tasks are closely related to firm core competencies and externalizing these tasks will undermine firm competitive advantage, the firm should not externalize these tasks.

The resource-based view of the firm is not restricted solely to exploring internal resources and capabilities. Researchers recognized that many of the resources and capabilities essential to the fully implementation of the firm's competitive advantage lie outside the firm's boundaries (Doz and Hamel 1998). Grant (1991), for example, acknowledged the importance of resources and capabilities within other firms. He

asserted that when needed resources and capabilities are not available internally, outsourcing should be considered. By using other firms' resources and capabilities, the firm can gain "otherwise unavailable competitive advantages and values for the firm" (Das and Teng 2000, p. 36). Applying this perspective to NPD, when the firm does not possess the resources and capabilities to perform certain NPD tasks, the firm can give these tasks to other firms to use their "best-in-world" resources and capabilities.

The resource-based view of the firm explicitly recognizes the importance of intangible assets such as organizational culture (Barney 1986) and knowledge (Teece 1981; Grant 1996, 1997). This offers a significant opportunity for research on links between firm NPD capability and the activities of getting knowledge from partner firms (this is discussed extensively in Chapter 3).

The strategic choice perspective, as developed by internalization theory and resource-based view of the firm, rests on the assumption that actors are economically rational and strive to maximize financial performance by enhancing their market positions relative to competitors' positions (Porter 1980, 1990). Internalization theory predicts that the firm externalizes or internalizes NPD tasks to enhance the NPD efficiency or strengthen core competencies. The resource-based view of the firm complements internalization theory and predicts that the firm can enhance the NPD efficiency by using other firms' resources and capability, i.e., by externalizing some NPD tasks. The resource-base view of the firm also stresses that the firm externalizes NPD tasks unrelated to their core competencies.

Theoretical Contributions

The framework of this study incorporates concepts from internalization theory and the resource-based view of the firm. The contributions of this dissertation to NPD theory could be summarized as follows.

Internalizing and Externalizing NPD Tasks

This dissertation attempts to provide a theoretical explanation for the externalization issue in NPD. In Chapter 2, I propose a framework based on internalization theory (Buckley and Casson 1976, 1998) and the resource-based view of the firm (Day and Wensley 1988). Considering the difficulties of the firm in developing new products internally, I propose a solution of developing new products both internally and externally. In particular, I propose that the firm could give part of its NPD tasks to partner firms in order to use other firms' resources and capabilities and accelerate NPD. Internalization theory stresses that the firm should internalize tasks that are critical and externalize unimportant tasks. The resource-based view of the firm also emphasizes the importance of protecting firm core competency. I propose that the firm should not externalize tasks that affect core competencies. In other words, the firm would benefit if it concentrates on new product tasks that are crucial and gives unimportant tasks to partner firms.

Enhancing NPD Capability Through Obtaining Knowledge

The above theoretical study aims at "giving" some tasks of NPD to other firms to improve NPD program performance. This dissertation also provides theoretical guidance for "taking" knowledge from other firms to enhance NPD capability.

Based on the premise that the firm is likely to internalize tasks that are connected to core competencies, a strong NPD capability is crucial for NPD program success. Improving firm NPD capability is, therefore, critical in this respect. I propose that the firm could improve its NPD capability through acquiring knowledge from other firms.

The theory of knowledge management stresses the importance of tacit knowledge and novel knowledge for the firm. Based on the premise that obtaining tacit knowledge requires repeated and intensive interaction between firms, I propose that the firm could get tacit knowledge from close partners. The literature on inter-firm relationship also stresses the role of weak relationships in getting new knowledge. I propose that the firm is likely to get novel knowledge from "friends of friends", or partners that are unique (not closely related to other firms) in the relationship.

Contributions to Managerial Practice

A large portion of this study is driven by the major concerns of NPD managers. As many product managers turn their attention from primarily internal design issues to the combination of internal and external designs, the study could provide some basic managerial guidelines for strengthening NPD capability and using external resources and capabilities to the greatest extent.

From a managerial standpoint, the results of this dissertation assist NPD managers in developing a strategy for managing different kinds of relationships. This dissertation provides specific guidance on how to acquire tacit or uncoded knowledge from close relationships and how to get novel knowledge from weak relationships (or from firms that

are unique in the relationships). Close relationships are very valuable for NPD success, but firms that are not close could be equally useful.

Two models are developed in this dissertation. Chapter 2 presents the first framework and hypotheses, which focus on externalization strategy and NPD program performance. Chapter 3 presents the second model, which deals with getting knowledge from other firms to enhance firm NPD capability.

CHAPTER 2

MODEL 1—ENHANCING FIRM NPD PROGRAM PERFORMANCE THROUGH EXTERNALIZATION

Figure 2.1 presents the model for studying NPD program performance through externalization. The less the importance and greater the complexity of NPD tasks, the more likely the firm is to externalize these tasks. The links from externalization to both NPD capability and NPD program performance are moderated by the importance of tasks. Externalizing less important tasks is beneficial to NPD capability and NPD program performance. Externalizing important tasks are likely to jeopardize NPD capability and NPD program performance.

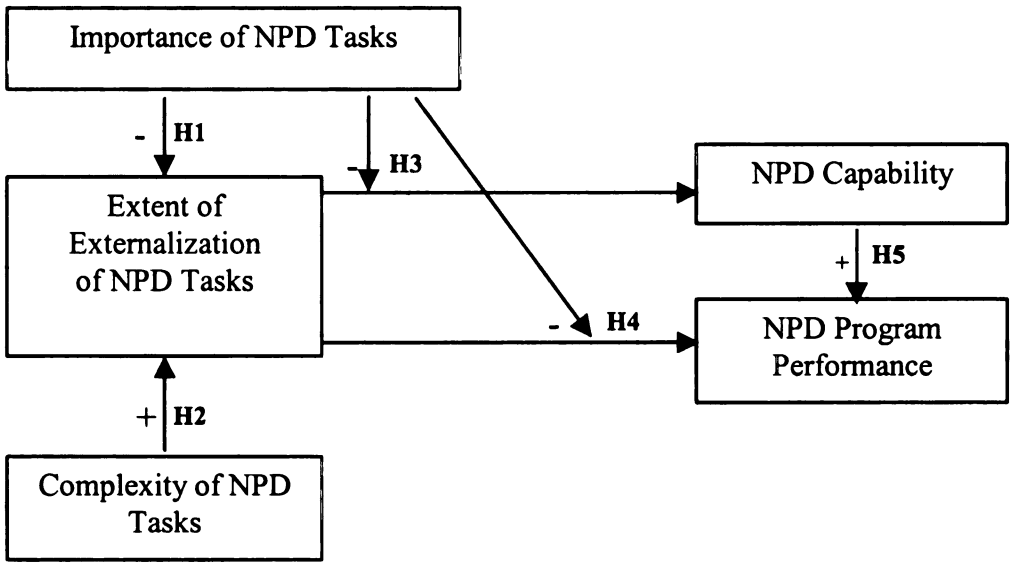


FIGURE 2.1: ENHANCING FIRM NPD PERFORMANCE THROUGH EXTERNALIZATION

Review of NPD Literature

Graham (1985) and Friar and Horwitch (1985) reported evidence of a paradigm shift from internal to external sources of NPD since 1975. Robertson and Gatignon (1998), Croisier (1999), and Kurokawa (1997) had brief reviews on in-house NPD versus externalization in their subsequent research.

Reasons for Externalization in NPD

Graham (1985) analyzed the strategic purpose for externalization of NPD from both long-term and short-term perspectives. He attributes short-term motivation for externalization to generic cost reduction (including cost spreading), redundancy avoidance, obtaining knowledge from outside sources, and technological objective evaluation. The long-term intention of externalization is mainly opportunity generation. It encompasses building the stock of usable technology, insulating researchers from day-to-day operating pressures, and enhancing the quality of research. Subsequent researchers have suggested several reasons why the firm externalizes its NPD tasks; these encompass cost reduction, NPD speed, and NPD quality.

Cost reduction. Cost reduction is often given as a main reason for externalization in NPD (Mohr and Spekman 1994; Bonaccorsi and Lipparini 1994; Ragatz, Handfield, and Scannell 1997). Cost of NPD is defined as the total financial requirements and associated human resources needed to complete the NPD process (Kessler and Chakrabarti 1996; Rosenthal 1992). The increasing complexity of the NPD process increases the cost of research. Many NPD plans fail because of the expense of NPD. Furthermore, because of rapid technological advances, the firm's R&D department may lack current technological expertise and equipment (Croisier 1999; Brockhoff 1992).

Many NPD programs may require several scientific and technical disciplines. It is commonly believed that an outside partner can provide the same level of technology at a lower cost than the internal R&D department when performing certain tasks. The often cited rationale is that the partner typically has more focused expertise in a particular area (Day and Wensley 1988; Collis 1994).

The expectation that externalization will cut cost is consistent with the strategic management view of competitive resource allocation (Kazanjian and Rao 1999). This viewpoint holds that all activities unrelated strategic core competencies should be externalized since economies of scale allow specialized firms to perform the tasks at lower costs. One interviewee observed that the fees charged by the partner firms had decreased because of increasing economies of scale.

NPD speed. NPD speed is another factor driving the paradigm shift in NPD. NPD speed is defined as the time elapsed between the initial development (such as idea generation and new product definition) and ultimate commercialization, which is the introduction of the new product into the market place (Kessler and Chakrabarti 1996). An increasing number of organizations have recognized the importance of speeding up NPD to build a competitive advantage (Kessler and Chakrabarti 1996; Griffin 1997b). NPD cycle time is critical because product life cycles are shrinking (Griffin 1997b). Griffin (1997b, p.25) reported that the NPD cycle time decreased by 25 - 50%. The growing popularity of speeding up NPD is partly based on the belief that being a faster innovator can give the firm either first-mover or second-mover strategies.

Quality. Quality is also important in NPD (Li and Calantone 1998; Jacobson and Aaker 1987). Quality has been defined as the perceived superiority or excellence in a

product as compared with competing alternatives from the perspectives of the marketplace (Sethi 2000; Garvin 1988). Many analysts who have studied the apparent success of Japanese firms have hypothesized that a key strategic ingredient has been product quality (Li and Calantone 1998; Song and Mark 1997). Many authors have proposed that best utilizing internal resources and capabilities, such as through cross-functional teams, is one way to enhance new product quality.

The main problem in NPD is that cost, speed, and quality goals are extremely difficult to be achieved simultaneously. Generally speaking, NPD speed has been positively related to NPD cost and new product quality. NPD cost is also positively correlated with new product quality. That is, speeding up development results in the firm committing more person-hours, materials, or equipment to NPD. Also, because of resource limitations, the firm speeding up NPD finds it hard to correct mistakes in NPD and to make accurate projections about competitors' movements and customers tastes and expectations, resulting in lower new product quality.

The firm, therefore, could outsource NPD tasks to simplify the NPD agenda, to focus on core competencies (Venkatesan 1992; Prahalad and Hamel 1990; Quinn and Hilmer 1994), and to speed up the development process (Bonaccorsi and Lipparini 1994; Robertson and Gatignon 1998). Technological reasons for externalization, such as improving the quality of the NPD process (Dyer and Ouchi 1993) and gaining access to new talent and technology, as well as the easy availability of partners with expertise, have also been proposed (Croisier 1999; Doz, Olk, and Ring 2000; Moorman and Miner 1997).

One executive mentioned that strategically externalizing non-core and low skill activities would offer existing staff more time to concentrate on core activities. Thus

externalization relieves existing staff of mundane, repetitive, and basic work, allowing them to focus on high value-added activities.

NPD Capability

NPD capability can be viewed as a subset of firm overall capability. It is defined as the comprehensive set of characteristics of the firm that facilitate and support NPD strategies (Hurley and Hult 1998). Moorman and Slotegraaf (1999) referred the NPD capability to the firm's technological ability to formulate and develop new products and related processes. Other researchers similarly have identified technical proficiency, R&D, and engineering or technical resources and skills as important to new product and process developments (Calantone and di Benedetto 1988; Cooper 1993; Roth and Jackson 1995). Montoya-Weiss and Calantone's (1994) meta-analysis of more than 40 studies examining new product success factors found that technical proficiency was important to new product success (see also Rothwell 1972; Song and Parry 1997). NPD capabilities are also important to the speed of product development, because greater R&D investments have been found to influence time to market (Li and Calantone 1998).

The existence of NPD capability rests on an accumulated expertise and a set of skills that support NPD. The firm with high NPD capability employs learning-by-doing, which makes it very difficult for competitors to buy this know-how in the market and also makes it extremely difficult for other firms to imitate. The difficulties of imitating this know-how are further exacerbated by the large tacit component of NPD. These characteristics of NPD capability enable the firm to succeed in NPD programs.

NPD Program Performance

Because of the high failure rate of new products, NPD program performance is an area that has attracted great attention (Li and Calantone 1998; Cooper and Kleinschmidt 1987; Wind and Mahajan 1997). NPD program performance is the level of success achieved by the NPD program in the market place (Song and Parry 1997). Traditionally, NPD program performance is described in terms of its actual and perceived outcomes (Calantone and Cooper 1979, 1981; Cooper 1979; Crawford 1977). Damanpour (1991a), however, found that organizational members' perceptions of innovation outcomes do not coincide with the actual innovation outcomes. When innovation outcome is highly effective, respondents are likely to overestimate the performance. When innovation outcome is highly ineffective, respondents tend to underestimate the performance.

Another problem concerning NPD program performance is that the firm has different perceptions about what constitutes NPD outcomes. Some studies, especially studies in the U.S. and Canada, emphasizes sales growth, market share, and profits. While others, typically studies in Japan, focus on speed of new product development process, or lead time and productivity (Song and Parry 1997; Clark and Fujimoto 1991).

As a result, both subjective and objective measures were used in this dissertation. NPD program speed, lead-time, and financial performance such as profitability, sales growth, market share, and return on investment are considered.

Hypotheses

The Importance of NPD Tasks and Externalization

Importance of a NPD task is defined as the degree to which the NPD task is related to the firm's core competencies (Veugelers and Cassiman 1999). The resource-based view of the firm emphasizes the critical role of firm core competencies. Core competencies are not products or those things the firm does relatively well. They are those activities—usually intellectually-based service activities or systems—that the firm performs better than any other enterprises. They are the set of skills and systems that the firm does at "best in the world" levels and through which the firm creates uniquely high value for customers (Day and Wensley 1988; Collis 1994).

Researchers of NPD warn of the danger of losing core competencies through externalization (Kurokawa 1997; Robertson and Gatignon 1998; van den Bosch and Elfferich 1993; Veugelers and Cassiman 1999; Rubenstein 1994). The simple way to protect core competencies is not to give away much of the firm's unique competence at the outset. In other words, the firm does not share all the basic technology, but simply performs these functions on its own. Coca-Cola, for example, develops its syrup, a secret formula, in its own plants and then distributes this syrup to its franchising partners.

In a NPD program, one risk the firm is subjected to is that other firms may imitate the technology and try to compete with the firm (Robertson and Gatignon 1998). Thus, firms such as Natsteel, IBM, and Microsoft pursue internal R&D for core NPD tasks. Core NPD tasks are usually associated with firm intangible assets. If the firm externalizes these tasks, it will leave the intangible assets unprotected (Teece 1996). Even if the firm gives the core tasks to close partners, the difficulties with regulating the transaction with

incomplete contracts and the cost of protecting against opportunistic behavior favor internal mode of NPD (Robertson and Gatignon 1998). Veugelers and Cassiman (1999) studied NPD in Belgian manufacturing firms and find that the firm seldom gives important tasks to other firms.

Creating uniquely high value for customers is one important aspect of firm core competencies (Woodruff 1997; Parasuraman 1997; Slater 1997; Prahalad and Hamel 1990). One executive stressed, "If we really provide satisfaction to customers through new product development, we will be profitable." The central organizational challenge in NPD is to maximize the effectiveness of the firm's customer value creation activities. Many firms responded that it is most effective to focus on developing and supporting core NPD tasks that can create and maintain a real and meaningful long-term distinctiveness in customers' minds.

Despite all best efforts, the design process often leads to the introduction of products that do not meet customer expectations. One possibility is that, when designing products, designers are not always able to effectively incorporate information about the customer. Veugelers and Cassiman (1999) have suggested to control key tasks that a vital to customers' satisfaction when designing a product. Incorporating the customer in the key design allows the actual participation of a customer in the product design. This form of design could involve customer as an "actor," using product prototypes and interacting with specific aspects of a design. Customers' voice could be effectively translated into engineers' language. The key design process thus remains centered on the customer.

One executive warned that ignoring customer input would lead to NPD failure. He further mentioned that for some NPD tasks, it is critical to seek customers' feedback

about designs. This feedback serves as the reality check and ensures that the superiority of NPD design is considered meaningful by customers. In some situations, the firm might proactively apply their own knowledge and expertise about the product and help customers discover and articulate their requirements. If the firm externalizes the tasks that are crucial for customer value creation, the required interactions between the firm and customers in NPD will be jeopardized. The resultant new products are less likely to be considered meaningful by customers. Hence, I propose,

H1: The greater the importance of tasks, the less the extent of externalization.

The Complexity of Tasks and Externalization

Griffin (1997b) uses the number of functions of a product to describe product complexity. The overall complexity of tasks in a NPD program can be referred to as the broadness of knowledge and technology required to fulfill these tasks relative to the firm's knowledge and technology base (Taggart 1997; Hobday 1998). Both internalization theory and the resource-based view of the firm support the notion of externalizing complex tasks, but from different perspectives. Internalization theory emphasizes the "push" effect. If a task requires novel knowledge, or if a task covers a variety of distinct knowledge bases, or if the task needs a variety of skills and engineering inputs that the firm does not have or which are prohibitively costly to acquire, then externalization is preferred to internalization. In research on UK manufacturing multinational corporations, Taggart (1997) posited that as complexity increases, an externalization decision becomes more likely.

Singh (1997) pointed out that the fundamental challenge the firm faces in

developing complex tasks is developing multiple competencies required by these designs. As complex NPD task design requires different knowledge bases, the firm that internally developing these tasks must possess the ability to design, manufacture, and coordinate many dissimilar components. The firm, however, is unlikely to have the ability to develop a broad set of competencies. Depending on limited knowledge base and competencies to develop these complex NPD tasks runs a great risk. One executive indicated: "If other companies could perform better than me, why should I do it myself?"

In the heavy machinery industry, for example, the design of a new product includes feeding speed control, mold design, pump design, and temperature control, and these designs cover several scientific and technical disciplines. Many companies simply do not have all the necessary resources to cope with these problems. Furthermore, the increasing complexity of NPD increases the cost of NPD. NPD may become less attractive without other firms to "share the burden" (van den Bosch and Elfferich 1993).

The resource-based view of the firm emphasizes the "pull" effect. The attractiveness of other firms' expertise encourages externalization (Quinn and Hilmer 1994). Other firms have the technology and knowledge to perform certain tasks in more efficient and effective ways than one firm can internally. For example, Natsteel let Vickers, the expert firm in hydraulic systems, to design the hydraulic press system. Time and costs were saved.

Doz and Hamel (1998) focused on the resources and capabilities within the boundaries of other firms. They further propose that many valuable resources and capabilities lie outside of the firm's boundaries. If the firm can use other firms' resources and capabilities, the firm could be in a superior competitive position in the marketplace.

Grand (1991), Das and Teng (2000), and Teece (1996) called for the utilization of other firms' "best-in-world" resources and capability. This perspective supports the notion of externalizing complex NPD tasks.

The firm may be able to develop the broad set of competencies required for complex NPD task design over a long period of time in a stable environment (Langlois 1992). However, environmental stability is uncommon in most industries, especially for firms in high-tech industries. Instead, environmental turbulence is a major characteristic that significantly affect firm strategic decisions.

One threat of developing a broad knowledge base is "technology unrelatedness." In other words, the firm's knowledge base will lack a "synergy" which is critical for NPD success. Meyer and Roberts (1986), Roberts and Meyer (1991), and Kurokawa (1997) found that the firm with more related technology performed better in NPD than those with wider knowledge diversity. Rumelt (1974) also demonstrated that firms with related technological activities outperformed those with diverse technological activities. Externalizing complex tasks affords the development of technological synergy or relatedness.

One could also argue that the firm should internalize complex NPD tasks because the firm may have the chance to develop technologies that are valuable. Singh (1997) argued that developing complex tasks that are not related to firm core competencies is extremely costly. Different knowledge bases are likely to reside in separate organizations. The firm is constrained in its ability to rapidly learn and implement these competencies and routines embodied in other firms.

Williamson (1991) suggested considering additional problems when analyzing

organizational forms in conjunction with the development of new products. When concerned with the NPD program, two important dimensions have to be added: timeliness and costs. In today's technological environment, new products are introduced at a faster pace and often combined with technological paradigm shifts (Robertson and Gatignon 1998).

The above discussion suggests that, in general, the firm tends to externalize complex tasks to increase speed and to reduce costs of new product development. I propose,

H2: The greater the complexity of tasks, the greater the extent of externalization.

Externalization and NPD Capability

Externalization gives the firm the opportunity to access other firms' core competencies (Quinn 1999). Through frequent interactions during the NPD process, partners' useful technology and management skills are acquired and NPD capability is strengthened.

Externalization increases the organization's focus (Venkatesan 1992). By giving certain tasks to other firms, the firm can concentrate its limited resources on core competencies and develop "best-in-world" technologies (Kurokawa 1997). This ultimately leads to high NPD capability. One approach to strategic NPD management is the focused investment, i.e., to invest on high value-added NPD activities (Quinn 2000). These investments further generate know-how related to core competencies. NPD capability is enhanced (Nonaka 1994).

Many executives maintain that externalizing unimportant NPD tasks increases

R&D department focus. The R&D department could then put much emphasis on the strategic side of NPD development. NPD capability thus is improved. Quinn (2000) pointed out that because of its size and focus, the firm applying an externalization strategy is very active in the marketplace.

Pisano (1990) supported externalizing NPD tasks from the organizational learning perspective. The interactions in externalizing NPD tasks facilitate knowledge transfer among firms, which would ultimately enhance NPD capability. He supported this view by citing examples from the pharmaceutical industry. The firm developing a specific therapeutic compound may also "generate knowledge and build R&D capabilities that are valuable for discovering other drugs for the same disease" (Pisano 1990, p. 159).

In contrast, externalizing important tasks discourages the firm from developing key technology, thus jeopardizing NPD capability (Verona 1999). One principle of "barbell-shaped" NPD is that the firm should strengthen internal capabilities by focusing on several key technologies and developing them into the "best in the world." The building of NPD capability is a cumulative process that needs the continuous investment in R&D (Robertson and Gatignon 1998). The firm giving critical tasks to other firms tends to ignore necessary investments in R&D, leading to lower NPD capability (Pisano 1990).

The interviewees were unanimous in their advice not to externalize NPD tasks related closely to firm core competencies. They stressed that externalizing core NPD tasks would result in the loss of NPD capability and diminish NPD quality. Therefore, I propose,

H3: The relationship between externalization and NPD capability decreases from

positive to negative as the level of the importance of NPD tasks increases.

Externalization and NPD Program Performance

The previous discussion summarized several advantages of externalization, such as reducing costs, gaining speed, improving quality, and sharing risks. Externalization, therefore, directly contributes to NPD program performance. Quinn (1999) asserts that externalization strategy allows the firm to return to its most successful work and enjoy the benefits of utilizing other firms' valuable resources and capabilities. In the analysis of "make-or-buy" decisions in R&D, Kurokawa (1997) proposed that internalizing NPD tasks that are not related to the firm's core competencies would be costly and the development period would be longer as compared to externalizing these tasks. The subsequent empirical tests supported the above assertion. In other words, externalizing less important NPD tasks is positively related to NPD program performance.

It has to be pointed out however that externalizing tasks critical to firm core competencies is harmful for NPD program performance because this gives other firms opportunities to develop better products (Quinn 1999; Prahalad and Hamel 1990; Robertson and Gatignon 1998). Robertson and Gatignon (1998) warned that other firms may imitate the technology and compete with the firm if the firm exposes the core competencies through externalizing key NPD tasks.

In the study of R&D boundaries in the pharmaceutical industry, Pisano (1990) found that externalizing tasks that are strategically important to the corporation was negatively related to R&D performance. He further explained that NPD tasks that are closely related to firm core competencies are likely to be those that the firm has experience with and can perform relatively better than other firms because technological

development is likely to be cumulative. Consequently, externalizing NPD tasks that the firm can perform efficiently will jeopardize NPD program performance. Stated formally,

> *H4: The relationship between externalization and NPD program performance decreases from positive to negative as the level of the importance of NPD tasks increases.*

NPD Capability and NPD Program Performance

The positive relationship between NPD capability and NPD program performance is uniformly supported by the NPD literature (Cooper 1984; Cooper and Kleinschmidt 1987; Hurley and Hult 1998; Han, Kim, and Srivastava 1998). The firm with great NPD capability develops new products with greater quality, lower cost, and at higher speed, leading to high NPD program performance (Li and Calantone 1998; Veugelers and Cassiman 1999; Gatignon and Xuereb 1997).

The firm with high NPD capability is likely to develop products that are highly valued by buyers. It synthesizes the knowledge of what is needed in the market and how to create a product to meet the need. Such a firm places the highest priority on continuously finding ways to provide superior customer value and thus can conceive of or implement NPD strategies that are superior to competitors' strategies (Han, Kim and Srivastava 1998; Barney 1986), resulting in high NPD program performance. Many studies suggest that the firm is able to improve NPD program performance only when its products are valuable to buyers.

Dumaine (1989) reported that the speed at which the firm brings new products to the market is crucial for NPD profitability. Speedy product development enjoys the pioneering advantage, such as earlier market segment and customer loyalty. It allows the firm to develop second-generation models based on the feedback from its original product

launch. Through speedy NPD the firm can deal with volatile market changes and maintain profitability. Speedy NPD requires that the firm have superior NPD capability: it is high NPD capability that allows the firm to develop new product at great speed and high quality, resulting in high NPD program performance. So, the proposition is,

H5: The greater the NPD capability, the higher the NPD program performance.

Control Variables

Two control variables, firm size and age, were included in the study. Firm size refers to the number of employees and annual sales. Firm age is the years the firm has been in business. They were included to account for the possible influence on externalization of NPD tasks, NPD capability, and NPD program performance.

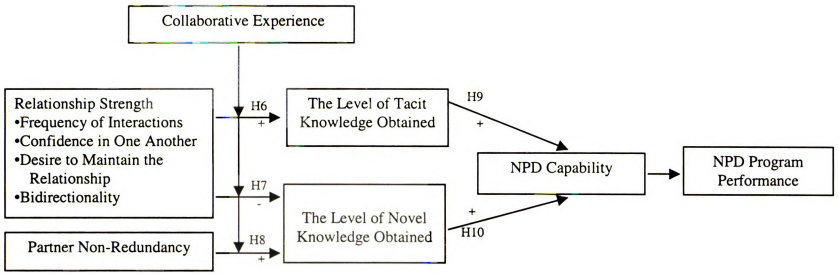
CHAPTER 3

MODEL 2—ENHANCING FIRM NPD CAPABILITY THROUGH OBTAINING KNOWLEDGE

Figure 3.1 presents the model for studying how to enhance firm NPD capability through acquiring knowledge from other firms. The key arguments are that firm NPD program performance depends mostly on firm NPD capability, and that tacit knowledge and novel knowledge are critical antecedents of the firm's NPD capability. A high level of tacit knowledge could be obtained though close interactions with partner firms, and novel knowledge could be acquired from firms not closely related.

Knowledge

The importance of knowledge for the firm is reflected in internalization theory and the resource-based view of the firm. Researchers in the resource-based view of the firm consistently stress that knowledge is one of the important firm resources because it is unique, inimitable, and valuable for the firm (Day and Wensley 1988; Collis 1994; Barney 1986). Some scholars propose a knowledge-based view of the firm (Grant and Baden-Fuller 1995; Grant 1997) to acknowledge the central role of knowledge in the firm. In internalization theory, scholars recognize the importance of knowledge (Buckley and Casson 1976) and postulate that some knowledge is too costly to develop internally. Acquiring knowledge from other firms is more efficient.



FIFURE 3.1: ENHANCING FIRM NPD CAPABILITY THROUGH KNOWLEDGE TRANSFER

Closely related to NPD are tacit knowledge and novel knowledge (Nonaka 1994; Tidd 1995; Tatikonda and Rosenthal 2000). Tacit knowledge is uncoded knowledge and resides in the firm's system. Tacit knowledge is important but difficult to interpret and transfer from one firm to another. Due to difficulties related to interpretation and transfer, previous studies are mostly descriptive in nature. Detailed research on it is lacking: in particular, how to get tacit knowledge from other firms is a neglected issue (Howells 1999; Madhavan and Grover 1998).

Novelty is defined as the newness, to the NPD firm, of the knowledge (Hansen 1999). It is an important concept for NPD but has received little attention (Tidd 1995; Tatikonda and Rosenthal 2000). In the NPD literature and studies of knowledge management, scholars often describe knowledge novelty on the basis of lack of familiarity with the given knowledge. In the operationalization, existing measures of technology newness and technology novelty were integrated and extended (Tatikonda and Rosenthal 2000).

Relationship Strength

Relationship strength is one characteristic of inter-firm relationships. It is central to relationship research (Morgan and Hunt 1994; Hansen 1999; Rindfleisch and Moorman 2001). Four dimensions of relationship strength are identified, which are (1) frequency of interactions, (2) confidence on one another, (3) desire to maintain the relationship, and (4) bidirectionality. Hansen (1999) proposed that close interfirm

relationships are characterized by (1) frequent interactions, (2) an extended history, and (3) intimacy or mutual confiding (see also Kraatz 1998).

Mutual frequent information sharing in a close relationship includes the formal as well as informal exchange of meaningful and timely information (Mohr and Nevin 1990). This is critical for a close relationship because one party seeks a dialogue with the partner, not only concerning the partner's operations and strategies, but also with respect to feedback on its own operations and strategies. This kind of give-and-take requires open-mindedness and a non-defensive attitude. Information sharing has a substantive effect when strategies and operations are modified and improved. The frequency and quality of information sharing signal the importance of the relationship and the respect that the parties have for each other (Mohr, Fisher, and Nevin 1996).

In marketing research on relationships, Morgan and Hunt (1994) emphasize that the nature of close relationship lies in mutual trust, commitment, and the high quality and frequency of communications. In a close relationship, compared with a weak relationship, both firms treat the relationship as valuable and important (Moorman, Zaltman, and Deshpande 1992). They desire that the relationship endure indefinitely and are willing to work together to maintain it. For example, when one party is in need of help, the other party is readily available (Morgan and Hunt 1994).

The closeness of the relationship between firms determines the extent of knowledge transfer. A close relationship allows for prolonged cohabitation of managerial and technical personnel and facilitates the replication of organizational routines (Teece 1981). A direct interface among the partner firms permits direct observation of operations and enables the gradual and experiential learning that is essential for successful transfer

of tacit knowledge (Davies 1977; Killing 1983; Osborn and Baughn 1990). For example, a supplier may get knowledge of inter-functional integration during its participation in the manufacturer's NPD. Furthermore, partnering relationships include a monitoring process (Stump and Heide 1996). Monitoring is especially valuable where tacit knowledge is concerned, since such knowledge is not readily codified, and hence cannot be transmitted in the form of reports and balance statements.

Recent research indicates that weak relationships could be as important as strong relationships (Hansen 1999; Rogers 1995; Kraatz 1998; Rindfleisch and Moorman 2001). Compared with strong relationships, weak relationships tend to be infrequent and distant. Firms with different values, interests, degrees of power, and ways of interacting often find it difficult to identify common bonds that build trust (Rowley, Behrens, and Krackhardt 2000). However, weak relationships that connect otherwise isolated firms have been noted for their capacity to bring new information and resources that would otherwise not be accessible (Ashman, Brown, and Zwick 1998). They are especially efficient for knowledge sharing because they provide access to novel information by bridging otherwise disconnected firms (Hansen 1999). Strong ties, in contrast, are likely to lead to redundant information because they tend to occur among a small group of actors; these actors tend to possess the same information and to hold similar opinions (Rogers 1995).

Hypotheses

Strength of Relationship and the Level of Tacit Knowledge Obtained

Strong ties are more likely to promote in-depth, two-way communication and to facilitate the exchange of detailed information between organizations (Kraatz 1998). A close relationship enhances the opportunities for people in both firms to share feelings, emotions, collaborative experiences, and mental models through physical, face to face contacts. A close relationship is therefore the base for tacit knowledge transfer (Nonaka 1994). Through frequent dialogue among the members of two firms, knowledge in one firm is converted into terms and concepts shared with another firm. Thus, tacit knowledge rooted in one firm is likely to be transferred into another firm's knowledge.

In the study of the knowledge transfer among the sub-units of an organization, Hansen (1999) found that units with strong ties have greater motivation to be of assistance and are typically more easily available to each other than units with weak ties. He highly valued the two-way interactions between the source and recipient in strong ties. Tacit knowledge transfer is not likely to be completed the first time due to the difficulty of transfer. Repeated two-way interactions are necessary, for then the recipient firm can "try, err, and seek instruction and feedback" from the source (Hansen 1999, p. 88). When problems occur and questions arise, the source firm is immediately available. Uzzi (1996) also noted that firms in strong relationships are likely to exchange "fine-gained" knowledge.

Examples from industry support the positive relationship between relationship strength and the level of tacit knowledge obtained. IBM obtained the valuable knowledge of image processing during a seven-year long cooperation with USAA (United States

Automobile Association), which had a strong capability in image processing. HP failed in the first four years in getting the knowledge necessary to deal with special conditions in China because it did not find the right partners and develop close relationships. Based on the above arguments, I propose,

> *H6. The stronger the relationship between the firm and a partner firm, the higher the level of tacit knowledge can be obtained from the partner firm.*

The Relationship Strength and the Level of Novel Knowledge Obtained

Hansen (1999) observed that strong relationships are less likely to provide novel knowledge because actors know each other very well. New information should be more readily available from firms with whom the firm has weak relationships. By contacting firms that are loosely coupled, diverse ideas are obtained. For example, the idea of a new feeding system for press machines in Mannesmann was from a textile factory. Some of Natsteel's most innovative projects were copied from a beverage company.

Rowley, Behrens, and Krackhardt (2000) synthesized previous studies on weak relationships and found that weak relationships are more likely to bridge distant others possessing new knowledge. Weak relationships can be thought of as representatives of remote networks. Through the weak relationships, new knowledge in remote networks is accessed and transferred.

Hakansson (1999) also suggested searching weakly related relationships for new ideas. On the one hand, weakly related firms are unlikely to be direct competitors in the market place. They may be willing to share useful knowledge in their interactions because there is less incentive to protect this knowledge (Constant, Sproull, and Kiesler 1996). On the other hand, general knowledge in one industry can generate a highly innovative idea

for the firm in a different industry. For example, the mechanism to fill the container in production line is the basic design in a beverage company. Natsteel's highly innovative project of feeding system design is from that "basic design." Therefore, it is more likely that the firm can get novel knowledge when searching in weak relationships. Stated in another way,

> *H7. The stronger the relationship between the firm and a partner firm, the lower the level of novel knowledge can be obtained from the partner firm.*

Partner Non-Redundancy and the Level of Novel Knowledge Obtained

The construct of non-redundancy is derived from studies of networks in NPD (Bonner 1999; Gabbay and Zuckerman 1998; McEvily and Zaheer 1997). Non-redundancy refers to the degree to which a partner is not directly nor indirectly related to other firms in the relationship (Burt 1992). Burt (1983) pointed out that expertise offered by members that are connected closely in the relationship tends to be redundant. Firms that are unique in the relationship are sources of new knowledge (Nonaka 1994).

Contacting the firm that is not related either directly or indirectly to other firms in the network relationships is to bridge a hole in the social structure (Constant, Sproull, and Kiesler 1996). The structural hole is an opportunity to access to diverse information from different clusters of firms. The probability of finding new knowledge is higher if searching in these relationships. Gabbay and Zuckerman (1998) observed that R&D work units with disconnected contacts have more chance to get novel knowledge than others who do not enjoy the same degree of access to structural holes. Therefore, the more the partner is not related to other firms in the relationship, the greater the probability the firm will get novel knowledge from this partner. Stated formally,

H8. The greater the partner non-redundancy, the higher the level of novel knowledge that can be obtained from the partner firm.

The Levels of Tacit Knowledge and Novel Knowledge Obtained and NPD Capability

The main premise of this study is that the more the tacit and novel knowledge are transferred, the greater the NPD capability. Rooted in the resource-based perspective, the reasoning behind this premise is that tacit—as opposed to explicit—knowledge is more difficult to transfer across borders, and hence more likely to be unique, rare, and difficult for rivals to replicate. Acquiring high explicit (or low tacit) knowledge is unlikely to be as effective for improving NPD capability and NPD program performance as acquiring high tacit knowledge through a close relationship. This is because explicit knowledge about innovation is easily available to all competitors, while tacit knowledge about innovation is not. At the same time, NPD is rooted in innovative ideas. Firms obtaining more novel knowledge are likely to have stronger NPD capability.

In today's highly dynamic environment, the firm searches for continuity to improve the competitive position in the marketplace. One continuity can be found in terms of the skills and knowledge used for product development. Several works in industrial economics emphasize that the nature of NPD is cumulative, and the firm's innovation capability is strongly related to the knowledge, tacit or novel, accumulated over time (Liebeskind 1996; Hedlund 1994; Nonaka 1994). They also underline the role of learning processes in improving technological competencies and continuously deepening and broadening the knowledge domain. Knowledge accumulation over time helps to make the NPD capability hard to imitate by competitors, and opens unique innovative opportunities. Hence,

H9. The higher the level of tacit knowledge obtained, the higher the firm NPD capability.

H10. The higher the level of novel knowledge obtained, the higher the firm NPD capability.

Moderating Effect of Firm Collaborative Experience

Collaborative experience is the firm's experience of collaboration (Simonin 1997), which correlates closely with the firm's collaborative history. The firm accumulates experience from long, frequent collaborations and intense interactions with different firms. The firm with rich collaborative experience, therefore, has strong capabilities to develop different relationships and to manage conflicts in interactions with other firms (Simonin 1997).

The relationships between (1) relationship strength and the level of tacit knowledge obtained, (2) relationship strength and the level of novel knowledge obtained, and (3) partner non-redundancy and level of novel knowledge obtained are all likely to be moderated by collaborative experience. Simonin (1999) argued that experience at collaborating is necessary to manage a diverse portfolio of collaborative ties and to deal with any emerging conflicts in the relationship. As empirically shown by Simonin (1997, 1999), collaborative experience is fundamental to building collaborative know-how which, in turn, translates into greater collaborative benefits.

The firm that has more collaborative experience should have more knowledge of how to manage, monitor, and acquire knowledge from its partners. Inkpen (1998) found that in the collaboration, the firm develops experience of cooperation and a reputation as a partner. The firm with more collaborative experience is likely to understand the learning

opportunities created in the relationship. Furthermore, as the firm's collaborative experience accumulates, the firm moves up the learning curve and the skills necessary for knowledge acquisition are refined.

For example, partner firms could protect their tacit knowledge instinctually. Experienced partners may resolve the conflict smoothly and get the tacit knowledge transferred to the greatest extent. Collaborative experience also affects the capability of the firm to recognize and understand the proper mechanisms of information gathering, interpretation, and diffusion. Familiarity with collaborative mechanisms and/or transfer processes facilitates the transfer of knowledge more effectively and efficiently.

Collaborative experience also serves as a "filter" in the identification of knowledge sources. The firm with high collaborative experience can efficiently find the right partners to collaborate with and filter out those with less value for collaboration. The firm also has the ability to convince potential candidate companies of the merits of collaboration, and to develop ways of easing these organizations through the collaboration "initiation" (for example, by assisting with hurdles such as contract negotiation).

The firm with high collaborative experience can establish trust in the relationship with little difficulty. Trust evolves relatively easily as partners develop mutual understandings from prior collaborative experiences. Opportunistic risks, therefore, are obviated by partners' anticipation of repeated transactions in the future. Also, the firm with high collaborative experience can quickly find the partner's strengths and weaknesses; it can manage better coordination and minimize bureaucratic complexity in the relationship.

I propose,

H11. The relationship between relationship strength and the level of tacit knowledge obtained is stronger for firms with more collaborative experience than for firms with less collaborative experience.

H12. The relationship between relationship strength and the level of novel knowledge obtained is stronger (in absolute value) for firms with less collaborative experience than for firms with more collaborative experience.

H13. The relationship between partner non-redundancy and the level of novel knowledge obtained is stronger for firms with more collaborative experience than for firms with less collaborative experience.

CHAPTER 4

METHODOLOGY

In this chapter, methodology is described. This chapter is organized into three sections. The first section introduces how the survey instrument was developed. The second section discusses measures for the constructs. The third section is about the data collection.

Survey Instrument

A questionnaire was used to collect data to test the two models in this dissertation. The questionnaire development followed the Churchill (1979) and DeVellis (1991) paradigms of developing better measures. The questionnaire was developed in four stages. In the first stage, a draft of the questionnaire was developed. Previous research and relevant literature were reviewed. Scales in previous studies were collected and categorized based on the constructs in this study. The purpose was to use well-developed scales from previous studies. New measures were generated if there were no existing scales in the literature. Items were generated from discussions with industry and academic experts in new product development. Based on these approaches, the first draft of the questionnaire was developed.

In the second stage, the questionnaire was evaluated by academic and industry experts. Four problems were revealed in this stage:

1. The wording of the questions: for example, items from previous studies did not fit the content of this dissertation well.

2. Imprecise and ambiguous questions: some questions were too long and not concrete.
3. The clarity of the instructions: there was confusion between the questions on specific relationships with a specific partner and questions of relationships with partners in general (the first two parts of the questions were about the relationships with one specific firm; the rest of the questions were about the general relationships with all partner firms).
4. Some measurement scales were not appropriate.

Based on the feedback from experts, questions were reworded and re-designed to be as short as possible. For example, multiple questions instead of a single question were used to make questions short and specific. Bipolar scales were used to measure knowledge novelty and a scale of thermometer was used to measure the extent of two-way communication. Instructions about the questions on relationships with a specific partner and the questions on relationships with partner firms in general were redesigned and clarified. The revised questionnaire was send back to these experts to let them review the changes. The second draft of the questionnaire was thus developed.

In the third stage, the questionnaire was pre-tested with a sample of 5 NPD programs. The objectives of the pre-test were (1) to identify unclear or difficult aspects of the questionnaire and (2) to test the reliability and validity of measures. Each manager who participated in the pretest was given a questionnaire and was asked to fill it out. They were then asked to report on the difficulty/clarity of the questionnaire and its individual items by filling out an additional form. After receiving the form, each respondent was contacted over the phone for further discussion of problems and concerns.

The pretest revealed that (1) the questionnaire was too long (taking 50 minutes on average), (2) the extent of externalization was a difficult concept to understand, and (3) some of the items used to measure knowledge novelty, knowledge tacitness, and task complexity were unclear. In response to these issues, items were removed from the questionnaire in order to reduce the completion time to around 20 minutes, task externalization was clarified, and measures of knowledge novelty, tacitness, and task complexity were modified.

In the fourth stage, the questionnaire was pretested on 15 NPD programs. In this stage, no major problems were revealed. In the next part, measures of the constructs are discussed.

Measures

Overall, multiple items were used for each construct. All measurements represented by the questions in the questionnaire were built on the existing literature and based on field research. When there was no existing measure, new scales were developed either by modifying relevant measures or scales were generated by experienced academicians or managers.

Relationship strength is the degree to which two firms are related to one another. It has four dimensions: frequency of interactions, confidence in one another, desire to maintain the relationship, and bidirectionality. Frequency of interactions was measured with three items examining how often the two firms communicated with each other. The respondents were asked to report how often the firm and its partner firm communicate with each other about work-related matters in the oral, written, and electronic forms on a

five-point scale: less than once per month, 1-3 times per month, once per week, several times per week, daily. The scales were from Maltz and Kohli (1996) and modified by field research. Two measures of information sharing from Heide and John (1992) and Lin and Germain (1999) were modified to capture the frequency of information sharing in general.

Confidence in one another was measured by four items, which were modified from measures of trust (Morgan and Hunt 1994; Anderson and Narus 1990; Moorman, Zaltman, and Deshpande 1992; Heide and John 1992; Dwyer, Shurr, and Oh 1987; Garbarino and Johnson 1999).

Desire to maintain the relationship was measured by seven items, which were modified from measures of commitment and expectation of continuity (Anderson and Narus 1990; Morgan and Hunt 1994; Gundlach, Achrol, and Mentzer 1995; Lusch and Brown 1996).

Bidirectionality was measured by four items that captured the degree to which two-way communications occurred (these were from Fisher, Maltz, and Jaworski (1997)).

Partner non-redundancy is the degree to which one partner is not linked to other firms in the firm's network. It was measured by four items that tapped the similarities between this partner firm and other firms in the network; these items were from McEvily and Zaheer (1997) and Bonner (1999). Respondents were asked to indicate the degree of similarities of this partner firm and other firms in the network in terms of technical competencies, market served, industry events attended, and competitive strategies.

Tacit knowledge refers to uncoded knowledge. The level of tacit knowledge obtained was the degree of tacitness of the knowledge that the firm got from the partner

firm. It was measured by six items that were from Hansen's (1999) and Subramaniam (1999) scales of non-codified knowledge. The level of novel knowledge obtained is the degree of newness of the knowledge that the firm got from the partner firm. It was measured by seven items, which were modified from scales of technology novelty (Tatikonda and Rosenthal 2000).

Collaborative experience was measured by five items which were modified from Robertson and Gatigonon (1998) scales of partnering experience.

Complexity of NPD tasks refers to the broadness of knowledge and technology required to fulfill tasks relative to the firm's knowledge and technology base (Taggart 1997; Hobday 1998). Six items were used to measure complexity of NPD tasks; these are from Singh (1997), Eliashberg and Robertson 1988, McCabe 1987, McQuiston (1989), Kozlowski and Hult (1986), and Jaworski, Stathakopoulos, and Krishnan (1993), and address (1) the degree of technological novelty, (2) the variety of distinct knowledge bases, or the variety of skills and engineering inputs of NPD tasks.

Importance of NPD tasks is the degree to which the tasks are related to firm core competencies. It was measured by four items. Two were modified from McQuiston (1989) and two were from field research. These items reflected the importance of NPD tasks for meeting customer needs and for firm core competencies.

Extent of externalization of NPD tasks was measured by two items. These were new items generated from field research. Respondents were asked to indicate the overall percentage of tasks that were performed by other firms (externalized) in the new product development program. Respondents were also asked to categorize tasks into three groups, very important tasks, important tasks, and unimportant tasks. They were asked to indicate

the percentage of tasks in each category that were performed by other firms.

NPD capability was measured by 12 items. According to Moorman and Slotegraaf (1999), there are two approaches to measure capability. The first approach is to measure directly the underlying knowledge and skills that are likely to constitute the capability. The second approach is to measure observable outcomes associated with the presence of capabilities. In this dissertation, both approaches were used. The first set of questions was to measure the knowledge and skills of innovation capabilities. The second set of questions was to measure the outcomes associated with innovation capability, such as the ability to enter into new markets and enter into multiple markets.

NPD program performance was measured by eight items. Both subjective and objective measures were used. They were from Li and Calantone (1998) and Moorman and Miner (1997). The first set of items was objective measures. Respondents were asked to report market share, pretax profit margin, and length of development of new product development programs. The second set of measures was subjective measures. The respondents were asked to judge the new product development program's performance on sales, profit margin, return on assets, and return on investment.

As for control variables, organizational size was operationalized as the number of people in the organization and annual sales of the organization. Organizational age is measured by the years the organization has been in business.

Data Collection

The sampling frame was drawn from a national mailing list of US high-tech firms. A total of 1741 executives and their associated firms were selected randomly from the

mailing list. The firms represented a variety of industries, which included chemicals (SIC codes begin with 28), machinery (SIC codes begin with 35), electronics (SIC codes begin with 36), aircraft (SIC codes begin with 37), instruments (SIC codes begin with 38), and computer software (SIC codes begin with 73).

The unit of analysis is NPD program. This is based on the following two considerations. First, NPD capability development is the task of the whole organization and should not be delegated to a technical team (Li and Calantone 1998). Second, the study is interested in the overall externalization of NPD tasks in the organization. Thus, respondents were asked to evaluate the NPD program in the survey.

The executives targeted in these firms held the position of Vice President of R&D, Vice President of Engineering, or technological manager (director). Of the 1741 surveys initially mailed, a total of 127 were returned marked "moved/not forwardable," "forwarding order expired," or "employee no longer works here." This reduced the actual sample frame to 1614 companies.

In order to get the largest response rate, following methods were used:

1. The survey packet contained a personalized cover letter that introduced the study, its potential value, and the importance of the executive's participation.
2. Respondents who participated were offered a copy of the survey results and research conclusions.
3. A reminder card was mailed five days after the initial mailing, reminding the executives of the request for their participation. This followup card again highlighted the relevance of the study to the executives and offered the survey results. I also included the name and telephone number of a contact person

from whom they could receive a replacement survey if it was needed.

4. A second round of mailing was conducted four weeks after the initial mailing. The target of the mailing was non-respondents.

Of these executives, 247 responded to the survey (a response rate of 15.3%). This was a reasonable rate for this type of study. Of the 247 surveys received, 14 were identified as unusable due to missing values. As a result, 233 usable questionnaires were used in the data analysis. Firm and respondent characteristics are summarized in Tables 4.1 to 4.3.

Table 4.1: Distribution of Sample by Industry

Industry (SIG Code)	Percent of the Sample
Chemical (28)	5.48
Mechanical (35)	14.61
Electronics (36)	48.33
Aircraft (37)	2.87
Instrument (38)	19.62
Computer software (73)	9.09
Total	100.00

Table 4.2: Distribution of Sample by Firm Size

Firm Size (# of Employees)	Percentage of the Sample
10,000+	9.09
5,000—9,999	6.70
1,000—4,999	17.22
500—999	16.75
100—499	25.84
Less than 100	24.40
Total	100.00

Table 4.3: Respondents:

Respondent Title	Percentage of the Sample
Vice President of R&D	52.15
Vice President of Engineering	37.32
Technology Manager (Director)	10.53
Total	100.00

Initial Data Analysis

Missing values were replaced following the procedure in Wilson and Collier (2000). The measurement items were grouped based on the constructs in the first model and the second model. If a question was not answered, the average score of the answered questions on the relevant scale would be used to replace the missing value. Missing values in demographic variables were replaced by the relevant sample average.

The normality of the data was tested by examining kurtosis and skewness of all measurement items. The kurtosis ranged from 0.06 to 1.28. They were below 2.00, a point beyond which nonnormality becomes a concern. Skewness of all items ranged from 0.04 to 0.97, which were acceptable. Kolmogorov-Smirnov tests further confirmed that the nonnormality was not present.

To assess non-response bias, the data were divided into two groups based on the date on which they were received. The first group, which represents the early responses, consisted of the data received from the first mailing process. The second group, which represents the later responses, was composed of the data received from the second mailing process. The two groups were compared on all the measurement items and constructs using t-tests (Armstrong and Overton 1977). The summary of the non-response bias testing is presented in Table 4.4. The t-values ranged from 0.21 to 1.19; none of them was significant. Therefore, there was no significant difference between the two groups on all variables.

Table 4.4: Results of Testing for Non-response Bias

Constructs	t-value	p-value
Externalization	.30	.76
Importance	.21	.84
Complexity	.32	.75
Relationship Strength	.46	.65
Non-Redundancy	.87	.39
Tacit Knowledge	.41	.68
Novel Knowledge	1.19	.24
NPD Capability	.32	.76
NPD Program Performance	.73	.47
Collaborative Experience	.26	.79

Following Armstrong and Overton (1977) and Stump and Heide (1996), non-response bias was also tested by comparing the sample statistics with the known population values. If there was no significant difference between the sample means and the population values, response bias is not present. The sample means of sales and employees were compared with population values of sales and employees through two-tailed t-test. The results are shown in Table 4.5. It was found that that t-values were –0.02 and –1.42 for sales and employees respectively. They were not significant. This further provided evidence that non-response bias might not be a problem.

Table 4.5: Comparison of Sample with Population

Variable	Sample[a]		Population	Results	
	Mean	S.D.	Mean	t-value	p-value
Sales ($) (n=179)	54314900	164110680	62269618	-.02	n.s.
Employees (n=177)	6389	15466	8041	-1.42	n.s.

Note: [a]: Missing values were not included in the test.
n.s.: not significant.

CHAPTER 5

FIRST MODEL TESTING AND RESULTS

In this chapter, the method to test the first model is described. Measurement issues are examined. Construct reliability and validity are tested. The first model is tested using seemingly unrelated regression.

Measurement Validation

There are five constructs in the first model: they are NPD program performance, NPD capability, externalization, importance of NPD tasks, and complexity of NPD tasks. Churchill (1979), Gerbing and Anderson (1988), Anderson and Gerbing (1982), and Durvasula et al. (1993) were followed in testing the reliability and validity of constructs. First, exploratory factor and Chronbach Alpha testing were run on each construct separately. Items with low item-to-total correlation and low loadings were discarded. Second, all constructs were subject to exploratory factor analysis. Items with high cross loadings were eliminated. It was assured that all the items loaded on their theoretically relevant factors.

After the preliminary analysis, all measurements were subject to confirmatory factor analysis (CFA) using LISREL to verify unidimensionality. Generalized least square estimation method was used for it is less sensitive to sample size (see Li and Calantone 1998). In the CFA testing, items with low item-to-construct and insignificant loadings were discarded. Again, care was taken to ensure that items loaded on their theoretically

relevant constructs.

Thirteen items were dropped in the analysis. For the NPD program performance construct, six of the eight items met the criterion of unidimensionality. Two items were deleted because of low or cross loadings. Reliability of the construct was 0.83.

As to the NPD capability construct, five of the twelve items met the above criteria. Seven items were removed from consideration. Reliability of the construct was 0.94.

Two items of externalization met the criteria. The Pearson correlation of the two items was 0.78.

Three of the four items of the importance of NPD tasks met the criteria. One item was removed. Reliability of the construct was 0.72.

With respect to the complexity of NPD tasks, three of the six items survived after the analysis. Three items were eliminated. Reliability of the construct was 0.90.

The CFA results are presented in Table 5.1. The measurement model is shown in Figure 5.1. The CFA testing resulted in five constructs (F1 to F5) with 19 measurement items (V1 to V19). It was found that the reliabilities of four constructs, measured by Chronbach alpha, were between 0.72 to 0.94. These alphas were above the traditional coefficient alpha cutoff of 0.70. The reliability of externalization, measured by Pearson correlation, was 0.78, indicating acceptable inter-item consistency.

Table 5.1: Results of Confirmatory Factor Analysis

Construct	Measurement Items	Standardized Loadings[a]	Cronbach Alpha[b]
F1: NPD Program Performance	V1: Pretax profit margin	.93	.83
	V2: Market share	.76	
	V3: Overall, how satisfied were you with this new product development program.	.78	
	V4: Sales, relative to objective	.73	
	V5: ROA, relative to objective	.55	
	V6: ROI, relative to objective	.70	
F2: NPD Capability	V7: The first-to-market	.97	.94
	V8: Our new product introductions have increased over the last five years.	.94	
	V9: We have a strong capability in penetrating new markets.	.89	
	V10: We have a strong capability in responding to unique requirements of different markets.	.88	
	V11: We have a strong capability in introducing new products simultaneously into several markets.	.79	
F3: Externalization	V12: Overall percentage	.72	.78
	V13: Average percentage	.97	
F4: Importance	V14: These tasks are important for meeting customer requirements.	.74	.72
	V15: These tasks are critical for our firm's long-term benefit.	.78	
	V16: These tasks are important for our firm's core competency.	.71	

Table 5.1 (Continued)

Construct	Measurement Items	Standardized Loadings[a]	Cronbach Alpha[b]
F5: Complexity	V17: These tasks involve technology never used in the industry before.	.84	.90
	V18: Because these tasks were so complex, if we had performed them ourselves, we would have involved more engineers than usual.	.96	
	V19: Overall complexity	.88	
Fit Indexes χ^2 =403.56 (d.f.=142); CFI=1.00; IFI=1.00; NFI=.99; RMSEA=.089			

[a]: All loadings are significant at p<.01.

[b]: The reliability of externalization is measured by Pearson correlation.

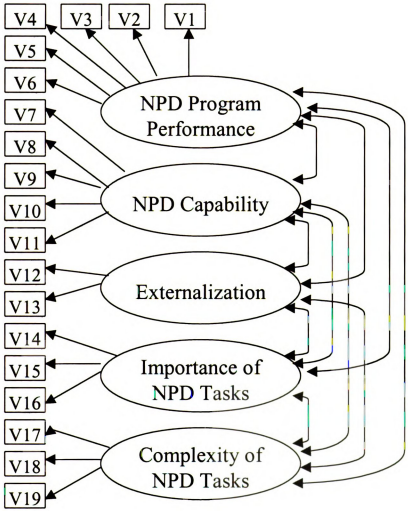


Figure 5.1: Measurement Model

The overall measurement model fit was judged to be satisfactory. Bentler and Bonett's Normed Fit Index (NFI) and Bender's Comparative Fit Index (CFI) were both above the desired minimum acceptable 0.90 level (Hair et al. 1995; Byrne, 1994). RMSEA indicated reasonable fit (RMSEA=0.082). Examining item-to-construct

loadings, they ranged from 0.55 to 0.97. The loadings were all significant at the 0.01 level, indicating convergent validity.

To test for discriminant validity, two approaches were adopted. The first approach was a series of chi-square difference tests of one, two, three, four, and five-factor models, as suggested by Durvasula et al. (1993). The five-factor model represented the hypothesized model in which NPD program performance, NPD capability, externalization, importance of NPD tasks, and complexity of NPD tasks were distinct constructs. In each four-factor model, one pair of factors was combined into one factor. The four-factor models, thus, were represented by 10 combinations of the measures as shown in Table 5.2. The three-factor models, two-factor models, and one-factor model were the combinations of three factors, four factors, and five factors into one factor respectively.

Table 5.2: Ten Four-Factor Models

Model	Constructs
Model 1	1. NPD program performance and NPD capability as one factor 2. Externalization 3. Importance of NPD tasks 4. Complexity of NPD Tasks
Model 2	1. NPD program performance and externalization as one factor 2. NPD capability 3. Importance of NPD tasks 4. Complexity of NPD Tasks
Model 3	1. NPD program performance and importance of NPD tasks as one factor 2. NPD capability 3. Externalization 4. Complexity of NPD Tasks
Model 4	1. NPD program performance and complexity of NPD tasks as one factor 2. NPD capability 3. Externalization 3. Importance of NPD tasks
Model 5	1. NPD Capability and externalization as one factor 2. NPD program Performance 3. Importance of NPD tasks 4. Complexity of NPD Tasks
Model 6	1. NPD capability and importance of NPD tasks as one factor 2. NPD program performance 3. Externalization 4. Complexity of NPD Tasks
Model 7	1. NPD capability and complexity of NPD tasks as one factor 2. NPD program performance 3. Externalization 4. Importance of NPD tasks
Model 8	1. Externalization and importance of NPD tasks as one factor 2. NPD program performance 3. NPD capability 4. Complexity of NPD Tasks

Table 5.2 (continued)

Model	Constructs
Model 9	1. Externalization and complexity of NPD tasks as one factor 2. NPD program performance 3. NPD capability 4. Importance of NPD Tasks
Model 10	1. Importance of NPD tasks and complexity of NPD tasks as one factor 2. NPD program performance 3. NPD capability 4. Externalization

Evidence of discriminant validity existed if the chi-square fit of the five factor model was better than that of the four-, three-, two-, and one-factor models. Table 5.3 shows the comparison of the five-factor model with the ten four-factor models. It was seen that the difference between the five-factor model and any of the four-factor models was significant at 0.01 level. It was concluded that the five-factor model was better than any of the four-factor models. In the same way, the five-factor model was compared with the three-, two-, and one-factor models. The results supported discriminant validity.

Table 5.3: Comparison of Five-Factor Model with Ten Four-Factor Models

Model	Chi-square	Difference with the Five-Factor Model	Significance level
Five-Factor Model	403.56 (d.f.=142)		
Four-Factor Model 1	455.60 (d.f.=146)	52.04 (d.f.=4)	.01
Four-Factor Model 2	454.95 (d.f.= 146)	51.39 (d.f.=4)	.01
Four-Factor Model 3	427.48 (d.f.= 146)	23.92 (d.f.=4)	.01
Four-Factor Model 4	466.61 (d.f.= 146)	63.05 (d.f.=4)	.01
Four-Factor Model 5	440.88 (d.f.= 146)	37.32 (d.f.=4)	.01
Four-Factor Model 6	425.90 (d.f.= 146)	22.34 (d.f.=4)	.01
Four-Factor Model 7	460.38 (d.f.= 146)	56.82 (d.f.=4)	.01
Four-Factor Model 8	427.54 (d.f.= 146)	23.98 (d.f.=4)	.01
Four-Factor Model 9	460.17 (d.f.= 146)	56.61 (d.f.=4)	.01
Four-Factor Model 10	433.31 (d.f.= 146)	29.75 (d.f.=4)	.01

The second approach to test discriminant validity was to examine Phi values as suggested by Anderson and Gerbing (1982) and Gerbing and Anderson (1988). Discriminant validity is supported if intervals of inter-factor correlations (Phi values) did not contain a value of one. Table 5.4 presented the inter-factor correlations. Absolute Phi values ranged from 0.01 to 0.44, and none of the confidence intervals of these estimates contained a value of one ($p<0.01$). Thus, it was concluded that the measurements were appropriate for the study.

Table 5.4: Inter-factor Correlation

	F1	F2	F3	F4	F5
F1	1.00				
F2	.19	1.00			
F3	-.01	.24	1.00		
F4	.44	-.15	-.35	1.00	
F5	-.01	.06	-.03	-.13	1.00

Note: F1: NPD Program Performance
F2: NPD Capability
F3: Externalization
F4: Importance of NPD Tasks
F5: Complexity of NPD Tasks

Hypothesis Testing

Moderated regression analysis was applied to test Hypotheses 1 to 5. The interaction term was used to test the moderating effect of importance of NPD tasks on the relationship between externalization and NPD capability and the relationship between externalization and NPD program performance as suggested by Aiken and West (1991) and Jaccard, Wan, and Turrisi (1990). Significant interactions in the model were examined through simple slope analysis, a technique that overcomes the need to create subgroups from continuous independent variables[1] (Aiken and West 1991).

An important concern in using this approach is the possible multicollinearity between the interaction terms and their components (Jaccard, Turrisi, and Wan 1990). An examination of correlations among independent variables showed that correlations ranged from 0.01 to .79 (see Table 5.5). It was found that the correlation between importance of NPD tasks and the interaction term was 0.79 ($p<0.01$). There was multicollinearity among the independent variables.

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[1] It was predicted that externalizing unimportant tasks had a positive impact on NPD capability and NPD program performance. Externalizing very important tasks had a negative impact on NPD capability and NPD program performance.

If using beta to represent the effect of externalization on NPD capability and NPD program performance, beta would decrease as the importance of NPD tasks increased. Beta would change from positive to negative at certain level of the importance NPD tasks, indicating that externalizing very important NPD tasks would be detrimental to NPD capability and NPD program Performance.

Table 5.5: Correlation Matrix of Factors (not mean-centered variables)

	F1	F2	F3	F4	F3*F4	F5
F1	1.00					
F2	.33	1.00				
F3	.13	.40	1.00			
F4	.27	-.16	-.29	1.00		
F3*F4	.26	-.03	.31	.79	1.00	
F5	-.05	-.06	.01	-.08	-.06	1.00

Note: F1: NPD Program Performance
F2: NPD Capability
F3: Externalization
F4: Importance of NPD Tasks
F3*F4: Interaction Term
F5: Complexity of NPD Tasks

To minimize multicollinearity among the interaction term and its constituent terms in the regression model, a technique suggested by Aiken and West (1991) and Jaccard, Wan, and Turrisi (1990) was employed. The interaction term and its constituent terms (importance of NPD tasks and externalization of NPD tasks) were mean centered (i.e., the mean of each scale was subtracted from each observation) (Aiken and West 1991). In other words, importance of NPD tasks and externalization of NPD tasks were mean-centered. Then the interaction term was created by multiplying the relevant mean-centered scales (i.e., mean-centered importance of NPD tasks and externalization of NPD tasks). The resulting correlation matrix is shown in Table 5.6.

Table 5.6: Correlation Matrix of Mean-Centered Factors

	F1	F2	F3M	F4M	F3M*F4M	F5
F1	1.00					
F2	.33	1.00				
F3M	.13	.40	1.00			
F4M	.27	-.16	-.29	1.00		
F3M*F4M	-.19	-.42	.05	.19	1.00	
F5	-.05	-.06	.01	-.08	.02	1.00

Note: F1: NPD Program Performance (not mean-centered)
F2: NPD Capability (not mean-centered)
F3M: Mean-Centered Externalization
F4M: Mean-Centered Importance of NPD Tasks
F3M*F4M: Interaction Term
F5: Complexity of NPD Tasks (not mean centered)

To check if this was successful, two widely used measures of multicollinearity were employed. The maximum variance inflation factor (VIF) was 1.53, which was well below the level of 10 that commonly signals detrimental multicollinearity. The maximum condition index (MCI) was 2.17, which is below the cutoff of 30 (Mason and Perrault 1991). Multicollinearity thus was not present[2].

[2] VIF and MCI for not mean-centered variables were 16.69 and 35.01 respectively. The mean-center technique was successful

All hypotheses were tested by estimating three regression equations:

(1) $\text{Externalization}_m = \beta_{10} + \beta_{11}\,\text{Importance}_m + \beta_{12}\,\text{Complexity} + \beta_{13}\,\text{Employees} + \beta_{14}\,\text{Sales} + \beta_{15}\,\text{Years} + e_1$

(2) $\text{Capability} = \beta_{20} + \beta_{21}\,\text{Externalization}_m + \beta_{22}\,\text{Externalization}_m * \text{Importance}_m + \beta_{23}\,\text{Importance}_m + \beta_{24}\,\text{Employees} + \beta_{25}\,\text{Sales} + \beta_{26}\,\text{Years} + e_2$

(3) $\text{Performance} = \beta_{30} + \beta_{31}\,\text{Externalization}_m + \beta_{32}\,\text{Externalization}_m * \text{Importance}_m + \beta_{33}\,\text{Importance}_m + \beta_{34}\,\text{Capability} + \beta_{35}\,\text{Employees} + \beta_{36}\,\text{Sales} + \beta_{37}\,\text{Years} + e_3$

Where,

- Externalization_m is mean-centered externalization of NPD tasks. Therefore, Externalization_m = Externalization – mean of Externalization.
- Importance_m is mean-centered importance of NPD tasks. Therefore, Importance_m = Importance – mean of Importance.
- Externalization_m * Importance_m denotes the interaction term between mean-centered Externalization of NPD tasks and mean-centered Importance of NPD tasks.
- Performance is NPD program performance (not mean-centered).
- Capability is the NPD capability (not mean-centered).
- Importance is importance of NPD tasks (not mean-centered).
- Complexity is complexity of NPD tasks (not mean-centered).
- Employees is the number of employees in the organization (not mean-centered).
- Sales is annual sales (not mean-centered).
- Years is the years of organization in business (not mean-centered).

To test if including the interaction term in equations 2 and 3 was appropriate,

Cohen and Cohen (1983) procedure was followed. The independent variables were entered into the model in three steps: (1) control variables, (2) main effects, and (3) interaction term. R-square change in step 2 and step 3 was examined. If the change in R-square was significant, then a significant moderating effect was present.

Table 5.7 shows the R-square changes for equations 2 and 3. It can be seen that in equation 2, when there was no interaction term, R-square was 0.1832. When the interaction term was added to the equation, R-square was 0.3788. F value for the R^2 difference test was 71.16 (degrees of freedom were 1, 226), which was significant at $p<0.01$. In equation 3, when there was no interaction term, R-square was 0.2461. When the interaction term was added to the equation, R-square was 0.2641. F value for the R^2 difference test was 5.50 (degrees of freedom were 1, 225), which was significant at $p<0.05$. Thus, it was concluded that adding the interaction term in equations 2 and 3 was appropriate.

Table 5.7: R^2 Difference Test of Interaction Term

Equation	R^2 of Unmoderated Model[a]	R^2 of Moderated Model[b]	F-Statistic (d.f.)	p-value
2	.1832	.3788	71.16 (1, 226)	<.01
3	.2641	.2461	5.50 (1, 225)	<.05

a: The interaction term was not included in the regression.
b: The interaction term was included in the regression.

After the justification of the interaction term in equations 2 and 3, seemingly unrelated regression was used to test the three equations simultaneously. Since some

variables, such as importance and externalization, were used in more than one equation, statistical estimation of the equations one at a time may lead to biases. Furthermore, externalization was both a dependent and an independent variable in the equations. So was NPD capability. Seemingly unrelated regression can estimate sets of equations that were related theoretically, as are Equations 1-3 (Johnston 1984).

Results

The results of seemingly unrelated regression are presented in Table 5.8. System weighted R-square is 0.2635. Most hypotheses are supported. Below, the test results for each hypothesis are described. In brief, four hypotheses (H1, H3, H4, H5) are supported. One hypothesis (H2) is not supported.

H1 posits that the sign of the relationship between importance of NPD tasks and externalization will be negative. The results in Table 5.8 show that there is a negative and significant effect of importance of NPD tasks on externalization (regression coefficient = -0.21, $t = -4.46$, $p<0.01$). This indicates that the less the importance of NPD tasks, the more the externalization of NPD tasks.

Table 5.8: Results of Seemingly Unrelated Regression Analysis

Variables	DF	Parameter Estimate	t-value	p-value
Equation 1: Dependent Variable—Externalization$_m$				
Intercept	1	.15	.39	n.s.
Importance$_m$	1	-.21	-4.46	< .01
Complexity	1	-.01	-.30	n.s
Employees	1	.07	1.22	n.s
Sales	1	-.06	-.82	n.s
Years	1	.15	.86	n.s
Equation 2: Dependent Variable—NPD Capability				
Intercept	1	3.43	7.70	<.01
Externalization$_m$	1	.65	8.21	<.01
Externalization$_m$ * Importance$_m$	1	-.39	-8.44	<.01
Importance$_m$	1	.05	.84	n.s.
Employees	1	-.03	-1.98	<.05
Sales	1	-.03	-.29	n.s
Years	1	.03	1.73	<.10

Table 5.8 (continued)

Equation 3: Dependent Variable—NPD Program Performance

Variables	DF	Parameter Estimate	t-value	p-value
Intercept	1	2.36	7.71	<.01
NPD Capability	1	.15	3.65	<.01
$Externalization_m$	1	.11	2.02	<.05
$Externalization_m$ * $Importance_m$	1	-.08	-2.35	<.01
$Importance_m$	1	.23	6.33	<.01
Employees	1	.02	1.45	n.s
Sales	1	.04	.62	n.s
Years	1	.03	2.38	<.01

System Weighted R-square=.2635.

Note: n.s.: not significant.

$Externalization_m$ and $Importance_m$ are mean-centered variables.

H2 predicts that the complexity of NPD tasks will be positively related to externalization of NPD tasks. The results in Table 5.8 indicate that there is not a significant relationship between complexity of NPD tasks and externalization of NPD tasks (regression coefficient = -0.01, t = -0.30, not significant).

To further explore the relationship between complexity of NPD tasks and externalization of NPD tasks, Figure 5.2 was analyzed. Complexity of NPD tasks was rescaled into 1, 2, 3: 1 represents low complex NPD tasks; 2 represents complex tasks; and 3 represents high complex tasks. A U-shape relationship between complexity of NPD tasks and externalization of NPD tasks was found. So, the firm externalizes both low and

high complex NPD tasks. Low complex NPD tasks may be of little interest for the firm to develop internally due to little added value to the firm. In the interview, most executives listed unimportant tasks as the industrial standard parts designs and manufacture, which were easily "ordered" from other firms. High complex NPD tasks add more uncertainty to NPD and may be given to firms with more expertise. NPD tasks in between, because they are doable within the firm, may be internalized to fertilize firm core competencies. This interesting finding will be discussed in Chapter 7.

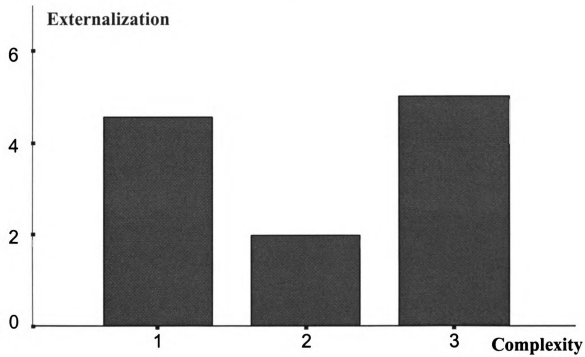

Figure 5.2: Complexity—Externalization Relationship

H3 states that the relationship between externalization and NPD capability decreases from positive to negative as the level of the importance of NPD tasks increases. To examine the moderating effect of importance of NPD tasks on the relationship between externalization and NPD capability, a new coefficient is defined:

$$\beta_c = \beta_{21} + \beta_{22}\ \text{Importance}_m$$

Equation 2 thus can be rearranged as follows:

$$\begin{aligned}\text{Capability} &= \beta_{20} + \beta_{21}\ \text{Externalization}_m + \beta_{22}\ \text{Externalization}_m * \text{Importance}_m \\ &\quad + \beta_{23}\ \text{Importance}_m + \beta_{24}\ \text{Employees} + \beta_{25}\ \text{Sales} + \beta_{26}\ \text{Years} + e_2 \\ &= \beta_{20} + (\beta_{21} + \beta_{22}\ \text{Importance}_m)\ \text{Externalization}_m + \beta_{23}\ \text{Importance}_m \\ &\quad + \beta_{24}\ \text{Employees} + \beta_{25}\ \text{Sales} + \beta_{26}\ \text{Years} + e_2 \\ &= \beta_{20} + \beta_c\ \text{Externalization}_m + \beta_{23}\ \text{Importance}_m + \beta_{24}\ \text{Employees} \\ &\quad + \beta_{25}\ \text{Sales} + \beta_{26}\ \text{Years} + e_2\end{aligned}$$

β_c thus is the effect of externalization of NPD tasks on NPD capability. Pluging in the results in Table 5.8 and substituting the original value of importance of NPD tasks (not mean-centered value),

$$\begin{aligned}\beta_c &= \beta_{21} + \beta_{22}\ \text{Importance}_m = 0.65 - 0.39\ \text{Importance}_m \\ &= 0.65 - 0.39\ (\text{Importance} - \text{Mean of Importance}) \\ &= 0.65 - 0.39\ (\text{Importance} - 3.69) \\ &= 2.09 - 0.39\ \text{Importance}\end{aligned}$$

A series of equations thus can be generated based on different levels of importance of tasks (see also Sethi 2000 and Griffin 1997b for similar reasoning). To illustrate the moderating effect, Figure 5.3 was analyzed based on the above equation. It is clear that the impact of externalization of NPD tasks on NPD capability decreases as the importance of NPD tasks increases. Also, when importance of NPD tasks is greater than 5.36, the impact of externalization of NPD tasks on NPD capability is negative. When importance of NPD tasks is less than 5.36, the impact of externalization of NPD tasks on NPD capability is positive.

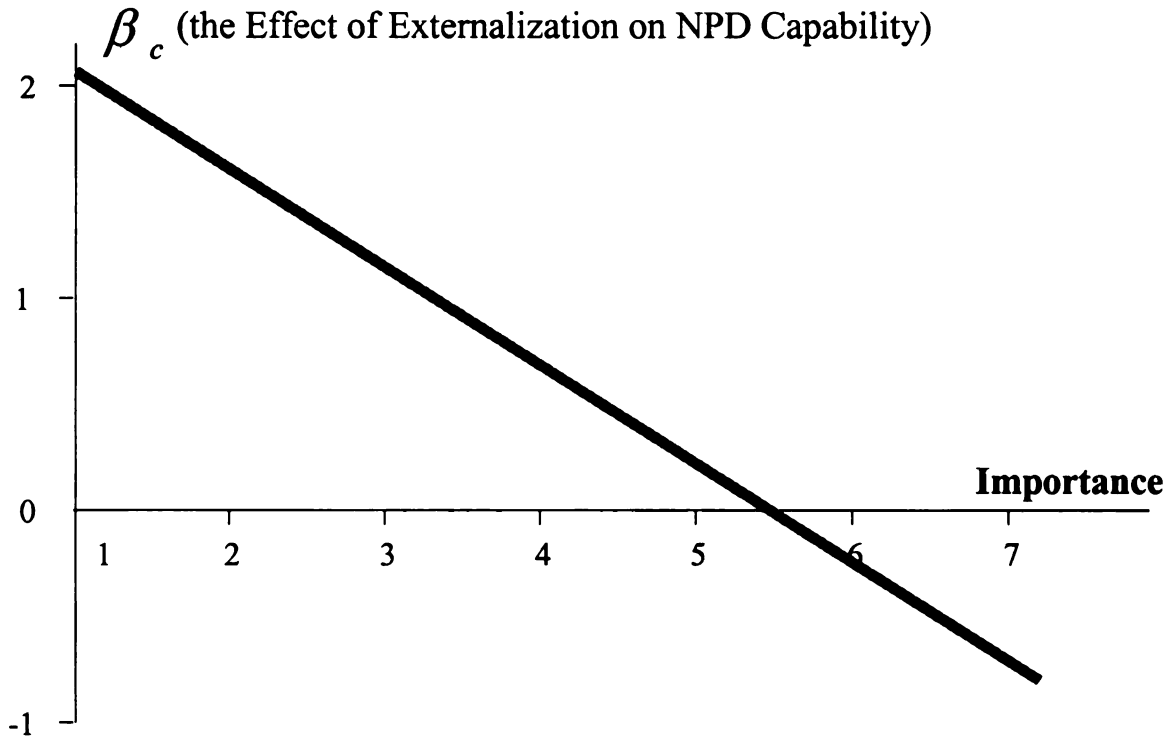

Figure 5.3: Moderating Effect of Importance on Externalization—NPD Capability Relationship

To illustrate clearly the moderating effect of importance of NPD tasks on NPD capability, Figure 5.4 was analyzed. When importance of NPD tasks equals two (unimportant tasks), the relationship between externalization of NPD tasks and NPD capability is positive and significant (regression coefficient = 0.1.17, $p<0.01$). When importance of NPD tasks equals 6.5 (very important tasks), the relationship between externalization of NPD tasks and NPD capability becomes negative and significant (regression coefficient = -0.54, $p<0.01$). This further illustrates that NPD capability will suffer if externalizing very important NPD tasks. However, externalizing unimportant tasks is beneficial to NPD capability.

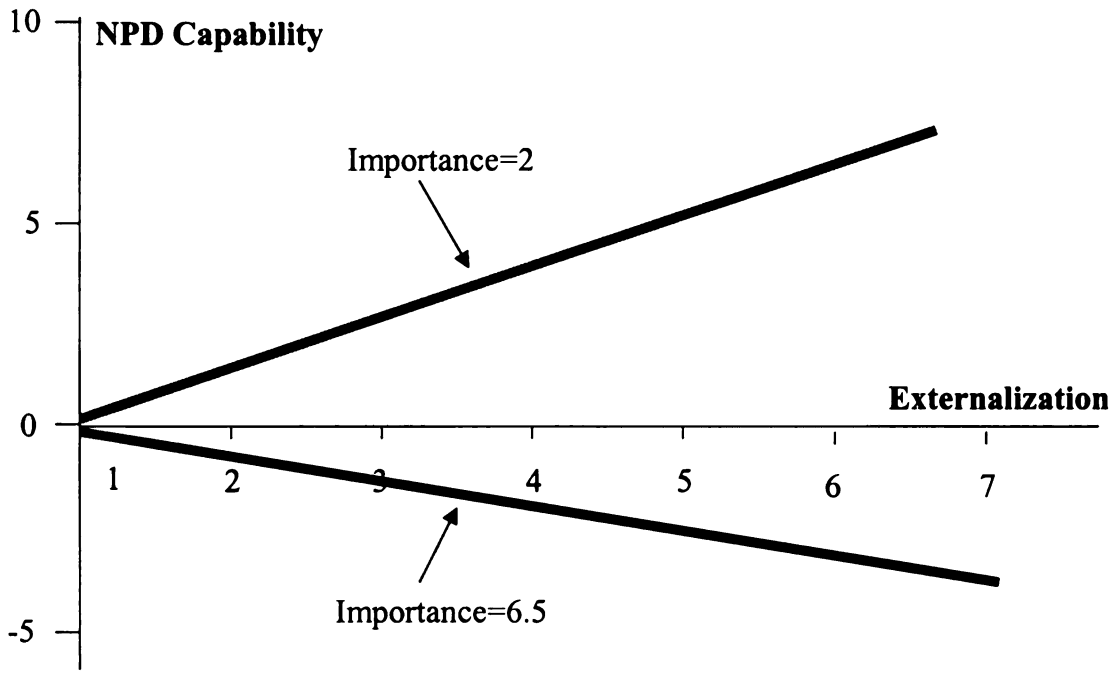

Figure 5.4: Externalization—NPD Capability Relationship

Similarly, according to H4, the relationship between externalization and NPD program performance decreases from positive to negative as the level of the importance of NPD tasks increases. Similar to the testing of H3, a new coefficient is defined:

$$\beta_p = \beta_{31} + \beta_{32}\,\text{Importance}_m$$

Equation 3 thus can be rearranged as follows:

$$\begin{aligned}\text{Performance} &= \beta_{30} + \beta_{31}\,\text{Externalization}_m + \beta_{32}\,\text{Externalization}_m * \text{Importance}_m \\ &\quad + \beta_{33}\,\text{Importance}_m + \beta_{34}\,\text{Complexity} + \beta_{35}\,\text{Employees} \\ &\quad + \beta_{36}\,\text{Sales} + \beta_{37}\,\text{Years} + e_3 \\ &= \beta_{30} + \beta_p\,\text{Externalization}_m + \beta_{33}\,\text{Importance}_m + \beta_{34}\,\text{Complexity} \\ &\quad + \beta_{35}\,\text{Employees} + \beta_{36}\,\text{Sales} + \beta_{37}\,\text{Years} + e_3\end{aligned}$$

β_p thus is the effect of externalization of NPD tasks on NPD program performance. Pluging in the results of Table 5.8 and substituting the original value of importance of NPD tasks (not mean-centered value), the equation is solved for β_p at

different levels of importance of NPD tasks.

$$\beta_p = \beta_{31} + \beta_{32}\,\text{Importance}_m = 0.09 - 0.08\,\text{Importance}_m$$
$$= 0.11 - 0.08\,(\text{Importance} - \text{Mean of Importance})$$
$$= 0.11 - 0.08\,(\text{Importance} - 3.69)$$
$$= 0.41 - 0.08\,\text{Importance}$$

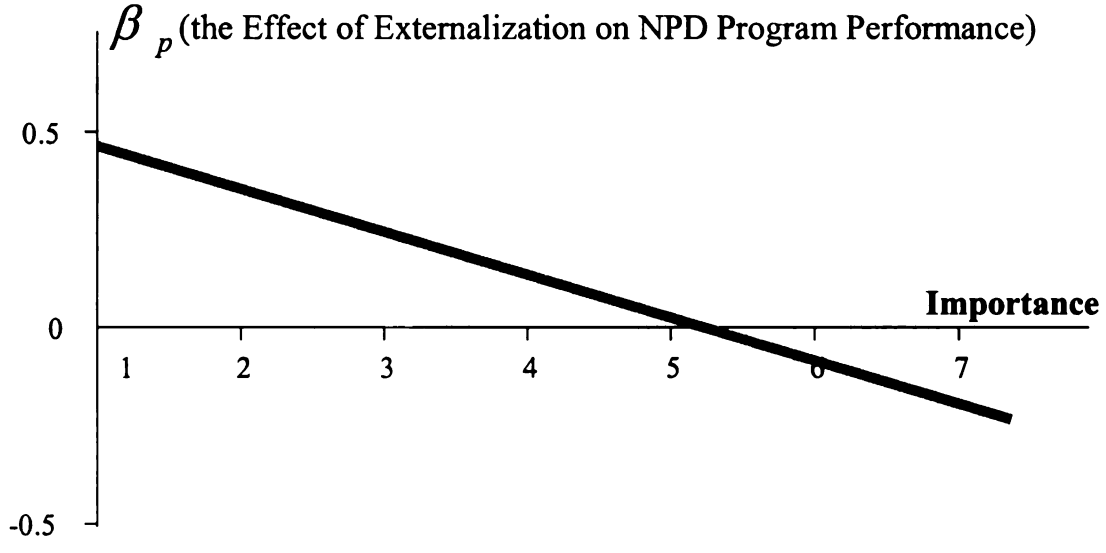

Figure 5.5: Moderating Effect of Importance on Externalization—NPD Program Performance Relationship

This yields a series of equations reflecting the effects of the externalization of NPD tasks under different levels of importance of NPD tasks. To illustrate the moderating effect of the importance of NPD tasks, Figure 5.5 was analyzed based on the above equation. It can be seen that the impact of externalization of NPD tasks on NPD program performance decreases as the importance of NPD tasks increases. When the importance of NPD tasks is greater than 5.13, the impact of externalization of NPD tasks on NPD program performance is negative. When the importance of NPD tasks is less than 5.13, the impact of externalization of NPD tasks on NPD program performance is positive.

Figure 5.6 was created to illustrate clearly the moderating effect of the importance of NPD tasks on NPD program performance. When the importance of NPD tasks equals two (unimportant tasks), the relationship between externalization of NPD tasks and NPD program performance is positive and significant (regression coefficient=0.20, $p<0.01$). When the importance of NPD tasks equals 6.5 (very important tasks), the relationship between externalization of NPD tasks and NPD program performance becomes negative and significant (regression coefficient=-0.16, $p<0.01$). This further illustrates that externalizing very important NPD tasks is detrimental to NPD program performance. However, externalizing unimportant tasks is beneficial to NPD program performance.

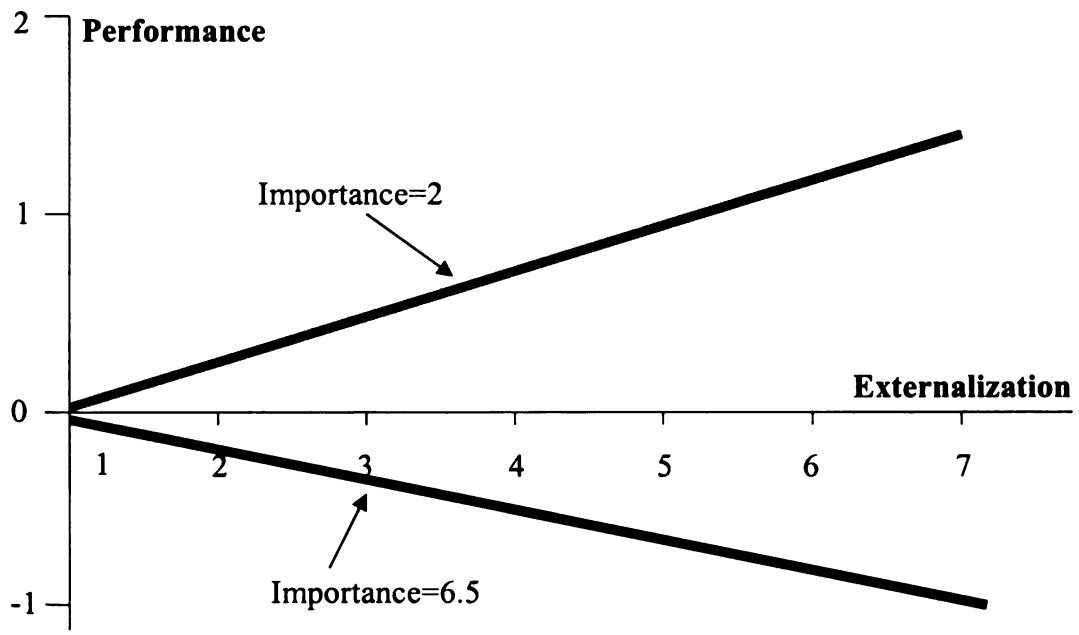

Figure 5.6: Externalization—NPD Program Performance Relationship

Consistent with expectations, NPD capability and NPD program performance are positively related (regression coefficient = 0.15, t = 3.65, $p<0.01$). Thus, NPD capability has a significant and positive impact on NPD program performance. H5 is supported.

As for the control variables, in the first equation, none of the control variables were found to be statistically significant. Firm size and age thus do not affect externalization of NPD tasks.

In the second equation, the number of employees was found to be negatively related to NPD Capability (regression coefficient = -0.03, t = -1.98, $p<0.05$). Thus, large firms (with more employees) tend to have lower NPD capability than small firms (with less employees). Years in business is positively related to NPD capability (regression coefficient = 0.03, t = 1.73, $p<0.1$). Old firms have greater NPD capability than young firms.

In the third equation, years in business is positively related to NPD program performance (regression coefficient = 0.03, t = 2.38, $p<0.01$). Old firms tend to have higher NPD program performance than young firms.

CHAPTER 6

SECOND MODEL TESTING AND RESULTS

In this chapter, the method to test the second model is described. Construct reliability and validity were tested. The second model is tested using structural equation modeling.

Measurement Validation

There were seven constructs in the second model. They were NPD program performance, NPD capability, the level of tacit knowledge obtained, the level of novel knowledge obtained, relationship strength, partner non-redundancy, and collaborative experience.

The Relationship Strength Construct

Relationship strength had four dimensions: frequency of interactions, confidence in one another, desire to maintain the relationship, and bidirectionality. In the analysis, relationship strength was designed as a higher-order construct with four dimensions. To reduce the complexity of the model, the relationship strength scale was aggregated to have four indicators by summing the measurement items of the first-order construct. Before the means were taken, reliability of each indicator was examined. They were acceptable (the reliability for frequency of interactions, confidence in one another, desire to maintain the relationship, and bidirectionality were 0.83, 0.79, 0.69, and 0.75 respectively). CFA was performed to ensure the convergent and discriminant validity.

Table 6.1 displays the results of the second-order confirmatory factor analysis of relationship strength, which posit relationship strength as a latent higher-order construct that is manifested by the four first order factors. The fit indexes were excellent (CFI=1.00; RMSEA=0.01). The standardized loadings of the first order factors on relationship strength were from 0.57 to 0.93, and were all significant at $p<0.01$. In addition, the item loadings on the first order factors were high and significant. It was concluded that second-order scale of relationship strength was adequate for the study.

Table 6.1: Relationship Strength Second-Order Measurement Model

Construct*	Measurement Items	Standardized Loadings**
A: First-Order Loadings		
Frequency of Interactions (0.83)	Interaction frequency.	.79
	We frequently interact with each other in managing the relationship.	.83
	The information sharing between our firm and this partner is prompt.	.76
Confidence in One Another (0.79)	In our relationship this partner cannot be trusted at times.***	.83
	This partner often breaks promises it made to our firm.***	.85
	In the relationship this partner can be counted on to do what is right.	.65
Desire to Maintain the Relationship (0.69)	Maintaining a long-term relationship with this partner is important to our firm.	.64
	We would like to develop a long-term relationship with this partner.	.65
	This partner is crucial for our future performance.	.70
	We would consider more investment in our relationship.	.49
Bidirectionality (0.75)	The extent of two way communications	.82
	There is a lot of two-way communication between our firm and this partner.	.73
	Our firm always responds to communication from this partner firm.	.61
B: Second-Order Loadings		
Relationship Strength (0.75)	Frequency of interactions	.63
	Confidence on one another	.71
	Desire to maintain the relationship	.57
	Bidirectionality	.93
Goodness of fit: χ^2=62.62 (d.f.=61), p=0.42; CFI=1.00; IFI=1.00; NFI=.97; RMSEA=0.01.		

Note: * Reliability of the constructs are in parentheses.
**All loadings were significant at p<.01.
*** Scale was reversed in the analysis.

The Second Model

Measurement validation follows a similar procedure to the first model testing. First, exploratory factor analysis and Chronbach Alpha testing were run on each construct separately. Items with low item-to-total correlations and low loadings were discarded. Second, all constructs were subject to exploratory factor analysis. Items with high cross loadings were eliminated. It was assured that all the items loaded on their theoretically relevant factors.

After the preliminary analyses, all measurements were subject to confirmatory factor analysis (CFA) analysis using LISREL to verify unidimensionality. The generalized least square estimation method was used. In the CFA analysis, items with low item-to-construct and insignificant loadings were discarded. Care was taken to ensure that items loaded on their theoretically relevant constructs.

Fifteen items were dropped in the analysis. For NPD the program performance construct, six of the eight items met the criterion of unidimensionality. Two items were dropped from consideration. Construct reliability is 0.83.

As for NPD capability construct, five of the twelve items met the above criteria. Seven items were deleted. Construct reliability is 0.94.

Five of the six items for the level of tacit knowledge obtained survived after the test. One item was removed. Construct reliability is 0.89.

Four of the seven items for the level of novel knowledge obtained met the criteria. Three items were eliminated. Construct reliability is 0.83.

For relationship strength construct, four items met the criteria. No item was deleted. Construct reliability is 0.87.

Four items for the construct of partner non-redundancy met the criteria. No items were deleted. Construct reliability is 0.85.

With respect to collaborative experience, three of the five items survived after the analysis. Two items were removed. Construct reliability is 0.90.

The CFA results were presented in Table 6.2. The CFA testing resulted in seven constructs (F1 to F7) with 31 measurement items (V1 to V31). It was found that the reliability of five constructs, measured by Chronbach alpha, was from 0.83 to 0.94. These measures were above the traditional coefficient alpha cutoff of 0.70, indicating acceptable inter-item consistency.

The overall measurement model fit was judged to be satisfactory. Bentler and Bonett's Normed Fit Index (NFI) and Bender's Comparative Fit Index (CFI) were all above the desired minimum acceptable 0.90 level (Hair et al.1995; Byrne, 1994). RMSEA is 0.049, indicating good fit. Examining item-to-construct loadings, they ranged from 0.51 to 0.95. The loadings were all significant at $p<0.01$. Convergent validity was supported.

Similar to the first model testing, discriminant validity was tested by two approaches. The first approaches is to conduct a series of chi-square difference tests of one-, two-, three-, four-, five-, six-, and seven-factor models. In each six-factor model, one pair of factors was combined into one factor. Thus, there were 21 six-factor models (represented by 21 combinations of the measures). The five-, four, three-, two-, and one-factor models were the combinations of three factors, four factors, five factors, six factors, and seven factors into one factor respectively.

Table 6.2: Results of Confirmatory Factor Analysis

Construct	Measurement Items	Standardized Loadings[a]	Cronbach Alpha
F1: NPD Program Performance	V1: Pretax profit margin	.88	.83
	V2: Market share	.84	
	V3: Overall, how satisfied were you with this new product development program.	.80	
	V4: Sales, relative to objective	.73	
	V5: ROA, relative to objective	.68	
	V6: ROI, relative to objective	.71	
F2: NPD Capability	V7: In a new product or service introduction, how often is your firm the first to market?	.94	.94
	V8: Our new product introductions have increased over the last five years.	.93	
	V9: We have a strong capability in penetrating new markets.	.84	
	V10: We have a strong capability in responding to unique requirements of different markets.	.82	
	V11: We have a strong capability in introducing new products simultaneously into several markets.	.77	
F3: Tacit Knowledge	V12: A useful manual describing this knowledge can be written.*	.59	.89
	V13: Extensive documentation describing critical parts of the knowledge exists in our firm.*	.95	
	V14: The knowledge we received from this partner is quite complex.	.65	
	V15: The knowledge could be easily understood from written documents.*	.76	
	V16: The knowledge could be easily communicated through written documents.*	.63	

Table 6.2 (Continued)

Construct	Measurement Items	Standardized Loadings[a]	Cronbach Alpha
F4: Novel Knowledge	V17: Please rate the knowledge acquired from this partner firm on "familiar—unfamiliar" (familiar is 1; unfamiliar is 7).	.94	.83
	V18: Please rate the knowledge acquired from this partner firm on " Previously known—previously unknown" (previously known is 1; previously unknown is 7).	.88	
	V19: The knowledge we acquired from this partner was totally new to us.	.80	
	V20: We had never used this kind of knowledge before.	.51	
F5: Relationship Strength	V21: Frequency of interactions	.90	.87
	V22: Confidence in one another	.70	
	V23: Desire to maintain the relationship	.89	
	V24: Bidirectionality	.86	
F6: Non-Redundancy	V25: Technical competencies	.79	.85
	V26: Market served	.87	
	V27: Industry events attended	.85	
	V28: Competitive strategies	.85	
F7: Collaborative Experience	V29: Overall, our collaboration with other firms in new product development has been a success.	.80	.90
	V30: Firm sales and profits have benefited from collaborating with other firms in new product development	.92	
	V31: Our track record on collaboration has been poor.*	.74	
Fit Indexes: χ^2 =641.72 (d.f. = 413); CFI=1.00; IFI=1.00; NFI=.99; RMSEA=.049.			

[a] All loadings are significant at p<.01.

* Scale was reversed in the analysis.

Chi-square difference tests showed that the seven-factor model was better than six-, five-, four-, three-, two-, and one-factor models. The difference between the seven-factor model and each of the six-, five-, four-, three-, two-, and one-factor models was significant at 0.01 level. It was concluded that the seven-factor model was better than any of the six-, five-, four-, three-, two-, and one-factor models. Discriminant validity was supported.

Discriminant validity is also supported if intervals of inter-factor correlations (Phi values) do not contain a value of one. Table 6.3 presents the inter-factor correlations. Absolute Phi values ranged from 0.01 to 0.57, and none of the confidence intervals of these estimates contained a value of one ($p<0.01$). Thus, it was concluded that the measurements were adequate.

Table 6.3: Inter-Factor Correlation

	F1	F2	F3	F4	F5	F6	F7
F1	1.00						
F2	.34	1.00					
F3	.11	.26	1.00				
F4	-.12	.11	-.11	1.00			
F5	-.02	-.04	.31	-.18	1.00		
F6	-.01	-.13	-.12	.01	-.04	1.00	
F7	.09	.57	.10	.13	-.17	.04	1.00

Note: F1: NPD program performance
F2: NPD capability
F3: The level of tacit knowledge obtained
F4: The level of novel knowledge obtained
F5: Relationship strength
F6: Non-redundancy
F7: Collaborative experience

Hypothesis Testing

The model in Figure 3.1 was tested using structural equation modeling. The path model is presented in Figure 6.1. The covariance matrix was as the input. The results of structural analysis are presented in Table 6.4. Examination of the overall fit measures indicated a good fit of the model to the data (CFI = 1.00; NFI = 0.99; chi-square = 570.36, d.f. = 343; RMSEA=0.053).

Table 6.4: Results of Path Analysis

Path	Hypotheses	Results
β_{12}: NPD Capability → NPD Program Performance	$\beta_{12}>0$	.23* (p<.01)
β_{23}: Tacit Knowledge → NPD Capability	$\beta_{23}>0$	.36* (p<.05)
β_{24}: Novel Knowledge → NPD Capability	$\beta_{24}>0$	.11* (p<.10)
γ_{31}: Relationship Strength → Tacit Knowledge	$\gamma_{31}>0$	.17* (p<.01)
γ_{41}: Relationship Strength → Novel Knowledge	$\gamma_{41}<0$	-.22* (p<.01)
γ_{42}: Non-Redundancy → Novel Knowledge	$\gamma_{42}>0$	Not Significant**

Fit Indexes: χ^2 =570.36 (d.f.=343); NFI=.99; CFI=1.00; IFI=1.00; RMSEA=.053.

*: Hypothesis is supported.

**: Hypothesis is not supported.

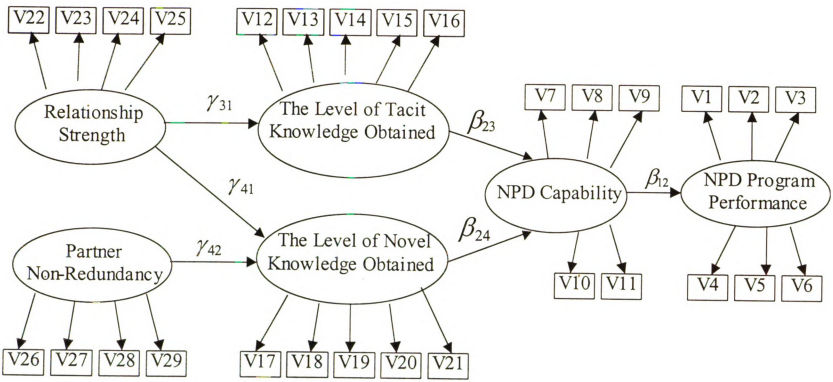

Figure 6.1: The Path Model

H6 proposes that the stronger the relationship between the firm and a partner firm, the higher the level of tacit knowledge obtained from the partner firm. In Table 6.4, the parameter estimate is 0.17 ($p<0.01$). This hypothesis is, therefore, strongly supported.

H7 states that the stronger the relationship strength between the firm and a partner firm, the lower the level of novel knowledge obtained from the partner firm. The parameter estimate is -0.22 ($p<0.01$). There is a negative relationship between relationship strength and the level of novel knowledge obtained. The hypothesis is supported.

H8 asserts that the greater the partner non-redundancy, the higher the level of novel knowledge obtained from the partner firm. The parameter estimate for the hypothesis is not significant. There is no relationship between partner non-redundancy and the level of novel knowledge obtained. The hypothesis is not supported.

H9 suggests that the higher the level of tacit knowledge obtained, the higher the firm NPD capability. The parameter estimate of the hypothesis is 0.36 ($p<0.05$). There is a positive relationship between the level of tacit knowledge obtained and NPD capability. The hypothesis is supported.

H10 indicates that the higher the level of novel knowledge obtained, the higher the firm NPD capability. The parameter estimate is 0.11 ($p<0.10$). The hypothesis is supported. There is a positive relationship between the level of novel knowledge obtained and the NPD capability.

Table 6.4 shows that there is a positive relationship between NPD capability and NPD program performance (parameter estimate = 0.23, $p<0.01$). This is consistent with

the results of the first model, in which the NPD capability is hypothesized to influence NPD program performance positively.

Testing the Moderating Effect

To evaluate the moderating effect of collaborative experience, the sample was split into two groups based on the mean of collaborative experience. The data above the mean were classified as high collaborative experience, and data below the mean as low collaborative experience. A two-group LISREL model was conducted to examine whether or not there was any significant difference in structural parameters between the high collaborative experience and the low collaborative experience groups.

Before conducting the two-group comparison, the two data sets were examined for metric unidimensionality following the same procedures as for the whole model. Reliability, convergent validity, and discriminant validity were at acceptable levels.

For the first analysis, the two-group model was estimated with all parameters unconstrained (freed). This model was the base for all of the comparisons. A parameter would be constrained to be equal when examining the moderating impact of collaborative experience on the relevant relationship. A significant chi-square difference between constrained and unconstrained models indicated a difference in the relationships for the high collaborative experience versus the low collaborative experience. In the testing, the parameters of the relationship between relationship strength and the level of tacit knowledge obtained, the relationship between relationship strength and the level of novel knowledge obtained, and the relationship between partner non-redundancy and the level of novel knowledge obtained were constrained to be equal, each in three separate models.

These models were compared with the unconstrained model. The results of the comparisons are shown in Table 6.5.

Table 6.5: The Results of Two-Group Comparisons

Path	Results of Multi-Group Comparison		χ^2 Difference	Conclusion
	High Experience	Low Experience		
γ_{31} : Relationship Strength → Tacit Knowledge	.10 (p<.10)	.23 (p<.05)	34.01; d.f.=1 (p<.01)	Hypothesis is not supported
γ_{41} : Relationship Strength → Novel Knowledge	-.34 (p<.10)	n.s.	50.37; d.f.=1 (p<.01)	Hypothesis is supported
γ_{42} : Non-Redundancy → Novel Knowledge	.31 (p<.10)	n.s.	1800.16; d.f.=1 (p<.01)	Hypothesis is supported

n.s.: not significant.

For the relationship between relationship strength and the level of tacit knowledge obtained, the constrained model produced chi-square = 889.40 (d.f. = 687). This model was compared with the unconstrained model (chi-square = 855.39, d.f. =686). Table 6.5 shows that the difference of the two models is 34.01 with degrees of freedom of 1 (significant at $p<0.01$). The value of the parameter estimate in the high collaborative experience group is 0.10 ($p<0.10$) and the value of the low collaborative experience group is 0.23 ($p<0.05$), which contradicts H11. The results suggest that the firm with low collaborative experience gets more tacit knowledge than the firm with high collaborative experience. This surprising finding will be discussed in Chapter 7.

When constraining the relationship between relationship strength and the level of novel knowledge obtained, the model produced chi-square = 905.76, d.f. = 687. Table 6.5

denotes that the difference between constrained and unconstrained models is significant (chi-square difference = 50.37, d.f.=1; $p<0.01$), indicating that collaborative experience moderates the relationship between relationship strength and the level of novel knowledge obtained. The values of the parameter estimates are consistent with the hypothesis (-0.34 for high collaborative experience, significant at $p<0.10$; and not significant for low collaborative experience). This implies that firms with high collaborative experience get more novel knowledge from weak relationships than firms with low collaborative experience. Hypothesis 12 is supported.

For the relationship between partner non-redundancy and the level of novel knowledge obtained, the constrained model generated chi-square of 2655.55 with degrees of freedom 687. Table 6.5 shows that the chi-square difference is 1800.16 and d.f. = 1 (significant at $p<0.01$). The parameter estimate for the high collaborative experience group is 0.31 ($p<0.10$). The parameter estimate for the low experience group is not significant. Thus, hypothesis 13 is supported. It is noted that in the full model, the relationship between non-redundancy and the level of novel knowledge obtained is not significant (see Table 6.4). The relationship is significant for the firm with high collaborative experience however. This interesting finding will be addressed in Chapter 7.

CHAPTER 7

DISCUSSION AND CONCLUSION

This chapter discusses the implications of the analyses presented in Chapter 5 and Chapter 6. The chapter begins with a summary of the findings from the two studies. The contribution to theory and research, as well as implications for managers, are then given. Finally, limitations and future research directions are discussed.

Summary

This dissertation addresses a paradigm shift in new product development, that is, the paradigm shift from do-it-all (football shaped NPD) to share-the-burden (barbell shaped NPD). Two models are tested. The first model studies how to externalize NPD tasks and how externalization impacts both NPD capability and NPD program performance. The second model focuses mainly on how to get knowledge (both tacit and novel) from partner firms to enhance both NPD capability and NPD program performance.

The First Model

The first model is developed based on the principles of internalization theory and the resource-based view of the firm, as well as on the NPD literature. It is hypothesized that the firm will externalize unimportant and complex NPD tasks. These hypotheses are based on the special requirements in NPD related to time, cost, and quality. It is also hypothesized that externalizing unimportant NPD tasks is beneficial to both NPD capability and NPD program performance, while externalizing very important tasks is

detrimental to both NPD capability and NPD program performance. These arguments are based on the principle that the firm should always protect and strengthen core competencies. Firm NPD capability is hypothesized to positively influence NPD program performance.

Data were collected from U.S. high-tech firms through a questionnaire survey. The sample represented a wide variety of industries, including chemical, mechanical, electronics, aircraft, instrument, and computer software. The respondents were executives in charge of NPD, such as vice presidents of R&D or engineering. This ensured that the respondents provide accurate information on the management of firm NPD program and firm level operations.

The above hypotheses were tested through a series of regressions. The results support hypothesis 1—the greater the importance of NPD tasks, the less the extent of externalization. The result is consistent with the principles of internalization theory and the resource-based view of the firm. That is, when NPD tasks are very important for customer value creation and for building and strengthening firm core competencies, the firm is likely to internalize these tasks. The firm can thus establish the core competencies by focusing on the key technologies and then take advantage of superior competitive position in the marketplace.

The results are consistent with previous studies on small technology based firms (Kurokawa 1997) and firms in pharmaceutical industry (Pisano 1990). Executives interviewed during the study also support the notion of externalizing non-core tasks to increase R&D department focus. The R&D department can act more strategically to deal with the unstable market.

The data do not support hypothesis 2—the greater the complexity of NPD tasks, the greater the extent of externalization. Further analysis found a U-shape relationship between complexity of NPD tasks and the extent of externalization. The firm externalizes low and high complex NPD tasks and internalizes the middle.

Externalizing highly complex tasks is consistent with the principle of internalization theory and the resource-based view of the firm. First, there is a cost analysis in the decision-making. Highly complex NPD tasks may require the firm to invest greatly to perform these tasks. Thus, the firm choose to externalize these tasks enhance the efficiency of NPD. Second, the time pressure does not allow the firm to internalize these complex tasks. For firms in a highly competitive environment, the need for investment in the NPD process and the time pressure would be the dominant factors in decision-making.

Surprisingly, it is found that the firm externalizes low complex tasks. One explanation would be the value-adding perspective in NPD. The firm should invest heavily only in its core competencies and wherever it sees a unique opportunity for adding value. Quinn and Hilmer (1994) pointed out that the firm should select and perform activities that will create unique value and competitive edge. As the firm focuses on value-adding tasks in NPD, it is willing to externalize more routine, low value-added research and technical activities. In other words, the firm would externalize low complex NPD tasks. The tasks in the middle are likely to have the great value-creation potential. This deserves the systematic examination in future research.

The results support the moderating effect of the importance of NPD tasks on the relationship between externalization and NPD capability. In particular, evidence is found

that the relationship between externalization and NPD capability decreases from positive to negative as the level of the importance of NPD tasks increases. In other words, externalizing unimportant NPD tasks contributes to NPD capability. Externalizing very important NPD tasks weakens NPD capability.

Hypothesis 4 is supported by the data. According to hypothesis 4, the relationship between externalization and NPD program performance decreases from positive to negative as the level of the importance of NPD tasks increases. Externalizing unimportant NPD tasks enables the firm to reduce cost, increase speed, and improve the quality of new product development. Externalizing very important NPD tasks may result in the loss of the identity of the firm in the marketplace, leading to poor NPD program performance.

This result suggests that when making externalization or internalization decisions, assessing the importance of NPD tasks is vital. Externalizing unimportant NPD tasks allows the firm to have a more focused strategy and frees limited resources for more value-added and/or strategic applications, thus strengthening NPD capability. Externalizing NPD tasks that are closely related to firm core competencies and/or to customer value creation would run the risk of losing firm core competencies. NPD managers must be aware that core competencies are the base for firm survival. Satisfying customers is the ultimate goal of NPD. NPD tasks that are related to firm core competencies and customer satisfaction should be under the firm's control. It is also noted that the purpose of externalizing NPD tasks is better utilization of firm internal resources and capabilities.

One danger of externalization is the loss of firm core competencies. For example, other firms may imitate the firm's key technology and compete with the firm. Eventually,

the firm may lose core competencies and be in a difficult situation in the marketplace. This is consistent with the opinion of interviewees. Many executives hold that an externalization strategy enables the firm to free some resources and capabilities to work on more value-added technology. At the same time, they warned that the firm NPD capability and performance might suffer if it forgot to protect core competencies.

Consistent with the NPD literature, NPD capability positively influences NPD program performance. NPD capability is the base for firm to develop competitive products. Griffin (1997a, 1997b) and Li and Calantone (1998) stress the product competitive advantage in the marketplace. This requires the firm to have high NPD capability and develop products effectively and efficiently. Furthermore, only with a super NPD capability can the firm deal with changing customer tastes and develop products customers want.

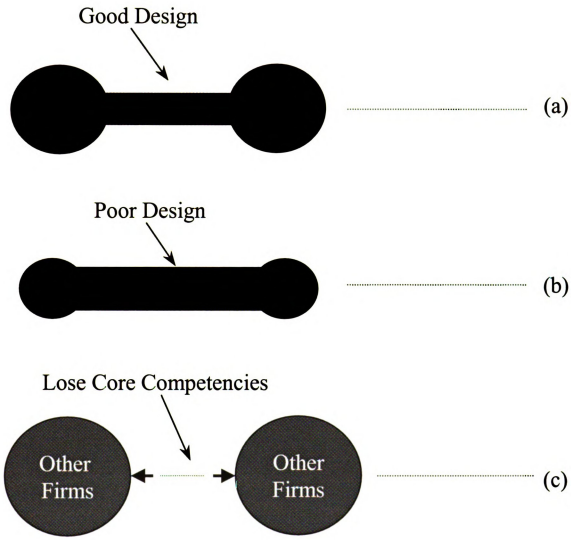

Figure 7.1: Three Types of Barbell Design

Figure 7.1 illustrates the importance of externalization. Scenario (a) is the ideal barbell design, in which the firm has strong internal capability. At the same time, the firm uses external resources and capabilities to the greatest extent. Scenario (b) is a poor design. Even though the firm possesses strong internal capability, it does not effectively mobilize external factors. Scenario (c) is the worst case, in which the firm loses

everything because of too much externalization. Once again, protecting and strengthening the core competencies during the externalization is emphasized.

The Second Model

The second model is built mainly on the principle of internalization, i.e., leveraging internal capabilities (strengthening the "bar" of the barbell). Internalization theory advises to internalize critical NPD tasks. The resource-based view of the firm recommends continuously enhancing internal capability. How to get knowledge from other firms in order to improve firm NPD capability is the main theme in the second model, as the resource-based view of the firm explicitly underscores that knowledge is a critical source for competitive advantage. It is proposed that relationship strength positively influences the level of tacit knowledge obtained and negatively affects the level of novel knowledge obtained. It is also hypothesized that partner non-redundancy positively affects the level of novel knowledge obtained. The level of both tacit knowledge and novel knowledge obtained positively influences firm NPD capability, which in turn affects firm NPD program performance. These theoretical predictions were tested using structural equation modeling.

The results support hypothesis 6. Relationship strength is positively related to the level of tacit knowledge obtained from the partner firm. Tacit knowledge transfer requires in-depth, frequent, two-way interactions, which is the characteristic of strong relationships. It is noted that tacit knowledge is not likely to be transferred completely from one firm to the other. The transferring of tacit knowledge is a cumulative process. The stronger the relationships, the more likely the firm is to get higher level of tacit knowledge.

Hypothesis 7 is supported by the data. Relationship strength is negatively related to the level of novel knowledge obtained. NPD requires innovative ideas and new knowledge. One disadvantage of strong relationships is the difficulty of obtaining new knowledge from partners. This study suggests that new knowledge is more likely to be found in firms not closely related.

Uzzi (1996) stresses the value of both strong and weak ties to competitive advantage. Different ties have different roles. The optimal network structure is composed of a few strong ties and many (large number of) weak ties. Obtaining tacit knowledge from strong ties is more efficient because it requires repeated transactions. Obtaining novel knowledge is more efficient from a large number of weak ties.

Surprisingly, partner non-redundancy is not correlated with the level of novel knowledge obtained. Hypothesis 8 is not supported. . In the two-group analysis, a positive relationship is found in firms with high collaborative experience, but only significant at a marginal level ($p=0.1$). Redundant partners are those closely related to other firms in the network. It is likely that managing similar partners is easier than dealing with a wide diversity of firms in the network. Processing information from wide variety of firms takes time and requires more experience. It is likely that valuable, novel knowledge is ignored due to too many distractions. This finding, however, cannot lead to the conclusion that more redundant partners are better in the network. Bartunek and Moch (1987) find that the firm is not willing to accept new knowledge or make change unless organizational members experience a crisis or to perceive that their existing schema is inadequate. Managing a wide diversity of firms in the network is a challenge for marketing managers. It is suggested that the firm develop efficient mechanism to manage external knowledge.

The levels of both tacit knowledge and novel knowledge obtained are positively related to NPD capability, supporting Hypotheses 9 and 10. This finding is consistent with the resource-based view of the firm, which continuously stresses the role of knowledge in firm NPD. Liebeskink (1996) states that the efficient way to protect valuable knowledge is to obtain knowledge from outside firms. Rokeach and Grube (1979) also note that the firm that obtains knowledge from partner firms is more active than the firm that creates knowledge relying on its own. As NPD becomes more complex and requires knowledge the firm does not have, obtaining knowledge from other firms become critical.

The firm with high collaborative experience gets less tacit knowledge from strong relationships than the firm with low collaborative experience. This contradicts Hypothesis 11. One explanation is the rigidity of decision making of the firm with high collaborative experience. Simonin (1997) points out that previous collaborative experience alone does not ensure that a firm will benefit from a collaboration. Staw (1981) suggests that prior experience may also induce rigid decision behaviors, or a tendency to process information in an automatic, habitual manner. The experienced firm, for example, is likely to acquire only the type of information with which it is familiar, which may result in judgment bias. Staw (1991) warns about the problems of belief structure rigidity and other related constructs, such as selective perception, perceptual screens, and escalation of commitment. The firm with low collaborative experience is likely to be that newly emerged in the market place. It is active, eager to learn, and follows the formal rule of knowledge acquisition, resulting in more tacit knowledge transfer.

The firm with high collaborative experience gets more novel knowledge from

weak relationships and from non-redundant partners, supporting hypotheses 12 and 13. Collaborative experience is important for obtaining novel knowledge. Both relationship strength and partner non-redundancy have a positive effect on the level of novel knowledge obtained for the firm with high collaborative experience. For the firm with low collaborative experience, these two relationships are not significant. Powell, Koput, and Smith-Doerr (1996) argue that collaborative experience is necessary to access new, diverse information. On the one hand, the firm with low collaborative experience is likely to have a smaller number of firms in the network. On the other hand, the firm with low collaborative experience lacks the capability to manage a diverse portfolio of ties, leading to the insignificant impact of relationship strength and partner non-redundancy on the level of novel knowledge obtained.

Contributions to Theory and Research

To the NPD Literature

Research on NPD is criticized as being "atheoretical", which inhibits the full understanding and explanation of NPD activities (Brown and Eisenhardt 1995). Montoya-Weiss and Calantone (1994) call for the integration of NPD literature using a theoretical framework. This study is a valuable attempt to fill this gap to frame NPD problems by expanding the vision of internalization theory and the resource-based view of the firm.

The rationales of internalization theory and the resource-based view of the firm fit excellently with the present research question. When considering the externalization problem, internalization theory advises to externalize unimportant tasks and internalize critical ones. The research-based view of the firm advocates internalizing tasks that are closely related to firm core competencies or customer value creation.

The resource-based view of the firm proposes to get knowledge from partner firms in order to enhance NPD capability. Both tacit knowledge and novel knowledge contribute to NPD capability development. Expanding on the work of Hansen (1999), this study suggests getting tacit knowledge from strong relationships and novel knowledge from weak relationships.

This study also advocates mobilizing both internal and external resources and capability to develop NPD capability and to improve NPD program performance by applying the most recently developed resource-based view of the firm. The internalization principle specifies the leverage of internal resources and capabilities, i.e., the best utilization of internal factors. The externalization principle indicates the leverage of external resources and capabilities, i.e., to mobilize external resources and capabilities to the greatest extent in NPD.

The study is driven by an interest in understanding how to strategically manage a portfolio of NPD tasks. A review of the literature revealed that little attention was given by scholars on the three research questions raised in Chapter One. A large scale empirical study has been lacking. In the present case, a conceptual model was developed based on internalization theory and the resource-based view of the firm. A set of hypotheses was tested with data from survey research involving R&D managers across a range of U.S. industries.

This is the first study to clearly address the paradigm shift from barbell to football, i.e., from do-it-all to share-the-burden. Research on this issue is imperative as the competition in the marketplace becomes increasingly brutal. It is hoped that this study

will begin a research stream that systematically examine the strategic management of NPD.

To Internalization Theory and Resource-based View of the Firm

This study also contributes to the development of internalization theory and the resource-based view of the firm in the NPD domain. This study is the first attempt to test the principle of externalization theory in NPD. Constructs of internalization theory were operationalized. Firm core competencies and customer value creation were identified as critical for firm success. Measures based on both theories were developed in the NPD context.

Implications for Managers

The study answers the managerial question of how to strategically manage a portfolio of NPD tasks to speed up product development, to increase quality, and to decrease cost. It provides some guidelines to managers for deciding what kinds of NPD tasks should be performed in-house and what kinds of NPD tasks should be given to other firms. Significant negative relationship between externalization and NPD capability, as well as between externalization and NPD program performance warns NPD managers to protect core competencies in strategic decision-making.

The findings on the relationship between the complexity of NPD tasks and externalization of NPD tasks suggest that the firm is likely to externalize both low and high complex NPD tasks. On the one hand, low complex tasks are usually industrial standard designs, which add little value to the firm. One the other hand, high complex NPD tasks need great investment if the firm wants to develop them in-house. Externalizing both low and high complex NPD tasks is likely to be the best choice.

Both tacit knowledge and novel knowledge are critical for the development of firm NPD capability. This study tells managers that tacit knowledge, which usually is uncoded, is more likely to be transferred between firms in strong relationships. Novel knowledge, however, is likely to be found in the firm not closely related.

The externalization dilemma—to internalize or to externalize—is of central importance. While cost is always important in any business decision, managers should consider strategic issues in conjunction with financial issues. Companies that continue to make decisions based solely on cost will eventually wither and die, as many already have.

Limitations and Future Research Directions

First, this study lacks a dynamic dimension in the model. It is recommended that longitudinal data be collected to study how externalization affects firm long-term performance.

Second, this study focuses on high-tech industries, which are in a highly competitive environment. The story may differ in other industries. In a highly competitive environment, the speed in NPD development weighs high in strategic decision-making. For firms in a relatively low competitive environment, the cost of NPD may be the major consideration. Data should be collected in other industries to test the model.

Third, externalization may take different forms such as strategic alliances or market-based transactions. Strategic alliance may desirable if the tasks are important for core competencies and include frequent transactions. For NPD tasks that are unimportant for core competencies and involve few transactions, a traditional market-based

relationship is recommended. The use of different organizational forms to manage externalization is an important area for future research.

Future research could also explore other ways to leverage external resources and capabilities, such as external acquisition, strategic alliance, supplier integration, and customer involvement in NPD.

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