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ENHANCING INNOVATION CAPABILITY THROUGH SUCCESSFUL INTER-FIRM COLLABORATIONS: TWO ESSAYS ON R&D ALLIANCES

By

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ABSTRACT

ENHANCING INNOVATION CAPABILITY THROUGH SUCCESSFUL INTER-FIRM COLLABORATIONS: TWO ESSAYS ON R&D ALLIANCES

By

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Innovation capability plays a critical role in establishing a firm's competitive advantage. With fast changing technologies and soaring costs, R&D alliances have become an important tool for firms to effectively conduct their new product development activities. Most research in this area has focused on inter-firm agreements in isolation, with a special emphasis on understanding dyadic information transfer and coordination. This two-essay dissertation addresses the R&D alliance issues from a portfolio approach by examining firms' whole inventory of alliance activities. We argue that the sustainability of a firm's competitive advantage comes primarily from the successful configuration of its R&D alliance portfolio more so than from the successful management of any particular R&D alliance project.

Essay One seeks to answer the research question: how do different characteristics of a firm's R&D alliance portfolio affect its ability to acquire external knowledge which in turn influences its innovation outcomes. A set of characteristics of R&D alliance portfolio are identified from both management and marketing literatures (vertical alliances vs. horizontal alliances, repeated partnering, multiple-partner alliances, multiple-technology alliances, and partner dispersion). Arguments are made that these characteristics influence both the number of knowledge domains (knowledge breadth) and the intensity of knowledge sharing between alliance partners in any particular area (knowledge depth).

While literature suggests both knowledge breadth and knowledge depth are positively associated with a firm's innovation output, a further argument is made in terms of the differential impacts of knowledge breadth and knowledge depth on radical innovation and incremental innovation. We hypothesize that radical innovations are impacted more by the diversity and novelty of incoming knowledge than by its quantity while incremental innovations are impacted more by the relatedness and quantity of the incoming information than by its novelty or newness.

Essay Two explores the form of the relationship between the number of a firm's R&D alliances and its innovation output. Past literature has normally hypothesized either a linear positive or inverse U-shaped relationship. We theoretically argue, from organizational learning and integrative capability perspectives, that the relationship should be inverse S-shaped. Our empirical test using data from the pharmaceutical industry supports our hypotheses.

To

My parents, my wife, and my daughter

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 The Importance of R&D Alliances

New product development plays a critical role in establishing a firm's competitive advantage in the market place. Successful new products often incorporate the most recent development in technologies and thus offer superior customer benefits than existing products in the market. As such, new products act as important engines for economic growth (2003) as well as provide an important source of sales, profits and competitive strength for organizations (Sivadas and Dwyer 2000). It is estimated that over forty percent of the sales for most large organizations come from products introduced in the past five years (Schmidt and Calantone 2002) and new products provide about one-third of the profits for Fortune 1000 companies (Booz and Hamilton 1982; Sivadas and Dwyer 2000). As a result, organizations devote considerable amount of resources to new product development realizing that their survival in the market depends on their ability to continuously introduce new products that meet customer needs over time (Dougherty and Hardy 1996; Nerkar and Roberts 2004).

However, most firms are finding it increasingly difficult to develop new products purely internally (Sivadas and Dwyer 2000; Wind and Mahajan 1997). First of all, new product development is a highly demanding endeavor in terms of both financial and human capital resources. Firms need to make huge resource commitment upfront without the guarantee that a successful new product will be developed. It is estimated that the average cost of developing a new drug in the United States is over 800 million dollars and this figure is increasing by over 10 percent annually (GAO 2006). With an investment this big, firms are not guaranteed any conceivable result for commercialization. In fact, it is estimated that over forty percent of new product development projects fail to come up with anything new (Schmidt and Calantone 2002). As such, firms with financial constraints may find it difficult to initiate new product development projects all by itself. Secondly, the risk associated with new products extends beyond the development stage. Only half of the introduced new products will survive the market test during commercialization (Page 1993; Schmidt and Calantone 2002; Zirger and Maidique 1990). As such, firms face considerable risk in their new product development endeavors.

However, the most important reason firms cannot take on new product development activities all by themselves may have something to do with the changing competitive environment in the market place. In order to develop a truly innovative product, firms need to pool knowledge from different areas(Cohen and Eliashberg 1997; Kogut and Zander 1992; Prabhu et al. 2005). Increasing complexity in new product development and fast advancing technologies often mandate firms to look beyond their boundaries to access knowledge and technology for their new product development purposes (Sood and Tellis 2005; Wuyts et al. 2004). In the agricultural industry, Cargill's Chief Technology Officer indicates that to bring an innovative product to the market place requires "...so much cooperation and integration of knowledge that you just can't get it done unless you pick partners" (Forbes Magnetic, 40, 2001, P. 66;Ireland et al. 2002).

As a result, inter-firm collaborations on R&D activities have become common practice for firms to: overcome the financial constraints; share the inherent risk associated with new product development; speed up the NPD process; and to get access to the most advanced technologies not available within a firm (Sivadas and Dwyer 2000; Wuyts et al. 2004). R&D alliances are defined as the ongoing, formal cooperative arrangements between two or more firms to achieve new product development goals (Sivadas and Dwyer 2000). Echoing the popularity of R&D alliances in business, marketing scholars have contributed considerable understanding to the issues of R&D alliances over the past two decades (e.g. Mohr et al. 1996; Rindfleisch and Moorman 2001; Rindfleisch and Moorman 2003; Sivadas and Dwyer 2000; Wuyts et al. 2004). Most of these studies have treated R&D alliances in isolation as the unit of analysis is normally at the project level (Wuyts et al. 2004), with particular emphasis on partner selection, individual alliance management, and knowledge transfer and coordination (Wuyts et al. 2004). Their emphasis is thus on the understanding of how each individual R&D alliance can be effectively managed.

1.2 The Importance of Alliance Portfolio Management

In spite of the extent literature on alliance management, very few studies have focused on the management of alliance portfolios as a whole (Bamford and Ernst 2002; Wuyts et al. 2004). Firm performance are very much tied to the successful management of entire portfolios of inter-firm agreements rather than the successful management of any one particular alliance (Wuyts et al. 2004). The sustainability of a firm's competitive advantage requires a firm's ability to benefit from its alliances activities over time.

Organizations enter into dozens of R&D alliances. A conservative estimate would be 30 alliances for most of them and many have more than 100 (Bamford and Ernst 2002). For example, in the aerospace industry, United Technologies is involved in over

100 worldwide collaborations (Ireland et al. 2002). For both practitioners and academia, however, there is a lack of understanding about how firms can successfully manage their alliances portfolios as a whole to achieve their competitive goals (Bamford and Ernst 2002; Hoffmann 2007; Wuyts et al. 2004). According to Bamford and Ernst (2002, p. 30-37):

> A company's alliance portfolio too often grows into a random mix of ventures assembled over the years by a variety of business units… Even if a deal made sense when first negotiated, the portfolio is unlikely to be as good as it could be in view of the current strategy of the company or even of a business unit. Companies often fail to recognize performance patterns across their alliance portfolios- patterns concerning particular deal structures, types of partners, or functional tasks. A failure to spot and fix such recurring problems can be costly…. Once a company better understand how its portfolio is performing, it can conduct a top-down review of overall strategy in order to ensure not only that its alliance portfolio is configured in the best possible way and contributes sufficiently to its performance but also that it has ranked new opportunities in a clear order of priority.

They further suggest that:

> (To achieve this), the first consideration is the performance of the portfolio as a whole. With a coherent strategy and an appropriate linking of partners, a portfolio can be more than its sum.

Portfolio's configuration is the second consideration. Does the company have the right set of alliances and the appropriate level of commitment to each?

The final element in a strategy review is to rank future initiatives in order of priority.

It has been shown in the literature that the portfolio descriptors have an important influence of a firm's innovation outcomes (Bamford and Ernst 2002; Wuyts et al. 2004). A portfolio approach, which examines the overall effect of the whole collection of strategic alliances of a firm, might be a more appropriate unit of analysis to our question (Wuyts et al. 2004). A firm's competitive position is more of a result of the history and accumulation of knowledge rather than a result of single alliance outcomes. Therefore, competitive advantage is and should be viewed as a result of successful management of alliance portfolios (Slowinski 2001).

Another research area that demands further attention is the differential roles of incremental innovation and radical innovation. Even though scholars have documented the different characteristics and performance impacts of these two types of innovations (Prabhu et al. 2005; Sood and Tellis 2005; Wuyts et al. 2004), it is not clear though what knowledge requirement differences exist for the development of these two different types of innovation.

1.3 Purpose of This Dissertation

This two-essay dissertation aims to facilitate the understanding of successful R&D alliance portfolio management. The first essay focuses on identifying key R&D alliance portfolio characteristics and explores their influence on firms' ability to develop knowledge reservoir on both breadth and depth dimensions. We further investigate the differential impact of knowledge breadth and knowledge depth on incremental and radical innovation development.

We take an exploratory approach, which involves an extensive literature review and in-depth discussions with industry executives, to identify key strategic decisions managers need to make in formulating their R&D alliance portfolios. The identified alliance portfolio characteristics include mangers' preferences of incorporating vertical partners vs. horizontal partners into their portfolio (Dussauge et al. 2000; Rindfleisch and Moorman 2001), tendency to work with the same partner over time (Wuyts et al. 2004), likelihood of building multiple technologies into their agreements (Khanna et al. 1998; Oxley and Sampson 2004), likelihood of bringing in unfamiliar partners (Goerzen and Beamish 2005), and propensity of involving multiple partners in their R&D alliances (Zeng and Chen 2003).

Due to the different levels of knowledge heterogeneity and governance challenges associated with each of these characteristics, a conceptual framework is proposed based on arguments from knowledge-based view and transaction cost analysis, which identifies the relationship between these key characteristics and a firm's knowledge breadth and depth development. In order to help organizations align their alliance portfolio management with their corporate strategies, further arguments are made in terms of the differential impact of knowledge breadth and depth on incremental innovation and radical innovation(Atuahene-Gima 2005; Chandy et al. 2003; Chandy and Tellis 2000; Chandy and Tellis 1998; Cooper 2000; Sood and Tellis 2005; Sorescu et al. 2003; Wuyts et al. 2004). Due to the different level of innovativeness in a new product, incremental innovation and radical innovation differs in their development processes in terms of which knowledge dimension (i.e. breadth and depth) plays a major role in the development success. Finally, in view of the inconsistent findings in the literature, we hypothesize relationships between innovation and financial performance.

Drawing on the combinative capability literature, which refers to firms' ability to integrate different knowledge domains in their innovation effort, the second essay aims to seek answer to one key unattended question: the *nature* of the relationship between a firm's number of R&D alliances and its innovation output. Existing literature on this question offers divergent findings. Some studies have found a positive liner relationship between the number of R&D alliances of a firm and its innovation outcome (e. g., Baum et al. 2000; Rothaermel and Deeds 2004; e. g., Shan et al. 1994). Other studies though have argued a non-linear relationship between the size of a firm's R&D alliance portfolio and its innovation output (Rothaermel and Deeds 2004). As such, it is very inconclusive as to the true functional from of the impact of the number of R&D alliances on innovations.

We argue that literature in this area has ignored an important capability of organizations, their ability to integrate knowledge sectors across partners (Henderson and Cockburn 1994). Based on this literature, we hypothesize an inverse S-shaped relationship between a firm's number of R&D alliances and its innovation output. Specifically, we argue that the marginal return of adding a new alliance to the portfolio would be increasing once a critical mass of knowledge is reached, which allows for options of multiple combinations among the newly added technology and existing ones.

To overcome the low response rate and common method bias that are prevalent in survey based studies, this dissertation uses secondary data to empirically test the hypothesized relationships. We collect data from multiple industry sources in order to provide accurate proxies for our constructs for empirical testing purposes.

1.4 Contribution of the Dissertation

This dissertation contributes to the literature by offering a framework guiding the successful management of R&D alliance portfolios. By explicitly linking each managerial preference to knowledge development outcomes, it offers guidelines as to what type of portfolio would help organizations achieve their knowledge development goals. It offers ideas about what type of partner agreement firms should pursue as well as those they need to avoid in their portfolio configuration process.

In addition, this dissertation also offers new insights about the different knowledge development strategies that would help firms achieve their innovation objectives. Because of differences in the corporate strategic emphasis on incremental vs. radical innovations, findings in this dissertation will help firms align their knowledge development strategies with their innovation goals. This, combined with insights of relationships between alliances attributes and knowledge development, should provide a complete picture about strategies firms should pursue in their innovation effort.

This dissertation is structured as follows: Chapter 1 illustrates the motivation and importance of the dissertation. Chapter 2 will provide an overview of existing streams of literature on R&D alliance management. Chapter 3 focuses on Essay one. More specifically, a knowledge-based conceptual model of successful R&D alliance portfolio management is presented. In this chapter, literature on knowledge-based view and transaction cost analysis are integrated to support the conceptualization and hypotheses development. Research methodology, statistical analysis, findings, and discussion of the first essay are also included in this chapter. Chapter 4 focuses on the second essay. Hypotheses development, research methodology, statistical analysis, findings, and discussions of the results of the second essay are all included in this chapter.

CHAPTER 2

THEORETICAL FOUNDATIONS OF STRATEGIC ALLIANCES

This section presents a comprehensive review of recent theoretical research on strategic alliance management literature, with an emphasis on R&D alliances. Strategic alliance embraces a diversity of causes, collaborative forms, and consequences (Grant and Baden-Fuller 2004). The prolific phenomenon associated with alliances challenges scholars' ability to develop an all-encompassing theory (Grant and Baden-Fuller 2004). As such, a wide array of theories has been applied in scholarly works in the area. The most commonly used theories in the alliance research are: 1) Resource-based review; 2) Knowledge-based view; 3) Transaction cost analysis; 4) Social network theory; and 5) Organizational learning theory. To date, researchers have used these theories to understand the formation, management, and performance implication of strategic alliances.

2.1 Resource-Based View and Alliance Partner Selection

The resource-based view of firm holds that a firm is a collection of heterogeneous resources (Wernerfelt 1984). Firms can obtain sustained above normal returns only when they possess superior resources which are protected by some form of isolating mechanisms tying the resources within the boundary of a firm (Barney 1991; Barney 2001; Kor and Mahoney 2004; Penrose 1959). As such, resources heterogeneity is the foundation for competitive advantage, and management's task, according to RBV, is to identify, develop, and deploy the key resources to maximize its return (Barney 1991).

True resources of a firm should have the following characteristics:

1) Valuable in that they help firms to conceive or implement strategies more effectively or more efficiently than competitors.

2) Rare in that the resource is only distributed among a limited number of competitors in the industry so that the rent cannot be diffused across firms.

3) Imperfectly imitable in that competitor cannot easily copy away the resources due to their unique development history, causal ambiguity, and social complexity.

4) Non-substitutable in that no equivalent strategic resources that by themselves either not rare or imitable.

As the market conditions become increasingly complex, firms seldom possess all the necessary resources to create competitive advantage or even achieve a particular marketing objective such as new product development all by itself (Ireland et al. 2002). As such, resource based view help us understand the motivation behind inter-firm alliances (Eisenhardt and Schoonhoven 1996).

It is agreed that a dominant motivation behind the formation of alliances is both to gain access to partner-specific resources and to jointly develop new resources through collaborations between partners (Ireland et al. 2002; Reid et al. 2001). Alliances provide access to technology, financial assets, information, and markets that a firm will find difficult to obtain otherwise (Hitt et al. 2001). Accessing and developing these resources is key to a firm's competitive position in the market. Glaister and Buckley (1996) found that resource access has a greater explanation power than other causes such as risk sharing and development of economies of scale in alliance formations (Ireland et al. 2002).

Besides shedding light on the general motivation of strategic alliance formation, the resource-based view also explains issues associated with partner selection. It is found that firms are more inclined to partner with firms with complementary resources than with firms possessing similar resources (Chung et al. 2000; Gulati et al. 2000). This finding applies to both large, resource rich firms from developed countries as well as small, resource scarce firms from developing countries (Hitt et al. 2000). As such, the resource composition of a firm relative to the market need plays a central role in its alliance activities (Stuart 2000).

Both a firm's resource inventory and the market need will have motivational values for alliance formations. For firms to be sought after as partners, they must be endowed with resources that other firms value but do not have (Das and Bing-Sheng 2000). On the other hand, firms without valuable resources will not be desirable partners, which inhibit their ability to locate the optimal resource configuration in which the value of their resource could be maximized due to their inability to offer the reciprocal benefits (Ahuja 2000b). Newly emerging market and innovative industries will prompt firms to actively seek alliances to maintain completive in the market place (Eisenhardt and Schoonhoven 1996).

The resource endowment of alliance partners also influences the outcome of the collaboration. Dussauge, Garrette and Mitchell (2000) observe more frequent reorganization and takeover when partner firms share similar resources. Harrison, Hitt, Hoskisson and Ireland (1991) also argue that alliances between partners with similar resources would not perform very well as they provide opportunities for exploiting based collaborations but prevents exploration based collaborations. This finding is supported by

Madhok and Tallman (1998) who argue that partners with complementary resources offer the potential for integrating complementary resources and thus create synergies to achieve new competitive advantage. Rindfleish and Moorman (2001) also find that firms with similar resources will experience inferior knowledge development outcome.

2.2 Knowledge-Based View and R&D Alliances

Even though resources can take on many forms such as assets, technologies, information, process, or even relationships, most scholars agree that true competitive advantage comes from a firm's access to its intangible idiosyncratic resources, those that are tacit and knowledge-based (Dussauge et al. 2000). As knowledge gains its focal position in explaining firm performance differences, a "knowledge-based view" emerged in the literature (Grant 1997; Grant 1996; Grant and Baden-Fuller 1995). As an outgrowth of the traditional resource-based view, knowledge-based view focuses on knowledge as the most strategically important resource of a firm. Fundamental to the knowledge-based view is that knowledge represents the single critical input in production and the primary source of value (Grant 1996). However, because of the bounded rationality, "efficiency in knowledge production requires that individual (firm) specializes in particular areas of knowledge" (Grant 1996 p.112).

While resource-based view offers theoretical explanation to the general alliance formations such as franchising (firms with product resources ally with firms possessing market resources) and outsourcing (firms with intellectual resources work with firms with production resources), knowledge-based view offers great insights to a particular type of inter-firm collaboration, the R&D alliances (Doz 1998; Grant and Baden-Fuller 2004). In explaining the formation and motivation issues of R&D alliances, several studies have identified accessing knowledge as their major objective (Dyer and Nobeoka 2000; Grant and Baden-Fuller 2004; Inkpen and Crossan 1995; Lyles and Salk 2007; Simonin 1999).

The knowledge-based view distinguishes two dimensions of knowledge management through alliance formations: knowledge acquiring and knowledge accessing. First, alliances may be formed for the purpose of augmenting a firm's knowledge inventory. This could be achieved either by learning from alliance partners or by jointly developing new knowledge with partners. This is referred to as "exploration" by March (1991) or "knowledge generation" by Spender (1992). Second, firms may be motivated to form alliances primarily for the purpose of deploying existing knowledge to create value without actively changing the knowledge base. This is referred to as "exploitation" by March (1991) or "knowledge application" by Spender (1992). Firms simply pool resources together in this case without actively learn or internalize knowledge from partners.

Grant and Baden-Fuller (2004) identified circumstances where alliances could serve better mechanisms for knowledge related activities than pure market transactions and better than merger and acquisitions. First, alliances can avoid many of the costs associated with knowledge transaction by limiting opportunism since both parties need to foster investment in trust (Simonin 1997; Teece 1992). Second, under highly diversified knowledge domains, alliances could be better integration mechanism than the market or firm. According to Grant and Baden-Fuller (2004) "as the range and diversity of knowledge increases, so integration mechanisms need to be increasingly differentiated, resulting in rising marginal costs of knowledge integration within the firm. In these circumstances, efficiency of integration may be maximized through separate firms integrating knowledge at the component or subsystem level, with overall integration through an alliance between firms" (p.69). Third, alliances offer better mechanism for knowledge utilization when the product domain of the firm and the knowledge domain of the firm are highly incongruent (Grant and Baden-Fuller 2004).

Knowledge transfer across partners is another heavily researched topic in alliance literature. Effective transfer of knowledge from partner to partner or from parent firms to the joint venture is critical for alliance success (Mowery et al. 1996). The effectiveness of knowledge transfer is heavily influence the nature of the knowledge (Simonin 1999). Explicit knowledge is much easier to transfer than tacit knowledge and knowledge ambiguity inhibits the success transfer of knowledge (Simonin 1999). Explicit knowledge can be easily codified into written forms, which allows for a much easier channel of communication of the content. Tacit knowledge, on the other hand, has codification difficulties. The transfer of tacit knowledge thus requires more frequent and more personal contacts between partners in order to fulfill a successful transfer.

The overall conclusion concerning the transferability of knowledge is that tacitness, complexity, cultural distance and organizational distance between partners are all positively related to ambiguity which in turn inhibits knowledge transfer (Simonin 1999). However, alliance partners could overcome these transfer difficulties by instituting structural mechanism such as training, internal consulting, and assistance (Ireland et al. 2002; Lyles and Salk 2007). Inkpen and Dinur (1998) advanced the importance of knowledge management strategies as certain types of strategies outperform others when knowledge types are different.

2.3 Transaction Cost Analysis and Alliance Governance

Transaction cost analysis maintains that the minimization of total production and transaction costs will determine the boundaries of firms (Hemphill and Vonortas 2003; Williamson 1991). Williamson (1991) states that certain dimensions of transactions give rise to transaction costs that allow the evaluation of alternative transaction structures or governance mechanisms. Due to environmental uncertainty which give rise to adaptation problem; behavioral uncertainty which leads to performance evaluation problem; and asset specificity which induces safeguarding problem, transactions incur different levels of costs depending on the completeness of contract to be agreed upon upfront (Williamson 1975; Williamson 1998).

One important behavioral assumption in transaction cost analysis is opportunism. It assumes that given the opportunity, firms may seek to serve their own interest at the partner's cost (Rindfleisch and Heide 1997; Williamson 1994). Opportunism poses a problem to the extent that relationships may require relationship-specific investment from parties and this would create safeguarding problem (Rindfleisch and Heide 1997).

Choice of governance mechanisms will be a function of the transaction cost and the production cost advantage of the market (Rindfleisch and Heide 1997). In particular, two types of governance mechanisms are emphasized: firms and market. Under perfect market competition where costs associated with adaptation, safeguarding and performance evaluation is low, given the high-powered price incentives, market is the choice of transaction by default. However, when market is imperfect, costs associated with contract enforcing and performance monitoring will increase which necessities a unified hierarchical governance structure, firm (Williamson 1991).

High transaction cost is a result of incomplete contract as the contract fails to fully specify all possible actions of each party in all states of the world (Hemphill and Vonortas 2003). Alliance partners often increase the complexity of their contracts when high asset specificity is involved (Reuer and Arino 2007). The circumstances around strategic alliances though, especially R&D alliances where technologies are the focal resources, often are conducive to high costs for writing a complete contract (Hemphill and Vonortas 2003). In an alliance where the shared goal is to develop a new technology, incomplete contracting for property rights is almost inevitable as the contracted asset do not even exist at time of contracting (Oxley 1997).

Both environmental uncertainly and behavioral uncertainty are present in technology based alliances. Environmental uncertainty such as the market and technology uncertainties due to the fluid stage of development, lack of dominant design, and ill-defined technological trajectories makes writing a complete contract almost impossible (Hemphill and Vonortas 2003). Firms in an alliance, especially a technology-based alliance, are also subject to opportunistic behaviors from their partners (Oxley 1997). These opportunistic behaviors could range form delivering less technology than specified in contract to using partner's technology in areas other than specified in the contract (Oxley 1997). When uncertainties present, writing a complete contract that would incorporate all the possible courses of future thus become difficult due to the bounded rationality of management (Rindfleisch and Heide 1997).

Knowledge as the major resource for alliance activities also brings about some unique difficulties. Knowledge, especially tacit knowledge, has approriability problems (Grant 1996). Appropriability refers to the ability for the owner of a resource to receive a return equal to the value of the creation of the resource (Grant 1996; Oxley 1997). Both tacit and explicit knowledge suffer from appropriability problems. For tacit knowledge, it is not appropriable because it cannot be directly transferred. It can only be appropriated through it application to productive activities (Grant 1996). For explicit knowledge, anyone who acquires it can resell it without losing it (Arrow 1971; Grant 1996). Second, the marketing process itself would in effect make it available to potential buyers (Arrow 1971; Grant 1996). Thus unless the knowledge is protected by legal establishment such as patents or copyright, knowledge is not appropriable by means of market transactions (Grant 1996).

Due to the appropriability hazards in alliance activities involving tacit know-how, full specification of the assets to be transferred and monitoring partner performance and behavior become problematic since both parties have incentives to act opportunistically. When parties face these problems, they are inclined to mitigate against the contracting hazard by moving up the market-hierarchy continuum of alliance forms (Oxley 1997). As a result, an equity-based alliance would emerge as it offers the shared equity, additional monitoring rights, and increased administrative control. In fact, any factors that may add to the difficulty of writing a complete contract such as number of partners, technology scope, as well as number of firms involved, may give alliance partners incentives to move to a more hierarchical governance structure (Oxley 1997).

Equity alliance governance is not the only solution to the possible opportunism problems. Alliance governance mechanism studies also drew from the relational exchange theory in which trust is a focal construct. Trust is defined as a firm's belief that its transaction party will perform actions that will result in positive outcomes for the firm, and will not take unexpected actions that would result in negative outcomes (Anderson and Narus 1990). The essence of trust is to alleviate opportunism (Gulati 1995). Predictability, dependability, and faith are the key components of trust (Andaleeb 1992). As such, trust suggests that alliance partners can depend on each other's actions without worrying about opportunistic behaviors (Ireland et al. 2002). Relational exchange theory suggests that trust evolves from past experiences and as such the history of the cooperation between partners is negatively related to the perceived opportunistic behavior of their partners (Parkhe 1993).

The trust-based approach to alliance management has received considerable empirical support. Studies have shown that trust between alliance partners emerge from prior collaborations that would be working as a substitute for formal governance (Reuer and Arino 2007). Oxley (1997) demonstrates that firms with prior collaborations are less likely to choose equity alliances than partners without prior collaborations. Japanese alliance partners, due to their inclination to ally with prior partners, experience less transaction costs than those in the United States (Dyer 1997).

To summarize, transaction-cost analysis have served as a powerful tool for scholars to understand how alliances could be effectively governed from opportunistic behaviors. The general conclusion is that when there is high uncertainty both in terms of partner actions and future environmental development, a more hierarchical governance structure is preferred to prevent any unwanted actions from either party involved in the alliance (Oxley 1997). In addition, firms can develop relational norms such as trust as a substitute for this formal governance structure through repeated partnering experiences (Dyer 1997).

2.4 Social Network Theory and Firm Performance

As most firms either form multiple alliances with different partners or involve multiple partners in a single alliance agreement, forming alliances actually serve as a gateway for firms to get into a broader network system through both direct and indirect ties (Gulati 1998). Recently scholars have brought a network perspective in understanding the benefits and challenges associated with alliance management (Gulati 1999). Research applying social network theory largely falls into two major streams: network structure analysis and network content analysis.

Two opposing views were expressed in the literature in terms of what structure offers members within the network the greatest benefits (Walker et al. 1997). Proponents of closed network emphasize the importance of social capital. Social capital is defined as the established norms of cooperation among firms within a network system (Coleman 1993). Social capital is regarded as a resource that helps the development of social norms for acceptable behaviors among members (Walker et al. 1997). Due to the high frequency of interactions among members within a closed network, information regarding any member's deviant behavior is rapidly diffused and consequently sanctioned. As such, self-interest seeking opportunistic behaviors are constrained among members which enhances cooperation among members (Walker et al. 1997).

On the other hand, proponents for open networks stress the importance of information diversity benefit. They content that closed network prevents the inflow of fresh information and hinders the innovative efforts of members (Burt 1992). One construct, the structural hole, has gained considerable attention in the literature. Structural holes refers to the sparse regions between the dense network regions (Burt 1992; Walker et al. 1997). Burt's (1992) argument is that firms in a closed network system lose independence in terms of their partner selection. However, an open network offers greater latitude in terms of whom they want to work with. This becomes an important attribute of open network system in innovation-driven firms, as they are more likely to obtain up to date technology and fresh information (Burt 1992).

At the micro level, studies have shown that firms' position within an alliance network has important implications to both their behaviors and performances (Powell et al. 1996). Members within a network differ from each other in terms of their location and number of ties they have relative to others (Freeman 1979; Freeman 1992). Centrality is a measure of the contribution of network position to the importance, influence, and prominence of an actor in a network (Freeman 1979).

Centrally located members within a network normally have more ties than those peripheral members and this offers them certain competitive advantage. For example, centrally located firms have alternatives to access resources due to their connections with multiple actors in the network and their dependency on any particular actor is thus greatly reduced. They also have access to a more diversified knowledge set because of their ability to work with more partners. In addition, their central location offers them the ability to identify unique opportunities for collaborations, themselves involved or not. They may simply refer third parties and benefit from these brokerage activities (Freeman, 1979). Centrally located firms in a network system also enjoy high visibility and reputation, which enhances their ability to attract talent and opportunities (Powell et al. 1996).

Firms in a network also differ in terms of how many direct ties and indirect ties they have. Ahuja (2000a) specifically identified three benefits of direct ties that would help a firm's innovation effort: knowledge sharing, complementarity, and scale. When firms collaborate with each other, the resultant knowledge developed is normally greater than knowledge that could be developed by any partner independently and it would be available to both parties. In addition, direct collaboration also brings together complementary resources and technologies as breakthrough innovation normally requires the simultaneous use of different sets of skills and knowledge base in the innovation process (Powell et al. 1996). The third benefit of maintaining a large number of direct ties in a network is the scale economy as large projects undertaken by multiple firms together generates significantly more knowledge than smaller ones (Powell et al. 1996).

The innovation output of a firm is also influenced by indirect ties, those indirect contacts firm has though its direct partners (Powell et al. 1996). A firm's direct ties bring the knowledge and skills from their interactions with other firms to the interactions with the focal firm (Gulati and Gargiulo 1999). As such, direct ties offer extended linkage to the focal firm by offering access to the resources held by the partner's partners. When firms need particular resources for innovation activities, they normally first seek help from their direct ties in the network. However, when this fails, their partners may offer referral services by linking them with their own direct ties who has possession of the focal resource (Powell et al. 1996). As such, firms also prefer to increase their indirect ties by working with partners who have extensive linkages by themselves.

Scholars also have started to understand the influence of the content of alliances networks, that is the characteristics of the nodes and the qualitative nature of the relationships on firm's performance (Goerzen and Beamish 2005). Two particular content factors have been identified as influential to firm's performance: repeated partnership and network diversity.

When firms need to form an alliance, they have the choice of working with either familiar partners or unfamiliar partners. Repeated partnering refers to firms' preferences to allay with partners that they have allied with before. From a network perspective, firms with linkages to a diversified network of partners enjoy the benefit of freshness and novelty in information acquisition. On the contrary, firms that have a great degree of redundancy in their partner portfolio are limited in terms of the range of technology, skills, and marketing information access. As a result, firm performance will be negatively affected by a high level of partner redundancy (Goerzen 2007).

Another important network content characteristic in the literature is the network diversity. Three benefits were identified for a diversified network. First of all, firms in a diversified network can access to a large number of partners. Secondly, firms normally enjoy timing advantage in terms of information in the market when they reside in a highly diversified network. Finally, firms also benefit from potential referrals as their partners may identify partnering opportunities for them. As such, a highly diversified network is initially found to be positively associated with firm performance (Goerzen and Beamish 2005). However, this positive effect will eventually start to diminish as the marginal benefit is overwhelmed by the marginal costs of management. To conclude, the relationship between network diversity and firm performance is inverse-U shaped (Goerzen and Beamish 2005).

2.5 Organizational Learning and Knowledge Acquisition

Grant (1996) argues that the benefit of strategic alliances is in resource accessing. However, most scholars argue that firms not only access resource, they learn and internalize resources from partners when possible (Khanna et al. 1998). As alliance partners need to partially open their resources to their partners and because of the frequent communication and interaction among partners, learning from each other inevitably happens in alliances. This is more so in alliances that are based on complementary resources than do alliances created for economies of scale (Ireland et al. 2002). Firms are motivated to learn from each other because the internalization process will greatly reduce its dependency level on its partner.

Organizational learning falls into two major categories in alliance literature, internal learning (learning to manage alliance activities), and external learning (learning knowledge from partners). Kale and Singh (2007) proposed a four-stage learning theory for alliance management. The first step is articulation of alliance management know-how. Alliance managers are supposed to externalize their personally held, tacit knowledge about alliance management by using different techniques such as spoken or written words, metaphors, analogies, or models. This is an important step in that articulated knowledge is easy to access and store and this would greatly enhance the learning process (Nonaka, 1994). It helps firms to create a record of its alliance history, to facilitate ex post sense making of actions and decisions, and to better understand causal relationships about alliance management (Kale and Singh, 2007).

The second step is codification of alliance management know-how. Going beyond simple documentation of existing knowledge, Kale and Singh (2007) defined codification as "creating and using knowledge objects or resources such as alliance guidelines, checklists, or manuals to assist actions or decision making in future alliance situation". This process is expected to enhance a firm's decision-making and actions in its alliance management and consequently lead to better alliance results in the future.

The third step is sharing of alliance management know-how. It is a process defined as "exchanging and disseminating individually and organizationally held alliance management knowledge, which is both tacit and/or codified, through interpersonal interactions within the organization". Face-to-face interactions among individuals are particular important in this stage as they provide opportunities to share individually held tacit know-how among members of an organization.

The fourth step is internalization of alliance management know-how. This involves individual's effort to facilitate absorption of accumulated organizational level knowledge (Nonaka 1994). It goes beyond simple dissemination process by emphasizing the absorption of relevant knowledge by individual receivers (Kale and Singh 2007). Organization members, especially those managing alliances on a daily basis, need to understand both the why and the how aspects of alliance management strategies.

Another stream of research in the alliance literature focuses on firms' active learning from their partners. In fact, one of the motives for forming alliances is the acquisition of new technologies, skills, or capabilities from partners (Mowery et al. 1996). Alliances offer great platform for this type of learning as it combines the incentive structure of market and the administrative controls associated with hierarchy to overcome the incomplete contracting problem when uncertainty regarding the focal technology or capability is involved (Mowery et al. 1996). Because knowledge and technological capabilities are the building block of competitive advantage, firms can simultaneously prevent inertia while promoting environmental adaptation by actively learning from their alliance partners (Doz 1998; Doz 1996; Ireland et al. 2002).

When firms are motivated to learn from their partners, learning race occurs in which each partner is trying to outlearn the other (Hamel 1991). The faster learner may achieve its learning goal and dissolve the alliance even though the other party has not accomplished its learning goal yet (Hamel 1991). This is especially true when alliance partners possess unequal learning abilities (Makhija and Ganesh 1997). As such, an alliance is simultaneously cooperative and competitive oriented (Hamel 1991). This creates a greater problem to partners in the same industry as the knowledge learned by a partner may be used directly against the knowledge originator.

Khanna, Gulati, and Nohria (1998) proposed a model to understand the alliance dynamics when cooperation and competition co-exists by introducing the concept of private and common benefits. Private benefits refer to those that a firm can pick up unilaterally by learning from its partner and apply them to its own operations in areas that are not related to the alliance activities. Common benefits, on the other hand, refer to those that accrue to each alliance partner from the collective application of learning that both parties go through by being in the alliance and these must be from operations in areas of the firm that are related to the alliance (Khanna et al. 1998).

The idea is that the ratio of private to common benefits will influence how the alliance evolves as well as firms' incentives to allocate resources in a particular area (Khanna et al. 1998). Different ratio of private to common benefits will result in different resource allocation patterns. For alliances with only common benefits, firms have no incentive to get ahead of the other in terms of learning, as both parties must advance their learning of each other's knowledge before any common benefit could be realized. This will result in a pure cooperation situation and resource allocation decision are made jointly by partners (Khanna et al. 1998).

On the other extreme when only private benefits exist, firms are motivated to engage in pure competitive behaviors (Khanna et al. 1998). Because each firm is interested in accessing knowledge from its partner and using it consequently in situations in which it can reap benefits that accrue only to itself and there is no common benefit to seek, each partner is inclined to terminate the alliance once it has achieved it learning goals. As such, each partner will try to achieve the leader position in this leaning race and competition mode controls the whole dynamic (Khanna et al. 1998).

Most alliances will involve both common and private benefits and the situation thus becomes more complicated than the two extreme cases discussed above. However, the general conclusion is that the competition will intensify and cooperation will diminish as the ration of the private benefit to common benefit increases (Khanna et al. 1998).

Several factors were identified as either facilitating or hindering organizational learning from partners. These include cultural distance (Barkema et al. 1996), absorptive capacity(Cohen and Levinthal 1990), partners' initial conditions (Doz 1996), relational capital between partners (Kale and Singh 2000), social capital (Yli-Renko et al. 2001), and age and size of firm (Stuart 2000). Of these, absorptive capability is a key construct that warrants some particular attention.

The basic idea of absorptive capability is that firms need to have a prior related knowledge base in order to successfully identify, acquire, assimilate, and exploit the external knowledge to which they are exposed (Cohen and Levinthal 1990). Evidence of absorptive capability largely comes from the cognitive and behavioral sciences. As individuals use linkage to its existing memory to facilitate leaning of a new object, the more objects and patterns in the memory the easier for the new information to be mapped into the existing memory structure (Cohen and Levinthal 1990). As such, learning is a function of what is already known in the related areas. Learning in a novel area is much more difficult than learning in a known area.

To summarize, different theoretical lenses have been used in understanding different aspects of strategic alliances. While each theory is primarily used to answer one particular question in alliance literature, their linkages should not be underestimated. For example, resource-based view is linked with organizational learning theory informing us what is being learned in the alliance process. Network theory, when linked with organizational learning theory may provide direct leaning and indirect learning differences and explain how much learning could take place in an alliance. Transaction cost analysis could also be combined with organizational learning theory in explaining what governance structure may facilitate the learning process given the approriability hazards associated with the focal resource, knowledge. As all the discussed theories are intrinsically linked with one another, scholars sometimes need to use multiple theories in building a comprehensive model to understand issues surrounding alliances. Table 1 presents a select list of literature using these theoretical lenses in understanding strategic alliance issues.

Table 1 Select List of Literature on Strategic Alliances

Study	Theories Employed	Major Topic
Afuah (2000)	Resource-based View	The influence of technological change on firms' relationship with alliance partners
Chung et al. (2000)	Resource-based View	The impact of resource complimentarily, social capital, and status similarities on alliance formation potential
Eisenhardt and Schoonhoven (1996)	Resource-based View	Explanation of strategic alliance formation motivations including stage of market, innovative strategy, size and previous industry exposure
Harrison, et al. (2001)	Resource-based View	Firms form alliances in order to gain access to strategic resources. The complementarities of partners resources are of great importance
Hitt et al. (2000)	Resource-based View	Understanding the different partner selection criteria between firms from developing countries and developed countries (financial assets, willingness to share, and technological capabilities vs. market knowledge and access)
Lampel and Shamsie (2000)	Resource-based View	Explains the impact of a firm's dominant logic on its manner in alliance forming and termination decisions
Simonin (1997)	Resource-based View	Proposes a model emphasizing the importance of converting experiences into know-how in order to influence firm alliance benefits
Grant and Baden-Fuller (2004)	Knowledge-based View	Argument about the importance of alliance formation lies in its ability of knowledge accessing rather than acquiring knowledge
Inkpen and Dinur (1998)	Knowledge-based View	Depending on the type of knowledge considered, different type of knowledge transfer strategies might lead to different knowledge transfer outcomes. Knowledge and strategy need to be aligned
Lam (1997)	Knowledge-based View	How the socially embedded nature of knowledge impede collaboration and knowledge transfer

Table 1 (Cont'd)

Study	Theories Employed	Major Topic
Lyles and Salk (2007)	Knowledge-based View	Examination of the organizational, structural, and contextual factors in influencing a firm's ability to acquire knowledge from foreign parent in IJVs.
Reid et al. (2001)	Knowledge-based View	Provides a detailed stage-based model of issues surrounding the alliance formation
Simonin (1999)	Knowledge-based View	Knowledge ambiguity is negatively related to knowledge transfer. Tacitness, specificity, complexity, partner protectiveness, organizational distance, and cultural distance increase the ambiguity of knowledge. Experiences is negatively related to ambiguity
Tiwana and Keil (2007)	Knowledge-based View	Demonstrates the role of peripheral knowledge in complementing control mechanisms in technology outsourcing alliances
Wiklund and Shepherd (2003)	Knowledge-based View	Knowledge-based resources positively influence firm performance. This relationship is moderated by entrepreneurial orientation
Glaister and Buckley (1996)	Transaction Cost Analysis	Strategic motivations for international alliance formation. Factors identified include relative partner size, primary geographical location, and the industry
Gulati (1995)	Transactional Cost Analysis	Shared R&D component and different national location increase the use of equity-based alliances. Experience with the partner, decreases the likelihood of equity alliances
McGee et al.(1995)	Transaction Cost Analysis	Examines the influence of different strategic focus and manager's alliance experiences on firm performance
Oxley (1997)	Transaction Cost Analysis	Examination of the governance properties of different alliance types. Focused on the appropriability hazard in knowledge based alliances

Table 1 (Cont'd)

Study	Theories Employed	Major Topic
Oxley and Sampson (2004)	Transaction Cost Analysis	Proposes an alternative governing mechanism to cope with the incomplete contract problems in strategic alliances: limiting the scope of collaboration
Parkhe (1993)	Transaction Cost Analysis	Examines the inter-linkage among the perceived "future", opportunistic behavior, history of collaboration, commitment, and payoff in strategic alliances
Reuer and Arino (2007)	Transaction Cost Analysis	Examines the dimensionality of the contractual complexity construct and the determinants of firm's decision to adopt various contractual provisions
Santoro and McGill (2005)	Transaction Cost Analysis	Governance is directly influenced by partner, task, and technological uncertainty and by interactions among asset co-specialization, partner uncertainty, and task uncertainty
White and Lui (2005)	Transaction Cost Analysis	The greater joint task complexity and inter-partner diversity, the greater the cooperation costs. Both cooperation costs and transaction costs influence the level of time and effort managers spend on managing alliances
Young-Ybarra and Wiersenma (1999)	Transaction Cost Analysis	Examines the effect of asset specificity, hostage arrangement, and dependence on firms' strategic flexibility when alliances are performing poorly
Ahuja (2000a)	Social Network Theory	The impact of firm's direct ties, indirect ties, and structural holes in the network on its innovation output
Baum et al. (2000)	Social Network Theory	The influence of the initial network set-ups of start ups on their early performance and strategies to enhance the outcome
Gulati (1999)	Social Network Theory	Determinants for firms entering into an alliance include the level of resources of the firm from prior alliances and its alliance formation capability

Table 1 (Cont'd)

Study	Theories Employed	Major Topic
Kraatz (1998)	Social Network Theory	Explain how network structure influences firm's ability to adapt to environmental changes.
Modhavan et al. (1998)	Social Network Theory	Explains the network position dynamics when major industry events occur such as structure reinforcing event and structure loosening event
Powell et al. (1996)	Social Network Theory	Examines the impact of the number of direct ties, indirect ties, and structural holes in a firm's alliance network on its performance
Tsai and Ghoshal (1998)	Social Network Theory	The centrality and shared vision of a business unit improves its trustworthiness which in turn impacts its resource exchange with other units.
Walker et al. (1997)	Social Network Theory	Proposes social capital as a better indicator of cooperation over time than structural holes propositions
Barkema et al. (1996)	Organizational Learning Theory	The influence of cultural distance on the longevity of foreign joint ventures and the learning effect in mitigating this influence
Cohen and Levinthal (1990)	Organizational Learning Theory	Discussion of absorptive capability and how this concept influences firm's allocation of resources on innovation
Doz (1996)	Organizational Learning Theory	The mediating role of learning in the relationship between the initial condition of the alliance partners and alliance outcomes
Kale and Singh (2007)	Organizational Learning Theory	Explains the learning process of successful alliance management. The four stages include: articulation, codification, sharing, and internalization
Khanna et al. (1998)	Organizational Learning Theory	Explains how the tension between cooperation and competition affects the dynamics of learning alliances. The ratio of common benefit and private benefit would be the major determinant of the cooperation level

Table 1 (Cont'd)

Study	Theories Employed	Major Topic
Parkhe (1991)	Organizational Learning Theory	Develops a multilevel typology of inter-firm diversity. Examines how learning and adaptation moderate the relationship between diversity and longevity/ diversity and effectiveness
Sampson (2005)	Organizational Learning Theory	Examines the effect of prior alliance experience on current alliance performance. Included are the factor such as uncertainty and level of experience
Ahuja (2000b)	Resource-based View/Social Network Theory	The creation of inter-firm linkages through collaboration
Anand and Khanna (2000)	Resource-based View/Organizational Learning Theory	Why and how the learning effect of alliance management experience is important to firms
Dussage et al. (2000)	Resource-based View/Organizational Learning Theory	The outcomes and durations of strategic alliances among competing firms, using alliances outcomes as indicators of learning by partner firms
Dyer and Nobeoka (2000)	Social Network Theory/Knowledge-based View	The creation and implementation of learning networks. Providing guiding coordination principles that facilitate knowledge transfer among partners
Goerzen and Beamish (2005)	Social Network Theory/Transaction Cost Analysis	Competing hypotheses were set up regarding the alliance network diversity based on network theory and transaction cost analysis. Results support network hypothesis
Goerzen (2007)	Social Network Theory/Transaction Cost Analysis	Competing hypotheses were set up regarding the repeated partnerships based on network theory and transaction cost analysis. Results support network hypothesis
Hamel (1991)	Resource-based View/Organizational Learning Theory	Extent and means through which alliances may lead to reappointment of skills of members. Unequal learning capabilities may change the stability and longevity of alliances

Table 1 (Cont'd)

Study	Theories Employed	Major Topic
Hemphill and Vonortas (2003)	Transaction Cost Analysis/Resource-based View/Knowledge-based View/Organizational Learning Theory	Applied multiple theories to recount business motives to engage in R&D alliances and point out that the differences among these theoretical arguments may not as sharp as they seem to be
Kale and Singh (2000)	Knowledge-based View/Organizational Learning Theory	Factors that enhance learning from partners and protecting core capabilities from partners (relational capital and integrative conflict handling)
Lorenzoni and Lipparini (1999)	Transaction Cost Analysis /Resource-based View/ Knowledge-based View/Organizational Learning Theory	Articulates the importance of firm's capability in interacting and coordinating knowledge sharing with other firm
Mowery et al. (1996)	Knowledge-based View/Organizational Learning Theory	Examines how equity based alliances and absorptive capability facilitate knowledge transfer among partners
Stuart (2000)	Network Theory/Organizational Learning Theory	Examines how partners' resources and performance influence the performance of the focal firm. The moderating effect of firm size and age is noted
Yli-Renko et al. (2001)	Organizational Learning Theory/Social Network Theory	Social capital facilitates the acquisition of knowledge from external sources

CHAPTER 3

ESSAY ONE: ALLIANCE PROTFOLIO CONFIGURATION, KNOWLEDGE DEVELOPMENT, AND INNOVATION: THEORETICAL FRAMEWORK AND EMPIRICAL EVIDENCE

3.1 Development of the Conceptual Framework

Even though dyadic relationship studies have dominated the literature of alliances, scholars have started to realize the importance of managing alliance portfolio as a whole (Hoffmann 2007; Powell et al. 1996; Reuer and Arino 2007; Reuer and Ragozzino 2006). Both scholars and practitioners have realized that competitive advantage of a firm seldom relies on one single successful alliance but on its ability to successfully configure its alliance portfolio (Bamford and Ernst 2002; Hoffmann 2007). As such, the configuration of the whole alliance portfolio becomes an important strategic issue for firms with numerous alliances (Hoffmann 2007).

Hoffmann (2007) identified both strategic and environmental determinants of configuration and evolution of strategic alliance portfolio. Strategic alliance portfolio configuration is thus defined as the structural and relational characteristics of the alliance portfolio (Hoffmann 2007). Drawing on knowledge based view and transaction cost analysis, this essay explores how characteristics of the R&D alliance portfolio configuration influence a firm's ability to develop its knowledge reservoir which in turn impacts its ability to innovate.

We define R&D alliance portfolio characteristics as firms' preference to include any particular type of agreement or partner in their alliance portfolio configuration process. In order to compile a comprehensive array of the characteristics, a systematic review of the alliance literature is conducted to identify managerially relevant partner and agreement types. This process resulted in the following five portfolio characteristics: partner dispersion (Goerzen and Beamish 2005; Hoffmann 2007; Koka and Prescott 2002; Parkhe 1991), vertical vs. horizontal alliances (Baum et al. 2000; Dussauge et al. 2000; Rindfleisch and Moorman 2001; Sivadas and Dwyer 2000); multiple partner agreements (Feinberg and Gupta 2004; Lazzarini 2007; Zeng and Chen 2003), alliance scope (Khanna 1998; Khanna et al. 1998; Oxley and Sampson 2004), and partner repeatedness (Goerzen 2007). These five characteristics were then presented to a panel of pharmaceutical practitioners at a strategic marketing conference and their managerial relevance in alliance portfolio management is confirmed.

Knowledge is particularly important for technology-based firms: generating and exploiting knowledge in high technology sectors demand knowledge to be continuously replenished (Lane and Lubatkin 1998; Yli-Renko et al. 2001). One of the most widely cited motivations for forming R&D alliances is the acquisition of new technical skills and technological capabilities from partner firms (Hamel 1991; Khanna 1998; Mowery et al. 1996). R&D alliances have advantages over conventional contracts and markets for this task because firm specific technological capabilities frequently are based on tacit knowledge and are subject to considerable uncertainty concerning their characteristics and performance (Mowery et al. 1996). Alliances with its trait of both market transaction and hierarchical arrangement, provide a superior means to gain access and assimilate the knowledge and other complex capabilities.

Alliance portfolio management is a very important tool for firms to gauge its existing knowledge inventory. Alliance portfolio configuration is a deliberate decision process that firms have to go through. With multiple potential partners to choose from, firms need to make decisions such as which partner to work with and what form of alliances will be employed. As a basic assumption of resources based view and knowledge-based view of firm, resources (knowledge) heterogeneity is inherent across firms. As such, the different choices of firms and forms of collaboration in a firm's R&D alliances portfolio configuration will affect its exposure to external knowledge and its opportunities for the transfer of that knowledge (Wuyts et al. 2004).

The role of inter-organizational partnerships as conduits of information, knowledge, and learning is well accepted in the literature (Goerzen and Beamish 2005). Studies have suggested that key characteristics of alliance portfolio would have an impact on a firm's ability and opportunity to acquire knowledge from their alliance partners (Goerzen and Beamish 2005). The resultant knowledge development from alliance activities is a function of both the knowledge and skill set of the partners, which represents the opportunity for learning, and partners' willingness to share, which represents the actual potential for learning.

One major assumption of knowledge-based view is that firms are heterogeneous in terms of knowledge and competencies they possess. As such, different types of partners will bring different kinds of skills and technologies to the revelation of the focal firm. As such, managers' preferences in their choice of partners will determine how much novel knowledge and skills they could be potentially exposed to. This would impact the knowledge development of the focal firm. For example, managers' preference for working with new partners will ensure a constant inflow of fresh and novel information into the organization. This would be advantageous compared with firms who only ally with a limited number of partners or ally with the same partner repeatedly.

Transaction cost analysis maintains that knowledge as the focal resources in R&D alliances poses considerable difficulties in contracting since knowledge use can not be effectively specified and monitored once it is transferred over to partners (Oxley 1997). As such, firms are subject to potential opportunistic behaviors from partners in knowledge sharing. Firms are thus motivated to withhold information, especially the critical and sensitive ones from their partners in order to avoid the risk. Therefore, alliance governance mechanism becomes an essential component in alliance management as it bears a direct impact on firms' willingness to share information with each other.

Alliance governance mechanism studies drew from the relational exchange theory and identified the trust-based approach of alliance management. The essence of trust is to alleviate opportunism (Gulati 1995). As such, trust suggests that alliance partners can depend on each other's actions without worrying about opportunistic behaviors (Ireland et al. 2002). Therefore, firms are more willing to exchange information and knowledge with each other when trust exists between partners.

A firm's alliance portfolio configuration that fosters trust development will thus have a positive impact on its knowledge development as partners are more willing to share information with the focal firm. Trust nurturing alliance portfolio could be a result of deliberate partner selection in the portfolio configuration process. Relational exchange theory suggests that trust evolves from past experiences and as such the history of the cooperation between partners is negatively related to the perceived opportunistic behavior of their partners (Parkhe 1993).

As such, firms' particular preferences for partner types or agreement types in their R&D alliance portfolio configuration will have an impact on the total amount of knowledge they are exposed to as well as the amount of knowledge partners are willing to share with each other. This will consequently either enhance or hinder the knowledge development of firms.

We distinguish two dimensions of knowledge development: knowledge breadth and knowledge depth. Knowledge breadth refers to the range of fields over which a firm has knowledge. Knowledge depth refers to the amount of the knowledge possessed by the firm in any particular area (Prabhu et al. 2005). It is important to distinguish these two dimensions of knowledge development, as we believe that the development of knowledge breadth and knowledge depth may have both different antecedents and consequences. While knowledge breadth development is primarily a function of the array of knowledge sectors a firm is exposed to, knowledge depth might be more a result of how much sensitive and in depth information partners are willing to share with each other.

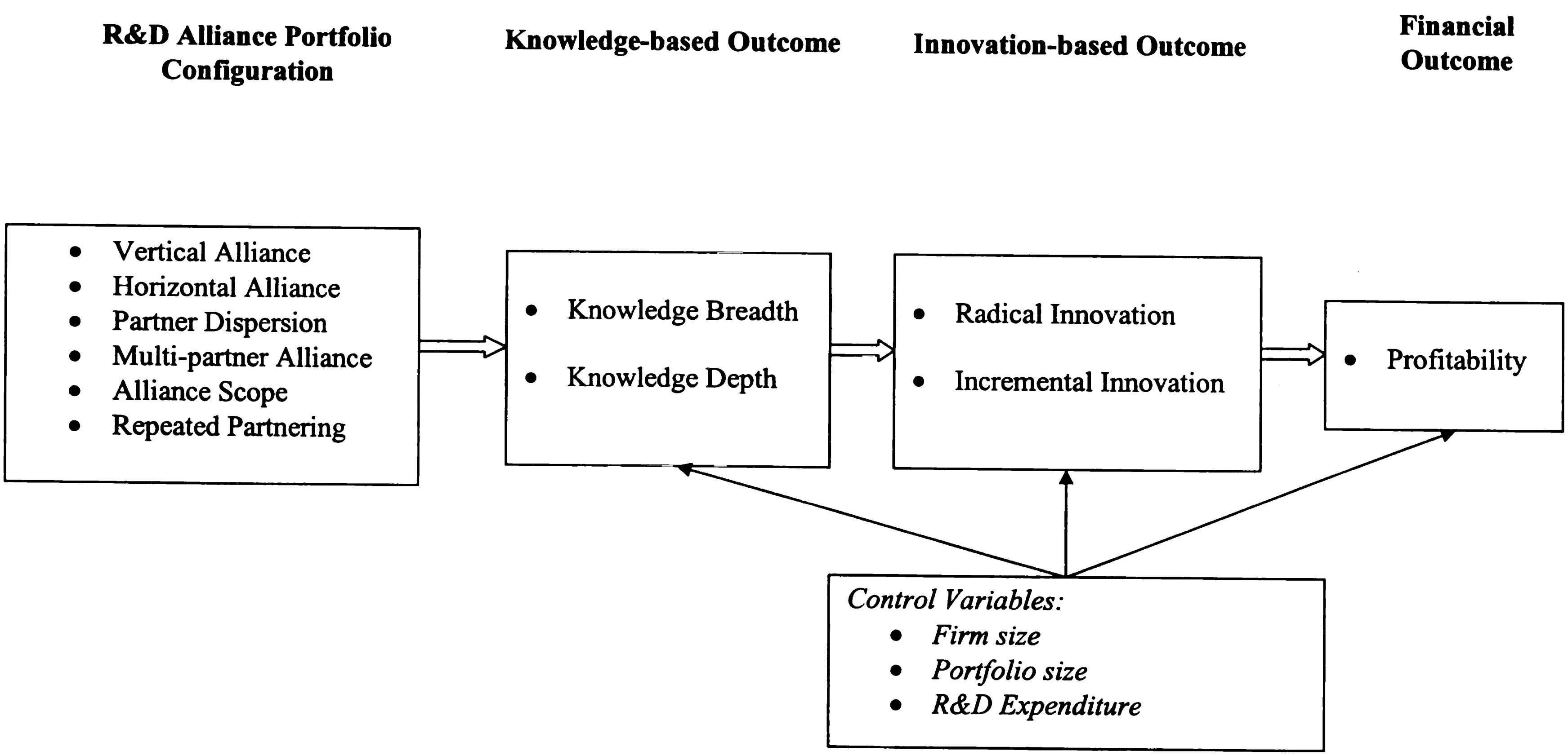
Past studies in understanding the influence of alliance characteristics on firm performance have largely ignored the different development requirements for knowledge breadth and knowledge depth. Take partner repeatedness as an example, past studies on its effect on firm performance have taken on both transaction cost analysis and social network theory which suggested quite opposite effects (Goerzen 2007). The findings thus become very much data oriented instead of theoretically driven.

However, we believe that to understand the impact of R&D alliance portfolio characteristics' influence on knowledge development, the two dimensions of knowledge development needs to be clearly delineated as the same characteristic may have different implications on the two knowledge dimensions. An illustration of this point could be demonstrated by a closer examination of the partner repeatedness. When a firm has a propensity to ally with the same partner repeatedly, the scope of knowledge the focal firm is exposed to is rather limited compared with firms who always ally with different partners. This would have a negative impact on its knowledge breadth development. However, this repeated interaction with the same partner allows for the development of trust between partners, which allows firms to share more in depth and sensitive information with each other. As a result, the focal firm's knowledge depth development will be enhanced.

As firms develop their knowledge inventory through learning from partners, they tend to add new products to their product portfolio using the newly acquired knowledge or by combining it with their existing knowledge base (Rothaermel et al. 2006). The newly acquired knowledge will allow firms to make improvements in their existing products or create totally new products that will serve the customer needs better. This process of knowledge creation also offer increased likelihood of success of related products in the portfolio (Rothaermel et al. 2006). Due to the different characteristics of radical and incremental innovations, we would expect knowledge breadth and knowledge depth play different roles on radical and incremental innovations.

The conceptual model is presented in Figure 1.

Figure 1: The Conceptual Model



3.2 Hypotheses Development

3.2.1 Vertical and Horizontal R&D Alliances and Knowledge Development

R&D alliance partners could be classified into two major categories: firms that are direct competitors and those that are channel members along the value chain. We define horizontal R&D alliances as formalized new product development collaborative arrangements among two or more partners from the same industry. We define vertical R&D alliances as formalized new product development collaborative arrangements among two or more partners operating at adjacent stages of the value chain (Rindfleisch and Moorman 2001). At times, firms need to enter into alliances with both types of partners in order to pursue their strategic goals. Even though it might be unexpected that firms that are direct competitors will collaborate with each other, such horizontal alliances do exist in practice (Dussauge et al. 2000; Rindfleisch and Moorman 2001).

The effect of knowledge sharing in horizontal R&D alliances stems from one major assumption: level of redundancy of knowledge stores among partners. Redundancy refers the degree of overlap in the knowledge base between two or more social actors or organizations. Horizontal R&D alliance partners (i.e. partners that are operating in the same industry) share very similar knowledge inventory as they use similar technologies to serve similar customer needs (Dussauge et al. 2000; Rindfleisch and Moorman 2001).

As Rindfleisch and Moorman (2001) point out, horizontal alliance partners, compared with vertical alliance partners, have a high redundancy in terms of the capabilities and skills each partner contributes to the joint effort. They have access to similar information because of common structural linkages through trade associations (Vives 1990), industry based norms and procedures (von Hippel 1987), and membership of common technological community (Powell et al. 1996). It should be acknowledged that firms in the same industry may also possess specific, idiosyncratic skills and capabilities (Dussauge et al. 2000). However, these idiosyncratic resources may be the cornerstone for a firm's competitive advantage on the market place. Firms may feel reluctant to share these critical resources with their direct competitors because of the zero-sum opportunity, increased opportunistic behavior potential, long term partner motives, and the vulnerability of the proprietary know-how (Sivadas and Dwyer 2000).As such, a firm that has an emphasis on forming R&D alliances with direct competitors has a limited exposure to new and novel knowledge which in turn limits its knowledge breadth.

Vertical R&D alliances, on the other hand, are characterized by a low redundancy of knowledge. Overlapping knowledge is the product of social actors occupying similar structural positions in which they are exposed to similar types of information, input and dominant logic (Bettis and Prahalad 1995; Rindfleisch and Moorman 2001). Vertical R&D alliance partners, which are defined as partners from different stages along the value chain, normally occupy very different social positions compared with horizontal alliance partners and thus result in very different knowledge composition. Partners bring highly complementary and fresh knowledge to the collaboration. As such, a firm's propensity to engage in vertical R&D alliances will have an advantage in developing its knowledge breadth.

Hypothesis 1: The higher the propensity of a firm entering into horizontal over vertical R&D alliances, the lower the knowledge breadth of the firm.

In order to develop knowledge depth, information freshness and novelty becomes a lesser issue compared with the relatedness and volume of information. Information richness, intensity of knowledge sharing, and knowledge absorption along a narrow domain become critical. The notion of absorptive capability thus plays an important role in a firm's knowledge depth development. The basic idea of absorptive capability is that firms need to have a prior related knowledge base in order to successfully identify, acquire, assimilate, and exploit external knowledge they are seeking (Cohen and Levinthal 1990). One key attribute of horizontal R&D alliances is the common knowledge base partners possess. It is argued that because of the similarity of the knowledge stores among partners in a horizontal alliance arrangement, this similarity enhances the absorptive capability of the partners to better assimilate the knowledge along a rather narrow scope of skills, which will positively influence the knowledge depth of the parties.

However, firms in vertical R&D alliances normally contribute very complementary knowledge to each other. Because of the knowledge complementary, not knowledge similarity, absorptive capability will be limited among partners. As such, firms that have a propensity to enter into vertical partnerships will be limited in its knowledge depth development.

Hypothesis 2: The higher the propensity of a firm entering into horizontal over vertical R&D alliances, the higher the knowledge depth of the firm.

3.2.2 Partner Dispersion and Knowledge Development

Partner dispersion refers to the spread of distinctive alliance partners in the portfolio. For any given portfolio size, it essentially measures the number of distinct partners. It is therefore an indicator of a firm's propensity to bring in new/unfamiliar partners into its R&D alliance network. A highly dispersed R&D alliance portfolio links the focal firm to a diversified set of partners from different strategic groups and industries (Hoffmann 2007). Thus it offers the focal firm access to a diversified pool of skills and knowledge.

A basic assumption of knowledge-based view is that firms are heterogeneous in terms of the knowledge they possess to compete in the market (Barney 1991; Barney 2001; Grant 1996). Knowledge heterogeneity refers to the variety of knowledge, know-how, and expertise to which a firm has access through its alliance activities (Rodan and Galunic 2004). In fact, this heterogeneity is supposed to be sustainable so that firms with superior resources and knowledge can achieve long run superior performance (Barney 1991; Wernerfelt 1984). A diversified partner portfolio of R&D alliances thus indicates a diverse inflow of knowledge into the focal firm. This diversity of inflow of information is thus a direct antecedent of knowledge breadth of the participating firms in the alliances. As such, we would expect a firm's R&D alliance portfolio dispersion to be positively associated with its knowledge breadth development.

As for the portfolio dispersion's influence on firms' knowledge depth development, different views exist in the literature. One thought maintains that knowledge depth is essentially about the richness of information and knowledge. As such, it focuses on firms' overall alliance experience and its history with the current partners (Koka and Prescott 2002). Prior alliance experiences with partners help to establish relational norms which include collaboration, continuity expectation, and non-coercive communication patterns (White and Lui 2005). All these bring the benefit of effective routines of accessing knowledge from each other (Koka and Prescott 2002). However, a firm's tendency to work with new, unfamiliar partners brings about the concern of behavioral uncertainty of partners. When the uncertainty of partners' behaviors, especially in regards to their future use of the shared knowledge and skills, partners may feel reluctant to share any sensitive, in depth information with each other.

Alliance portfolio dispersion measures a firm's propensity to work with new/unfamiliar partners. A highly dispersed R&D alliance portfolio indicates that the firm prefers to work with new partners. In this case, the relational capital does not exist and this would hinder the assimilation of knowledge in depth. As such, portfolio dispersion would be negatively related to the knowledge depth development of a firm.

On the contrary, another stream of research may suggest that alliance portfolio dispersion actually enhances the knowledge depth of a firm. The diverse inflow of knowledge is proven to enhance the assimilative power, enable novel associations (Cohen and Levinthal 1990; Wuyts et al. 2004), and stimulate broader perspectives and synthesis (Dewar and Dutton 1986). It is demonstrated that exposure to heterogeneous knowledge should improve both the creative potential of the focal firm and its ability to implement its ideas and to execute complex tasks in general (Rodan and Galunic 2004). It is often times that the newly assimilated information, which seems to be unrelated to the existing knowledge inventory, may turn out to be intriguing in new interpretation of existing knowledge in the future (Pelled et al. 1999). This is in nature a process of reintegration of concepts or blending of ideas which is a fundamental cognitive process in the generation of novel insights into the existing knowledge of a firm.

Our position regarding the effect of alliance portfolio dispersion is that in order for the dispersion to have a positive effect on the knowledge depth, successful knowledge assimilation is the necessary antecedent for this positive effect to take place. However, without the incentive to share, the new information will not be assimilated. As such, the knowledge that has the potential to offer new perspectives on the existing knowledge base will remain outside the firm boundary and its effect can not be realized. Thus, we believe that the dispersion property of an R&D alliance portfolio will have a negative effect on a firm's knowledge depth development.

Hypotheses 3: The higher a firm's R&D alliances portfolio partner dispersion, the higher its knowledge breadth.

Hypotheses 4: The higher a firm's R&D alliances portfolio partner dispersion, the lower its knowledge depth.

3.2.3 Partner Repeatedness and Knowledge Development

We define partner repeatedness as a firm's preference to ally with a particular partner repeatedly over time. An example would be helpful to clarify its relationship with the partner dispersion construct. Let's assume firm X and firm Y both have nine R&D alliances in their R&D alliance portfolio and the distributions of partners are as follows:

Firm X (A, A, A, B, B, B, C, C, C)

Firm Y (A, A, A, A, A, A, A, B, C)

Since both firms have three distinct partners out of nine alliances, their partner dispersion level is equivalent. However, a closer look at the distributions of the three partners in these two firms' R&D alliance portfolio indicates that firm Y shows a much stronger preference for one of its partners, A than X does. As such, the partner repeatedness of Y's portfolio is higher than that of X.

From a transaction cost perspective, repeated partnering offers partners opportunities to better understand each other's goals, long run motivation, and capabilities. Repeatedness indicates intense and frequent interactions between two social organizations. The frequent interactions between partners can thus nurture trust-based governance mechanism, which would greatly reduce the monitoring costs (Goerzen 2007). The intensified social interaction is proven to be beneficial in knowledge acquisition in alliances (Ring and Van de Ven 1994; Yli-Renko et al. 2001) as the increased trust level gives firm incentives to share knowledge and information with each other (Dyer and Singh 1998; Zahra et al. 2000). The intense and frequent interaction between repeated partners also enhances firm's ability to identify pertinent knowledge that are valuable to the firm's innovation effort (Cohen and Levinthal 1990; Lane and Lubatkin 1998). Inter-firm knowledge sharing routines, which develop through the specific alliance experiences, will lay a foundation for the absorptive capability that enables alliance partners to recognize valuable knowledge and effectively transfer it across firm boundaries.

Ring and Van de Ven (1994) note that firms enjoy greater intensity and frequency of knowledge sharing with partners of high social interaction. The more intense social interaction between partners, the more confident firms are with their partner's intentions and capabilities (Yli-Renko et al. 2001). A general benefit of repeated partnering is that the focal firm comes to know its partners better and thus would be able to cooperate with each other better (Wuyts et al. 2004). Kogut and Zander (1996) proves that close and intense social interaction help firms to overcome the tastiness of technological know-how and thus greatly enhance knowledge transfer. Thus the repeated social interaction among partners is beneficial for assimilation of tacit, deeper knowledge from partners which would increase a firm's knowledge depth.

Secondly, through repeated partnering, dyadic partners may be induced to make transaction specific investment that reduces transaction costs and thus increase the value created (Dyer and Singh 1998). Yli-Renko, Autio,and Sapienze (2001) actually described the whole process as self-enforcing. Intense social interactions give firms confidence in each other's capability and behavioral certainty. This would intensify the frequency and depth of information exchange. A direct result of this process is the development of relationship-specific common knowledge. This increased common knowledge would lead to better absorptive capacity of the partners as the internalization of novel knowledge depends on the existence of the prior related knowledge within the firm (Cohen and Levinthal 1990). As both parties' ability to absorb the other party's knowledge increases, they are more motivated to invest in knowledge sharing routines which would greatly enhance knowledge learning for both parties.

Knowledge depth is also closely related to knowledge complexity. Repeated partnering generates a specific advantage in transferring complex and tacit knowledge across firm boundaries (Zucker et al. 2002). Frequent and repeated interaction facilitates the transfer of the tacit knowledge (Hansen 1999) and generates a deeper understanding of the newly identified and existing knowledge (Dewar and Dutton 1986) as repeated interactions allow for the emergence of relationship specific heuristics (Uzzi 1997) and shared mental models (Madhavan and Grover 1998). These heuristics and mental models in turn facilitate the process of assimilating complex knowledge (Polanyi 1966; Wuyts et al. 2004).

However, Hoang and Rothaermel (2005) argue that a portion of knowledge and skills that accumulate based on repeated partnering over time may be partner specific. As such, the positive effect of alliance experience on alliance performance is partner specific. The notion of absorptive capability also lends support to the idea that the ability of firms to learn form each other in an alliance depends on the similarity between the two firm's knowledge bases, organizational structure and dominant logic (Lane and Lubatkin 1998). It is argued in the literature that the more allying experiences two firms have, the more likely they will develop a technological bases that are overlapping with each other (Dussauge et al. 2000; Nakamura et al. 1996). Even though repeated partnering help firm to learn from a particular partner, the knowledge range it is exposed to though, is limited to what that particular partner possess. As such, knowledge breadth would be limited.

As such, we hypothesize:

Hypothesis 5: The higher the repeated partnering in a firm's R&D alliance portfolio, the lower its knowledge breadth.

Hypothesis 6: The higher the repeated partnering in a firm's R&D alliance portfolio, the higher its knowledge depth.

3.2.4 Multiple Partner R&D Alliances and Knowledge Development

We define multiple partner R&D alliances as R&D alliances that involve more than two partners. A firm's R&D alliances portfolio will also differ in terms of how often firms enter into alliances that involve multiple partners in each R&D alliance project. Even though it is common that a firm will ally with only one other firm to achieve new product development objectives, multiple partner alliances do occur in practices (Zeng and Chen 2003).

The influence of a firm's propensity to enter into multiple partner alliances on its knowledge breadth development is evident. For any given size of a portfolio, firms with a higher propensity to enter into multiple partner agreements are in effect allied with a lot more partners than firms who prefer two-party alliances. This increased number of partners offer better access to a broader range of knowledge and skills. A multi-partner alliance, compared with a two-party alliance, allows firms to get access to more diversified knowledge bases. As such, knowledge breadth of participating firm will be greatly enhanced.

Even though a firm's propensity to engage in multi-partner alliances have an obvious positive effect on its knowledge breadth development, its effect a firm's knowledge depth might be negative. Due to the unique characteristics of knowledge as a resource, opportunistic behavior would be a major concern for firms to share knowledge with others as they cannot effectively control the use of it by their partners once it is transferred (Oxley 1997).

First of all, the increased number of partners in alliances by itself increases the possibility that some one will act opportunistically. Due to the increased number of players in the joint activity, firms' screening ability of every partner's credibility and dependability will be imperfect. This concern would limit firm's willingness to share any sensitive, in depth information with the whole group. In addition, in a two-party alliance, each player can effectively punish the other for opportunistic behaviors by choosing non-cooperation in subsequent interactions. Thus, each player can attempt to shape the other's behavior and hence indirectly influence the outcome of the alliance. This is however not the case when multiple partners are brought together. In a project that involves multiple partners, it is much harder to for any single player to shape the group dynamics effectively (Zeng and Chen 2003). This causes a lack of controllability of other's behavior and the alliance outcome is more likely to increase the defective behavior. When firms are not sure of the behaviors of the other firms which include but is not limited to the application of the shared knowledge, firms may be reluctant to share any sensitive, critical, and in depth knowledge with each other, especially those that are critical for competitive purposes. As such, we hypothesize:

Hypothesis 7: The higher the propensity of a firm to enter into multiple partner alliances, the higher its knowledge breadth.

Hypothesis 8: The higher the propensity of a firm to enter into multiple partner alliances, the lower its knowledge depth.

3.2.5 Alliance Scope and Knowledge Development

We define R&D alliance scope as the number of technologies included in an alliance agreement. When a firm wishes to undertake an R&D project for which it does not currently possess all of the relevant technical knowledge, forming an alliance is normally a solution. However, before an alliance is established, managers have to make many critical decisions. One of these decisions is to define an appropriate scope of activities included in the alliance agreement (Oxley and Sampson 2004).

Researchers have distinguished between vertical scope and horizontal scope of alliances (Reuer et al. 2002). Vertical scope refers to the extent partners combine multiple and sequential functions of value chain activities within the alliance such as R&D,

manufacturing, and marketing. Horizontal cope of alliance refers to the size, complexity, and technology variety that is covered in an alliance. Previous studies on alliance scope have normally focused on the vertical scope of alliances due to the availability of secondary data. However, as our focus is on the scope effect on knowledge accumulation, we choose to focus on the horizontal scope of alliances as this normally refers to the technology diversity involved, which has a direct impact on the knowledge a firm is exposed to by his partners.

First of all, horizontal scope of alliances is a direct indication of the diversity of knowledge that firms need to share with each other. For any given portfolio size, a firm's propensity to engage in multi-technology alliances will surely increase its exposure to a broader span of knowledge as firms need to share their expertise in multiple areas to achieve the common benefit. This, as argued before, will increase the knowledge breadth of participating firms.

On the other hand, when multiple technologies are included within one alliance agreement, these technologies are normally related with each other. Because of the contracting hazards associated with knowledge-based collaborations, transaction cost is a major concerns for such endeavors (Oxley 1997). When multiple technologies are involved in one agreement, the transaction cost in terms of monitoring partner behavior becomes a major challenge. Unless there are synergistic values associated with the multiple technologies specified in the agreement, it would be irrational to put two or more unrelated technologies into one package for development purposes. As such, the depth of knowledge would also increase as a result of the relatedness of the multiple technologies.

Hypothesis 9: The higher the average scopes of R&D alliances in a firm's alliance portfolio, the higher its knowledge breadth.

Hypothesis 10: The higher the average scopes of R&D alliances in a firm's alliance portfolio, the higher its knowledge depth.

3.2.6 Knowledge Development and Innovation Output

The positive impact of a firm's knowledge development on its innovation outcome has been documented in the literature (Prabhu et al. 2005; Sorescu et al. 2003). It is asserted that a firm's ability to generate knowledge is a vital antecedents to its ability to innovate (Prabhu et al. 2005). Newly developed knowledge allows firm to see existing knowledge stores from new perspectives and the integration of new and old knowledge is a major source of creativity of serving customer needs.

Prabhu, Chandy, and Ellis (2005) argues that both knowledge depth and knowledge breadth contribute to a firm's innovation success. The development of knowledge depth allows firms to better identify and assimilate external knowledge and turn them into innovative products and services (Cohen and Levinthal 1990). Firm with low knowledge depth may suffer from technological lock out problem and fall short in accurately assessing innovation potentials (Cohen and Levinthal 1989). Firms with high knowledge depth are better at evaluating knowledge and using it for innovation purposes (Prabhu et al. 2005).

From a knowledge-based perspective, the breadth of knowledge is a key input factor for innovation (Cohen and Levinthal 1990; Henderson 1994; Henderson and Cockburn 1994). Knowledge breadth indicates the diversity of knowledge a firm possesses. A wide array of knowledge sectors allow firms to integrate them in creative ways to improve customer benefits (Henderson and Cockburn 1994; Volberda 1996). Broader knowledge base of a firm also offers greater flexibility and adaptability to turbulent environment as the availability of diverse knowledge safeguards the value of the firm when technologies change rapidly (Prabhu et al. 2005). The bulk literature strongly supports that idea that the broader a firm's knowledge, the greater its ability to create innovations (Prabhu et al. 2005).

While the impact of knowledge depth and knowledge breadth on firm innovation is well researched, we would like to make a contribution to the literature by theorizing the differential impact of knowledge depth and knowledge breadth on radical and incremental innovation. Due to the different natures of radical innovation and incremental innovation, development of these two types of innovations may have very different knowledge requirements (Sivadas and Dwyer 2000).

A further argument could be made in terms of the different impacts of knowledge breadth and knowledge depth on radical innovation and incremental innovation respectively. By definition, radical innovations are those that are built on new technologies and often rely on the integration of a diversified pool of technologies (Wuyts et al. 2004). As such, firms with a diversified pool of knowledge enjoy greater advantage for the experimentation of new ideas and concepts. Because of the integrative capability, which refers to firms' ability to combine knowledge from different areas for innovation purposes, the potential for integration increases exponentially with any addition of new piece of information. As such, we would expect that the novelty of the incoming information and the overall diversity of the knowledge inventory of a firm will have a much greater impact on its radical innovation than the mere quantity of its knowledge inventory.

As for incremental innovation which is more of modification of existing products, the quantity and relevance of incoming information may be more important than its novelty (Wuyts et al. 2004). Incremental innovation is mostly based on an increased understanding of the existing product. Sivadas and Dwyer (2000) also note that the development of incremental innovation is strongly based on existing technologies. Firms may arrive at incremental innovations without accessing novel knowledge or integrating different technologies. What is important for incremental innovation from a learning perspective is that the incoming information should be clearly associated with what is already known. This could be translated into the idea that firms need to build a richer understanding within a given knowledge domain to come up with incremental innovation.

Given the differences in the nature of the two kinds of innovation and their different knowledge requirements, we hypothesize:

Hypothesis 11: A firm's knowledge breadth has a greater impact on its radical innovation than knowledge depth.

Hypothesis 12: A firm's knowledge depth has a greater impact on its incremental innovation than knowledge breadth.

3.2.7 Innovation and Firm Financial Performance

It is well proven in the literature that innovation and new product development is the major source for a firm's competitive advantage in the market place and its financial performance (Geroski et al. 1993; Sorescu et al. 2003). Due to the increased customer benefit associated with a new product, firms enjoy higher return on their investment when new product could be successfully commercialized (Chaney et al. 1991). Firms manage to build stocks of radical and incremental innovations over time to maintain competitive in the market place. Higher levels of innovation enhance a firm's financial performance (Geroski et al. 1993).

Cho and Pucik (2005) have identified three streams of work that support a direct relationship between innovation and firm performance. The first is the positive relationship between organizational innovation and firm performance. Examples are given as Damanpour and Evan (1984) and Subramanian and Nilakanta (1996). The second stream is the positive relationship between product innovativeness and firm performance. Examples include the studies by Kleinschmidt and Cooper (1991). The third stream is on value innovation with an example of Kim and Mauborgne (1997). All these studies offer empirical support for the positive relationship between innovation and firm performance.

Hypothesis 11: A firm's stock of incremental innovation is positively related to its financial performance.

Hypothesis 12: A firm's stock of radical innovation is positively related to its financial performance.

3.2.8 Control Variables

In addition to the relationships discussed above, we control for other variables that may affect a firm's knowledge development, innovation outcome, and financial performance but are outside our theoretical focus. Specifically, we control for portfolio size, R&D expenditure, and firm size for knowledge and innovation based dependent variables. We will control for the number of radical and incremental innovation introduced that year for financial performance.

Portfolio size. When the dependent variables are knowledge and innovation, portfolio size (i.e., the total number of R&D agreements in a portfolio) is found to be positively related to both types of outcomes. Studies have shown that a larger portfolio offers more exposure to different knowledge bases (Dewar and Dutton 1986) and the portfolio size's positive effect on innovation has also been documented (Powell et al. 1996; Shan et al. 1994; Wuyts et al. 2004).

R&D expenditures. We would also control for the R&D expenditure for knowledge and innovation based outcomes. It is expected that the more resources devoted to research and development, the greater firm's knowledge base would be and the better their innovation volume (Wuyts et al. 2004).

Firm size. We would also control for the size of the firm for all three types of dependent variables (knowledge, innovation, and financial performance). The effect of firm size on knowledge and innovation development largely stems for the seminal work of Schumpeter (1942). Different effects (positive, negative, and insignificant) were documented in the literature (e. g., Ahuja and Lampert 2001; Chandy and Tellis 2000; Miles et al. 2000). The effect of firm size on performance is based on the idea that large have advantage in obtaining lower cost of capital while simultaneously lowering risk (Chang and Thomas 1989; Goerzen 2007). Previous studies have suggested that the number of employees, sales, and assets are all appropriate proxies for firm size (Harrison et al. 1988; O'Sullivan and Abela 2007). We operationalize firm size as sales in our study.

Number of innovations introduced. In testing the influence of firms' stock of innovation on its financial performance, our conversation with practitioners suggest that we need to control for the number of innovations introduced that year. When a new product is introduced, abnormal expenditures may occur due to the change in the production, distribution, and inventory processes. This is particularly true for radical innovation which may require huge investment on the manufacturing facility. As this is expected to negatively affect the bottom line of the firm, we would control this in our study.

To summarize, a conceptual model is developed which first identifies a firm's R&D alliance portfolio characteristics and their influence on a firm's ability to develop knowledge breadth and knowledge depth. Due to the different opportunities these characteristics offer to the focal firm in terms of the diversity of knowledge it is exposed to as well as the different level of contracting difficulties associated with each characteristic, firms' ability to develop knowledge breadth and knowledge depth is either enhanced or constrained. We further analyzed the differential impact of knowledge breadth and knowledge depth on incremental and radical innovations. Finally, innovation is hypothesized to be positively related to firm performance due to the increased customer benefits.

3.3 Research Methodology

3.3.1 Empirical Setting

We choose to empirically test our model in the pharmaceutical industry. In particular, we examine the effect of pharmaceutical firms' portfolio of R&D alliances on their knowledge breadth and knowledge depth development which in turn influence their innovation and financial performance. There are several reasons we prefer the pharmaceutical industry. First, pharmaceutical industry is a technology intensive industry in which both knowledge development and innovation effort play significant roles in establishing and sustaining firms' competitive advantage (Wuyts et al. 2004). Second, inter-firm cooperation in the pharmaceutical industry has been a popular business practice since the 1980s. Most pharmaceutical firms have entered into numerous agreements and these portfolios of R&D agreements enjoy substantial variation in their composition. As our model focuses on the different characteristics of R&D alliance portfolio, this context would be ideal for testing our model (Wuyts et al. 2004).

Third, secondary data are available on all inter-firm agreements between pharmaceutical firms in the United States since 1985 through various sources such as Verispan, Bioscan, Recap, and IMS. These sources trace in great details of alliance activities in the pharmaceutical industry. Finally, pharmaceutical industry has long been a preferred context for empirically testing innovation and alliance related topics (e. g., Nicholls-Nixon and Woo 2003; Prabhu et al. 2005; Rothaermel and Deeds 2004; Sorescu et al. 2003; Wuyts et al. 2004).

3.3.2 Sample

Our sample consists of 66 public pharmaceutical companies in the United Sates. We limited our sample within public firms because we need to obtain financial measures as our dependent variable and control variables. Public firms are mandated to disclose this information to their shareholders in their annual reports. We compiled data of R&D alliance agreements, new patent approval, new drug approval, and financial information from 1991 to 2005. The starting point of 1991 is selected based on the fact that FDA did not provide detailed information about newly approved drugs before then which would prevent us from effectively classifying them into radical vs. incremental innovations.

The 66 pharmaceutical firms include most of the major players in the market such as Pfizer, GlaxoSmithKlein, Eli Lilly, and Merck. A total of 3828 R&D alliances were compiled into our data base for these 66 firms over the 15 year period. As expected, firms demonstrated considerable variation in terms of their R&D alliance portfolio characteristics such as size, repeatedness, dispersion etc; For example, some firms have as many as 370 R&D alliances in their portfolio while some have zero. The average R&D alliances portfolio size is 31. Table 2 provides a summary of the sample characteristics.

Table 2 Summary of Sample Characteristics

Dimensions	Minimum	Maximum	Mean	Standard Deviation
Portfolio Size	0	370	31	56
Sales (in millions)	-1.22	310,979.00	11,627.76	23,411.56
Horizontal vs. Vertical	-1.00	1.00	.60	.47
Repeatedness	0	1.00	0.26	0.34
Dispersion	0.5	1	0.91	0.11
Multiple Partner	1.00	2.00	1.10	0.18
Alliance Scope	1	3.00	1.38	0.33
Knowledge Breadth	0	634.00	78.65	115.41
Knowledge Depth	1.00	5.44	2.02	0.93
Radical Innovation	0	4.00	0.92	0.39
Incremental Innovation	0	25.00	1.13	2.54
R&D (in millions)	0	16,923.85	991.48	1,615.87

3.3.3 Data Sources

Four separate data sources provide information for our empirical testing: Recap, US Patent and Trademark Office/Delphion, FDA, and Compustat.

For the R&D alliance portfolio related constructs, we collect data from Recombinant Capital Database. Recombinant Capital is a consulting firm that specializes in pharmaceutical and biotechnology alliances based in the San Francisco Bay Area. They use multiple sources such as trade literature, press releases, and annual reports to compile a database of all the alliance activities of pharma/biotech companies. It also provides detailed information about each identified alliance activity such as parties to the agreement, nature of the agreement, development stage when alliances are formed, and the technologies that the agreements cover. This database has been used in the literature to construct alliance related variables (Wuyts et al. 2004).

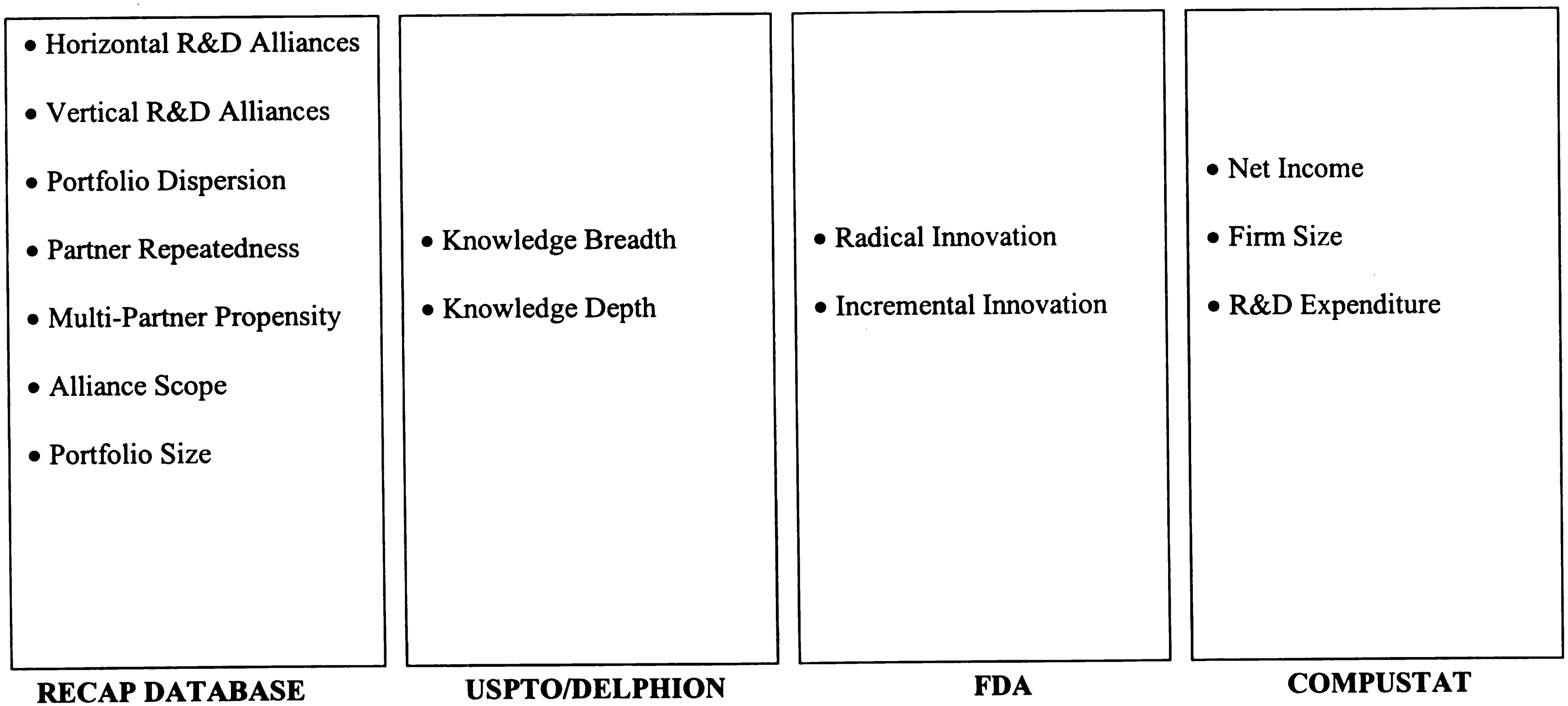
For the knowledge-based constructs, we use information from US Patent and Trademark Office and Delphion. In the pharmaceutical industry, patent is an excellent indicator of firms' technical knowledge (Prabhu et al. 2005; Rothaermel and Deeds 2004; Sorescu et al. 2003; Wuyts et al. 2004). Patent office also classifies patents into different classes and subclasses that indicate their field of use. Therefore, it is possible to identify the number of technical fields in which a firm has knowledge by studying the classes/subclasses. Delphion is an excellent database that offers search functions. The number of approved patents in each patent class and subclass for each firm in each year is available from the Delphion database.

Third, we collect data on new drugs from the drug approval list of the Food and Drug Administration (FDA) as our innovation based outcome constructs. FDA publishes all the approved new drugs weekly since 1991. The publication provides additional useful information about each drug, such as its therapeutic potential and chemical type. This would help us to classify radical vs. incremental innovations. First, FDA categorizes all new drugs according to their treatment potential and distinguishes between "standard review" (therapeutic qualities are similar to those of an already marketed drug) and "priority review" (Therapeutic qualities are significantly superior to those drugs already on the market) drugs. FDA also assigns a chemical type to each drug. Those that incorporate a new technology is classified as Chemical Type 1, otherwise it will be type 2, Type 3, etc. Following the literature, we would use both piece of information to classify radical vs. incremental innovations.

Finally, we collect financial performance (net income) as well as control variables (firm size and R&D expenses) from the Compustat database.

Figure 2 is a graphical illustration of the data sources for our study.

Figure 2: Data Sources for Empirical Testing



3.4 Measures

Horizontal alliances over vertical alliances (HOVA)

This construct measures a firm's preference of allying with horizontal partners to vertical partners. We classify an alliance as horizontal if the partner is another pharmaceutical firm. We classify it as vertical if the partner is a biotech, university or device firm. It is measured as the difference between the total number of horizontal R&D alliances up to year t for firm i minus the total number of vertical R&D alliances up to year t for firm i then divided by the total alliances portfolio size for firm i up to year t. Formally,

$$HOVA_{it}^{cum} = \frac{H_{it}^{cum} - V_{it}^{cum}}{A_{it}^{cum}}$$

This construct will equal to 1 if the firm only allies with horizontal partners in its R&D alliance portfolio. It will be –1 if it only allies with vertical partners.

Alliance Partner Dispersion (DISP)

This construct measures the distinct number of partners in a firm's R&D alliance portfolio for a given portfolio size. We measure it as the ratio of number of distinct partners over the total number of R&D alliances.

Formally,

$$DISP_{it}^{cum} = \frac{P_{it}^{cum}}{A_{it}^{cum}}$$

This will equal to 1 when there are as many partners as there are alliances in the portfolio, which means firms always find new partners to work with. It will be close to zero when there are many alliances but only a small number of distinct partners in the portfolio.

Multiple partner alliance propensity (MULT)

This measures a firm's preference to involve more than one partner in an R&D alliance agreement. We first count the total number of partners (including the repeated ones) and then divide it by the total number of alliances.

Formally,

$$MULT_{it}^{cum} = \frac{PT_{it}^{cum}}{A_{it}^{cum}} \qquad \text{Where } PT_{it}^{cum} = \sum_{j=1}^{j} p_{it,j}^{cum}$$

This measure will take a value of 1 if there are as many partners as there are alliances which indicates that in each and every alliance in the portfolio there is only one partner to the firm. However, the value will become significantly bigger if the total number of partners (including the repeated ones) is more than the number of alliances, which indicates the firm has a preference to include more than one partners in each agreement.

Partner Repeatedness (RPEA)

This measures a firm's preference to work with a subset of its partners repeatedly over time. We operationalize it in the following way.

$$RPEA_{it}^{cum} = \sum_{j=1}^{j} p_{it,j}^{2} \qquad \text{Where } p_{it,j} = \frac{n_{it,j}}{\sum_{j} n_{it,j}}$$

The partner repeatedness index equals one when a firm allies with only a single partner and it is close to zero when a firm spreads its R&D alliance activity over many partners.

Alliances Scope (SCOP)

This measures a firm's preference to include multiple technologies within one alliance agreement. We measure it by calculating the average number of technologies covered in each alliance agreement in the portfolio. That is, we first count the total number of technologies (including the repeated ones) in the portfolio for a firm up to year t and then divide it by the portfolio size up to year t.

Formally,

$$SCOP_{it}^{cum} = \frac{T_{it}^{cum}}{A_{it}^{cum}}$$

This construct will take on a value of 1 when there are as many technologies (including the repeated ones) as there are alliances, which indicate the firm, have a preference to include only one technology in each alliance agreement. Otherwise, the value will be greater.

Knowledge Breadth (KLBR)

Knowledge breadth has normally been measured by the number of classes in which a firm holds patents. However, our sample consists of a single industry and as such most of their patents fall into to classes 514 and 424. Both classes are defined by USPTO as "Drug, bio-affecting, body healing compositions". When most of the patents are limited to just two classes, the count of classes as a proxy for a firm's knowledge breadth may not be accurate (Prabhu et al. 2005). As such, we decided to use the subclass under these two classes as indicators of a firm's knowledge breadth. As such, knowledge breadth is measured as the number of patent subclasses under class 514 and 424 for each firm up to year t (Prabhu et al. 2005).

Knowledge Depth (KLDP)

Following the operationalization approach used by Prabhu, et al., (2005), we measure knowledge depth as the average number of approved patents per patent subclass for each firm up to year t.

Radical Innovation (RINO)

We measure this construct as the total number of new radical drugs that are approved for firm i in year t. A new drug's radicalness is based on two factors: its therapeutical potential and technology type. FDA assign a new drug a priority review status if they confirm that a new drug offers significant better therapeutical benefit to patients than other drugs already on the market. If not, it will be a standard review status. FDA also distinguishes chemical type used in the new drug. If it is involves an ingredient that has never been used, it is labeled as chemical type 1. We classify a new approved drug as a radical innovation if it is classified both priority review and chemical type 1. This classification is consistent with practices in the literature (Rothaermel and Deeds 2004; Sorescu et al. 2003; Wuyts et al. 2004).

Incremental Innovation (IINO)

We measure this construct as the total number of new incremental drugs that are approved for firm i in year t. All drugs that do not satisfy both radicalness conditions are classified as incremental innovations (Rothaermel and Deeds 2004; Sorescu et al. 2003; Wuyts et al. 2004).

Radical Innovation Stock (RIST)

We measure this construct as the total number of new radical drugs that are approved for firm i up to year t.

Incremental Innovation Stock (IIST)

We measure this construct as the total number of new incremental drugs that are approved for firm i up to year t.

Table 3 lists the measures of the constructs in the study and their corresponding data sources.

A correlation matrix among the key constructs and control variables with their means and standard deviations are presented in Table 4.

Table 3 Constructs Operationalization and Data Sources

Construct	Measure	Rationale	Data Sources
HOVA	$\frac{H_{it}^{cum} - V_{it}^{cum}}{A_{it}^{cum}}$	H_{it}^{cum} is the cumulative number of horizontal alliances for firm i up to year t. V_{it}^{cum} is the cumulative number of vertical alliances for firm i up to year t. A_{it}^{cum} is the cumulative number of alliances for firm i up to year t. It will have a value between -1 to 1 indicating a firm's preference for horizontal partners.	RECAP
DISP	$\frac{P_{it}^{cum}}{A_{it}^{cum}}$	P_{it}^{cum} is the cumulative number of distinct partners for firm i up to year t. A_{it}^{cum} is the cumulative number of alliances for firm i up to year t. It will take on a value of 1 if the firm extensively spreads out its agreements with different partners. Otherwise, the value will be close to zero.	RECAP
RPEA	$\sum_{j=1}^{j} p_{it,j}^2$ where $p_{it,j} = \frac{n_{it,j}}{\sum_j n_{it,j}}$	For firm i up to year t, we denote the number of times that the firm has allied with firm j as $n_{it,j}$. Then $p_{it,j}$ represents the proportion of occurrence of firm j relative to the cumulative occurrence of all firms in firm i's portfolio. The partner repeatedness equals one when a firm allies on only a single partner and it is close to zero when a firm spreads its R&D alliance activities over many partners.	RECAP
MULT	$\frac{PT_{it}^{cum}}{A_{it}^{cum}}$ Where $PT_{it}^{cum} = \sum_{j=1}^{j} p_{it,j}^{cum}$	PT_{it}^{cum} is the total partners in the alliance portfolio for firm i up to year t. this includes the repeated ones. It will be close to 1 if they only include one partner in the agreement every time. The value will become bigger if they include more than one partner in a single agreement.	RECAP

Table 3 (Cont'd)

Construct	Measure	Rationale	Data Sources
SCOP	$\frac{T_{it}^{cum}}{A_{it}^{cum}}$	T_{it}^{cum} refers to the total number of technologies (including the repeated ones) in the portfolio for firm i up to year t. It will take a value of 1 if every agreement only includes one technology. Otherwise, the value will be bigger.	RECAP
KLBR		Number of patent subclasses covered by each firm's approved patents up to year t under class 514 and 424.	USPTO/Delphion
KLDP		The average number of approved patents per patent subclass for each firm up to year t.	USPTO/Delphion
RINO	Therapeutical potential: high, priority review Chemical type: 1	The total number of new radical drugs of firm i that received FDA approval in year t	FDA
IINO	Therapeutical potential: low, standard review Chemical type: other than 1	The total number of new incremental drugs of firm i that received FDA approval in year t	FDA
R&D expenditure			Compustat
Firm size	Sales		Compustat
Financial Performance	Net income		Compustat
Portfolio size (PFSZ)		Total number of R&D alliances in a firm's portfolio up to year t	RECAP

(HOVA: preferences of horizontal alliance over vertical alliance; DISP: partner dispersion; RPEA: partner repeatedness; MULT: multiple partner alliance; SCOP: alliance scope; KLBR: knowledge breadth; KLDP: knowledge depth; RINO: radical innovation; IINO: incremental innovation)

Table 4 Correlation Matrix of Key Constructs

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.HOVA	1												
2. DISP	-.06	1											
3. RPEA	-.01	.38**	1										
4. MULT	-.02	-.62**	-.22**	1									
5. SCOP	.17**	-.11**	-.30**	.10**	1								
6. KLBR	.21**	-.48**	-.42**	.18**	.19**	1							
7. KLDP	.19**	-.33**	-.13**	-.00	.04	.67**	1						
8. RINO	.04	-.26**	-.15**	.18**	.04	.29**	.18**	1					
9. IINO	.13**	-.24**	-.24**	.18**	.02	.29**	.11**	.35**	1				
10.SALES	.10*	-.03	-.03	-.01	-.01	.25**	.15**	.03	.07**	1			
11. R&D	.17**	-.35**	-.30**	.18**	.11**	.59**	.35**	.16**	.24**	.68**	1		
12. PFSZ	.12**	-.54**	-.43**	.17**	.17**	.82**	.52**	.30**	.29**	.20**	.67**	1	
13. NETINCOME	.14**	-.27**	-.29**	.11**	.06	.60**	.40**	.18**	.32**	.66**	.74**	.60**	1
Mean	.60	.91	.26	1.10	1.38	78.65	2.02	.09	1.13	11627.76	991.48	30.98	1129.04
s.d.	.47	.11	.34	.18	.33	115.41	.93	.39	2.54	23411.56	1615.8	56.10	1957.69

** correlation is significant at 0.01 level; * correlation is significant at 0.05 level
(HOVA: preferences of horizontal alliance over vertical alliance; DISP: partner dispersion; RPEA: partner repeatedness; MULT: multiple partner alliance; SCOP: alliance scope; KLBR: knowledge breadth; KLDP: knowledge depth; RINO: radical innovation; IINO: incremental innovation; PFSZ: portfolio size)

3.5 Analysis and Findings

3.5.1 Model Specification

A close examination of our data set suggests that there are several characteristics of the data that may require special consideration to obtain robust results.

First of all, we collected data on a firm-year basis and obtained a panel dataset (66 firms across 15 years of time). For econometric analysis of panel data, assuming the observations are independently distributed over time is thus unfounded for our dataset (Wooldridge 2003). Our model specifications need to account for the heterogeneity caused by the unobserved firm-specific effects as unobserved factors other than those explicitly addressed in our model could also bear some influence on the dependent variables (Prabhu et al. 2005). In order to truthfully assess the influence of our hypothesized variables on the dependent variables, we need to control for these unobserved effects. Secondly, some of the dependent variable such as knowledge breadth, radical innovation, and incremental innovation are measured as count variable (nonnegative and integers). Ordinary least squares is thus inappropriate for count data as the distribution of the count variables may not follow normal distribution patterns (Sorescu et al. 2003).

To successfully account for the heterogeneity and count variable problems, we formulate a Poisson Random Effects model when dependent variable is count variable and a simple random effects model when it is not. Using a random effects model over a fixed effects model is consistent with practices in the literature concerning knowledge and innovation related topics (Prabhu et al. 2005; Sorescu et al. 2003).

Specifically, to test the influence of R&D alliance portfolios properties on knowledge development, we use the following model specification:

$$KLBR_{it} = \beta_0 + \beta_1 DISP_{it} + \beta_2 RPEA_{it} + \beta_3 MULT_{it} + \beta_4 SCOP_{it} + \beta_5 HOVA_{it} + \beta_6 SALES_{it} + \beta_7 R\&D_{it} + \beta_8 PFSZ_{it} + \zeta_i + \upsilon_{it}$$

$$KLDP_{it} = \beta_0 + \beta_1 DISP_{it} + \beta_2 RPEA_{it} + \beta_3 MULT_{it} + \beta_4 SCOP_{it} + \beta_5 HOVA_{it} + \beta_6 SALES_{it} + \beta_7 R\&D_{it} + \beta_8 PFSZ_{it} + \zeta_i + \upsilon_{it}$$

Where ζ_i is unobserved firm-specific effect

υ_{it} is the remaining error term.

To test for knowledge development impact on innovation outcomes, we estimate the following model:

$$RINO_{it} = \beta_0 + \beta_1 KLBR_{it} + \beta_2 KLDP_{it} + \beta_3 SALES_{it} + \beta_4 R\&D_{it} + \zeta_i + \upsilon_{it}$$

$$IINO_{it} = \beta_0 + \beta_1 KLBR_{it} + \beta_2 KLDP_{it} + \beta_3 SALES_{it} + \beta_4 R\&D_{it} + \zeta_i + \upsilon_{it}$$

Where ζ_i is unobserved firm-specific effect

υ_{it} is the remaining error term.

To test for firm's innovation impact on financial performance, we estimate the following model:

$$NETINCOME_{it} = \beta_0 + \beta_1 RINO_{it} + \beta_2 IINO_{it} + \beta_3 RIST_{it} + \beta_4 IIST_{it} + \beta_5 SALES_{it} + \zeta_i + \upsilon_{it}$$

Where ζ_i is unobserved firm-specific effect

υ_{it} is the remaining error term.

3.5.2 Statistical Results

3.5.2.1 R&D Alliance Portfolio Characteristics and Knowledge Development

We estimated two models to show the impact of firms' R&D alliance portfolio characteristics' effect on their knowledge breath and knowledge depth development. It is important to note that while knowledge breadth is a count variable which is thus estimated as a Poisson Random Effects model. The knowledge depth though is not count variable and is estimated using a simple random effects model.

Table 5 presents the statistical results of the two models. H1 argues that a firm's preference for horizontal partners over vertical alliances has a negative impact on its knowledge breadth development. The coefficient of horizontal/vertical is negative and significant ($\beta = -0.08$, $p<0.1$). Therefore, H1 is supported. H2 suggests that a firm's preference for horizontal partners over vertical partners has a positive impact on its knowledge depth development. However, the coefficient is not statistically significant. Therefore, H2 is not supported

The coefficient of alliance portfolio dispersion on knowledge depth is negative and significant ($\beta = -2.81$, $p<0.01$). This is a contrary finding to H3 in which we hypothesized a positive relationship. However, H4 is supported as the coefficient on knowledge depth is negative and significant ($\beta = -1.75$, $p<0.01$) indicating dispersion of the portfolio partners negatively influences its knowledge depth development.

Partner repeatedness is hypothesized to have a negative impact on knowledge breadth (H5) and a positive effect on knowledge depth (H6). The result supports H5 as the coefficient is negative and significant ($\beta = -1.87$, $p<0.01$). We find, a significant and negative coefficient ($\beta = -0.41$, $p< 0.01$) for knowledge depth though which contradicts the hypothesized relationship in H6.

Results support both H7 and H8. H7 hypothesized a positive relationship between multiple partner alliances and knowledge breadth. The coefficient is positive and significant ($\beta = 0.39$, $p<0.01$). Thus, H7 is supported. H8 is also supported with a negative and significant coefficient ($\beta = -0.55$, $p<0.1$) indicating a negative relationship between multiple partner preferences and knowledge depth development.

The result also supports both H9 and H10. H9 hypothesized a positive relationship between alliance scope and knowledge breadth. The coefficient for this relationship is positive and significant ($\beta = 0.42$, $p<0.01$). H9 hypothesized a positive relationship between alliance scope and knowledge depth. The coefficient for this relationship is also positive and significant ($\beta = 0.23$, $p<0.05$).

Overall, the result largely supports the general idea that alliance portfolio configurations have significant impact on firms' knowledge development.

3.5.2.2 Knowledge Development and Innovation Output

Again, we estimated two models to test the impact of knowledge breadth and knowledge depth on two types of innovations. Both dependent variables are count variables and thus both were estimated as a Poisson Random Effects model.

Table 6 presents the result of the analysis. The results generally support H11 and H12. H11 hypothesized knowledge breadth will have a greater impact on radical innovation than knowledge depth does. The result support H11 as the coefficient of knowledge breadth on radical innovation is positive and significant ($\beta = 0.01$, $p<0.05$) while the coefficient of knowledge depth is not significant ($\beta =-0.02$, $p=96$).

H12 hypothesized that knowledge depth will have a greater impact on incremental innovation than knowledge breadth does. The coefficient on knowledge depth is positive and significant (β = 0.36, $p<0.05$). However, we found a negative and significant coefficient for knowledge breadth on incremental innovation (β = -0.00, $p<0.01$).

Table 5 Alliance Portfolio Characteristics on Knowledge Development

Independent Variables	Knowledge Breadth	Knowledge Depth
Intercept	6.02***	3.60***
Partner Repeatedness	-1.87***	-0.41***
Horizontal/Vertical	-0.08*	-0.10
Alliances Scope	0.42***	0.23**
Multi-Partner	0.39***	-0.55*
Dispersion	-2.81***	-1.75***
Firm Size	-0.00	0.00
Portfolio Size	0.00***	0.01***
R&D Expenditure	-0.00	-0.00
Log Likelihood	-2956.05	
Overall R^2		0.28
Wald χ^2	8173.76***	892.79***

Unstandardized coefficients are shown.
*** $p<0.01$
** $p<0.05$
*$p<0.1$

Table 6 Knowledge Development and Innovation Outcome

Independent Variables	Radical Innovation	Incremental Innovation
Intercept	-2.25***	0.44
Knowledge Breadth	0.01**	-0.00***
Knowledge Depth	-0.02	0.36**
Firm Size	-0.00**	0.00
R&D Expenditure	-0.00	-0.00
Log Likelihood	-193.73	-767.87
Wald χ^2	16.67***	68.11***

Unstandardized coefficients are shown.
*** $p<0.01$
** $p<0.05$

Table 7 Innovation and Firm Financial Performance

Independent Variables	Net Income
Intercept	85.20
Radical Innovation Stock	39.09*
Incremental Innovation Stock	44.65***
Firm Size	0.04***
Radical Innovation Launch	-319.81***
Incremental Innovation Launch	-4.20
Overall R^2	0.66
Wald χ^2	1055.31***

Unstandardized coefficients are shown.
*** $p<0.01$
* $p<0.1$

3.5.2.3 Innovation and Firm Financial Performance

We estimated a simple random effects model to test the relationship between radical innovation stock and incremental innovation stock on firm financial performance. Table 7 presents the statistical results.

As hypothesized in H13 and H14, both radical innovation stock and incremental innovation stock have a positive impact on firm performance. H13 was supported as the coefficient of radical innovation stock on performance is positive and significant ($\beta = 39.09$, $p<0.1$). The coefficient of incremental innovation stock on performance is also positive and significant ($\beta = 44.65$, $p<0.01$) indicating a positive relationship between a firm's incremental innovation stock on its performance.

We controlled for the number of radical and incremental innovations for that year as we would expect the introduction of new drugs would incur abnormal expenses in manufacturing and distribution, which would negatively impact the bottom line. Our results indicate that introducing radical innovation will significantly influence the bottom line of a firm with a negative and significant coefficient of $\beta = -319.81$ ($p<0.01$).

Table 8 provides a summary of our hypotheses testing results.

Table 8 Summary of Hypotheses Testing Results

Hypotheses	IV	DV	Hypothesized Relationship	Result
H1	HOVA	KLBR	-	Supported
H2	HOVA	KLDP	+	N.S.
H3	DISP	KLBR	+	Contrary Finding
H4	DISP	KLDP	-	Supported
H5	RPEA	KLBR	-	Supported
H6	RPEA	KLDP	+	Contrary Finding
H7	MULT	KLBR	+	Supported
H8	MULT	KLDP	-	Supported
H9	SCOP	KLBR	+	Supported
H10	SCOP	KLDP	+	Supported
H11	KLBR>KLDP	RINO	+	Supported
H12	KLDP>KLBR	IINO	+	Supported
H13	RIST	NET INCOME	+	Supported
H14	IIST	NET INCOME	+	Supported

(HOVA: preferences of horizontal alliance over vertical alliance; DISP: partner dispersion; RPEA: partner repeatedness; MULT: multiple partner alliance; SCOP: alliance scope; KLBR: knowledge breadth; KLDP: knowledge depth; RINO: radical innovation; IINO: incremental innovation; PFSZ: portfolio size)

3.6 Discussion

Our findings support our central argument that the configuration of R&D alliance portfolio has significant impacts on a firm's knowledge development. We found that those managers' preferences for different types of agreements and partners influence its ability to develop knowledge inventory. We also found that knowledge depth and knowledge depth play different roles in firms' radical and incremental new product development.

Next, I would like to offer some potential explanations to the unexpected significant effects of portfolio dispersion on knowledge breadth and partner repeatedness on knowledge depth development. An extremely dispersed portfolio suffers from the lack of trust and common knowledge base for learning to occur. Even though partners possess complementary skills, they will not be able to assimilate it if they are not willing to share with each other. Even if they are willing to share, the lack of common knowledge base as a requirement for learning may also affect how well they can assimilate knowledge form each other. As such, extreme alliance portfolio dispersion may result in a negative impact on a firm's knowledge breadth.

The negative impact of highly repeated partnering could probably be due to the limitation of knowledge stores of partners can share with each other. Even though the social relatedness and trust level is high and firms are thus willing to share with each other what they know, the sharing is limited to what they know. As the repeated partnering gets overly redundant, partners may find it difficult to find anything new to offer to their partners as the proprietary information from each other is depleted.

The negative influence of knowledge breadth on incremental innovation is yet another surprising finding. One explanation could be offered that when firms overly expand its knowledge domains, management will lose focus on any particular knowledge sector. Information overflow and knowledge over-inventory may thus limit management's ability to identify new opportunities for innovation possibilities.

3.6.1 Theoretical Contribution

Our study is a timely contribution to the call for more research on alliance issues from a portfolio approach (Bamford and Ernst 2002; Hoffmann 2007; Wuyts et al. 2004). Our framework greatly enhances our understanding of the configuration effects of firms' R&D alliance portfolio on its knowledge and innovation influence. Wuyts, Dutta and Stremersch (2004) have pointed out the importance of examining the alliances from a portfolio perspective. They identified two related descriptors: technological diversity and repeated partnering. Our framework builds on this work and advances our understanding by incorporating a more complete array of agreement characteristics and empirically demonstrated their influences on firms' knowledge development and innovation output.

Our study also makes a major theoretical contribution by incorporating knowledge into the framework. Previous studies normally have made a direct linkage between alliances and innovation (e. g., Rothaermel and Deeds 2004) or directly with the financial performance (e. g., Goerzen 2007; Goerzen and Beamish 2005). Even though we did not formally test the mediation function of knowledge and innovation on firm financial performance, the differential impact of a particular R&D alliance portfolio characteristic on knowledge breadth and knowledge depth as well as the differential direct influence of knowledge breadth and knowledge depth on radical innovation and incremental innovation indicate that the relationships could be much more complicated than what we had assumed in the past studies.

Past studies in establishing a linkage between alliances portfolio descriptors to economic performance has normally acknowledged that there could be different theories that would lead to quite opposite conclusions even for the same descriptor. For example, Goerzen and Beamish (2005) used both network theory and transaction cost analysis in analyzing the effect of network diversity on firm performance. These two theories predicted two contrary conclusions. Even though their findings in the end support the transaction cost analysis prediction which is quite contrary to some other findings in the literature, it is a difficult conclusion to make that the network theory has limited application in alliance management given the vast literature in support of it.

In another study of Goerzen (2007) in which partner repeatedness is the focal characteristic, network theory and transaction cost analysis are both used in making opposite predictions. The findings in the study supported network theory predictions. Again, in view of the mass literature on the transaction cost analysis, coming to a conclusion that transaction cost analysis has a limited application is not completely convincing. Considering that network theory normally predicts along the line of resources and knowledge heterogeneity and transaction along the line of relational embeddedness, our findings suggest that there is actually a fine balance that firms need to keep in terms of the benefit of these two dimensions. Going extremes in either high dispersion or overly repeated partnering could be detrimental on a firm's knowledge breadth or depth development.

We also make a theoretical contribution to the innovation literature by demonstrating the differential impact of knowledge breadth and knowledge depth on innovation output. Our findings are complementary to that of Prabhu et al. (2005) who identified the differential impact of different sources of knowledge on a firm's innovation capability: internal knowledge and external knowledge. Our findings mostly examined the dimensions of knowledge and their differential impact on radical and incremental innovations. Precious research has mostly focused on the differential financial implications of radical and incremental innovation (e. g., Ahuja 2000b; Dewar and Dutton 1986; Sorescu et al. 2003; e. g., Wuyts et al. 2004). Our study demonstrates that there are different knowledge dimension requirements in order to come up with these two types of innovations. While incremental innovation is most directly influenced by knowledge depth, radical innovation is only directly related to a firm's knowledge depth. As such, a theoretical argument can be made that research on alliances' impact on innovation need to clearly differentiate two types of knowledge as well as two types of innovations in the future.

One caution needs to be made in terms of the interpretation of the knowledge dimensions and different types of innovation. It would be incorrect to state that knowledge depth is not important for radical innovation or knowledge breadth is not important for incremental innovation. As we only tested for the main effects of the knowledge dimensions, we can only conclude that developing knowledge depth without developing breadth will not lead to radical innovation. The same can be said about the incremental innovation. We can only conclude that developing knowledge breadth without developing knowledge depth will not lead to incremental innovation outcome.

There could be, however, interaction effects between these two dimensions of knowledge that would be beneficial to both types of innovations. As that is beyond the scope of our study, it offers a great opportunity for future research.

3.6.2 Managerial Contribution

First of all, alliance portfolio configuration has a large impact on how well firms can build up their knowledge reservoir. From partner selection, alliance structure, and alliance content, firms can strategically formulate and configure their alliance portfolios to achieve knowledge development objectives. If the strategic goal of a firm is to expand its knowledge breadth, that is to expand on the number of domains with which they have skills, firms can first of all increase their partnership with vertical partners. Vertical partners bring the benefit of complementary rather than similar skills and technologies. Knowledge sharing among vertical partners is also enhanced by the fact that they are not directly competing with each and firm will be less concerned about the opportunistic behaviors when they disclose information to their partners. The combined effect of fresh information base and the willingness to share would certainly help them expand their knowledge breadth more efficiently.

From an alliance structure perspective, they could also increase their knowledge breadth by incorporating multiple partners in each individual alliance. Including multiple partners in the agreement is equivalent to setting up multiple alliances simultaneously from a learning perspective. Firms are exposed to the knowledge stores of all the partners. The effect of simultaneous access to different sources is more than an additive game. Firms could potentially combine knowledge they learned from different partners and put them in new perspective and integrate them in creative ways which will result in completely new insights.

Firms also need to restrain from showing extreme preference for a subset of partners, as this will be an inhibitor of knowledge breadth development. Repeatedly partnering with the same partner limits firms' exposure to new and fresh information. Their knowledge is thus limited to the extent what that particular partner has to offer. As the technology develops rapidly in the market place, over preference of a partner may create a lock in problem for the focal firm as they continuously invest in the partner specific capabilities.

Changing the content of the alliance agreements could also expand firms' knowledge breadth. Instead of focusing only on one technology in the agreement, alliance partners can incorporate multiple related technologies to increase the span of knowledge sharing. These related technologies would foster a better learning opportunity among partners due to the increased volume and breadth of learning.

For firms whose strategic goal is to develop its knowledge depth, certain strategies could also be formulated from this study. First of all, they need to limit their portfolio dispersion. This means that always looking for new partners to work with may not be a good idea for knowledge depth development. Knowledge development needs two critical conditions, firms' willingness to share and firms' ability to learn. Both conditions require the nurturing of social capital between partners. Due to the contracting hazard problem associated with knowledge transfer, trust between partners is a determinant of whether partners will be willing to disclose and share sensitive and critical information with each other. On the other hand, firms need to build some common knowledge in order to facilitate the learning process. Always looking for new partners to work with indicates that the every time an alliance is formed, the knowledge bases between partners may be completely different. This would create the problem of inability to learn, as partners do not share the bases for learning.

They should also try to limit their use of multiple partner agreements. Due to the increased potential of opportunistic behaviors, firms in this kind of alliances may only share superficial or public knowledge with each other but would be reluctant to share critical and sensitive information. This would work against the learning objective of the focal firm as mostly what partners share with each other are what they already know. Knowledge depth thus cannot be developed efficiently.

Lastly, they could also work on the content of the alliances agreements by increasing the number of technologies partners collaborate on. As discussed before, the relatedness of these technologies within each agreement should have a facilitating impact on the understanding of knowledge elements. In addition, due to the high relatedness of multiple technologies, their combination or integration will result in new understanding as well.

Our findings also suggest that there is something firms can do to achieve both knowledge breadth and knowledge depth development simultaneously. The strategy would be to increase the alliances scope as it is found to be positively related with both knowledge-related dependent variables. All the other strategies favor the development of one knowledge dimension but inhibit the other.

Our findings also shed on some light on knowledge development strategies for innovation purposes. This study provides insights in terms of what dimension of knowledge firms need to focus on depending on the innovation type they are after. For firms that emphasize radical innovations as this type of innovation normally has a better marketing position compared with incremental innovations, their strategic focus should be on obtaining newer and fresher information. They need to develop their ability to integrate knowledge they learned from different sources to come up with innovative products. On the other hand, when a firm's strategic goal is to come up with incrementally new products (mature industry), their focus of learning should be on knowledge depth development. Try to have a deeper and better understanding within the established technology domain is proven to be critical for incremental innovations.

To summarize, our findings offer a complete framework on how to achieve innovation objectives through successful knowledge management. And successful knowledge management comes from careful configuration of R&D alliance portfolio. Management needs to use a back loop style of thinking when using findings from this study. They should first identify what their innovation objectives are as radical innovation may not be the optimal route for all firms and all industries. Firms with limited resources and with industry constraints may consider incremental innovation as the strategic priority. Once the type of innovation is identified, our study should guide them in terms of the appropriate knowledge development strategy that should help them to achieve their goals. Again, findings in our study would provide suggestions on how they should configure their alliance portfolio to secure the necessary knowledge elements.

3.6.3 Limitations and Future Research

Our study has several limitations that need to be noted. First of all, the generalizability of our study needs to be considered as we only sampled publicly traded pharmaceutical firms. Even though we only attempt to generalize the findings to technology intensive industries such as telecommunication and electronics, the applicability of the findings in other industries needs to be carefully evaluated. This is particularly a concern when we think about the stringent government regulations imposed on the innovation measure that we adopted in the study.

The second limitation is that causal inferences of our findings are limited, as we did not take time lags in our model. This is largely due to the nature of our data. We have a panel data set that includes count variables and potentially lagged count dependent variables. Econometric techniques in dealing with all three issues (panel data, count dependent variables, lagged effect) involved here are still in their infancy (Prabhu et al. 2005). Even though the generalized method of moment (GMM) has the potential to account for all the unique characteristics, we did not use it in testing our model because our subject/time ratio is considerable low compared with what is required for the application of GMM. As such, we could only make inferences in terms of the correlation not causality.

Our framework only depicts a direct effect model. The knowledge depth and knowledge breadth dimensions offers future research opportunities in terms of understanding how knowledge breadth and knowledge depth interact to impact radical and incremental innovations. A firm's knowledge depth would be helpful in choosing the target with the most promising knowledge, absorbing the knowledge more rapidly, and exploiting it to come up with innovative products (Prabhu et al. 2005).

There could also be some moderating factors that worth further studies. Even though the discussed hypotheses are based on the assumption of knowledge heterogeneity across firms, the breadth and depth of knowledge that each firm is exposed to only represent the potential of the knowledge learning. In order to realize the knowledge benefits from these portfolio characteristics, firms need to ensure that knowledge is effectively transferred across the firm boundaries. Future studies could examine the mechanisms that would facilitate the knowledge transfer process.

By definition, inter-firm R&D alliances involve two or more firms combining resources for some agreed upon activities. Partners have fewer incentives to make such investments ex ante if they might be subject to ex post opportunism in the distribution of resulting surpluses (Oxley 1997). Equity participation reduces the possibility of opportunistic behavior by aligning the incentives of the partners. Their mutual interest in the success of collaboration reduces problems of moral hazards often associated with cost-plus scheme. Opportunism by an equity partner is penalized through the reductions in the value of its equity holding. As a result, firms have less concern for their knowledge sharing behaviors. In addition, in certain equity based R&D alliances such as joint ventures, the environment provides much better opportunities for personal contacts, teaching, participation, and communications among partners which are necessary for the acquiring difficult-to-articulate knowledge (Polanyi 1966). As such, the effect of equity R&D alliances in a firm's portfolio needs to be further addressed.

The relationship between knowledge breadth and knowledge depth on radical and incremental innovation also could be moderated by a firm's ability to utilize the knowledge. It would be reasonable to argue that a firm with a superior capability in integrating knowledge may realize a higher rate of innovation output than firms who lacks this capability. As such understanding the firm level capability on both types of innovation and financial performance offers another venue for future research.

CHAPTER 4

ESSAY TWO: NON-ADDITIVITY EFFECT OF R&D ALLIANCE PORTFOLIO SIZE ON INNOVATION: AN INTEGRATION CAPABILITY PERSPECTIVE

4.1 Introduction

New product development capability plays a critical role in a firm's growth and survival in the market place and firms need to constantly introduce innovative and better products that meet market needs over time (Dougherty and Hardy 1996; Nerkar and Roberts 2004; Penrose 1959). However, most firms are finding it increasingly difficult to develop new products purely internally (Sivadas and Dwyer 2000; Wind and Mahajan 1997). First of all, new product development is a highly demanding endeavor in terms of both financial and human capital resources. Firms need to make huge investment commitment upfront without the guarantee that a new product will be developed. Secondly, the risk associated with new products extends beyond the development stage. Only half of the introduced new products will survive the market test during commercialization (Page 1993; Schmidt and Calantone 2002; Zirger and Maidique 1990).

However, the most important reason firms can not take on the new product development all by themselves may have something to do with the changing competitive environment in the market place. In order to develop a truly innovative product, firms need to pool knowledge from different areas(Cohen and Eliashberg 1997; Kogut and Zander 1992; Prabhu et al. 2005). Increasing complexity in new product development and fast advancing technology mandates firms to look beyond their boundaries to access knowledge and technology for their new product development purposes (Sood and Tellis 2005; Wuyts et al. 2004).

As a result, inter-firm collaborations on R&D activities become a common practice for firms to overcome the financial constraints, share the inherent risk associated with new product development, speed up the NPD process, and to get access to the most advanced technologies not available within a firm (Sivadas and Dwyer 2000; Wuyts et al. 2004). R&D alliances are defined as voluntary arrangements between firms to exchange and share the knowledge as well as resources with the intent to develop a new product (Gulati 1998).

Firms seldom rely on a single R&D alliance to achieve their innovation goals. Due to the knowledge heterogeneity across firms in the market, they have to form alliances with multiple partners either simultaneously or sequentially to establish and maintain their competitive positions (Hoffmann 2007). Organizations enter into dozens of R&D alliances as organizations evolve into loosely knit organizations (Bamford and Ernst 2002). A conservative estimate would be 30 alliances for most of them and many have more than 100 (Bamford and Ernst 2002).

Academic studies of R&D alliances have largely been through the lens of knowledge-based view, an offspring of the classic resource based-view of the firm. Studies following this tradition have drawn from works by Penrose (1959) and Teece and Pisano (1992) and maintained that the inimitable firm heterogeneity, or the possession of unique "knowledge", "competences", or "capabilities" may be an important source of sustainable competitive advantage. Past research in this area has discussed the features of alliance partners that facilitate the flow of knowledge across firms (e. g., Cohen and Levinthal 1990). Others examined the motivation differences in firms' decision of entering alliances (e. g., Grant and Baden-Fuller 2004). All these studies addressed alliance issues from an isolation perspective by taking the unit of analysis at the project level.

Scholars have also realized that understanding the R&D alliance portfolio issues may be of greater value to business practitioners (Hoffmann 2007). Firms need to successfully configure their alliance portfolio in order to enjoy a "sustainable" competitive advantage. As such, scholars have studied portfolio related topics from different perspectives. These topics cover drivers of portfolio design (Hoffmann 2007), portfolio's influence on innovation and profitability (Wuyts et al. 2004), and the impact of alliance experience on subsequent alliance success (Hoang and Rothaermel 2005; Rothaermel and Deeds 2004).

Despite the rich literature on the R&D alliance portfolio related issues, ranging from partner selection to alliance management, there is still one key question seeking a satisfactory answer: the *nature* of the relationship between a firm's R&D alliance portfolio size and its innovation output. Existing studies on this question have offered different findings. Some studies have found a positive liner relationship between the number of R&D alliances of a firm and its innovation output (e. g., Baum et al. 2000; Rothaermel and Deeds 2004; e. g., Shan et al. 1994). Other studies though have argued a non-linear relationship between the size of a firm's R&D alliance portfolio and its innovation outcome (Rothaermel and Deeds 2004). As such, it is very inconclusive as to the true functional from of the impact of the number of R&D alliances on innovation. One research question that remains is then: how does firm's learning capability and combinative capability change the marginal returns on innovation by adding one more alliance into a firm's R&D alliance portfolio? In this study, we draw on the literature of organizational learning and combinative capability and argue that the relationship between the size of a firm's R&D alliance portfolio and its innovation output demonstrates diminishing returns at low to moderate level and increasing marginal returns at moderate to high level. The relationship is thus inverse S-shaped.

The following of the manuscript is organized as follows: we will first provide a brief review of the literature on alliance portfolio size and innovation. We then present our theoretical arguments and develop hypotheses. We then provide an overview of the research design including the sample, data sources, and measures. This will be followed by statistical analysis and results. We wrap this essay up with a discussion of the results.

4.2 Received Wisdom on R&D Alliance Portfolio size and Innovation.

R&D alliances provide firms with access to novel information and technological know-how which can be an important input factor in new product development (Shan et al. 1994). Studies addressing the relationship between the number of R&D alliances and firm's innovation output have all agreed that there should be a positive influence of the number of a firm's R&D alliances on its new product development success (Baum et al. 2000; Rothaermel and Deeds 2004). However, there are different views regarding the actual functional form between the number of R&D alliances and new product development.

Most studies on R&D alliances and innovation have postulated a positive linear relationship between the number of R&D alliances a firm has and its new product development. This is evident in several studies where number of alliances is used as either a direct predictor or control variable in proposed models. One caution of word need to be stated though that all these studies are merely interested in proving there is a positive relationship between R&D alliances and innovation outcome. Their research questions are not specifically addressing the functional form regarding the impact. The reason why we classify them in to the liner positive relationship category is because of the statistical treatment they have used on the number of R&D alliances in testing their models. Therefore, they are analyzing the relationship in a more general approach.

Two studies in support of the linear positive relationship are conducted in the startups context. Startups, due to their newness to the industry, face considerable hazards in securing their position in the market (Baum et al. 2000). Alliances with established firms offer the benefit of accessing to knowledge, obtaining critical resource, establishing stability, and offering legitimacy in the industry (Baum et al. 2000; Shan et al. 1994). Using data from BoiScan with a sample of 85 US biopharmaceutical firms, Shan, Walker and Kogut (1994) found that a startup's cumulative cooperative ties positively influences their innovation output. The finding is supported by the Baum, et al. (2000) study in which the innovation output of the firm is positively related to the number of alliance a firm establishes at founding.

Rothaermel and Deeds (2004) further classified R&D alliances into exploration and exploitation alliances based on motivation differences. Exploration alliances are motivated to discover new and novel technology and information. Exploitation, on the other hand, aims to benefit from existing technologies or know how. They postulate that there are actually a linkage between these two type of R&D alliances as exploration based R&D alliances motivate subsequent exploitation based R&D alliances. They also further classified innovation into product in development and product on market. The overall framework is that exploration positively influences product in development, which positively impacts exploitation-based alliances, and this will positively impact product on the market. Their framework is tested in the pharmaceutical industry and the positive linear relationship between alliances and innovation obtained statistical support.

Due to the prevalence of the implicit positive linear relationship between number of alliances and innovation output, studies that address alliances and innovation issues normally control for the size of alliance portfolio in a linear fashion (e. g., Wuyts et al. 2004).

However, other studies have argued different functional forms between the number of R&D alliances and innovation. Deeds and Hill (2004) argue that the functional form should be an inverted U-shape. They argue that even though the number of alliances will have a positive impact on innovation output, anticipating a constant return from each individual alliance may not be realistic. In fact, they argue that the marginal returns of adding alliances to the whole portfolio should demonstrate diminishing and even negative returns. The rationale is that not all alliances contribute equally to the focal firm. Firms choose to ally with the most promising partners first and the later partners will normally contribute much less than previous partners. Thus the marginal return is expected to be diminishing as the number of alliances grows. In addition, extremely large number of R&D alliances also increases the burden of the management. Bounded rationality, the limitation of management capability in managing an extended alliance portfolio will lead to negative marginal returns. The inverted U-shaped relationship is tested in the biotechnology industry and was statistically supported.

To summarize, there exists two formulations in the literature of the relationship between the number of R&D alliances and innovation output: positive linear and inverted

U-shaped. Even though both forms were supported statistically, we would like to propose an advanced functional form of the relationship and empirically compare it against both existing forms in the literature. We would argue that even though the marginal return of alliances will decrease at the low to moderate level, it will actually increase after a critical point where firms would have accumulated enough knowledge mass that would enable the application for the combinative capability to increase the innovation output exponentially. The functional form of relationship between the number of R&D alliances and innovation output is inversed S-shaped as shown in Figure 3. We next present the theoretical foundation and hypotheses development.

4.3 Theoretical Foundation and Hypotheses Development

4.3.1 Diminishing Returns with Limited Number of R&D Alliances

While we agree with previous studies that the total number of R&D alliances will in general have a positive impact on a firm's innovation output, we concur with Deeds and Hill (2004) that the relationship is non linear. Several reasons may contribute to the decreasing marginal returns of R&D alliances at low to moderate level.

First of all, all alliances partners are not created equal. Neither is their contribution to the focal firm in new product development. Firms tend to ally with the most promising partners first (Hoang and Rothaermel 2005; Rothaermel and Deeds 2004). As such, diminishing returns on newer alliances become a natural result due to the fact that the later partners will only make less contributions compared to earlier partners as the complementary resources they possess will be relatively minor to the needs of the focal firm (Rothaermel and Deeds 2004). Selecting the next best partner becomes particularly challenging when the foundation of the collaboration is the tacit knowledge, which is exactly the case for R&D alliances (Hoang and Rothaermel 2005).

Secondly, firms with limited alliance experiences also suffer from management inability to effectively screen partners and monitor alliance performance (Rothaermel and Deeds 2004). Due to the long durations of most R&D alliances which often last for years, firms have to enter into multiple R&D alliances simultaneously. As the number of alliances grows, managers with limited alliance experience may find it increasingly difficult to monitor its partner's behaviors and keep up its own learning actions (Hoang and Rothaermel 2005). This will give a higher probability of partner opportunistic behaviors and inefficient learning from external sources. As such, with the bounded rationality, firms may not be able to benefit as much from their later alliances as they can from the early few alliances.

Third, management's inexperience in alliance management may also contribute to the decreasing marginal return in terms of partner selection. Firms with limited alliance experience may often enter into alliances with the expectation that the partners will contribute complementary resources to their new product development efforts, only to find out ex post that the resources from the partner is a poor match for their new product development goals (Rothaermel and Deeds 2004).

Due to the inherent risks associated with R&D alliances, particularly in terms of potential partner opportunistic behaviors, firms may prefer to ally with partners that share certain attributes with their successful prior partners. This in turn will contribute to the decreasing marginal return, as there will be overlap of the complementary resources that the new and the prior partners share with the focal firm. As such, the novelty and complementarities of the resources of the new alliances will be discounted.

Even if firms in their early alliances stage venture into completely new partners, the marginal return may still be decreasing. Firms then need to go beyond their comfort zone and go through a process of dealing with unfamiliar entities. This process will increase the odds of adverse selection in that firms may end up allying with partners with inferior properties. Given the limited experience the focal firm possess in dealing with alliance partners, the focal firm may draw on what it has learned from the prior limited experiences, the strategy may not be appropriate for the current partner given its newness in terms of resources and managerial styles (Sampson 2005). However, establishing new processes and routines that would accommodate the current partner will increase the managerial information-processing demand due to the lack of trust and familiarity between partners (Goerzen and Beamish 2005).

Finally, a major motivation of forming R&D alliances is to access new and novel information. With limited knowledge base, any newly assimilated information may not be readily mapped into the technological network within the firm and thus does not directly contribute to development efforts the focal firm is actively engaging in. As such, forming new alliances in the early stage may provide a venue for knowledge accessing but may not be able to materialize the know how in face of limited internal knowledge base (Macher and Boerner 2006).

As such, we hypothesize:

Hypothesis 1: The positive effect of number of a firm's alliances on its innovation output exhibits decreasing marginal returns when the alliance numbers are low to moderate.

4.3.2 Increasing Returns with Expanded Number of R&D Alliances

Two major arguments support the idea of increasing marginal returns of R&D alliances on innovation output once firms have accumulated certain amount of alliance management experiences and knowledge base: the learning effect of alliance management and the combinative capability.

Successful management of alliances has been regarded as a critical capability that establishes competitive advantage for firms (Dyer and Singh 1998). This capability is developed through the accumulation of repeated experiences and active learning over time by dealing with a diversified portfolio of alliance partners (Hoang and Rothaermel 2005; Kale and Singh 2000).

Alliance management is not an easy task. Partners in an alliance often times have competing interests and expectations (Sampson 2005). They may also have divergent managerial styles, communication mechanisms, and business routines. These differences make successful coordination across firm boundaries a daunting task. What firms can do to overcome those barriers is to establish what scholars call "alliance capability" (Kale et al. 2002).

Alliance capability is a direct result of participation in diverse alliance activities. Experiences in managing alliance play a critical role in developing this capability (Hoang and Rothaermel 2005; Sampson 2005). However, performance does not improve automatically as the experiences accumulate. It is rather an outcome of the deliberate learning that accompanies the alliance experiences (Pisano et al. 2001).

Organizational learning on alliances management occurs in an iterative fashion (Hoang and Rothaermel 2005). When firms repeatedly participate in alliance activities, they would accumulate some fundamental understanding of the coordination mechanisms in dealing with partners and learn about the potential outcomes of various alliance management practices and routines (Sampson 2005). These inferred learning is then coded, stored, and disseminated within the organization that can be effectively activated when certain stimuli is present in future alliance management activities (Hoang and Rothaermel 2005).

As such, extensive experiences in alliance management help firms gain insights to identify effective processes for exchanging information with their partners and to manage complex activities with highly uncertain outcomes (Sampson 2005). In addition, firms also gain hands-on experiences on how to disseminate the knowledge or know how they learned from their partner within the organization by actually engaging in all these activities (Sampson 2005). When all these experiences, understandings, inferences, and insights are coded and disseminated across the organization, alliance capability has emerged in the firm.

The alliance capability is said to have a positive impact on current and future alliance outcome (Hoang and Rothaermel 2005; Kale et al. 2002; Sampson 2005). Alliances capability enables firms to establish effective manual, databases, diagnostic tools, and simulation systems to aid in the assessment of current alliance performance, selection of future partners, and evaluation of alternative actions (Hoang and Rothaermel

2005). As such, a firm's ample experiences would lead to increased marginal returns on the number of alliances by securing higher benefits from future partners.

The second major reason for increasing marginal returns once a firm has established a critical mass of knowledge and know how is the combinative capability. Henderson and Cockburn (1994) identify two types of "competences" that may serve as the foundation of a firm's enduring competitive advantage: component competence and architectural competence. Component knowledge refers to the local capabilities and knowledge that are fundamental to day-to-day problem solving and architectural knowledge refers to the firm's ability to use this knowledge by integrating them effectively and developing fresh component competence. While both competences are important elements for a firm to remain competitive in the market, the architectural knowledge is more fundamental as they are more heterogeneously distributed within an industry, impossible to buy or sell in the available factor market, and difficult to replicate as suggested by the resource based view (Barney 1991).

One key assumption of the knowledge-based view is that firms are heterogeneous in terms of knowledge they possess. Firms seldom stick with one alliance but normally enter into different alliances depending on the demand of the task at hand. In fact, firms may simultaneously enter into different alliances with different partners. A larger number of alliances bring the benefit of more diversified knowledge and skills to the exposure of the focal firm.

There are two views in terms of the motives of firms' entering strategic alliances: Knowledge accessing and knowledge acquiring. These two concepts correspond to two conceptually distinct dimensions of knowledge management in the knowledge-based literature. First, firms are interested in increasing its stock of knowledge and this is referred by March (1991) as exploration and Spender (1992) as knowledge generation. On the other hand, firms also engage in activities that deploy existing knowledge to create value and this is referred by March (1991) as exploitation and Spender (1992) as knowledge application.

In relation to R&D strategic alliances, knowledge generation points to alliances as vehicles of learning in which each partner uses the alliance to transfer and absorb the partner's knowledge and skills. On the other hand, the knowledge application points to alliances as vehicles to simply access the knowledge base of the partners in order to exploit complementarities but with the intention to maintain its distinctive base of specialized knowledge (Grant and Baden-Fuller 2004). Even though there is a clear distinction conceptually about these two types of knowledge sharing, the accepted wisdom is that learning occurs in all alliance activities. The only difference is the degree or level of learning that occurs. For example, Inkpen (1998) observes that knowledge acquiring occurs in all alliances while some are more aggressive than others. Grant and Baden-Fuller (2004) also notes that learning occurs in all alliances and some alliances are more motivated primarily by the desire to acquire partner's knowledge. Hamel (1991) explicitly stated that the acquisition of new knowledge is often the motivation for establishing inter-organizational collaborations.

In this manuscript, we take on the idea that learning occurs in all strategic R&D alliances. Even if the primary motive of some alliances is exploitation-orientated, learning occurs due to the fact that firms need to reveal to a certain level of their knowledge base to each other in order to accomplish the common goal. Knowledge acquiring (learning) implies internalization of alliance partner's expertise, skills and processes. The internalization process leads to the fact that the focal knowledge becomes an integrative part of the knowledge base of the firm. Once a firm has internalized the knowledge and skills acquired from its partner, it often enjoys the freedom in terms of the application of it (Oxley 1997).

Prior studies have suggested that knowledge diversity has a positive performance effect given that diversity can enhance the breadth of perspectives, cognitive resources and overall problem solving capabilities (Goerzen and Beamish 2005; Hargadon and Sutton 1997; Koka and Prescott 2002). Due to the fact that firms not only access knowledge through their alliance activities but also acquire knowledge from their partners (Mowery et al. 1996), the effect of obtaining one new piece of information or technological skill on a firm's innovation output may be more than additive. Once firms internalize their partner's knowledge, they could combine the newly learnt knowledge with their existing knowledge to come up with innovation that is not possible with either one alone.

The architectural competence of an organization allows it to make use of its component competencies: to integrate them together in new and flexible ways and to develop new architectural and component competencies as they are required. Once a new knowledge element is acquired from an alliance partner, the firm has at its discretion to the use of it at its own will. Knowledge, unlike other resources that are physical in nature, does not diminish its value by being employed somewhere else. That is, the value of a piece of metal to task A is going to be lessened if it were to be used in task B. However, knowledge does not suffer from this consumption deficiency. Kogut and Zander (1992) argues that the central competitive dimension of what firms know need to know is to create and transfer knowledge efficiently within an organizational context. They further argue that knowledge of a firm is competitively consequential; learning cannot be characterized as independent of the current capabilities and knowledge base. When a firm enters into an R&D alliance, the knowledge that it absorbs from partner may be component in nature. However, this knowledge will not necessarily be locked in any particular area where it is initially applied. Instead, knowledge flows in an organization and its applicability and value is realized by combining it with the existing knowledge base of the firm.

Knowledge of alliance partner is primarily exposed to individuals that engage in the daily communication with the partners. The ability of individual to transfer their knowledge from one domain to another and to combine other knowledge in more productive ways makes humans distinct from other resources (Penrose 1959). Innovation, as an outcome of the new learning is a product of the firm's combinative capability by applying its newly acquired knowledge to its existing knowledge (Kogut and Zander 1992). Innovation is thus viewed as the new combination of existing knowledge and incremental learning.

Due to the firm's possession of the combinative capability, we can thus expect that the marginal return to the diversity of a firm's R&D alliances could be increasing once firms have accumulated a critical mass of knowledge to apply and integrate the newly assimilated knowledge. That is to say, a firm's capability to come up with innovative product or services displays super additive characteristic. In a standard analysis of production, economies of scope are present when the costs of conducting two or more activities jointly are lower than if they are conducted separately. This occurs most obviously when these activities can share inputs at no additional cost, which is an important aspect of knowledge based innovation (Henderson and Cockburn 1994). The public goods aspect of knowledge means that knowledge capital acquired in one alliance process may be utilized as a productive input to other related programs, at little or no additional cost to the firm.

An illustration of this super additive nature of knowledge accumulation and innovation is that when a firm is forming its 101 alliances, the effect of this alliance is not simply an additive of another possible innovation to the firm. Instead, the firm may combine the knowledge that it acquires from its 101 partner with knowledge that it obtained with its first 100 partners and the possibility of the innovation outcome clearly goes beyond the simple innovation outcome of the focal activity of the 101 alliance itself.

Benefits of diversity may also arise if discoveries made in one program stimulate the output of another through cross fertilization of ideas and other forms of knowledge spillovers. Henderson and Cockburn (1994) identifies the fact that in pharmaceutical research, several important central nervous systems therapies were discovered as the result of the search for drugs in the cardiovascular system.

To illustrate how the combinative capability is established within a firm, Hargadon and Sutton (1997) give an example of a California-based product development company, IDEO, consciously attempts to leverage the heterogeneity of knowledge in the generation of new ideas. At its brainstorming sessions, the firm not only assembles teams with diverse knowledge but the team is encouraged to recall, recontextualize, and to recombine elements of seemingly unrelated knowledge in the idea generation process.

Rodan and Galunic (2004) further argue that knowledge diversity is useful for the implementation of the new ideas in innovation. It may help managers build a sound causal understanding of the relationships between the elements in the complex system (McGrath et al. 1996). However, we expect the combinative effect will only take place when there exists a critical mass of knowledge and know how within the firm which allows for easy identification of relatedness to integrate the newly assimilated knowledge. Otherwise, firms may find it difficult to establish linkage and integration across completely novel information with its current knowledge structure as the integration possibility is limited by the knowledge base the firm.

To conclude the above discussion, we could expect an increasing marginal return to a firm's moderate to high number of alliances. Thus we hypothesize:

Hypothesis 1: The positive effect of number of a firm's alliances on its innovation output exhibits increasing marginal returns when the alliance numbers are moderate to high.

To summarize, we hypothesize that when firms only have limited number of alliances, the marginal return will be diminishing due to the limited experiences firms has in managing alliances and lack of knowledge mass for the combinative capability to be effective. However, once a firm has passed a critical point in terms of the number of alliances it has, the marginal return will be increasing for the following two reason: 1) the increased capability in managing alliances due to learning effect which result in more knowledge intake by entering into a new alliance; 2) the knowledge mass that already resides within the firm offers opportunity for the firm to combine the new knowledge or know how with its existing knowledge to come up with novel innovation. As such, the overall functional form of the relationship between the number of alliances and innovation output will demonstrate an inverse S-shape as depicted in Figure 3.

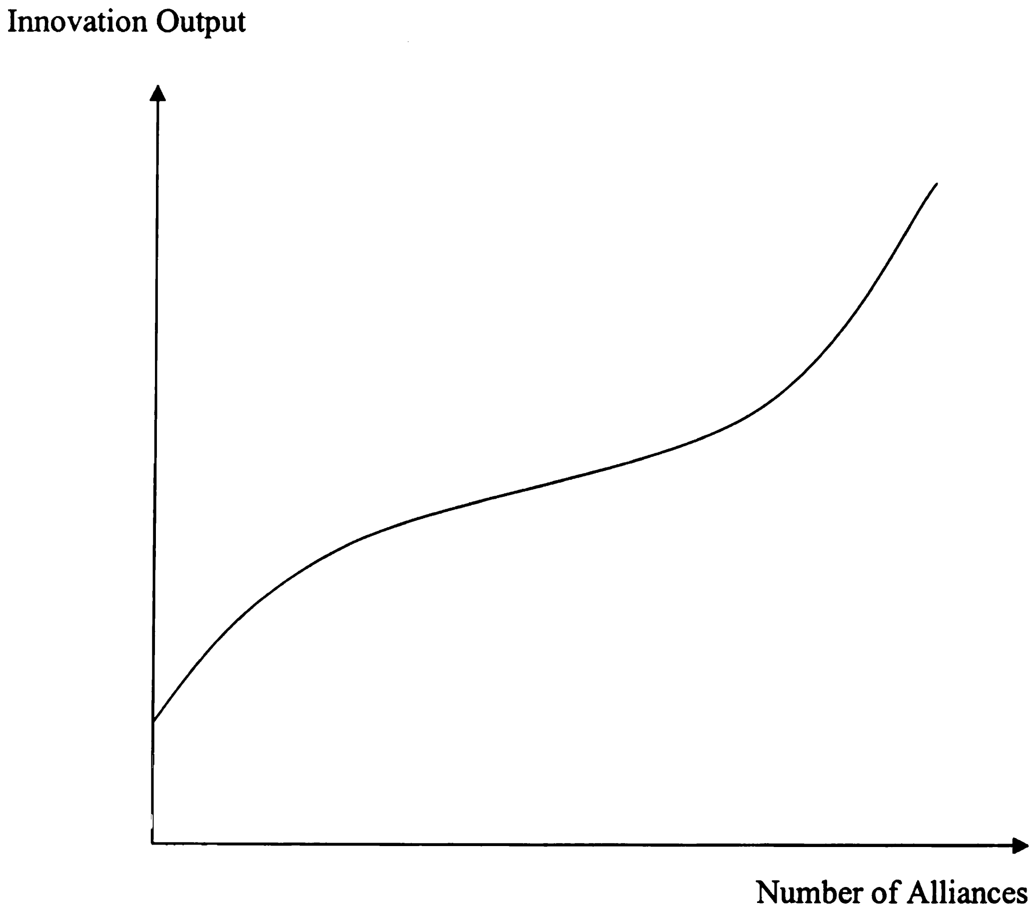
4.3.3 Control Variables

In addition to the relationships discussed above, we control for other variables that may affect a firm's innovation output that are outside our theoretical focus. Specifically, we control for R&D expenditure and firm size.

R&D expenditures. We would control for the R&D expenditure for knowledge and innovation based outcomes. It is expected that the more resources devoted to research and development, the greater firm's knowledge base would be and the better their innovation volume (Wuyts et al. 2004).

Firm size. We would also control for the size of the firm for all three types of dependent variables (knowledge, innovation, financial performance). The effect of firm size on knowledge and innovation development largely stems for the seminal work of Schumpeter (1942). Different effects (positive, negative, and insignificant) were documented in the literature (e. g., Ahuja and Lampert 2001; Chandy and Tellis 2000; Miles et al. 2000). The effect of firm size on performance is based on the idea that large have advantage in obtaining lower cost of capital while simultaneously lowering risk (Chang and Thomas 1989; Goerzen 2007). Previous studies have suggested that the number of employees, sales, and assets are all appropriate proxies for firm size (Harrison et al. 1988; O'Sullivan and Abela 2007). We operationalize firm size as sales in our study.

Figure 3: Relationship between Number of Alliances and Innovation Output



4.4 Methodology

4.4.1 Empirical Setting

We choose to empirically test our hypotheses in the pharmaceutical industry. There are several reasons we prefer the pharmaceutical industry. First, the pharmaceutical industry is a technology intensive industry in which a firm's innovation output plays a significant role in establishing and sustaining a firm's competitive advantage (Wuyts et al. 2004). Second, inter-firm cooperation in the pharmaceutical industry has been a popular business practice since the 1980s. Most pharmaceutical firms have entered into numerous agreements. As our focus is on the relationship between the number of R&D alliances and innovation output, the large number of alliances in the industry is important, especially considering we hypothesized different effects on low and high number of alliances on innovation. This would greatly enhance the testability of our model (Wuyts et al. 2004).

Third, secondary data are available on all inter-firm agreements between pharmaceutical firms in the United States since 1985 through various sources such as Verispan, Bioscan, Recap, and IMS. These sources trace in great details of the alliance activities in the pharmaceutical industry. Finally, pharmaceutical industry has long been a preferred context for empirically testing innovation and alliance related topics (e. g., Nicholls-Nixon and Woo 2003; Prabhu et al. 2005; Rothaermel and Deeds 2004; Sorescu et al. 2003; Wuyts et al. 2004).

4.4.2 Sample

Our sample consists of 66 public pharmaceutical companies in the United Sates. We limited our sample to public firms because we need to obtain financial measure such as sales as our control variable. Public firms are mandated to disclose this information to their shareholder in their annual reports. We compiled data of R&D alliance agreements, new drug approval, and financial information from 1991 to 2005. The starting point of 1991 is selected based on the fact that FDA did not provide detailed information about newly approved drugs before then.

The 66 pharmaceutical firms include most of the major players in the market such as Pfizer, GlaxoSmithKlein, Eli Lilly, and Merck. A total of 3828 R&D alliances were compiled into our data base for these 66 firms over the 15 year period. As expected, firms demonstrated considerable variation in terms of their R&D alliance portfolio size. Some firms have as many as 370 R&D alliances in their portfolio while some have zero. The average R&D alliances portfolio size is 31.

4.4.3 Data Sources

Three separate data sources provided information for our empirical testing: Recap, FDA, and Compustat.

For the number of R&D alliances, we collect data from Recombinant Capital Database. Recombinant Capital is a consulting firm that specializes in pharmaceutical and biotechnology alliances based in the San Francisco Bay Area. They use multiple sources such as trade literature, press releases, and annual reports to compile a database of all the alliances activities of pharma/biotech companies. It also provides detailed information about each identified alliance activity such as parties to the agreement, the nature of the agreement, development stage when alliance is formed, and the technologies that the agreement covers. This database has been used in the literature to construct alliance related variables (Wuyts et al. 2004).

We collected data on new drugs from the drug approval list of the Food and Drug Administration (FDA) as our innovation output. FDA provides all the approved new drugs weekly since 1991.

Finally, we collected control variables (firm size and R&D expenses) from the Compustat database.

4.5 Analysis and Findings

4.5.1 Model Specification

A close examination of our data set suggests that there are several characteristics of the data that may require special consideration to obtain robust results.

First of all, we collected data on a firm-year basis and obtained a panel data (66 firms across 15 years of time). For econometric analysis of panel data, assuming the observations are independently distributed over time is unfounded (Wooldridge 2003). Our model specifications need to account for the heterogeneity caused by the unobserved firm-specific effects. Unobserved factors other than those explicitly addressed in our model could also bear some influence on the dependent variables (Prabhu et al. 2005). In order to truthfully assess the influence of our hypothesized variables on the dependent variable, we need to control for these unobserved effects. Secondly, the dependent variable, number of innovation is a count variable (nonnegative and integers). Ordinary least squares is thus inappropriate for count data (Sorescu et al. 2003).

To successfully account for the heterogeneity and count variable problems, we formulate a Poisson Random Effects model. Using a random effect model over a fixed effects model is consistent with practices in the literature concerning alliances and innovation related topics (Prabhu et al. 2005; Sorescu et al. 2003).

As such, we test the hypotheses with the following cubic random effect Poisson regression model.

$$INNOVATION_{it} = \beta_0 + \beta_1 ALLIANCES_{it} + \beta_2 ALLIANCES_{it}^2 + \beta_3 ALLIANCES_{it}^3 + \beta_4 SALES_{it} + \beta_5 R\&D_{it} + \zeta_i + \upsilon_{it}$$

Where ζ_i is unobserved firm-specific effect

υ_{it} is the remaining error term

To control for the multicollinearity problem associated with a cubic regression model, we used orthogonal polynomial variables as predictor variables (Homburg et al. 2005). Orthogonal polynomial variables are linear combinations of the simple polynomials and are pair-wise uncorrelated which completely eliminates the problem of multicollinearity.

4.5.2 Statistical Results

In order to compare our model with existing models in the literature, we estimated four different models. We present the statistical results in Table 9. Model 1 is the base model in which only control variables are included. Model 2 is the prevalent linear relationship model in which the original number of alliances is entered as a predicator. Model 3 is the inverted U-shape model with the square term added. Model 4 is our proposed inverted s-shaped model with the cubic term added as a predictor.

We used model 4 to test our hypotheses. The coefficient for the cubic term is statistically significant ($\beta = 0.09$, $p<0.01$). More importantly, it is positive and significant. This supports our model which indicates that the marginal returns decreases at the beginning but increases at the end showing an inverse s-shaped relationship. Therefore, our model is supported.

In order to compare our model with proposed models in the literature, we conducted Wald tests on the significance of each added variable. All the Wald Chi squares are statistically significant. This proves that the inclusion of the cubic term significantly improves the model fit which supports the advantage and adequacy of our proposed model. We also compared the fit of the models using Akaike's Information Criterion (AIC) of model evaluation (Akaike 1974). The result support the cubic model over other specifications as the corresponding AIC value (2897.32) is smaller than that of all the other three models. We also compared the three models using the Schwartz Bayesian Information Criterion (Schwarz 1978). The BIC statistics of the four models also leads to the same conclusion that the cubic model is superior to the other three models.

Overall, the findings support our proposed model (both hypotheses). The function is concave for low to moderate number of alliances and convex for moderate to high number of alliances. There is an inflection point where the function changes from concave to convex.

Table 9 Number of R&D Alliances and Innovation Output

Independent variables	Model 1	Model 2	Model 3	Model 4
Intercept	2.20**	2.19**	1.98**	1.99**
Firm size	0.40	-0.22*	0.45	-0.99
R&D Expenditure	0.00**	-0.00**	1.10	-0.00**
# of Alliances		0.45**	0.46**	0.64**
# of Alliances squared			-0.12**	-0.19**
# of Alliances cubed				0.09**
Wald χ^2	910.46**	998.77**	1216.81**	1238.54**
Wald χ^2 (1)		307.98**	238.56**	114.51**
AIC	3863.08	3252.44	3011.25	2897.32
BIC	3881.28	3274.97	3038.28	2928.86

Unstandardized coefficients are shown.
** $p<0.01$
* $p<0.05$

4.6 Discussion

4.6.1 Contribution

Our results strongly support our hypothesized inverse S-Shaped relationship between a firm's number of alliances and its innovation output. This means that when the alliances numbers are low, the innovation output impact demonstrates the sub-additivity due to the inexperience in manager's ability to manage alliances in an effective way and the limited knowledge base firms can draw on to integrate the newly acquired knowledge. However, firms will start to enjoy an increasing marginal return once they have established a critical mass of knowledge to have a base for the occurrence of knowledge integration as well as a better capability in managing alliances more successfully.

This finding is consistent with the general conclusions from previous studies in that the number of alliances a firm has is positively related to its innovation output (Kotabe et al. 1996; Rothaermel and Deeds 2004; Shan et al. 1994). Our findings is also consistent with the non linearity conclusion drawn by Deeds and Hill (2004). However, our findings contribute to the literature by theorizing that the true functional form of the relationship in not linear, not an inverse U-shaped but in fact follows an inverse S-Shape.

Theoretically, we motivated our study by the combinative capability of firms. Our research thus goes beyond the constraints of the simple knowledge accessing foundation and establishes that firms actually integrate what they learn from their partners with existing knowledge base to increase the innovation output. By proving that there are actually both concave and convex relationships in a firm's alliance portfolio building process in terms of innovation implication, our model provides a basis for firms to find out the optimality in their alliance activities.

Our study supports the idea of developing two important capabilities as a foundation for a firm's competitive advantage: alliances management capability and combinative capability. In order to shorten the path of the early diminishing marginal returns, firms need to increase their learning pace in terms of how to better manage their alliances and increase their alliance success. Even though an alliance experience is an important factor in determining the learning process of alliance management, it does not necessarily need to be a passive learning.

There are several strategies firms can employ to speed up the learning process that will help them to reach the increasing marginal return stage early. First of all, firms need to formalize their alliance management learning process. They need to establish a learning culture in their alliance management process in that the learning not only involves the learning of technological capabilities from partners, but also involve the learning of the alliance management itself. This involves the deliberate efforts to articulate, codify, share, and internalize alliances management know how within the firm (Kale and Singh 2007).

Firms need to encourage the sharing of individually held alliance management know how by establishing practices such as formal and regular debriefing of alliance manager, establishing internal reports and presentations, or even keep a simple logbook of all the alliances related activities, actions, and outcomes. Managers need to actively participate in the process of codifying these tacit knowledge into manual and tools to have a clear understanding of what works, what does not work, and why. Experiences from individual alliance cases also need to be shared among managers through informal mechanism such as daily conversations and discussions or formal mechanisms such as alliance committee or task forces (Kale and Singh 2007). A culture that facilitates the learning would speed up the capability development of the firms in terms of the management of alliance. This would help firms to ride over the diminishing marginal returns faster than competitors and realize the increasing marginal returns in an earlier stage.

In order to increase the learning effectiveness of alliance management, organizations also need to make organizational changes that accommodate such a learning culture. Kale, Dyer and Singh (2002) argue that experiences by itself may be a necessary condition for alliance success but not a sufficient one. They suggest one way firms can effectively capture, integrate, and disseminate the alliance-management know how is to create a separate, dedicated alliance management function. This unit will coordinate all the alliances related activities and generate higher returns from alliances. Such a function will facilitate a systematic and routine implementation of the steps involved in the learning process (Kale et al. 2002).

A dedicated alliance management function not only becomes the focal point for codifying, sharing, and internalizing the tacit know how of alliance management, it also increase the external visibility of the firm as it would actively interact with potential alliance partners. As a result, adverse selection problems will be mitigated, as the increased attractiveness of the focal firm will lead to a larger pool of alliance candidates. In addition, such a dedicated also establishes legitimacy to reach and access resources across division within an organization to support alliances related decision. The function also motivates firms to systematically evaluate its alliance performance and create metrics to this evaluation end which will both enhance the learning benefit of the alliance management (Kale et al. 2002).

Another important capability firms need to develop is the combinative capability in integrating knowledge sections. This is an important organizational principle which deals with the successful structure and coordination of individual and group knowledge within the firm (Kale et al. 2002). A firm's unique capability to deploy and integrate its existing and newly assimilated knowledge is fundamental to its long term success and is difficult t replicate by its competitors (Henderson and Cockburn 1994). In fact, the close linkage between knowledge accessing and knowledge integrating make the combinative capability highly desirable to organizations. Henderson and Cockburn (1994) comment that two forms of integrative competence (combinative capability) are particular important: the ability to access knowledge from outside the boundary of the organization and the capability to integrate knowledge flexibly across divisions and units within the organization.

In order to foster the development of such a capability, firms need to carefully coordinate the activities and knowledge sharing across different divisions. Grant (1996) views the organizational capability as an outcome of knowledge integration and proposed strategies that would facilitate the emergence of such a capability. Firms need to establish a centrally located decision maker. Centrally coordinated activities and product designs will have a positive impact on its product success in the market (Clark and Fujimoto 1990).

The above discussion confers to the notion in the literature that organizational capability is the foundation for firms' long-term competitive advantage. The two capabilities we identified in our manuscript helps firms to cut down the concave curve of alliances' impact and boost the convex stage of the alliances' impact on innovation. Organizations need to establish both an organizational culture and corresponding organizational structure and process to realize the benefit.

4.6.2 Limitations and Future Research

Our study has several limitations that need to be noted. First of all, the generalizability of our study needs to be considered as we only sampled publicly traded pharmaceutical firms. Even though we only attempt to generalize the findings to the technology intensive industries such as telecommunication and electronics, the applicability of the findings in other industries needs to be carefully evaluated. This is particularly a concern when we think about the stringent government regulations imposed on the innovation measure that we adopted in the study.

The second limitation is that we could not make strong causal inferences, as we did not take time lag in our model. This is largely due to the nature of our data. We have a panel data set that includes count variables and a potentially lagged dependent variable. Econometric techniques in dealing with all three issues involved here (panel data, count dependent variable, lagged impact) are still in their infancy (Prabhu et al. 2005). Even though the generalized method of moment has the potential to account for all the unique characteristics, we did not use it in testing our model because our subject/time ratio is relatively low compared with what is required for the application of GMM. As such, we could only make inferences in terms of the correlation not causality.

As for future research, we believe that literature could greatly benefit examinations of certain moderating factors between the number of alliances and innovation output relationship. For example, firms differ in their capability to combine knowledge in its possession. Combinative capability develops in an organization as the firm learns to manage its knowledge flow more effectively. As the combinative capabilities differ across firms, we may expect a moderating effect of the combinative capability in the proposed inverse s-shape relationship between the number of alliances and innovation outcome. It is not difficult to see that firms that have a superior capability to combine their knowledge elements will obtain more innovation outcomes than those with lesser capabilities. The logic follows that firms will be at a better position in identifying new opportunities and have better chances of discovering new products by combining their knowledge due to effective flow knowledge within the organization. As such, at the same level of the number of alliances, these firms will result in more innovation outcomes than others.

A firm's product portfolio may also moderate this relationship. The most widely cited source of synergy in organizations with multiple businesses is the resources relatedness among business units. Resource relatedness refers to the presence of similar activities and shared resources across business units of the firm. Researchers building on the RBV of diversification posit that sharing of strategic resources among business units creates cross business resource based synergy (Feinberg and Gupta 2004). As such, we also expect that the inverse S-shaped relationship to be moderated by the product scope a firm competing in. The reasons are the following.

First, an organization with multiple business units are more likely to have the experiences and expertise in effectively moving around human resource with diverse knowledge stores to better identify new opportunities (Feinberg and Gupta 2004). The reason is that more business units offer greater opportunity and greater experience at building communication linkages among the various units. These intrafirm linkages are likely to serve as an asset in utilizing the knowledge accumulated by any new R&D alliances in a particular business unit to the whole organization (Feinberg and Gupta 2004).

Second, a more direct reason for the moderating effect of scope of business units lies in the fact that a firm with more business units simply has more places within the organization that may have the capacity to utilize the newly acquired knowledge from its alliance partner. In addition, these businesses units are likely to have developed the ability to absorb knowledge from outside through prior interactions with other business units. As such, we would expect that, holding constant the number of alliances, a firm with more business units or product scope would probably come up with more innovations than a firm that has a narrower business unit scope. These potential moderators offer great future research opportunities

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