國立臺灣大學管理學院國際企業學研究所

博士論文

Graduate Institute of International Business

College of Management

National Taiwan University

Doctoral Dissertation

全球生技製藥產業研發聯盟成對夥伴關係與共同創新績效之研究：組織學習與社會交換觀點

Study on Dyadic Partnership and Joint Innovative Performance of R&D alliance in Global Biopharmaceutical Industry: Organizational Learning and Social Exchange Perspectives

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中華民國 102 年 1 月

January 2013

誌 謝 辭

本論文的順利完成，首先要感謝指導教授吳青松老師與吳學良老師，從兩位老師身上，不但學到了做學問的態度與嚴謹的方法，而且在研究過程中，老師的細心、體諒和關懷，使我遇到困難或疑問時，總是能得到老師不厭其煩地提供指引與協助。另外，論文進行期間，各口試委員們對本研究提出了許多寶貴之意見，著實讓這個論文更臻完備。

在臺大國企所求學期間，還要感謝所上所有教授過我的老師們，他們對我在學問上的傳道、授業與解惑，使我在悠遊於學術殿堂的同時，更加磨練了個人的思維和決策能力。此外，我更要感謝所有曾經一起上課的同學們，從大家的身上我學習到很多，也讓我的博士班研究所生涯充實又愉快。

徐之昇　謹誌

中華民國102年1月

中文摘要

研發聯盟於高科技產業之各類策略聯盟當中極為重要，且它已成為許多企業在國際商務上取得競爭優勢的重要途徑。但是，僅管研發聯盟為企業帶來了諸多好處，為數不少的研發聯盟卻仍然以失敗收場。究竟是什麼因素造成這些研發聯盟的高失敗率？過去許多學者提出研發聯盟中的夥伴關係是影響聯盟績之關鍵因素之一，並且認為未來需要更多的進一步實證研究來解答上述這個問題。本論文即回應這些學者的呼籲，利用經濟與社會之雙元觀點，檢視了夥伴間不對稱性(技術異質性、網絡資源不對稱性)與創新績效(創新速度、創新產量)之聯繫。研究結果指出夥伴間技術異質性與創新速度呈倒U型關係；對於1991-2000年間的聯盟與兩家生技公司共同合作的聯盟來說，網絡資源不對稱性與創新速度呈正向關係；網絡資源不對稱性與創新產量呈倒U型關係；此外，產品距離上市的時間會顯著地負向干擾上述關係。藉由解析各類夥伴關係對研發創新所造成的影響，以及了解產品研發階段因素之調節效果，本論文對於生技製藥產業研發聯盟之夥伴關係議題提出了許多理論上與實務上的貢獻。

關鍵詞：研發聯盟、夥伴關係、創新、組織學習觀點、社會交換觀點

英文摘要

Research and development (R&D) alliance is of great importance among various strategic alliances in high-tech industries, and it has become a vital strategy for many corporations to achieve competitive advantage in international business. Despite more and more companies benefited from R&D alliances, however, most of these alliances have failed. How come the high failure rate of R&D alliance happened? Prior researchers have proposed that the partner relationship plays a critical role for the performance of R&D alliance, and further empirical studies were consequently suggested for future research. In response to recent calls for inquiry into the issue regarding the effects of mutual relationships between partners, this dissertation aims to examine the links between partner asymmetries (technological heterogeneity and network resource asymmetry) and innovative performance (speed and quantity) from both economic and social dual perspectives and focusing on global biopharmaceutical industries. The results reveal an inverse U-shaped relationship between technology heterogeneity and innovation speed, a positive linear relationship between network resource asymmetry and innovation speed for 1991-2000 alliances and for BB partner type alliances, as well as an inverse U-shape relationship between network resource asymmetry and innovation quantity. Besides, there are significantly negative moderating effects of time to market on the above linear relations. Finally, this study makes important theoretical and practical contributions to partner selection literature on R&D alliances in the biopharmaceutical industry by highlighting not only the impacts of partner relationships on innovation, but also the moderating effects of product's stage along the R&D process.

Keywords: R&D alliance, Partnership, Innovation, Organizational Learning Perspective, Social Exchange Perspective

目錄

表目錄

圖目錄

Chapter 1: Introduction

1.1 Research Background

Strategic alliance has become a vital strategy for many corporations to achieve competitive advantage and has played a major role in international business. Through a variety of collaborative forms, companies could overcome trade barriers (Contractor and Lorange, 1988; Hagedoorn, 1993), enter new markets (Garcia-Canal et al., 2002), increase their economies of scale and scope (Mohr and Spekman, 1994), market power (Kogut, 1988; Eisenhardt and Schoonhoven, 1996) and strategic renewal (Borys and Jemison, 1989), exchange resources and capabilities (Hamel, 1991; Kogut, 1991; Mowery et al., 1996) and share risk of investment (Anderson, 1990; Ring and Van de Ven, 1992). This is the why the use of strategic alliances has grown dramatically over the last two decades, particularly in high-technology industries (Hagedoorn, 1993; Rothaermel, 2006).

Research and development (R&D) alliances are of great importance in high-tech industries, like the biopharmaceutical industry. Firms engaged in innovation are aware of the necessity of establishing R&D cooperation to obtain access to expertise which cannot be generated in-house. Collaboration with other firms and institutions in R&D is a crucial way to of making external resources usable. It promises efficient resource exchange, knowledge transfer, organizational learning, and economies of scale (Jorde & Teece, 1990; Ahuja et al., 2008). One of the key management challenges in increasing R&D productivity is to raise the percentage of successful compounds in clinical trials, because the success rate is critical factor in valuing an individual drug, or a company's pipeline of drugs (Danzon et al., 2005). Therefore, biopharmaceutical firms invest a greater percentage of their sales in R&D alliance, and such alliances have become an important worldwide mechanism for biotechnology and pharmaceutical firms to excel in drug discovery, development, and commercialization under the pressure of mass resources needed in R&D and increasingly intense global competition.

An R&D alliance is not a guarantee of innovation for bio-pharmaceutical firms. Even though many bio-pharmaceutical firms benefited from R&D alliances, many of these alliances have failed. How come the high failure rate of R&D alliance happened? Prior researchers have proposed that the partner relationship plays a critical role for the performance of R&D alliance, For instance, the selection of the wrong partner, inefficient alliance governance, conflicts between partners, barriers to knowledge sharing, and cultural or economic distance result in inferior performance (Geringer, 1991; Hitt et al., 2000; Baum et al., 2010; Islam et al., 2011). Hence, further empirical studies about the effects of partner relationships on alliance's performance were consequently suggested for future research (Lhuillery, 2009; Xia, 2011).

Prior researchers have suggested that the choice of a partner is an important variable in the performance of alliance (Parkhe, 1991; Mohr and Spekman, 1994; Park and Ungson, 1997), because it influences the combination of skills and resources which will be available to the alliance and thus the ability of the alliance to achieve its strategic objectives (Geringer, 1991; Li and Glaister, 2006). Selecting the right partner is beneficial for firms' technology and financial performance; the wrong partner is harmful. In R&D alliances, various partners may be involved at different phases and their participation can lead to success or failure. Therefore, a company that launches an R&D alliance has to select its partners carefully.

There have been many studies of regarding partner selection, which is one of the most popular topics in the literature on international strategic alliances. There are several currents in this research field. Shah and Swaminathan (2008) proposed a contingency approach grounded in management control theory that suggests that the criteria that managers use in choosing alliance partners will depend on the alliance project. Roy and Oliver's (2009) research explored how the host-country's legal environment affects the criteria for the selection of international joint venture partners, and found that this environment negatively affects appropriation and coordination cost concerns, but

positively influences partner-related criteria.

The second line of research is the effect of the partner's objective conditions, like type (source) of partner, on alliance performance. Belderbos et al. (2006) analyzed the performance effects of simultaneous engagement in R&D cooperation with competitors, clients, suppliers, universities and research institutes, and suggested that the joint adoption of cooperation strategies could be either beneficial or detrimental to firm performance, depending on firm size and strategy combinations.

The most recent stream explores the impact of partner's subjective dimensions, such as the relationship between partners, on alliance performance. Xia's (2011) research, for example, investigated the effects of mutual dependence, partner substitutability and repeated partnership on the survival of an alliance. Goerzen's (2007) research indicated that the negative effect of repeated partnerships on performance is strongest in environments of greater technological uncertainty.

1.2 Research Motivation

Over the past few years, a considerable number of studies have been made on partner selection. There are several research trends or gaps in the literature:

(1) The lack of the effect of mutual relationship on alliance's performance: Previous researchers have suggested future research to explore the effects of the mutual relationships between partners, including partners' types and features (Shah & Swaminathan, 2008; Li et al., 2008; Xia, 2011).

(2) The lack of multi-theoretical perspectives: Most of the previous studies on alliance were described from an economic perspective, but research has ignored the social perspective. Apart from the considerations of resource, cost, transaction, effectiveness about the alliance, social factors like network, dependence and legitimacy also have a critical influence on the outcome of alliance.

(3) The lack of dyadic approach: The dyadic relationship between alliance partners is a more appropriate way to identify the feature of the alliances, because the similarities, differences, asymmetries and the interactions between partners matter on both input and output of alliances. Information about individual firms within the alliance only contributes to a partial understanding of the alliance (Contractor et al., 2005; Bearce et al., 2006).

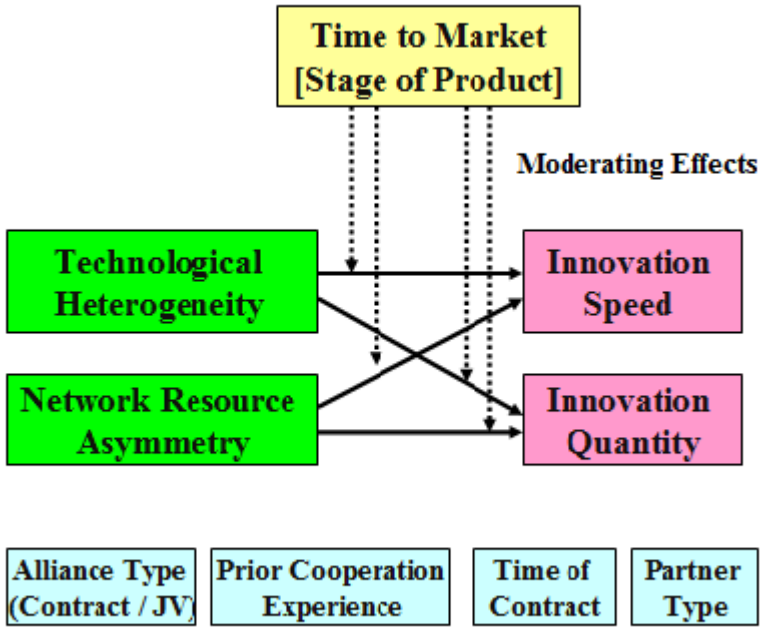
(4) The lack of using innovation speed as the measurement of alliance's performance: With the development of technology and international business environment, except the quantity and quality of innovation, innovation speed has become important than ever for organizations' gaining of a competitive advantage (Capon & Glazer, 1987; Gupta & Wilemon, 1990; Craig & Hart,1992), especially for short-path industries. The speed of innovation reflects the efficiency of innovation. Rapid innovation allows firms not only to acquire returns earlier, but also to defeat their competitors and gain a larger market share (Carbonell & Escudero, 2010). A great

deal of effort has been made on the financial performance or innovation quantity following the R&D alliances. What seems to be lacking, however, is research on the effect of innovation speed.

1.3 Research Objectives

The partner relationships have been regarded as a very important factor on alliance's performance (Belderbos, R. et al., 2004). In response to recent calls for inquiry into the issue regarding the effects of mutual relationships between partners and to explore each research issue thoroughly, the dissertation consists of two studies: (1) How the partner asymmetries affect innovation speed? (2) How partner asymmetries affect innovation quantity? The overall research framework is as figure 1.

Figure 1. Overall Research Framework



The first study aims to examine the ways in which partner asymmetry (technological heterogeneity and network resource asymmetry) affect innovation speed from both organizational learning (economic) and social exchange (social) dual perspectives. Considering the theoretical and methodological problems in prior studies, we offer an improved model about the effects of type of partner on innovation speed of alliance under multiple conditions.

Partner asymmetry includes two critical issues. The first issue is technological heterogeneity

between partners. In most high-tech industries (including the biopharmaceutical industry), firms make horizontal alliances with homogeneous firms and vertical alliances with heterogeneous firms. Several studies have examined the effect of the heterogeneity (or homogeneity) of partners' resources, and the connection to alliance performance (Baumet et al., 2000; Katila, 2001; Sampson, 2007). However, there is no significant evidence to verify which type of partner (with heterogeneous or homogenous technology) is more likely been used by firms and which one is more beneficial for the alliance. Bio-pharmaceutical firms sometimes make R&D alliance with partners with similar technology capability, and at other times they ally with firms with divergent technology. For instance, the biotech company Geron allied with the pharmaceutical company Pharmacia which had different technology in 1996, and it allied with Johns Hopkins University, which had similar technology in 1997. The biotech company ImClone Systems, allied with the University of North Carolina which had similar technology in 1988, and then with the pharmaceutical company Merck which had different technology in 1990. Therefore, this study explored the relation between technological heterogeneity of dyadic alliance and innovative performance.

The other central issue is the asymmetry of partners' network resource, which could be an indication of the network asymmetry of the dyad alliance. Many firms have formed alliances with small and large alliance networks with other firms. For example, the biotech company NPS Pharmaceutical allied with the pharmaceutical company Pfizer which had has 25.63 times as many alliances as it did in 1987, and then allied with Brigham and Women's Hospital which has only 1.63 times as many alliances as it did in 1993. The biotech company Poniard Pharmaceuticals allied with Southern Research Institute which has fewer alliances (0.85) than it did in 1993, and then allied with the pharmaceutical company Schwarz Pharma which has 1.62 times as many alliances as it did in 1997. Although researchers have studied the impact of the firm's number of alliance on its scale

or performance, scant attention has been given to the effects of partners' network asymmetry. Therefore, this study investigates the relationship between network resource asymmetry of dyadic alliance and innovative performance.

To improve our understanding of the research issues pertaining to partner selection of R&D alliance in the biopharmaceutical industry, this study proposes an integrated and multi-theoretical framework. An integrated framework is needed, because exploring multiple aspects through divergent perspectives is a more comprehensive means of analysis (e.g. Lin et al., 2009; Jiang et al., 2010). By referring to both the economic and social perspectives (organizational learning theory and social exchange theory), we can explore the impacts of distances of inside technology and outside resource within R&D alliances on innovation.

Moreover, the appropriate unit of analysis shall be emphasized on partner selection of alliance research. The dyadic approach is better than firm-specific. Most of the literature, takes the single-firm rather than the dyadic partner perspective (e.g. Hitt et al., 2000; Fritsch, 2003; Gulati & Higgins, 2003; Becker & Dietz, 2004). Those articles focus on individual firms, while more new research has adopted the dyadic approach (e.g. Li et al., 2008; Lin et al., 2009; Gulati et al., 2009; Yang et al., 2010; Jiang et al., 2010; Xia, 2011; Cui et al., 2011). It shows that dyadic approach is a research trend in partner selection of alliance studies. Following this trend, we look at asymmetries from a dyadic rather than dingle-partner perspective.

More organizations than ever now recognize the importance of innovation speed (Gehani,1992), and have sought ways to speed up R&D through the formation of R&D alliances, partly because they expect to be a fast innovator and to gain a pioneering advantage in the field (Millson et al., 1992). Even if a later entrant, it needs to have faster R&D (or new product development) capability, because it could enhance its competitive advantages by acquiring exclusive patent protection, creating new products and being first to market. Therefore, the first

study uses innovation speed as the construct of innovative performance to interpret the efficiency of innovation.

Further, in order to compare the effects of network resource asymmetry on innovation speed and innovation quantity, the second study extends the first study and examines how mutual network resource asymmetry between partners in biopharmaceutical firms' R&D alliances affects the innovative quantity. Moreover, it also examines the moderating effects of product's stage along the R&D process.

1.4 Research Procedure

This dissertation is divided into six chapters. It begins by introducing the background, motivation, objectives of this study. In the first section, the literature relevant about the main issues of this study are reviewed, including the development of alliance research, advantages of R&D strategic alliance and various partner selection studies. With the reviewing of literature, we realized several trends and gaps about the issues of partner relationship, and these findings drive the research objectives and goals of this study. In chapter 1.3, we pointed out the overall research framework and divided the dissertation into three studies, as well as described the objective of each study. Chapter 2 provides theoretical perspectives and develops the hypotheses of this dissertation. We briefed the concepts of organizational learning and social exchange theories, as well as those of key elements of this dissertation, including innovation speed, technological heterogeneity and network resource asymmetry. According to the main research questions and issues which we tend to explore, several hypotheses are then developed from several theoretical perspectives, both main effects and moderating effects are considered and proposed. Chapter 3 outlines the research design and presents the research framework based on the above hypotheses. The measurements of independent, dependent, moderating and control variables and analytical approaches of the empirical study are presented in this chapter. Chapter 4 describes the statistic results of each study by using texts, tables and figures. Subsequently, we discuss the implications of results thoroughly based on the previous findings. Both theoretical and practical dialogues for each result were carried on and were appeared in chpater 5. Finally, we also summarized our findings and outlined the critical contributions and limitations with future research directions at the end of this dissertation in chapter 6.

Chapter 2: Background and Hypotheses Development

We take advantages of two theories from both the economic and social perspectives (organizational learning perspective and social exchange perspective) to clarify the effect of technological heterogeneity and network resource asymmetry of alliance on innovation. Organizational learning theory expresses substantial technology consideration between partners, but social exchange theory explores mental sensation and interaction between partners.

2.1 Theoretical Background

The concept of organizational learning is a field of organizational theory that studies models and theories about the way an organization learns and adapts. In organizational development, learning is a characteristic of an adaptive organization, one that senses and responds to changes in signals from its internal and external environment (Argyris & Schön, 1978; Huber, 1991; Cyert & March, 1992). Organizational learning theory predicts that a firm's performance of an activity increases with the level of knowledge (Levitt & March, 1988; Argote, 1999; Delios & Beamish, 2001). Organizational search is one part of the organizational learning process through which firms attempt to solve problems in an ambiguous world (Huber, 1991). Organizations engage in a wide variety of searches, such as search for knowledge creation or innovation (Von Hippel & Tyre, 1995) and search for manufacturing methods (Jaikumar & Bohn, 1992; Katila & Ahuja, 2002). In R&D alliances, the technology capability most likely needs technological experience to collaborate with the technology source and to apply the knowledge for innovation (Hoang & Rothaermel, 2005; Sampson, 2005).

The concept of social exchange is defined as "voluntary actions of individuals that are motivated by the returns they bring from others" (Blau, 1964). Unlike macro and micro economic theories, which were designed to examine economic exchanges, social exchange theory was designed to examine interpersonal exchanges that were not considered to be purely economic. As

such, the theory analyses people's social behavior in terms of exchanges of resources (Bignoux, 2006). Social exchange theory was developed since Homans' (1958) article "Social Behavior as Exchange." He argued that people are willing continue with certain behaviors is that they have received benefits from those behaviors. Within a dyad relationship, people interact only on the basis of good exchange relationships, and they need to adjust their behaviors dynamically to meet their opponents' requirements under various contingencies (Hallén et al., 1991). Blau (1964) proposed that reciprocity is the crucial element in mutual exchange. The exchange type could be divided into economic and social. The former regards formal contracts, precise principles and practical rewards, such as transaction contracts; the later has no definite obligations, principles and rewards, instead, it is based on trust, such as mental contracts. This concept could be extended to the organizational and inter-organizational levels, like R&D alliance. Within an alliance, economic exchange relationships assess the value of target transaction objects, and emphasize the balance of input and output. However, the key factor in the social exchange relationship is the quality of interaction between partners; in other words, the better the quality, the higher the exchange benefit.

2.2 Technological Heterogeneity and Innovation Speed / Quantity

Innovation speed is as the time that elapses between the development of an innovation and patent acquisition or commercialization (Mansfield, 1988; Clark & Fujimoto, 1991; Murmann, 1994). Thus the concept of innovation speed is the acceleration of activities from first spark to final product, including activities that occur throughout the R&D process (Kessler & Chakrabarti, 1996). To biopharmaceutical firms, innovation speed has acquired greater importance because of increasing R&D cost, patent competition and barriers of examination prior to approval by the Food and Drug Administration (FDA). Innovation speed is important for R&D alliances made by biopharmaceutical firms, because creating first innovation and applying for co-patent are the main objectives for most biopharmaceutical R&D alliances. Once they have reached their first milestone, they can occupy an exclusive position of new technology development, gain visibility and legitimacy, attract investment, and increase the likelihood of survival and high market share (Heirman & Clarysse, 2007).

The factors that affect innovation speed are complex (Crawford, 1992; Blau, 1994). Allocca and Kessler (2006) explored the relationship between firm's size and the innovation speed. They found a negative relationship between speed and steady product specification, because less rigid specifications allow managers to think more creatively, and to react favorably in uncertain and turbulent technology contexts (Iansiti & Mac Cormack, 1997). They also found that departure from familiar technology had a positive effect on innovation speed. Heirman and Clarysse (2007) investigated whether tangible and intangible assets matter for innovation speed in start-ups, and found that having a prototype, or beta version, matters for firms in medical, telecom, or other nonsoftware technologies; however, it does not increase innovation speed for software firms.

Zhong and Ozdemir (2010) analyzed the effects of network structure on innovation speed. They argued that the more potentially connected the structure in which actors interact is, the faster

the actors are able to innovate collectively. Besides, the potential connection structure in which actors interact has a curvilinear effect on the speed of collective innovation. Although the initial increases in potential connectivity rapidly increase the speed, additional increases in potential connectivity are less effective. Furthermore, several articles have studied the benefits of innovation speed, and there is a consensus that innovation speed contributes firms' development and performance (Teece, 1986; Zehir & Özşahin, 2008; Carbonell & Escudero, 2010).

Generally speaking, the technology owned by biotech firms (ex. biotechnology) is different from that owned by pharmaceutical firms (ex. synthetic technology). Biopharmaceutical R&D alliance consists of multiple types of partners, including biotechnology firms, two pharmaceutical firms, even universities and government laboratories, and alliances made by divergent types of partners might generate technological heterogeneity. In contrast to alliances between two biotech firms, alliances between one biotech firm and one pharmaceutical firm might have greater technological heterogeneity.

According to the social exchange perspective, exchange is created and maintained by the scarcity of resources, prompting actors to engage with one another to obtain valuable inputs (Das & Teng, 2002). Reciprocal resource commitments and relational influence between partners will ensure collaboration and alliance success (Das & Teng, 1998; Steeusma & Lyies, 2000; Subramani & Venkatraman, 2003; Muthusamy et al., 2007). Because reciprocity and mutual influence between partners are tangible norms and manifest as mutual control and power sharing or joint decision making, they can supplement trust in collaboration (Provan & Gassenheimer, 1994; Steensma & Lyies, 2000; Dekker, 2004). Partners are willing to exchange their technology (knowledge) once they predict that they can benefit from it. R&D alliances made by firms with high technological heterogeneity might help them to have divergent technology (knowledge) pooling and to establish the essential conditions of technology (knowledge) exchange. Technological heterogeneity

contributes to technology (knowledge) exchange because partners would like to access and integrate technology (knowledge) that their rivals possess and they themselves do not. The interaction of technology (knowledge) is the most important ingredient of knowledge creation and innovation, and the higher level of technological heterogeneity is an incentive, which would trigger the technology (knowledge) exchange (Lin, T.C. & Huang, 2010; Bertsch et al., 2011). For instance, when a pharmaceutical firm with synthetic technology forms a R&D alliance with a biotech firm with biotechnology, the pharmaceutical company may contribute to the synthetic technology about screening the molecular structure of drug; conversely, the biotech firm may use its biotechnology about gene transfer and duplication to develop new products.

Organizational learning theory helps us to understand the difference between homogeneous and heterogeneous technology. Through various types of technology searches, an organization could choose the right technology to access and learn from R&D alliances, and then enhance its innovative performance. A technology search could be local search or distant (Stuart & Podolny, 1996; Rosenkof & Nerkar, 2001). A local search focuses on similar (homogeneous) technology, creates incremental innovations, and becomes more expert in its domain (Rosenkof & Nerkar, 2001). In distant research, firms focus on other kinds of (heterogeneous) technology. Previous studies have indicated that firms could easily accumulate expertise and acquire competitive advantages from local searches. Other empirical studies have found a linearly positive relationship between local search and the frequency of exploratory innovation (Methé, Swaninathan, & Mitchell, 1996). At the same time, a distant search leads to recombination inefficiency, because technological heterogeneity increases knowledge integration costs and time (Katila & Ahuja, 2002). The more divergent the knowledge to be integrated, the more complex the problems of creating and managing integration (Grant, 1996). In terms of the innovation speed of R&D alliance, cooperation with partners that have homogeneous technology can enable firms to adopt local searches and create

incremental innovations through the development of routines, and to generate innovation more quickly than distant search.

Actually, both too much and too little technological heterogeneity may be detrimental to innovation. As mentioned above, local search helps firms to access homogeneous technology, to increase technology capability and development of routines, and to speed up innovation. However, the competence made by local search might lead firms to develop core rigidities or fall into competency traps (Levitt & March, 1988; March, 1991; Leonard-Barton, 1995; Rosenkof & Nerkar, 2001), because those organizations exploit only the value of existing knowledge (Cohen & Levinthal, 1990), and organizations with homogeneous resources have limited opportunities for development. However, even though technological heterogeneity triggers the exchange of technology, and the acquisition of heterogeneous technology by distant search also contributes to the probability of successful R&D, leaning heterogeneous technology from a partner is not easier than learning homogeneous technology, because more time and money must be invested in learning it. In addition, heterogeneous technology is not readily integrated, because every technology has its limits, especially for biopharmaceutical high-technology. Recent developments in research on absorptive capacity contradicts this point of view, for which there is an enhanced role for absorptive capacity as a facilitator for more distant search, thus enabling more explorative learning (Lavie & Rosenkopf, 2006). Furthermore, the majority of conflicts of alliances happened when partners had different technology and objectives.

We argue that technology heterogeneity between partners will be both beneficial and harmful to innovative performance. When a biotechnology company allies with a pharmaceutical company, they might have a better innovative performance, since they have heterogeneous technology; however, extremely different technology comes at a high cost and difficulty of integration and cooperation. We therefore predict that the relation between heterogeneous technology and

innovative performance is a non-linear curve rather than a linear straight line.

H1: An inverse U–shaped relationship is predicted between technological heterogeneity and innovation speed: the relationship between technological heterogeneity and innovation speed will be nonlinear with innovation speed increasing up to an optimal level beyond which higher levels of technological heterogeneity transfer lead to a decline in innovation speed.

H2: An inverse U–shaped relationship is predicted between technological heterogeneity and innovation quantity: the relationship between technological heterogeneity and innovation quantity will be nonlinear with innovation quantity increasing up to an optimal level beyond which higher levels of technological heterogeneity transfer lead to a decline in innovation quantity.

2.3 Network Resource Asymmetry and Innovation Speed / Quantity

Alliance activity is a way for companies to obtain external resources from partnerships. A prospective partner's resources are a factor that a firm has to consider. Apart from internal resources like assets, number of employees, number of patents, and financial returns, external resources like number of alliance partners is also an important consideration. The number of friends an organization has is a good indicator of its external social resources. A company with more friends has higher status and a better reputation in the industrial structure. Once a company makes an alliance with a partner that has more friends, it has access to more resources. In a dyadic alliance, the distance of partner's number of alliance partners could be observed. When the distance is small, we have a "matched dyad," otherwise, a "non-matched dyad." "Matched dyads" include alliances of two firms with abundant network resources or two firms with limited network resources; "non-matched dyads" include alliances made by one firm with abundant network resources and one firm with limited network resource.

In general, the larger technology (R&D) alliance network has broader technology (knowledge), and the smaller technology (R&D) alliance network has deeper technology (knowledge). According to the organizational learning perspective, local search encourage firms to integrate similar knowledge and to generate synergy, which deepens technology, while distant search allows firms to integrate divergent knowledge and generate radical innovation, which widen the scope of technology (Katila & Ahuja, 2002). "Matched dyads" might have large technology scope ("large-large" network resource) or deep technology ("small-small" network resource); while "non-matched dyads" have both wide and deep technology ("large-small" network resource). Both "search depth" and "search scope" enable firms to achieve innovation, however, the possession of both deep and large network resources enable R&D alliances to become more innovative more quickly, because those alliances have high quality (depth) and number (scope) of technology.

Therefore, greater network resource asymmetry (“non-matched dyad”) is helpful for biopharmaceutical R&D alliance, because they have a combination (interplay) of high technology depth and scope.

The “matched dyad” in a R&D alliance could be explained with reference to social exchange theory. Within a dyadic alliance, the effort one partner would like to put in the alliance is related with its cognition of its partner’s input. Once the inputs from both sides are not equal, the conflicts between partners may be occurred, and their innovation speed and performance of alliance would be influenced accordingly. This phenomenon was easily happened in “non-matched dyad," because one who has more alliances need to be deal with has less attention on this target alliance, and it would not pay full effort to the alliance due to the perceived unfairness. On the contrary, “matched dyad” with relatively equal resource will trigger partners to put more effort to the R&D alliance and speed up the innovation. In this case, “matched dyad” might be a more stable alliance than a “non-matched dyad."

On the bases of these perspectives, we propose that moderate level of “matched dyad” is beneficial for innovation, because too many “matched dyads” have only technology depth without a combination of depth and scope (economic perspective) and too many “non-matched dyads” reduce social exchange (reciprocity) (social perspective). We therefore predict that the relation between network resource asymmetry and innovative performance is a non-linear curve (inverse U-shaped), instead of a linear straight line.

H3: An inverse U–shaped relationship is predicted between network resource asymmetry and innovation speed: the relationship between network resource asymmetry and innovation speed will be nonlinear with innovation speed increasing up to an optimal level beyond which higher levels of network resource asymmetry transfer lead to a decline in innovation speed.

H4: An inverse U–shaped relationship is predicted between network resource asymmetry and innovation quantity: the relationship between network resource asymmetry and innovation quantity will be nonlinear with innovation quantity increasing up to an optimal level beyond which higher levels of network resource asymmetry transfer lead to a decline in innovation quantity.

2.4 Moderating Effects of Time to Market

Global pharmaceutical research teams discover thousands of new chemical substances each year. Only a few become new drugs. It can take up to 15 years for a new drug to go through development and testing before reaching the market. Development and testing begins with extensive laboratory tests before being tested on humans in clinical trials. There are four stages in clinical trials. In those trials, a drug is tested on healthy volunteers, to see how it affects the body, and on sick volunteers, to see how effective the drugs are.

R&D alliances generated along the product development states. Early-stage collaborations within the biopharmaceutical industry are vital in driving innovation evolution through therapeutic and technological diversification (Belsey & Pavlou, 2005). DiMasi (2002) examines the financial benefits that can accrue to drug developers from improvements in drug development. He proposed that whether faster development times, quicker termination decisions or higher success rates derive from public policy initiatives, better management, or new technologies, the impact on R&D costs can be substantial. Ultimately, increased efficiency could result in more innovation and new therapies reaching patients sooner.

The process of basic discovery and development through new drug approval consists of discovery, preclinical and clinical development. Discovery often begins with the choice of a biochemical mechanism involved in a disease condition. Drug candidates, discovered in academic and pharmaceutical/biotech research labs, are tested for their interaction with the drug target. The early stage includes formulation, discovery, molecule issues. The pre-clinical phase represents bench (in vitro) and then animal testing, including kinetics, toxicity and carcinogenicity. In the US, an investigational new drug application (IND) is submitted to the Food and Drug Administration to obtain permission to begin the heavily regulated process of clinical testing in human subjects. There are three phases of clinical trials: human pharmacology, therapeutic exploratory, and

therapeutic confirmatory.

The effects of technological heterogeneity on innovation speed are supposed to be different for divergent stages of collaborating products. In many cases, the technology behind earlier-stage product belongs to academic and fundamental technology, such as basic chemical structure analysis, biological identification technology, because early-stages along with the development process focus on finding active substances and exploring their toxicity, only single basic technology is needed for those products. On the contrary, it is necessary that companies integrate heterogeneous technology for developing later-stage products, because more complicated technology should be applied to examine the toxicity, safety and effectiveness during the later stages. For example, the aims for developing phase II or phase III products consist evaluating safety, appropriate dosages, potential side effects for numerous patients in the clinical trials, and complicated technology like pharmacokinetics, gene transferring, monoclonal antibodies hybridoma technique and other testing technology for clinical trials. Therefore, technological heterogeneity in R&D alliance is more important for developing later-stage products than those of earlier-stage products in order to reach innovation easily and efficiently.

H5: Among alliances which focus on new products closer to commercial stage, the technological heterogeneity between partners leads to faster innovation speed.

H6: Among alliances which focus on new products closer to commercial stage, the technological heterogeneity between partners leads to larger innovation quantity.

Likewise, partner network resource asymmetry is more crucial for developing later-stage products than those of earlier-stage products. As mentioned above, “non-matched dyads” have both wide and deep resources and capabilities, because the combination of both “search depth” and “search scope” enable firms to achieve innovation more easily and quickly. Take a R&D alliance

made by a firm with a large network resource and a firm with a small network resource as example, the alliance has both wide and deep technology as well as divergent capabilities, experiences, and even financial supports, and these resources help partners gain innovation easily and quickly. Hence, we argue that the stage of product affects the relationship between network resource asymmetry and innovation speed and quantity, and the network resource asymmetry is more demand for reaching innovation when the collaborating product is in the later stages.

H7: Among alliances which focus on new products closer to commercial stage, the network resource asymmetry between partners leads to faster innovation speed.

H8: Among alliances which focus on new products closer to commercial stage, the network resource asymmetry between partners leads to larger innovation quantity.

The above hypotheses are summarized in the table 1 and figure 2 ~ figure 4.

Table 1 Summary of Hypothesis

Study	Issue	Hypotheses
1	Partner Asymmetry and Innovation Speed	H1: An inverse U–shaped relationship is predicted between technological heterogeneity and innovation speed: the relationship between technological heterogeneity and innovation speed will be nonlinear with innovation speed increasing up to an optimal level beyond which higher levels of technological heterogeneity transfer lead to a decline in innovation speed. H3: An inverse U–shaped relationship is predicted between network resource asymmetry and innovation speed: the relationship between network resource asymmetry and innovation speed will be nonlinear with innovation speed increasing up to an optimal level beyond which higher levels of network resource asymmetry transfer lead to a decline in innovation speed. H5: Among alliances which focus on new products closer to commercial stage, the technological heterogeneity between partners leads to faster innovation speed. H7: Among alliances which focus on new products closer to commercial stage, the network resource asymmetry between partners leads to faster innovation speed.
2	Partner Asymmetry and Innovation Quantity	H2: An inverse U–shaped relationship is predicted between technological heterogeneity and innovation quantity: the relationship between technological heterogeneity and innovation quantity will be nonlinear with innovation quantity increasing up to an optimal level beyond which higher levels of technological heterogeneity transfer lead to a decline in innovation quantity. H4: An inverse U–shaped relationship is predicted between network resource asymmetry and innovation quantity: the relationship between network resource asymmetry and innovation quantity will be nonlinear with innovation quantity increasing up to an optimal level beyond which higher levels of network resource asymmetry transfer lead to a decline in innovation quantity. H6: Among alliances which focus on new products closer to commercial stage, the technological heterogeneity between partners leads to larger innovation quantity.

		H8: Among alliances which focus on new products closer to commercial stage, the network resource asymmetry between partners leads to larger innovation quantity.

Figure 2. Partner Asymmetry and Innovation Speed (Hypotheses)

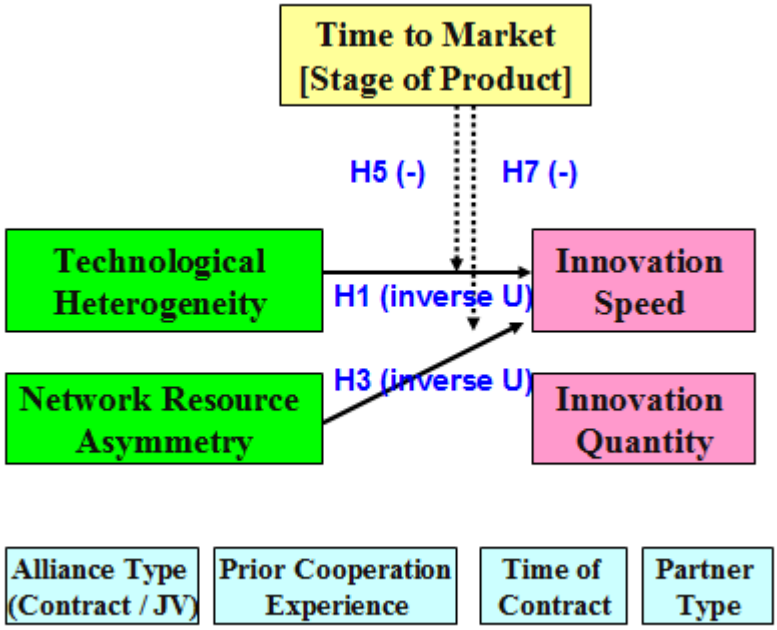
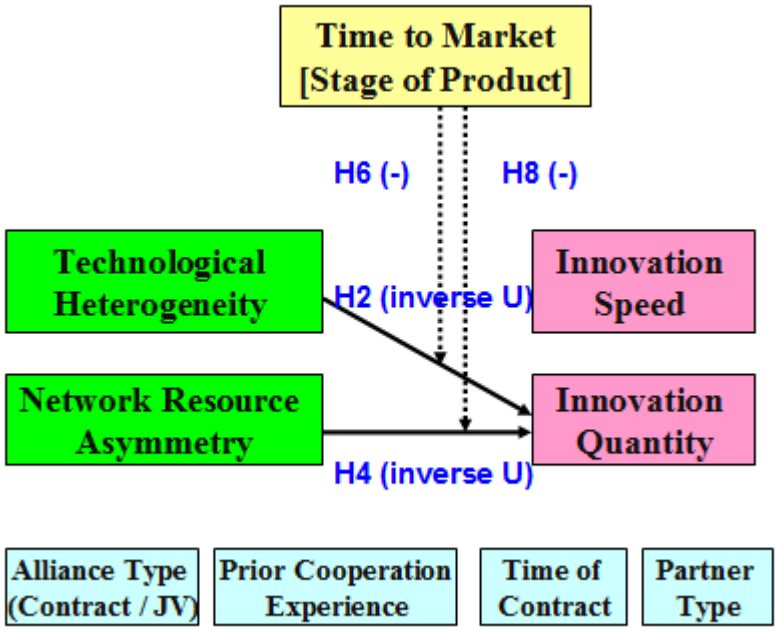


Figure 3. Partner Asymmetry and Innovation Quantity (Hypotheses)



Chapter 3: Methodology

These studies have extended our understanding of partner selection in strategic alliances. Drawing on a range of perspectives, the former two studies explore the links among two factors within partnership of R&D alliance and innovative performance of alliance by empirical analyses: we investigate the effects of technological heterogeneity (distance of technology) and network resource asymmetry (distance of network resource) on innovative speed and quantity. We also examined the indirect moderating effects of "time to market" on these relations. Furthermore, several factors, including alliance type, prior cooperation experience, time of contract and partner type were used as control variables in this study.

The considerations motivated the choice of the biopharmaceutical industry as the setting of the study. First, biotechnology and pharmaceutical firms invest a greater percentage of sales in R&D than any other industry (Danzon, 2005). Technological innovation behavior in the biopharmaceutical industry appears more often than it does in other industries. Second, R&D alliances have become an important mechanism for drug discovery, clinical trials, development and commercialization (Audretsch & Feldman, 2003; Xu, 2006).

3.1 Data Collection

We use data from the REDCap (Research Electronic Data Capture) database to obtain essential information about R&D alliances, including partner's name, core technology of firms, co-patent from each alliance, time of alliance, the number of alliance, size of alliance, type of parties, and clinical stage. REDCap originated out of the Vanderbilt Institute for Clinical and Translational Research. It is a web-based system for data collection. Data entry operators enter data in a web browser, either locally or from remote locations. The data is stored centrally in a secure MySQL database. The REDCap Consortium is comprised of 267 active institutional partners from Clinical

and Translational Science Awards, General Clinical Research Centers, Research Centers in Minority Institutions, and other institutions. The consortium supports this secure web application designed exclusively to support data capture for research studies. The REDCap application allows users to build and manage online surveys and databases quickly and securely, and is currently in production use or development build-status for more than 21,000 studies with over 31,000 end-users spanning numerous research focus areas across the consortium.

There are several criteria for exclusion and inclusion. Our data set analyzes the R&D alliance activity of bio-pharmaceutical firms and research institutes from 1981 to 2010. It includes all medical treatment products for human beings (drug and diagnosis reagent), and excludes all medical prevention products (medical electric devices). In addition, is limited to alliances that have only two members and excludes those alliances with three members or more. We select only alliances with at least one co-patent. Data with many missing values were excluded. Since the majority of parties belong to three categories: biotech-biotech (BB), academic-biotech (AB) and biotech-pharmaceutical (BP), only these types of alliance were included in our research.

3.2 Measures

3.2.1 Dependent Variable

(1) Time to first co-patent

We count the number of years from the time of alliance to the time to first co-patent for each target alliance. Accordingly, this research used the time to first co-patent to represent the speed of innovative performance. The longer time to first co-patent the slower a company's innovative performance.

Time to first co-patent = The year of alliance -- The year of first co-patent

(2) Number of Co-patents

A patent represents a company's capability of innovation, technology and production (Griliches, 1990). For this reason, number of patent is a reliable indicator of innovative performance. Since this research is about alliances, not firms, the research used the number of co-patents as a measurement of the quantity innovative performance of alliance.

3.2.2 Independent Variables

(1) Technological heterogeneity

This research used the data of main technology category for each organization in RECAP database to recognize the discrepancy in technology between partners within the alliance. Five levels of technological heterogeneity were classified: low, lower medium, medium, higher medium and high technological. Since RECAP database uses the name of technology rather than technical code system to identify different technologies of firms, and there is no linkage between the name of technology and technical code in other database, we used the following criteria and process which was agreed upon by experts in the biotech and pharmaceutical technology fields to identify and categorize partners' technology. First, each technology was divided into biotech and synthetic two groups. The scores from one to three were given to those partners' technology that belonged to the same group, otherwise, scores from three to five were given. Second, biotechnology was subdivided into two subgroups: basic technology (ex. DNA, RNA, proteins, peptides, monoclonal antibody…) and applied technology (ex. stem cells, gene therapy, vaccines…); synthetic technology was subdivided into two subgroups: basic technology (ex. molecular structure, receptors/inhibitors…) and applied technology (ex. drug delivery, support anti-cancer agent, diagnosis…). According to whether or not partners' technology are always the same (1), belong to the same subgroup (2), belong to the same group but different subgroups (3), belong to different

groups but both of them are either basic or applied technology (4), totally different groups and subgroups (5), the final score of technological heterogeneity was given to each alliance.

(2) Network resource asymmetry

The number of prior alliance (friends) an organization has is a good indicator of its external social resources. A company with more alliance (friends) has larger network scale. In this research, the distance of partners' number of alliance was used to measure the asymmetry of network scale for each alliance. We first counted each partner's number of alliance prior to the target alliance, and then used following formula to measure the value of network resource asymmetry.

Network resource asymmetry = √| Partner A's number of alliance prior to the target alliance -- Partner B's number of alliance prior to the target alliance |

3.2.3 Moderating Variable

Time to market

This research uses the stage of clinical trial of production to analyze the time to market. There are nine types of stage of clinical trial of production in RECAP database, and it is based on the process of drug development: "Formulation," "Discovery," "Lead Molecule," "Preclinical," "Phase I," "Phase II," "Phase III," "BLA/NDA Filed," and "Approved." We assigned number 9 (long time) to 1 (short time) for to represent time to market.

3.2.4 Control Variables

(1) Alliance Type (Contract or Joint Venture)

We obtained the information about whether the alliance contains capital transaction from the RECAP database. We assigned 0 to those alliances that belonged to contract (without capital transaction), and 1 to those belonged to a joint venture (with capital transaction).

(2) Prior Cooperation Experience

This variable represents whether the target dyadic partners has had cooperation experience before the alliance. If the target alliance is the first cooperation within our collected data, we assume that they have 0 prior cooperation experience. Likewise, if the target alliance is not the first cooperation, we assume that they have at least 1 prior cooperation experience.

(3) Time of Contract

We gained the data about the year of contract for each alliance from RECAP database. Each time of contract was categorized into three groups: 1981-1990, 1991-2000 and 2001-2010. Since the variable belongs to category variable, this research took advantage of the dummy variable method before running the regression.

(4) Partner Type

In this research, there are three categories of alliance: biotech-biotech (BB), academic-biotech (AB), biotech-pharm (BP). Since the variable belongs to category variable, this research used the dummy variable before conducting the regression.

3.3 Analysis Approach

Study 1. Partner Asymmetries and Innovation Speed

This research used multiple regressions since the independent variable belongs to continuous data. In addition, we carried out interaction analysis by moderators (time to market) to see the indirect effects among variables, since it might significantly affect the innovation performance. Moreover, we used several control variables to be the subgroups, and to see the correlation between independent and dependent variables in various subgroups and conditions. For category data, this research used the dummy variable method before running regression. In order to achieve the research purposes and test the hypotheses, this study used SAS and STATA software for data analysis.

Study 2. Partner Asymmetries and Innovation Quantity

Negative binomial regression method was used in this study, since number of patent is times of event and belongs to count data, which are not continuous data with the same distance among each scale. The negative binomial regression method was often used for those sample with larger variance compared with the mean or there might be cluster for collected samples. In addition, this research carried out interaction analysis by moderators (time to market) to see the indirect effects among variables, since it might significant affect the innovation performance. Moreover, we also used alliance type (contract or joint venture), prior cooperation experience, time of alliance and partner type as control variables in this study. In the mean time, this research also used these control variables to be the subgroups, and to see the correlation between independent and dependent variables under various subgroups and conditions. For category data, this research used the dummy variable method before running regression. In order to achieve the research purposes and test the hypotheses, this study used SAS and STATA software for data analysis.

Chapter 4: Results

4.1 How the Partner Asymmetries affect Innovation Speed?

4.1.1 Descriptive Statistics

The sample size of this study is 506 dyad R&D alliances, including 102 alliances in 1981-1990, 339 alliances in 1991-2000 and 65 alliances in 2001-2010. Among 506 dyad alliances, 148 are AB type, 98 are BB type, and 260 are BP type. The mean of score of technological heterogeneity is 3.25; the mean of network resource asymmetry is 5.03; the mean of time to first co-patents after the creation of alliances is 3.77 years. The descriptive statistics with means, standard deviations and correlations of variables regarding research in technology discrepancy are depicted in Table 2.

Table 2. Results of Correlation Analysis (n=506)

		Mean	Std. Dev.	C1	C2	C3a	C3b	C4a	C4b	M1	X1	X2	Y
C1	Alliance Type (Contract or Joint Venture)	0.88	0.33	1									
C2	Prior Cooperation Experience	0.08	0.27	0.06	1								
C3a	Time of Contract (1991-2000 vs 1981-1990)	0.67	0.47	0.15	0.003	1							
C3b	Time of Contract (2001-2010 vs 1981-1990)	0.13	0.33	(-) 0.16	0.04	(-) 0.55	1						
C4a	Partner Type (BB vs AB)	0.19	0.4	(-) 0.12	0.04	(-) 0.05	0.34	1					
C4b	Partner Type (BP vs AB)	0.51	0.5	0.06	0.04	0.02	(-) 0.11	(-) 0.5	1				
M1	Time to Market	6.43	2.06	(-) 0.05	(-) 0.04	(-) 0.01	(-) 0.15	(-) 0.1	0.03	1			
X1	Technology Heterogeneity	3.25	1.19	0.04	0.06	(-) 0.01	0.04	(-) 0.29	0.82	0.08	1		
X2	Network Resource Asymmetry	5.03	3.67	0.02	0.07	0.01	0.03	(-) 0.17	0.45	(-) 0.06	0.36	1	
Y	Time to First Co-patent	(-) 3.77	3.36	0.12	0.02	0.08	0.2	0.15	0.05	0.02	0.15	0.02	1

+ p < .10; * p < .05; ** p < .01; *** p < .0001

4.1.2 Regression Results

Table 3 presents the results of multiple regression analysis. The second model reports the effects of the alliance types (contract/JV), prior cooperation experience, time dummy, partner types included and time to market as controls. This model served as a baseline from which the analysis proceeded. In model 3, we introduced technological heterogeneity to assess the possibility of its nonlinear effects on innovation speed, and we found that a positive relationship exists between them (β= 0.52, $p<0.05$). Besides, the negative moderating effect of "time to market" on previous positive relationship was observed ($\beta1$= 1.59, $p<0.001$; $\beta2$= (-) 0.17, $p<0.01$) (model 4 and figure 5). In model 5, we introduced technological heterogeneity and its squared term to assess the possibility of its nonlinear effects on innovation speed. An inverse U-shaped relationship between a dyadic alliance's technological heterogeneity and its innovation speed was observed ($\beta1$= 9.53, $p<0.001$; $\beta2$= (-) 1.56, $p<0.001$) (model 5 and figure 4). However, the moderating effect of "Time to market" on previous relationship was not observed (model 6).

In model 7-10, we analyzed network resource asymmetry and its squared term to assess the possibility of its linear and nonlinear effects on innovation speed. It appears that there are no significant linear and nonlinear effects. However, the results of subgroup analysis indicate that, in terms of R&D alliances created during 1991-2000, a positive relationship exists between a dyadic alliance's network resource asymmetry and its innovation speed, as well as a negative moderating effect of "time to market" on the previous relationship ($\beta1$= 0.38, $p<0.01$; $\beta2$= (-) 0.06, $p<0.01$) (model 11 and figure 6). Also, we found that, in terms of BB partner type R&D alliances, a positive relationship exists between a dyadic alliance's network resource asymmetry and its innovation speed, as well as a negative moderating effect of "time to market" on the previous relationship ($\beta1$= 0.76, $p<0.05$; $\beta2$= (-) 0.12, $p<0.05$) (model 12 and figure 7).

Finally, the results of interaction analysis between technological heterogeneity and network

resource asymmetry show that there are significant negative moderating effects of them mutually (β= (-) 0.17, $p<0.001$) (model 13 and figure 8).

Table 3. Results of Multiple Regression (n=506)

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
												1991-2000	BB		
constant		(-) 7.39***	(-) 8.38***	(-) 9.19***	(-) 12.69***	(-) 19.03***	(-) 19.02***	(-) 8.28***	(-) 9.12***	(-) 8.41***	(-) 10.35***	(-) 8.38***	(-) 11.97***	(-) 11.81***	(-) 20.10***
C1	Alliance Type (Contract or Joint Venture)	1.48**	1.53***	1.50**	1.55***	0.93**	0.94**	1.53***	1.57***	1.54***	1.57***	1.12*	(-) 0.11	1.53***	0.90**
C2	Prior Cooperation Experience	(-) 0.17	(-) 0.15	(-) 0.20	(-) 0.22	(-) 0.39	(-) 0.4	(-) 1.13	(-) 0.13	(-) 0.13	(-) 0.13	0.54	0.79	(-) 0.13	(-) 0.38
C3a	Time Dummy (1991-2000 vs 1981-1990)	1.75***	1.82***	1.76***	1.74***	1.19***	1.19***	1.83***	1.82***	1.84***	1.78***		5.17**	1.84***	1.15***
C3b	Time Dummy (2001-2010 vs 1981-1990)	3.28***	3.47***	3.21***	3.19***	1.97***	1.98***	3.50***	3.51***	3.51***	3.50***		6.72***	3.32***	1.95***
C4a	Partner Type (BB vs AB)	1.26**	1.28**	1.08*	1.17**	0.32	0.33	1.29**	1.32**	1.28**	1.32**	1.54**		0.84+	0.36
C4b	Partner Type (BP vs AB)	0.98**	0.98**	(-) 0.12	(-) 0.04	1.09**	1.09**	1.08**	1.09**	1.08**	1.10**	1.36***		(-) 0.35	1.28**
M1	Time to Market		0.13+	0.11	**0.66****	0.08+	0.86	0.13+	0.26	0.13*	0.42*	0.44**	0.56**	0.12+	0.27
X1	Technology Heterogeneity			**0.52***	**1.59*****	**9.53*****	9.33***							**1.28*****	9.56***
X1^2	(Technology Heterogeneity)^2					**(-) 1.56*****	(-) 1.51***								(-) 1.53***
M1*X1	(Time to Market)*(Technology Heterogeneity)				**(-) 0.17****		0.23								(-) 0.007
M1*X1^2	(Time to Market)*(Technology Heterogeneity)^2						(-) 0.007								(-) 0.007
X2	Network Resource Asymmetry							(-) 0.03	0.12	0.03	0.66	**0.38****	**0.76***	**0.62*****	0.43
X2^2	(Network Resource Asymmetry)^2									(-) 0.004	(-) 0.04				(-) 0.05+
M1*X2	(Time to Market)*(Network Resource Asymmetry)								(-) 0.02		(-) 0.09	**(-) 0.06****	**(-) 0.12***		(-) 0.07
M1*X2^2	(Time to Market)*(Network Rresource Asymmetry)^2										0.005				0.007+
X1*X2	(Technology Heterogeneity)*(Network Resource Asymmetry)													**(-) 0.17*****	0.01
	N	506	506	506	506	506	506	506	506	506	506	339	98	506	506
	R^2	0.13	0.14	0.15	0.16	0.57	0.57	0.14	0.14	0.14	0.15	0.09	0.21	0.18	0.58
	adj-R^2	0.12	0.13	0.14	0.15	0.57	0.57	0.13	0.13	0.12	0.13	0.07	0.15	0.16	0.57
	F-statistic	12.73	11.52	10.86	10.88	74.37	60.66	10.13	9.2	9	7.62	4.63	3.49	10.57	42.17

+ p < .10; * p < .05; ** p < .01; *** p < .001

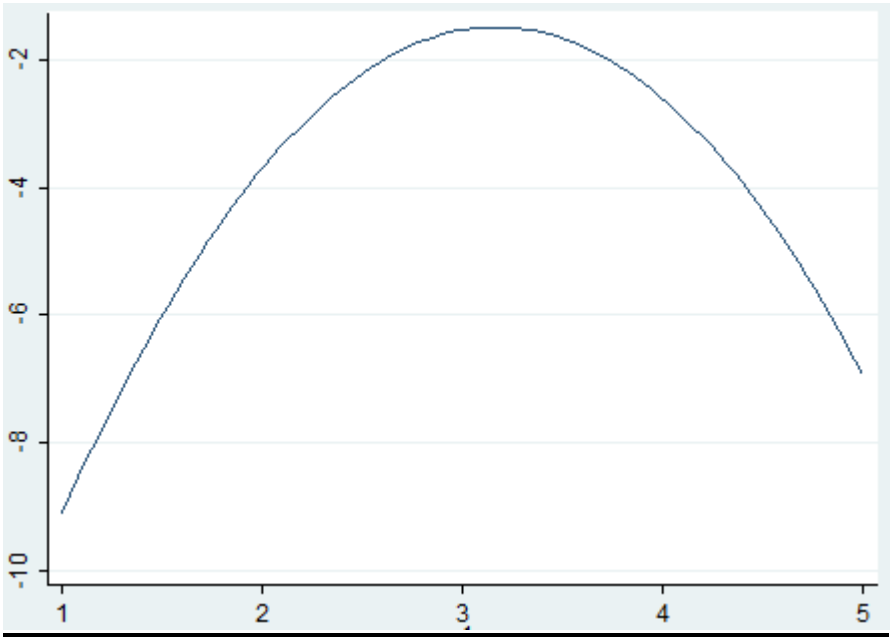


Figure 4. The relationship between technological heterogeneity and innovation speed (full sample)

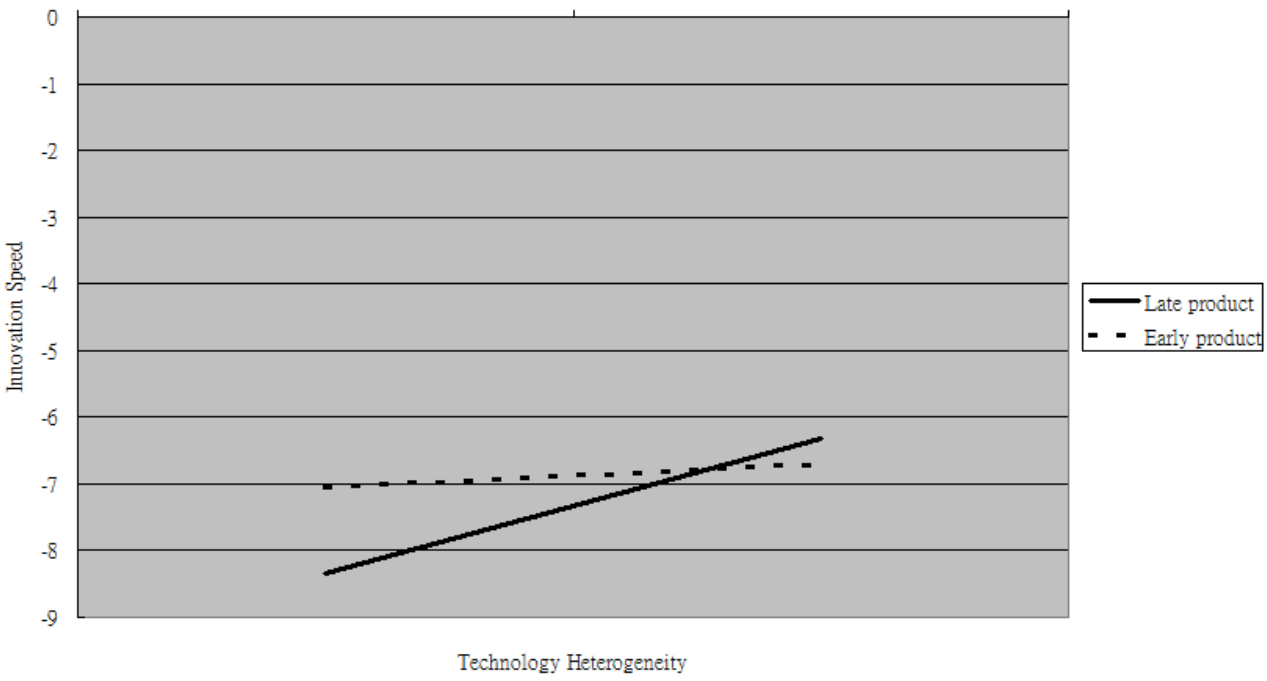


Figure 5. The moderating effect of time to market of product on the relationship between technological heterogeneity and innovation speed (full sample)

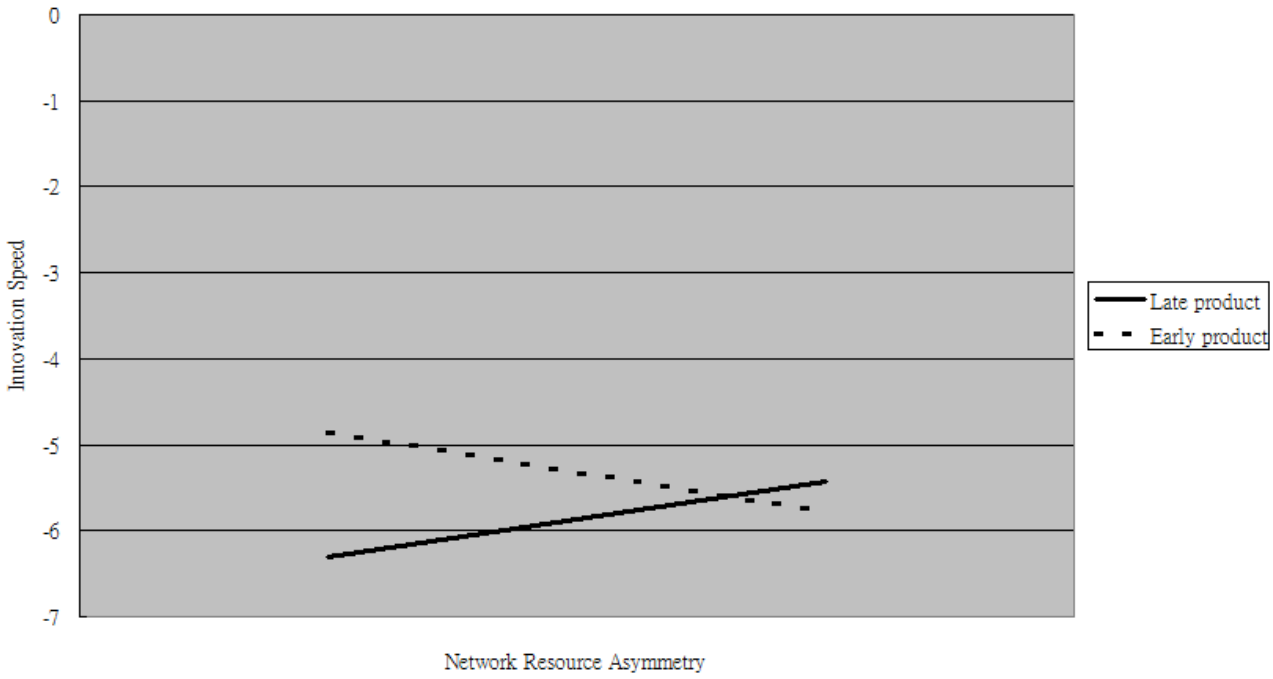


Figure 6. The moderating effect of time to market of product on the relationship between network resource asymmetry and innovation speed (1991-2000)

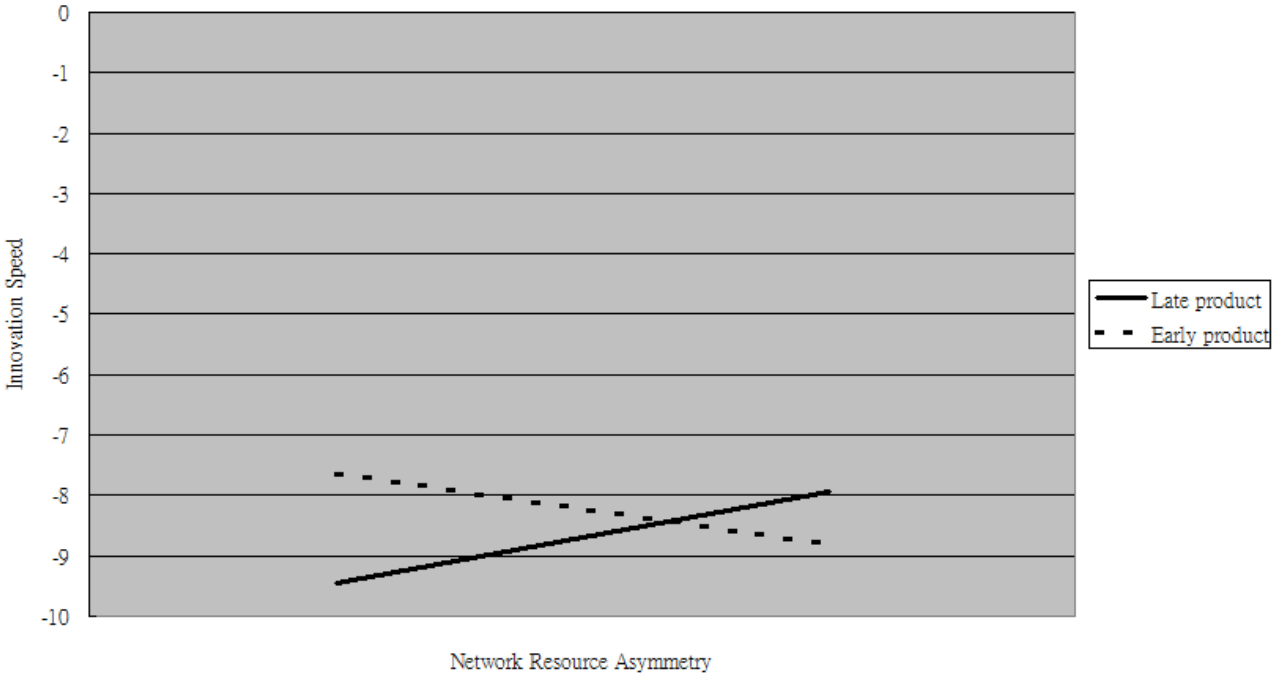


Figure 7. The moderating effect of time to market of product on the relationship between network resource asymmetry and innovation speed (BB)

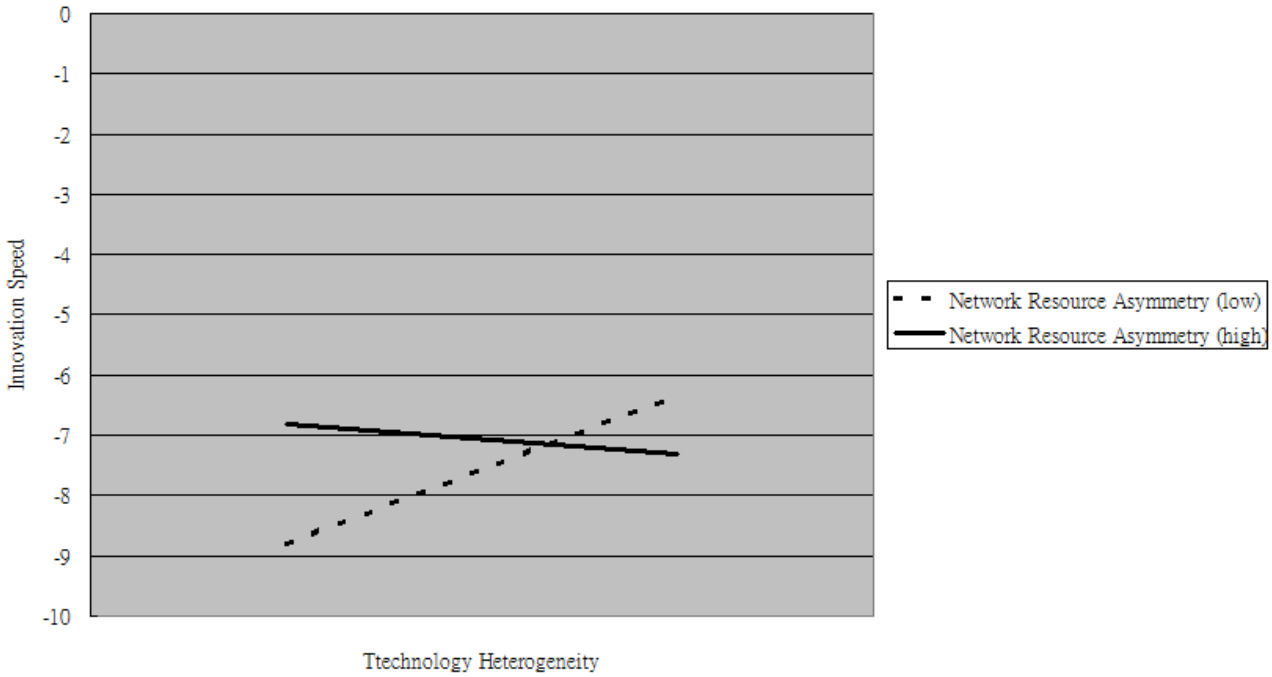


Figure 8. The moderating effect of network resource asymmetry on the relationship between technological heterogeneity and innovation speed (full sample)

4.2 How the Partner Asymmetries affect Innovation Quantity?

4.2.1 Descriptive Statistics

The sample size of this study is 506 dyad R&D alliances: 102 in 1981-1990, 339 in 1991-2000 and 65 in 2001-2010. Among 506 dyad alliances, 148 are AB type, 98 are BB type, and 260 are BP type. The mean of technological heterogeneity is 3.25; the mean of network resource asymmetry is 5.03; the mean of number of co-patents following the R&D alliances is 8.01. The descriptive statistics with means, standard deviations and correlations of variables regarding research in technology discrepancy are depicted in Table 4.

Table 4. Results of Correlation Analysis

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C2	Prior Cooperation Experience	0.08	0.27	0.06	1								
C3a	Time of Contract (1991-2000 vs 1981-1990)	0.67	0.47	0.15	0.003	1							
C3b	Time of Contract (2001-2010 vs 1981-1990)	0.13	0.33	(-) 0.16	0.04	(-) 0.55	1						
C4a	Partner Type (BB vs AB)	0.19	0.4	(-) 0.12	0.04	(-) 0.05	0.34	1					
C4b	Partner Type (BP vs AB)	0.51	0.5	0.06	0.04	0.02	(-) 0.11	(-) 0.5	1				
M	Time to Market	6.43	2.06	(-) 0.05	(-) 0.04	(-) 0.01	(-) 0.15	(-) 0.1	0.03	1			
X1	Technological Heteogeneity	3.25	1.19	0.04	0.06	(-)0.01	0.04	(-) 0.29	0.82	0.07	1		
X2	Network Resource Asymmetry	5.03	3.67	0.02	0.07	0.01	0.03	(-) 0.17	0.45	(-) 0.06	0.36	1	
Y	Number of Co-patent	8.01	10.28	0.1	(-) 0.03	0.08	(-) 0.07	0.01	0.006	(-) 0.03	(-)0.01	0.06	1

+ p < .10; * p < .05; ** p < .01; *** p < .0001

4.2.2 Regression Results

Table 5 presents the results of negative binomial regression. The second model reports the effects of alliance types (contract or joint venture), prior cooperation experience, time dummy, partner types included and time to market as controls. This model served as a baseline from which the analysis proceeded. From model 3 to 6, we introduced technological heterogeneity to assess the possibility of its linear and nonlinear effects on innovation quantity. However, we did not find any significant relationships about them.

In model 7, we introduced network resource asymmetry to assess the possibility of its linear effects on innovation quantity, and we found a significant positive relationship between them. Then, we introduced network resource asymmetry and its squared term to assess the possibility of its nonlinear effects on innovation, and a significant downward curve correlation (inversed U-shape) between network resource asymmetry and number of co-patent following the alliance was observed ($\beta1= 0.12$, $p<0.01$; $\beta2= -0.01$, $p<0.05$) (Model 9 and Figure 9). The regression equation is as follows:

Number of co-patents *= 1.46 + 0.45 (Alliance Type) – 0.16 (Prior Cooperation Experience) + 0.06 (Time of Contract [1991-2000 vs. 1981-1990]) – 0.26 (Time of Contract [2001-2010 vs. 1981-1990]) + 0.11 (Partner Type [BB vs. AB]) – 0.04 (Partner Type [BP vs. AB]) – 0.02 (Time to Market)* ***+ 0.12 (Network resource asymmetry) – 0.01 (Network resource asymmetry)^2*** *+ e.*

Even though the moderating effect of "Time to market" on the above linear relation between network resource asymmetry and innovation quantity was not observed (model 8), the results of subgroup analysis indicate that "Time to market" weakens the previous positive linear relationship when the alliances belong to contract rather than joint venture ($\beta1= 0.17$, $p<0.05$; $\beta2= -0.02$, $p<0.1$) (Model 11 and Figure 10) and when the alliances were made by a biotechnology firm and a

pharmaceutical firm (BP type) ($\beta1$= 0.09, $p<0.1$; $\beta2$= -0.01, $p<0.1$) (Model 12 and Figure 11).

Table 5. Results of Negative Binomial Regression (n=506)

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
												Contract	BP		
constant		1.61***	1.77***	1.83***	2.42***	2.03***	2.20**	1.66***	1.56***	1.46***	1.72***	1.32+	0.89+	1.50***	1.84*
C1	Alliance Type (Contract or Joint Venture)	0.43**	0.43**	0.43**	0.40**	0.44**	0.41**	0.43**	0.44**	0.45**	0.46**		0.43*	0.44**	0.45**
C2	Prior Cooperation Experience	(-) 0.13	(-) 0.14	(-) 0.13	(-) 0.14	(-) 0.13	(-) 0.15	(-) 0.14	(-) 0.14	(-) 0.16	(-) 0.17	(-) 0.23	(-) 0.41+	(-) 0.14	(-) 0.15
C3a	Time Dummy (1991-2000 vs 1981-1990)	0.09	0.07	0.08	0.09	0.1	0.11	0.06	0.06	0.06	0.06	(-) 0.60*	0.2	0.07	0.09
C3b	Time Dummy (2001-2010 vs 1981-1990)	(-) 0.19	(-) 0.23	(-) 0.20	(-) 0.19	(-) 0.17	(-) 0.18	(-) 0.26	(-) 0.25	(-) 0.26	(-) 0.26	(-) 0.54	(-) 0.16	(-) 0.22	(-) 0.22
C4a	Partner Type (BB vs AB)	0.15	0.15	0.17	0.17	0.2	0.19	0.13	0.14	0.11	0.11	(-) 0.19		0.13	0.15
C4b	Partner Type (BP vs AB)	0.04	0.05	0.16	0.15	0.14	0.14	(-) 0.04	(-) 0.04	(-) 0.04	(-) 0.06	(-) 0.18		0.04	0.01
M	Time to Market		(-) 0.02	(-) 0.02	(-) 0.11+	(-) 0.02	(-) 0.05	(-) 0.02	(-) 0.004	(-) 0.02	(-) 0.06	0.1	0.10+	(-) 0.01	(-) 0.05
X1	Technology Heterogeneity			(-) 0.02	**(-) 0.23+**	(-) 0.24	(-) 0.08							0.02	(-) 0.12
X1^2	(Technology Heterogeneity)^2					0.03	(-) 0.02								(-) 0.02
M1*X1	(Time to Market)*(Technology Heterogeneity)				0.03		(-) 0.01								(-) 0.01
M1*X1^2	(Time to Market)*(Technology Heterogeneity)^2						0.01								0.01
X2	Network Resource Asymmetry							**0.03***	0.04	**0.12****	(-) 0.03	**0.17***	**0.09+**	0.08	0.12*
X2^2	(Network Resource Asymmetry)^2									**(-) 0.01***	0.01				(-) 0.001
M*X2	(Time to Market)*(Network Resource Asymmetry)								(-) 0.003		0.02	**(-) 0.02+**	**(-) 0.01+**		(-) 0.004
M*X2^2	(Time to Market)*(Network Resource Asymmetry)^2										(-) 0.002				(-) 0.001+
X1*X2	(Technology Heterogeneity)*(Network Resource Asymmetry)													(-)0.01	
	N	506	506	506	506	506	506	506	506	506	506	62	260	506	506
	Log Likelihood	(-) 1577.13	(-) 1576.58	(-) 1576.33	(-) 1574.97	(-) 1575.75	(-) 1574.62	(-) 1574.59	(-) 1574.48	(-) 1572.36	(-) 1571.54	(-) 157.83	(-) 807.20	(-)1573.80	(-) 1569.18

+ p < .10; * p < .05; ** p < .01; *** p < .001

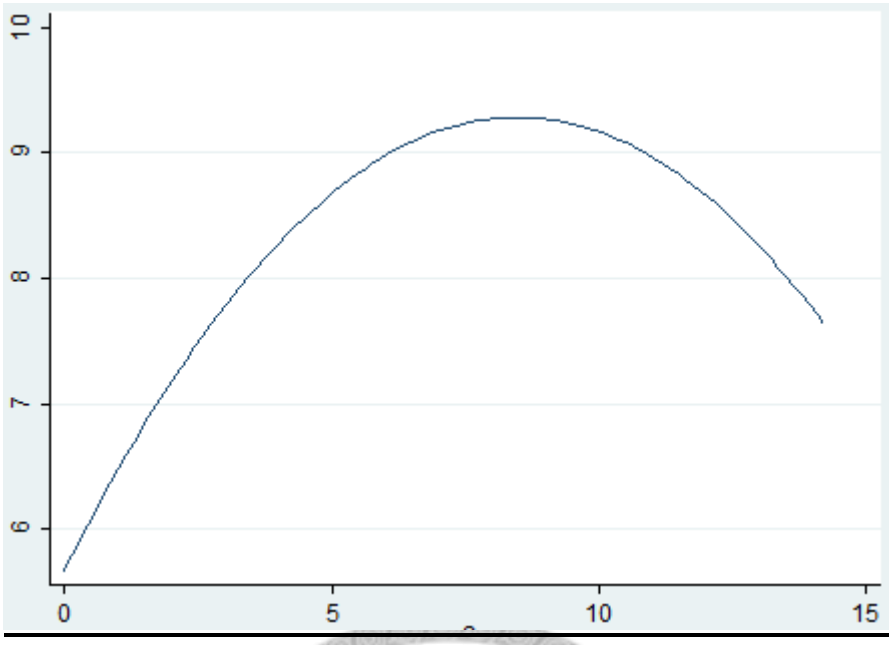

Figure 9. The relationship between network resource asymmetry and innovation quantity (full sample)

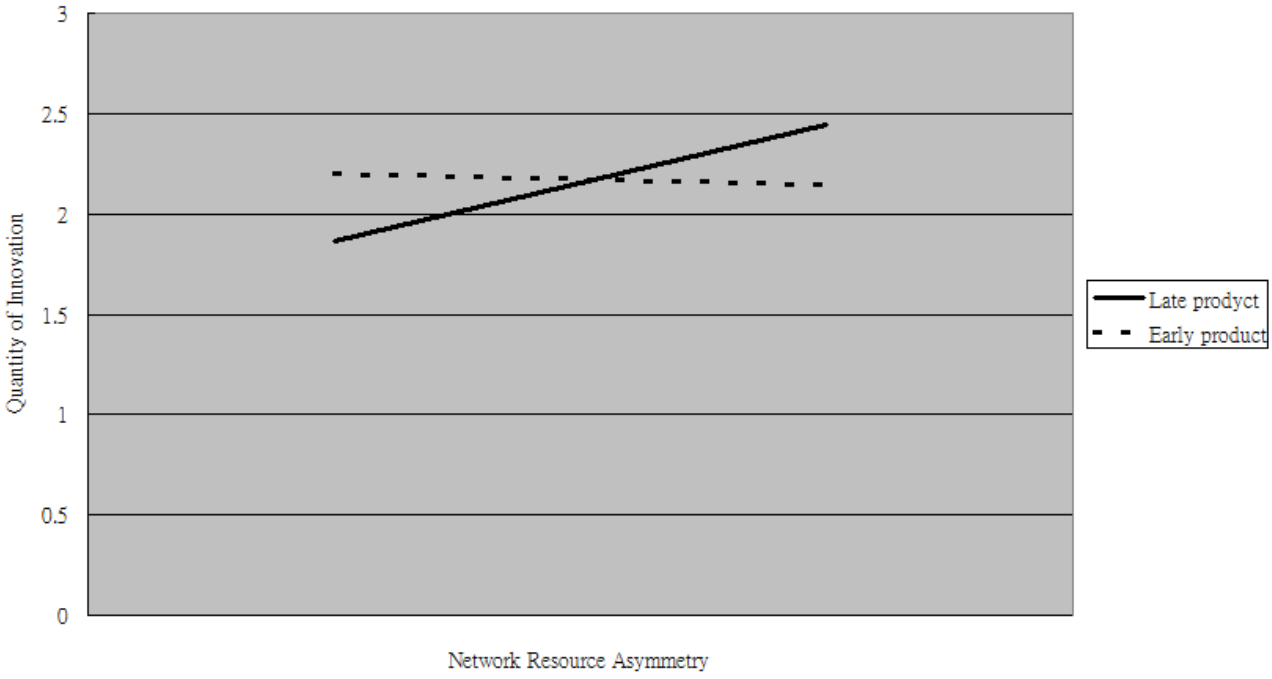

Figure 10. The moderating effect of time to market of product on the relationship between network resource asymmetry and innovation quantity (Contract)

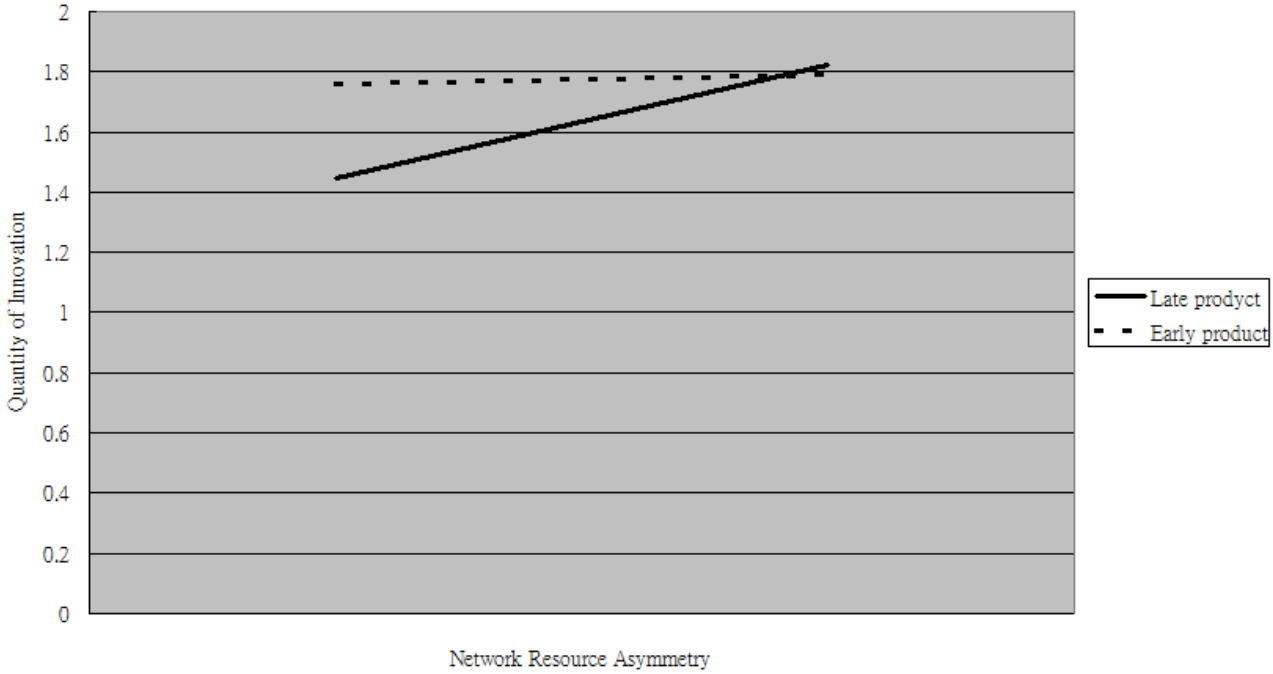

Figure 11. The moderating effect of time to market of product on the relationship between network resource asymmetry and innovation quantity (BP)

Chapter 5: Discussion

5.1 Partner Asymmetries and Innovation Speed

The findings of this research revealed new mazes about partner asymmetries features acting on innovation. Our hypotheses were developed on the basis of organizational learning theory, social exchange theory and practical ratiocination. Overall, it appears that our hypotheses could be explained partly by established theories and practices. In this section, we analyze our empirical results, and discuss their implications.

The statistical results revealed a significant inverse U-shaped relationship between technological heterogeneity and innovation speed. These results support hypothesis H1. In other words, technological heterogeneity of alliance might be beneficial and detrimental for innovation speed, both insufficient or excessive technological heterogeneities result in slow innovation; only appropriate technological heterogeneity benefits innovative efficiency.

According to our argument for H1 from social exchange perspective, technological heterogeneity contributes the interaction of knowledge and technology between partners due to the generation of reciprocity, which accelerate the innovation. From organizational learning perspective, even though making alliances with high technological heterogeneity will create opportunities for a distant search, recombination inefficiency would be generated quite often due to the difficulties of integrating various types of technology, and it delays the innovation. On the other hand, making alliances with low technological heterogeneity will have more opportunity to do local search and to refine their quality of technology, which benefits the speed of innovation. For biopharmaceutical R&D alliances, our empirical study revealed that the middle level of technological heterogeneity comes together with appropriate search and learning will lead to faster innovative performance.

In biopharmaceutical cases, there is no direct influence of technological heterogeneity on innovation speed. Several companies made alliances with lower technological heterogeneity gained

sooner innovation than that with higher technological heterogeneity. Geron (a biotech company) is a typical example. It allied with Pharmacia (a pharmaceutical company) which had different technology in 1996, and then allied with Johns Hopkins University, which has similar technology, in 1997. Finally, the first alliance took more than two years to get the first co-patent, while the second alliance got the first co-patent within one. In contrast, several companies made alliances with higher technological heterogeneity gained sooner innovation than that with lower technological heterogeneity. ImClone System allied with the University of North Carolina which has similar technology in 1988, and then with Merck which has different technology in 1990. Eventually, the previous alliance took 12 years to get the first co-patent, while the later alliance got its first co-patent after 8 years. Therefore, firms are not advised to seek partners with high or low technological heterogeneity in order to increase the speed of innovation. Instead, appropriate heterogeneity and other factors are important.

According to our statistical results, we did not find a significant inversed U-shaped non-linear relation between network resource asymmetry and innovation speed, so H3 was not supported. However, a positive linear relationship between network resource asymmetry and innovation speed exists when the R&D alliances were created during 1991-2000, and when the partner type belongs to BB type. In other words, network resource asymmetry of alliance has an important influence on innovation speed (efficiency) under specific contingencies, and the higher network resource asymmetry, the higher innovation speed.

According to the organizational learning perspective, larger network resource asymmetry ("non-matched dyad") is helpful for biopharmaceutical R&D alliance, because they combine high technology depth with scope. Our statistic results confirmed this ratiocination, because the interplay of depth and breadth within resource asymmetry "non-matched dyad" helps to increase the innovation speed. Although we also argued that too much network resource asymmetry might

harmful for innovation speed due to the perceived unfairness on social exchange perspectives, and proposed an inverse U-shaped nonlinear relationship between network resource asymmetry and innovation speed. However, in many biopharmaceutical R&D alliance cases, our results still indicate that “non-matched dyad” is better than “matched dyad” for innovation speed. Undeniably, both organizational learning and social exchange perspectives are useful explanations for overall conditions, since we did not find a significant positive linear relation between network resource asymmetry and innovation speed for all cases.

In biopharmaceutical cases, there is no direct influence of network resource asymmetry on innovation speed. Several companies formed alliances with larger network resource asymmetry gained innovation more quickly than that with smaller network resource asymmetry. A typical example is the biotech company NPS Pharmaceutical which with allied with the pharmaceutical company Pfizer which has 25.63 times as many alliances as it did in 1987, and then allied with Brigham and Women’s Hospital which has only 1.63 times as many of alliances as it did in 1993. Finally, the previous alliance took 5 years to gain first co-patents later on, while the later alliance took 6 years to get it. In contrast, several companies made alliances with smaller network resource asymmetry gained innovation more quickly than that with larger network resource asymmetry. For example, the pharmaceutical company Depomed allied with the Bristol-Myers Squibb which had 10.08 times as many alliances as it did in 1996, and then allied with the biotech company Biovail which had 1.23 times as many alliances as it did in 2002. Consequently, the previous alliance took 8 years to gained first co-patents, while the later alliance took only 2 years. Hence, firms could make alliances with both “matched” and “non-matched” partners to benefit from faster innovation.

In H5, we proposed that an alliance’s product time to market negatively moderates the relationships between technological heterogeneity and innovation speed, and the relationship was supported. As figure 6, higher technological heterogeneity results in better innovation speed,

particularly for those later-stage products, because the slope of later product is larger than that of earlier product. Due to this, we know that the beneficial effects of technological heterogeneity on innovation speed become more obvious when the target product is closer to market. In other worlds, for those R&D alliances focusing on later-stage products, selecting partners with higher heterogeneous technology benefits their future innovation speed.

As for the moderating effect of time to market on the relationship between network resource asymmetry and innovation speed, the statistic results did not appear a significant effect so that H7 was not supported overall. Only for R&D alliances happened during 1991-2000 and for BB partner type alliances, the negative moderating effects exist. Both figure 7 and figure 8 show that network resource asymmetry is beneficial for the innovation speed of later-stage products but is detrimental for that of earlier-stage products under specific conditions (1991-2000 alliances and BB type alliances). Therefore, H7 was partial supported, which means that the network resource asymmetry is more demand for reaching innovation when the collaborating product is in the later stages. In other worlds, for those R&D alliances focusing on later-stage products, selecting partners with higher network resource asymmetry benefits their future innovation speed.

Further, we conducted the interaction analysis between technological heterogeneity and network resource asymmetry on innovation speed. Our finding shows significant counteracting effects on innovation speed. As Model 13 in table 3 shows, both heterogeneous technology and network resource asymmetry increase the speed of innovation, but when both are high, the previous benefits would be weakened or disappear.

5.2 Partner Asymmetries and Innovation Quantity

Our hypotheses were developed on the basis of organizational learning theory, social exchange theory and practical ratiocination. It appears that some but not all of the hypotheses could be partially explained by established theories and practical points of view. In this section, we analyze our empirical results and discuss their implications.

According to our statistical results, we did not find a significant linear or inversed U-shaped non-linear relation between technological heterogeneity and innovation quantity, so H2 was not supported. In other words, technological heterogeneity of alliance has no important influence on innovation quantity.

According to the argument for H2 from social exchange perspective, technological heterogeneity contributes the interaction of knowledge and technology between partners due to the generation of reciprocity, which increases the innovation quantity. From organizational learning perspective, even though making alliances with high technological heterogeneity will create opportunities for a distant search, recombination inefficiency would be generated quite often due to the difficulties of integrating various types of technology, and it reduces the innovation quantity. However, above argument could only used to interpret the linkage between technological heterogeneity and innovation speed, rather than innovation quantity, which means technological heterogeneity makes innovation more efficiency, but it is not much helpful on the long-term innovation quantity. On the other hand, making alliances with higher technological heterogeneity will not have more opportunity to get a lot of innovation output. Undeniably, both social exchange perspectives and organizational learning are still useful explanations for overall conditions, since we did not find significant positive or negative linear relations between technological heterogeneity and innovation quantity for all cases.

According to the statistical results, we found a significant inverse U-shaped non-linear relation

between network resource asymmetry and quantity of co-patent following the alliance, which supports hypothesis 4. R&D alliances with moderate network resource asymmetry benefit more from innovation than do alliances with very low or very high levels of network resource asymmetry. In other words, both too low or too high network resource asymmetries result in poor innovation.

The larger network resource asymmetry ("non-matched dyad") is helpful for biopharmaceutical R&D alliance from organizational learning perspective, because alliances with large network resource asymmetry have combination of high technology depth and scope immediately. However, too much "non-matched dyad" is worse than "matched dyad" for innovation due to the perceived unfairness, based on the social exchange theory. Our statistic results partially confirmed this finding, because either asymmetry or non-asymmetry can increase the innovation. Therefore, both organizational learning and social exchange perspectives are useful explanations.

This result is inconsistent with several previous studies of the asymmetry within alliances. For example, Veugelers and Kesteloot (1996) explored the asymmetry of size, R&D capability and production issues. They argued that the asymmetry between partners will influence the incentives to form a joint venture through their impact on the payoffs of own development. In addition, the larger the size of asymmetry, the larger (smaller) the big (small) firm's development profits. With lower asymmetries, profits in all scenarios are affected negatively (positively) for the big (small) firm.

In biopharmaceutical cases, several companies that formed alliances with larger network resource asymmetry gained more innovation than that with smaller network resource asymmetry. A typical example is the biotech company NPS Pharmaceutical. It allied the pharmaceutical company Pfizer which had 25.63 times as many alliances as in 1987, and then allied with Brigham and Women's Hospital which has only 1.63 times as many alliances as in 1993. Finally, the previous alliance gained three co-patents later on, while the later alliance received only one. In contrast, several companies made alliances with smaller network resource asymmetry gained more

innovation than that with larger network resource asymmetry. For example, the pharmaceutical company Microcide allied with a pharmaceutical company, Ortho-McNeil, which had 3.43 times as many alliances as it did in 1995, and then allied with the pharmaceutical company, Pfizer, which had 29.29 times as many alliances as it did in 1996. Consequently, the previous alliance gained seven co-patents, while the later alliance got only two.

In Hypothesis 6, we proposed that time to market moderates the linear relationship between technological heterogeneity and quantity of innovative performance, however, this relationship was not observed. So Hypothesis 6 was not supported. In Hypothesis 8, we proposed that time to market moderates the linear relationships between network resource asymmetry and quantity of innovative performance, so that the correlations are affected by the clinical development stage of products. Although there is no significant moderating effect of time to market overall, the results of subgroup analysis indicate that time to market weakens the positive relationship between network resource asymmetry and innovation quantity when the alliance was created by contract without financial investment. Figure 11, show that network resource asymmetry is beneficial for the innovation quantity of later-stage products (negative slope) but is a little bit detrimental for that of earlier-stage products (positive slope) under specific conditions (contract type alliances). Similarly, for BP type R&D alliances, the beneficial effects of network resource asymmetry on innovation quantity become more obvious (larger slope) when the target product is closer to market. In other worlds, for those R&D alliances focusing on later-stage products, selecting partners with higher network resource asymmetry benefits their future innovation quantity (figure 12). Therefore, H8 was partial supported.

Several researchers have explored the role of the stage of new product development on the outcomes in biopharmaceutical industry. Frahm et al. (2007) argued that the success of a new product depends on the stage of product discovery pipeline. They proposed that firms have to adapt

divergent strategies and behaviors on products in different stages. Some previous studies suggested that later stage biopharmaceutical products have higher potential for innovation and success than earlier stage products (Vanderbyl & Kobelak, 2006). However, our results further indicate that R&D alliances focusing on early products gain more innovation than late products; while the network resource asymmetry helps partners receive more co-patents for later products. In other words, the stage of new product development moderates the relationship between network resource asymmetry and quantity of innovative performance, especially for those products closer to market.

Chapter 6: Conclusion

6.1 Summary

Over the last two decades, biotechnology has changed the way in which large pharmaceutical firms obtain critical R&D capabilities through alliances with biotechnology firms. Due to the immature but complex nature of biotechnology, knowledge transfer in biotechnology R&D often entails technological uncertainty. Therefore, the exchange of knowledge in biotechnology requires stronger governance structures. With the development of bio-pharmaceutical technology, R&D alliances provide companies with another way to integrate resources, knowledge and technologies, create more research and business ideas, and facilitate innovation. Despite many studies on partner selection of R&D alliance, less research has been done on topics of technological heterogeneity and network resource asymmetry. This study explored the relationships among these factors and presents the empirical results. We have developed a research framework and developed hypotheses which were tested by quantitative analysis approach using secondary data. The results confirm that the effects of technological heterogeneity on innovation speed like an inverse U-shaped (non-linear) relationship, while the effects of network resource asymmetry on innovation speed is positive (linear) under specific conditions. Appropriate asymmetries of technology and network resource are suggested to be strategies for partner selection in order to get better innovation speed and quantity. Moreover, considering various factors and conditions prior to making decision is helpful for innovation of R&D alliance.

6.2 Contributions

The dissertation contributes to the literature in many ways. First, based on organizational learning theory (economic perspective) and social exchange theory (social perspective) these two lenses, as well as practical logics, we designed an integrated framework to explain a complex phenomenon, presented our arguments, developed our hypotheses, and clarify the effects of technological heterogeneity and network resource asymmetry on innovation speed and quantity.

Second, the unit of analysis should emphasize the selection of an alliance partner. Dyadic approach is a better than a firm-specific one, since selecting optimal partner merely relies on the perspective from only one of partners is inadequate; while the dyadic approach for partner asymmetry study is more objective. Following this trend, we look at the technological heterogeneity and network resource asymmetry in dyadic approach instead of using one partner's resource as a research object.

Third, in terms of the measurement of alliance performance, most previous studies rely on financial indicators, market value, and patents of distinct partners rather than on the performance of the alliance itself (e.g. Lunnan & Haugland, 2008; Gulati et al., 2009; Lin et al., 2009; Jiang et al, 2010). However, the measurement of individual performance might not reflect real outcomes of the alliance. The second study uses "innovation of target alliance" as the construct of performance of alliance in order to measure the outcomes more precisely. Further, in terms of innovation performance, we used not only innovation quantity (effect) in the second study, we introduced the concept of "time" by using innovation speed as performance of innovation. Innovation speed represents the efficiency of the innovation, which is a kind of dynamic performance.

Forth, we often see alliances composed of both biotechnology firms and pharmaceutical firms or of both universities and biotechnology firms. In fact, beyond inter-firm alliance, the R&D cooperation has been made by universities or academic institutions and bio-pharmaceutical firms.

Since this study covers academic institutions, biotechnology firms, and pharmaceutical firms, the finding will broaden the choices for diversified organizations in this industry. The results of this study contribute to the industry's future decision making of partner selection.

Finally, this study discusses the effects from multiple perspectives, at the industrial (partner type), organizational (prior cooperation experience and timing of alliance), and product levels (the stage of products). Over the past couple of years, the emergence of biotechnology has provided another new technology for drug development. In the real world, these factors influence innovative performance of alliance. These results might also provide several helpful suggestions for partner selection of biopharmaceutical R&D alliances.

6.3 Limitations and Future Research Directions

Despite its findings, the dissertation does have some limitations. First, this study has proposed that partner asymmetry on technology and network resource should be considered before forming a R&D alliance. However, this study is concerned with technological heterogeneity and network resource asymmetry, and focused on the effect of these factors on innovation. These points are not only ways to select a partner. Other factors to be considered are partner's complementary experience, government model, stockholders' characteristics, shared values, reciprocity. Much more also needs to be known about other determinants of innovation s speed or quantity.

This study should provide a descriptive basis for additional research. Fine-grained future research will provide additional insight into the issue of partner selection for a strategic alliance. Moreover, even though we explored the quantity (effectiveness) and speed (efficiency) of innovative performance, the patents acquired by firms do not capture the full value of underlying innovations (Griliches, 1990; Sampson, 2007). Other indicators like quality of innovative permanence might be useful for understanding the impacts of various factors on innovation of R&D

alliance. As empirical evidences increasingly show a strong correlation between the citations of a patent and the estimated value of the underlying invention (Trajtenberg, 1990), the more comprehensive measurements combined quantity, quality and speed are suggested for future studies.

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