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Research on firm-level diversification framework with respect to measurements and activities

-Focused on the empirical case of pharmaceutical industry-

다각화 지수 및 활동에 관한 기업 다각화 프레임워크 연구
: 제약 산업의 실증 사례를 중심으로

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이 논문을 경제학박사학위 논문으로 제출함

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Abstract

Research on firm-level diversification framework with respect to measurements and activities

-Focused on the empirical case of pharmaceutical industry-

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In a market economy, maintaining profits and competitive advantages are important issues for firms. It is necessary for firms to enhance their competitive capabilities to survive and pursue consistent growth while facing unexpected challenges from within and without the market. From this perspective, diversification has been one of the most important research topics in the field of strategic management. Diversification, however, is a complex and risky task as it requires new skills, technologies, and facilities. This study highlights and focuses on the role of strategic alliances for diversification; firms engage in multiple

strategic alliances simultaneously with different partners as it allows them to manage risks and uncertainties. An alliance portfolio is important for understanding the promotion of diversification and has begun to be regarded as a unit of analysis.

Although diversification has been widely studied by various researchers, existing studies show the following limitations. Firstly, the selection issue of diversification indices has not been sufficiently discussed prior to the main analysis. Although each diversification index contains different properties of diversity and the result may differ depending on the nature of the selected diversification index, the selection of an appropriate diversification index remains an unresolved issue. Secondly, market and product diversification are not clearly distinguished; previous studies use the same measurement for both activities. Since a firm's actual strategic decisions depend on which market to enter and which product to develop, the existing approach has limitations in providing the relevant implications for each activity. Lastly, the effect of an alliance portfolio on firm-level diversification is not discussed taking into consideration open innovation activities and alliance portfolio management capabilities (APMCs). As more firms are now entering into various alliances with different partners, an exploration of the effects of an alliance portfolio with respect to open innovation activities and APMCs is needed.

With respect to the abovementioned issues, this thesis comprises three different articles. In the first article, the selection of a diversification index is examined empirically with respect to the properties of diversity. In order to obtain the content validity of the diversification index, technology diversification using patent data is examined with three different cases and various diversity indices. Based on Stirling (2007)'s diversity framework, each diversification index is classified based on its relevant properties. For the empirical analysis, a principal component analysis is conducted to analyze the patterns and similarities between the indices. As a result, diversification is classified based on two principal components. The first group relates to the balance of diversification while the second group reflects variety and disparity. In this sense, the consideration of two diversification perspectives (balance-centered and hetero-centered diversification) is suggested for diversification studies.

In the second article, the effects of firm-level diversification on firm performance are explored. Here, firm-level diversification includes a firm's market, product, and technological diversification activities. Market and product diversification are distinguished by measuring each with the market type and the product type. In addition to this, balance-centered and hetero-centered diversification perspectives are applied for the measurement of diversification. For the empirical analysis, a case involving pharmaceutical firms is selected and panel data is constructed by integrating a firm's market, product, and patent data. The following distinct strategic implications for each activity are derived from the results: more balanced and less heterogeneous diversification for product diversification, heterogeneous market diversification, and concentrated technology diversification.

In the third article, the relationship between open innovation activities and firm-level diversification are investigated taking into consideration the moderating effect of APMCs.

For this purpose, a network analysis is implemented to measure APMCs and a firm's open innovation activities are evaluated using individual deal records. With respect to the moderating effect of APMCs, outside-in activities promote focused and less-heterogeneous market and product diversification while coupled activities increase balanced technology diversification.

This study proposes a firm-level diversification framework including market, product, and technological diversification activities with two diversification perspectives (balance-centered and hetero-centered), which can overcome and address the limitations of previous studies. The proposed diversification perspectives can be used to classify firms' diversification behaviors into four types: generalist, specialist, pioneer, and conservative. In addition, this study integrates open innovation activities and APMCs to derive an understanding of firm-level diversification. With this approach, further studies can be implemented to elucidate the trends in each diversification activity.

Keywords: firm-level diversification, diversity property, patent analysis, alliance portfolio, alliance portfolio management capability
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Chapter 1. Introduction

1.1 Research background

In a market economy, maintaining profits and competitive advantages are important issues for firms. It is necessary for firms to enhance their competitive capabilities to survive and pursue consistent growth while facing unexpected challenges from within or without the market. From this perspective, diversification has been one of the most important research topics in the field of strategic management (Hoskisson & Hitt, 1990; Palich, Cardinal, & Miller, 2000).

In previous studies, diversification has been discussed in two major streams. Firstly, industrial organization economists focused on the relationship between diversification and market power (Berry, 1971; Utton, 1979). Through the diversification process, firms can not only reduce risk (Amihud & Lev, 1981) but also secure market power (Shleifer & Vishny, 1989). Rather than producing a limited line-up of products, a firm can enhance its market power through diversification. Another approach is from the perspective of resource-based theory. According to Wan, Hoskisson, Short, & Yiu (2011), resource-based theory provides a unified theoretical framework for corporate diversification along with the related ideas of distinctive competence (Hitt & Ireland, 1985), dominant logic (Prahalad & Bettis, 1986), and core competence (Prahalad & Hamel, 1990). From the resource-based perspective, firms can enhance their performance by maximizing their resources across several businesses to realize additional returns (Wan et al., 2011). Through diversification, a firm can achieve economies of scope (Penrose, 1995) and enhance their competitive advantage. In this sense, if a firm possesses the necessary resources to make diversification economically feasible, diversification can be adopted into its strategy (Teece, 1982; Wan et al., 2011; Wernerfelt, 1984). The resource-based view is now integrated with organizational economics such that a firm's core resources affects the firm's incentives to pursue asset-specific investments (H. C. Wang & Barney, 2006).

The concept of a firm's diversification was first introduced by Ansoff (1957). From his article, diversification is described as one of a firm's growth strategies. For instance, firms can increase sales without departing from an original product or market strategy; otherwise, firms seek the development of a new product or adapt to a new market. Diversification represents a distinct break from past business experience as it requires a new perspective of both markets and products. From a managerial standpoint, therefore, diversification is a complex and risky task as it requires new skills, technologies, and facilities (Ansoff, 1957). As more industries become knowledge-intensive and technology-centered, technology diversification is also widely discussed in previous studies (Breschi, Lissoni, & Malerba, 2003; Garcia-Vega, 2006; M Gort, 1966; O Granstrand, 1998; Suzuki & Kodama, 2004).

Firms may experience difficulties diversifying as a result of its complexity and risk, highlighting the importance of the role of strategic alliances in diversification. Firm involvement in various strategic alliances has become a ubiquitous phenomenon in today's business landscape (Contractor & Lorange, 2002; Gulati, 1998; Wassmer, 2010). As one of the methods for cooperating with other organizations, the role of a strategic alliance—defined as a contractual agreement for the achievement of a mutually beneficial goal in a promised period of time between at least two partners (J. E. Coombs & Deeds, 2000; Deeds & Hill, 1996; Veilleux, 2014)—is discussed by various researchers. The strategic alliance has been considered an important strategic method in many industries such as telecommunications, electronics, pharmaceuticals, and air transportation.

Through strategic alliances, firms can access the valuable resources of their partners (Das & Teng, 2000; Eisenhardt & Schoonhoven, 1996; Doven Lavie, 2006), reduce transaction costs (C. Inkpen, Child, & Faulkner, 2000; Kogut, 1988), and improve competitive positions (Gimeno, 2004; Kogut, 1988; Silverman & Baum, 2002). Most importantly, strategic alliances allow firms to manage their risks and uncertainties (George, Zahra, Wheatley, & Khan, 2001; Hoffmann, 2007; Kogut, 1991). Therefore, firms are often engaged in multiple simultaneous strategic alliances with different partners, resulting in the use of the alliance portfolio—a set of alliances in which a firm is involved (Bae & Gargiulo, 2004)—as a unit of analysis (Gulati, 1998; Doven Lavie, 2006; Wassmer, 2010). As a result, the role of the alliance portfolio is important to the understanding of the promotion of diversification.

1.2 Problem statement

Although diversification has been widely studied by various researchers, there are three limitations that have to be overcome to improve the analysis.

Firstly, the selection of the appropriate diversification index has not been sufficiently discussed prior to the main analysis. The importance of diversification studies has led to the development of various indices to measure diversification. All of the indices used in previous studies have not only been adopted by various researchers but are also well-designed to capture the differences in diversification. However, the selection of the diversification index remains a critical issue because the result may differ depending on the nature of the selected diversification index. There are three different properties of diversity (variety, balance, and disparity) that affect the development of a certain diversification index. As stated by Stirling (2007), there is no index that perfectly represents all three properties of diversity. Since the properties of diversification indices are not empirically considered in depth in previous studies, the selection issue of diversification indices should be addressed.

Secondly, market and product diversification are not clearly distinguished. In practice, a firm's diversification activities can be divided into market, product, and technological diversification activities. These three activities are one of the main indicators for a firm's strategic decisions as each one of them represents different stages of product development. In previous studies, however, market and product diversification are not clearly separated as the same measurement was used for both activities (Chavas & Kim, 2010; Gemba & Kodama, 2001; Michael Gort, 1962; Sirmon, Hitt, Ireland, Ireland, & Hitt, 2007). Since a firm's actual strategic decisions depend on which market to enter and which product to develop, the existing approach has limitations in providing the relevant implications for each activity. In addition, the absence of diversification properties led to a limited understanding of the interpretation. Accordingly, an investigation into the effects of firm-level diversification activities including market, product, and technological diversification activities with respect to the properties of diversity is needed.

Lastly, the effect of alliance portfolios on firm-level diversification is not discussed taking into consideration open innovation activities and alliance portfolio management capability (APMC). Due to its complexity and risk, diversification is not an easy task for a firm to accomplish on its own. From a firm's perspective, it is important to determine the means by which it conducts alliances depending on the type of diversification activities it undertakes. In addition, a firm's ability to manage various alliances should also be considered as more firms are now engaged in numerous strategic alliances with various partners. Accordingly, the effect of alliance portfolios on firm-level diversification should be examined taking into consideration the type of collaboration method and the firm's ability to manage alliance portfolios.

1.3 Research objective

As outlined in the problem statements, this study addresses the research objectives by presenting three articles, each of which deals with the three problems in turn.

The first article aims to provide a reliable reference for selecting a diversification index. In order to provide for the content validity of a diversification index, three different patent data sets are constructed including data from six top patent-application countries (the

United States, Korea, Japan, Germany, China, and Europe). For the empirical analysis, a principal component analysis (PCA) is conducted to find out distinctive relations among the indices and derive the dominant index for each principal component.

The second article examines the effects of diversification on performance using the proposed firm-level diversification framework. For this purpose, panel data is constructed by integrating a firm's product, patent, and financial data. Here, market, product, and technology diversifications are measured with reference to the two diversification perspectives and the effects of diversification are estimated from each perspective. In addition, two different dependent variables of business and innovation performance are implemented to reflect the performance of different development stages.

The third article investigates the effects of open innovation activities on firm-level diversification taking into consideration the moderating effect of APMCs. For this purpose, panel data is constructed by integrating a firm's deal, product, patent, and financial data. The records of each firm's strategic alliances are classified based on an open innovation model. In order to gauge a firm's APMCs, an alliance network is constructed to derive the relevant measurements for the components of APMC: proactiveness, portfolio coordination, and relational governance. For the empirical analysis, a hierarchical regression is conducted to observe the moderating effect of alliance management portfolio capabilities.

1.4 Research question

Based on the research problems and research objectives, this study formulates an overall research question with three subsets of research questions as follows:

The overall research question and the three main research questions with respect to firm-level diversification

- What should be considered to advance firm-level diversification studies?
  - Which diversification index should be selected taking into consideration the properties of diversity?
  - What are the effects of firm-level diversification activities on performance?
  - How do alliance portfolios promote firm-level diversification?

The first subset of research questions with respect to diversification perspectives

- What are the diversification cases that should be considered for the content validity of selecting a diversification index?
- How are the properties of diversification indices observed in an empirical analysis?
- What are the dominant diversification indices that explain each diversification perspective?

The second set of research questions with respect to firm-level diversification activities (market, product, and technological) and performance taking into consideration balance- and hetero-centered diversification

- What are the effects of each firm-level diversification activity on business and innovation performance?
- How do balance- and hetero-centered diversification influence business and innovation performance?

The third set of research questions with respect to alliance portfolios and firm-level diversification activities taking into consideration open innovation activities and APMCs

- What are the effects of open innovation activities (coupled and outside-in) on diversification?
- How can APMCs be measured from the perspective of network theory?
- How do a firm's APMCs moderate the relationship between open innovation activities and diversification?

1.5 Research outline

The structure of this study is described as follows. In Chapter 2, the overall theory and practice of diversification used in the following chapters is reviewed. The purpose of Chapter 2 is to provide theoretical evidence for the proposed diversification framework and explain how it can be interpreted for academic purposes.

Chapter 3 examines the selection issue of diversification indices using patent data. Based on Stirling's diversity property framework (2007), three different properties of diversification indices are reviewed. For the content validity of selecting a suitable diversification index, the relevant diversification indices and empirical cases that are used most frequently in the previous studies are selected. A PCA is conducted to examine how diversification indices are distinguished and which diversification indices are influential for each perspective. As a result, this study proposes the consideration of two diversification perspectives: balance-centered and hetero-centered diversification.

In Chapter 4, the effects of firm-level diversification activities on performance are investigated using the proposed firm-level diversification framework. For the empirical study, a panel data set is constructed by integrating a firm's product, patent, and financial data. Accordingly, this study suggests implications for the performance of diversification strategies highlighting different approaches for each activity.

Chapter 5 is designed to find the effects of alliance portfolios on diversification activities taking into consideration open innovation activities and APMCs. A network analysis is implemented to measure and reflect a firm's APMCs. This study emphasizes the role of APMCs in realizing the effects of open innovation activities.

Chapter 6 summarizes the overall results, addresses the implications and contributions, and concludes with the limitations and outlook.

Chapter 2. Literature Review

2.1 A resource-based view

In earlier studies, efforts to understand a firm's performance focused mostly on industry factors (Porter, 1979). Researchers began to shift their focus from industry- to firm-specific factors (Spanos & Lioukas, 2001) after a firm's internal factors, such as its resources and capabilities, were found to be determinative of the firm's profit (Wernerfelt, 1984). The central premise of this argument is that a firm's competitiveness is based on its resources and capabilities (Peteraf & Barney, 2003). This is the resource-based view or the resource-based theory, which emphasizes the role of a firm's resources and capabilities in explaining the firm's competitive advantages that result in better firm performance. The resource-based view contributed to the explanation and prediction of a firm's competitive advantage and performance (J. B. Barney, Ketchen, & Wright, 2011; Slotegraaf, Moorman, & Inman, 2003; Vorhies & Morgan, 2005).

In firm-level studies, "resources" includes all assets, capabilities, organizational processes, firm attributes, information, and knowledge, (J. Barney, 1991). In this context, resources have to satisfy two fundamental conditions to contribute to a firm's sustained competitive advantage (J. Barney, 1991). Firstly, resources should be rare and valuable. For instance, if a firm conducts a certain activity with rare resources or high levels of efficiency, it can achieve a competitive advantage over competing firms. Secondly, resources should be not imitable, substitutable, or transferable. Simply speaking, if a resource is unique, the firm can keep its advantage over a long period of time. In summary, a firm with a rare, valuable, non-imitable, non-substitutable, non-transferable resource can have a sustained competitive advantage.

With these fundamental conditions, the resource-based view relies on the following two theoretical assumptions: resource immobility and resource heterogeneity (J. Barney, 1991; Kozlenkova, Samaha, & Palmatier, 2014; Priem & Butler, 2001). Resource immobility implies that resources cannot be transferred among firms without cost (Peteraf & Barney, 2003). Resource heterogeneity indicates that a firm with unique resources is better at certain activities (Peteraf & Barney, 2003). The bundles of resources possessed by each firm are not the same even for those competing in the same industry. Each firm’s bundle of resources may differ depending on the types of markets they enter, the types of products they produce, and the types of technologies they develop. It not only reflects the status of the resources possessed by a firm, but also its competitive advantages over other firms. Under the assumption of resource immobility, this benefit may persist only if firms do not collaborate. Accordingly, the resource-based view can be implemented in firm-level studies to understand the determinants of firm profit or performance.

2.1.1 Diversification and resource-based view

The resource-based view is one of the theoretical backgrounds widely adopted by various diversification studies. From the resource-based view, a firm’s diversification activities are explained with reference to economies of scope (Teece, 1982) and economies of scale

(Pennings, Barkema, & Sytse, 1994). Basically, diversification allows firms to manage their resources (such as production facilities or distribution channels) to create value (Hitt, Hoskisson, & Kim, 1997). In this sense, firms can obtain synergistic effects and increase their average returns through diversification (Pennings et al., 1994). For instance, if firms have excess resources that are transferable to other markets, firms may use them to diversify at a lower operational cost (Penrose, 1995). Through diversification, firms not only reduce their operational costs but also increase their business efficiency (Montgomery & Hariharan, 1991; Nath, Nachiappan, & Ramanathan, 2010). From previous studies, this sort of diversification is regarded as related diversification, which implies a diversification activity using similar resources. Robins & Wiersema (2003) stated that the sharing of resources among related businesses is an important factor of successful diversification.

In addition to this, diversification provides greater opportunity to extend the reach of a firm's competency (Hitt et al., 1997). This type of diversification is described as an unrelated diversification. From the resource-based view, unrelated diversification can also increase a firm's competitive advantage as it creates economies of scope by sharing market and technoloical resources (Chang & Wang, 2007). Most importantly, firms can enlarge the scope of their resources through diversification. For instance, if a firm internationally diversifies, which indicates an unrelated diversification with respect to geography, an expansion of market scope is expected (Chang & Wang, 2007; Hitt et al., 1997). A firm with the ability to diversify its resources in different ways will be able to maintain a sustainable competitive advantage.

In this study, therefore, the resource-based view provides a theoretical background for explaining firm-level diversification and its relation to firm performance and the role of alliance portfolios. More specific theoretical backgrounds regarding the effect of diversification and its implementation are covered in a later chapter.

2.1.2 Firm-level diversification

In general, a firm’s diversification activities can be distinguished into two types: market/product (Chavas & Kim, 2010; Gemba & Kodama, 2001; Michael Gort, 1962) and technology (Breschi et al., 2003; Garcia-Vega, 2006; Quintana-García & Benavides-Velasco, 2008). The former is regarded as the extent of the firm’s diversification in its industry or product market while the latter indicates the degree of technology diversification. In previous studies, various terms (e.g., firm diversification, corporate diversification, industry diversification) were used but all of them refer to the same concept. In general, diversification refers to the horizontal expansion of a firm’s market presence (Chakrabarti, Singh, & Mahmood, 2007; Sun & Govind, 2017). In this context, diversification is where firms have operations in more than one industry or product market (Su & Tsang, 2015). Along with product diversification, technology diversification has been regarded as an important aspect of firm-level diversification due to the increased importance of technology. Technology diversification represents the degree of diversity or the breadth (or width) of a firm’s technology base (Ove Granstrand & Oskarsson, 1994). Simply put, technology diversification indicates the degree of diversification by a firm in the area of technology. Scherer & Ross (1990) regarded technological opportunity as an important factor behind differences in the innovativeness of different industries. Firms require diverse technological knowledge in order to cope with the uncertainties in a changing environment (March, 1991).

To understand firm-level diversification activities, both market/product and technology diversification should be considered together. Ross et al. (1999) insisted that diversification itself cannot produce value. In order to benefit from diversification, business units need to be reorganized to achieve economies of scope. Particularly for technology-centerd firms, the relation between technology and product diversification needs to be considered. Penrose (1995) considered technology to be one of the important sources of new opportunities for product diversification. Through diversification-related enhancements, firms can capture technological spillovers between products (Jovanovic, 1993). In this sense, economies of scope can be achieved by utilizing the research and development (R&D) inputs in the production of different product types (Baumol, Panzar, & Willig, 1982). Since technological exploration in a wide range of technologies is considered a prerequisite for production, technological diversification anticipates market and product diversification (Breschi et al., 2003; Keith Pavitt, 1998).

As mentioned, market/product and technological diversification are important aspects of understanding firm-level diversification. Therefore, firm-level diversification covers both market/product and technological diversification in this study.

2.2 Firm-level diversification framework

2.2.1 Proposed conceptual framework of firm-level diversification

This study proposes a firm-level diversification framework comprising three domains: market, product, and technology. These three domains not only indicate different diversification types but also different value chains (Figure 2-1). Since market/product and technological characteristics originate in different stages of the value chain as a result of different motivations (Garcia-Vega, 2006), they should be considered separately. Both market and product diversification are observed from a firm's commercialized products and technological diversification is derived from patent data.

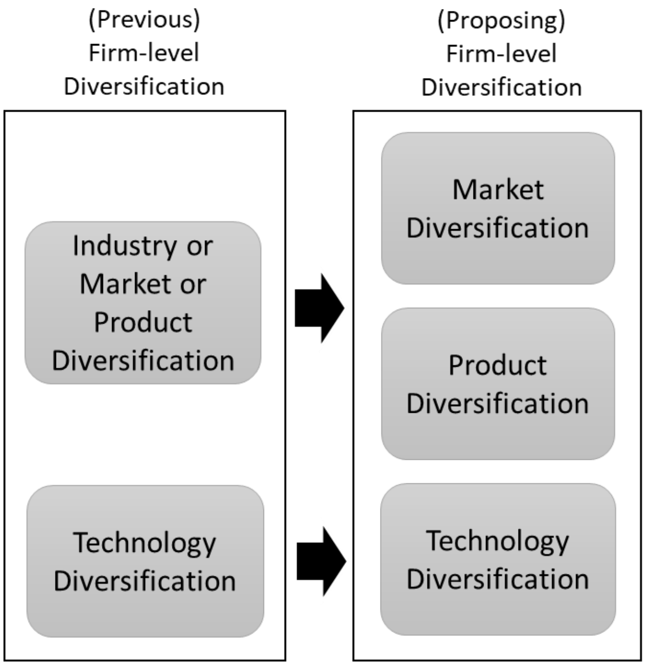

Figure 2-1. Firm-level diversification framework

2.2.1.1 Market diversification

In economics, a market is regarded as a place in which people exchange goods and services. In previous studies, however, there been some confusion surrounding the use of the terms "market" and "industry" (Nightingale, 1978). The difference between a market and an industry should be clarified as the actual target of interest may be different depending on the research purpose (Nightingale, 1978; Phillips, 1976; Robinson, 1956). Andrews (1949) distinguished an industry and a market by differentiating from the perspective of a buyer or a seller: an industry is where a firm influences others while a market only refers to consumers who purchase firms' products. While this definition can be adopted to all common cases, it has some limitations (Nightingale, 1978). Two firms using different technologies and resources are considered as being in the same industry if they sufficiently affect each other. Based on this approach, the industry and the market are not clearly distinguished as many different businesses that can influence the behavior of a firm can be included. Instead, Andrews & Brunner (1975) proposed defining an industry based on the concept of Andrews's (1949) "chief characteristic," which classifies firms with similar processes and technical products into the same industry; the market definition remains the same as before. As a result, all sellers in a market are no longer grouped into the same industry.

Market type can be classified from two different perspectives: marketing and the Standard Industrial Classification (SIC). In the field of marketing, market types are often discussed in the context of market segmentation. Market segmentation, which was first introduced by Smith (1956), is a process of dividing a market into groups of consumers by demographics, psychographics, and behavioral variables. Demographic segmentation is based on demographic factors such as age and income. It assumes that a group of people sharing similar demographic factors will exhibit similar preferences (Baker, 2012). The psychographic approach considers the lifestyles of customers. By studying the activities, interests, and opinions (AIO) of consumers, it can provide a better understanding of consumers' motivations. Lastly, behavioral segmentation classifies consumers by their observed behaviors such as product purchases and usage and user status. Due to differences among industries, market segmentation can vary depending on industrial characteristics and the focus of the researcher's interest. For instance, in the lodging industry, a hotel's market diversification is observed based on pricing: luxury, upscale, mid-priced, economy, and budget (M. J. Lee & Jang, 2007). In the case of the construction industry, market diversification is measured by market sector: general building, manufacturing, power, water supply and sewerage/solid waste, industrial process and petroleum, transportation, hazardous waste, and telecommunications (H. J. Kim & Reinschmidt, 2011).

In industry- or firm-level studies, the SIC, which follows "activities of establishment," is often used. Since most establishments are specialized into a certain group of technologies and technological changes may outstrip the SIC, the SIC is recommended for use in industrial studies where the importance of the market classification is not very high (Nightingale, 1978). However, it is still a useful method for firm-level studies as it satisfies the definition of diversification and complements firms' overall financial information. In order to focus on a firms' product sales, actual market information where the firm's products are merchandized can be used. This is somewhat similar to the traditional understanding of product diversification but varies slightly as it is based on a firm's merchandized product. Accordingly, this study measures market diversification with reference to the market in which a firm's products are merchandized.

2.2.1.2 Product diversification

In previous studies, market/product diversification was measured using sales information distinguished by industry classification, but used different terms such as industry, market, firm, or product diversification (Oh, Sohl, & Rugman, 2015; Su & Tsang, 2015; Y. Wang, Ning, & Chen, 2014). This approach was accepted by many studies because it not only satisfies the definition of diversification but also only requires firms' sales information. However, it has limitations for deriving practical implications for firms' strategic decisions. From a firm's perspective, its strategic decisions are often implemented either with respect to sales or product or technological development. In practice, a firm needs to decide where to make investments into R&D, what to develop as a product, and which market to sell in. If firm diversification is measured with reference to sales information, it represents the overall diversification of sales and products. However, a firm's actual strategic decisions can differ based on its product and the merchandized market as they do not always belong to the same category. For instance, firm A, a content provider, can produce a single movie but sell it to various markets such theaters, DVD rental markets, or web services. On the other hand, firm A can produce various movies but only sell them to a single market. Another possible example is the automobile industry. An automobile company can produce a single type of car but sell it to various markets including rental services, taxis, or general users.

Given the above, Ansoff (1957)'s definition of diversification can be implemented to classify firm diversification into product and market characteristics. Since a firm's strategic decisions are implemented in either product development or sales and marketing, this approach can provide more practical and relevant implications. In this study, product diversification refers to the degree of diversification of the product type. Product type here refers to the product itself, distinguishing its component and functional differences.

2.2.1.3 Technology diversification

Unlike product and market diversification, the concept of technological diversification is clear. Technological diversification indicates the level of diversification of technological components derived from patent data. Following previous studies, technological diversification is measured with reference to the technological classification assigned to a firm's patent applications. Here, the International Patent Classification (IPC) is used as a target of diversification. Since the IPC reflects the technological component of a patent (Strumsky, Lobo, & Leeuw, 2012), measuring diversification using the IPC can show more specific levels of a firm's technological diversification. In this study, the sub-class IPC is used as it designates an intuitive and representative level of technology (Keungoui Kim, Jung, Hwang, & Hong, 2018).

2.3 Alliance portfolio

2.3.1 Strategic alliance

Strategic alliances are a strategic tool for enhancing a firm's competitiveness in a fluctuating and competitive business environment (Schilke & Goerzen, 2010). Firms can deal with a great amount of investment made through various types of strategic partnerships such as mergers and acquisitions, joint ventures, and alliances (Alcacer & Gittelman, 2004). Moreover, strategic partnerships between firms facilitate knowledge exchange (Caiazza, 2015; Gassmann, Enkel, & Chesbrough, 2010). Particularly for high-technology industries, technological innovation is achieved through strong inter-organizational ties (Ander & Levinthal, 2008).

In general, firms' motivations to enter into alliances are based on their market positions and resource conditions (Park & Zhou, 2005). Child, Faulkner, & Tallman (2005) classified them into five types: transaction-cost, resource-based, strategic-positioning, learning, and other motivations. Transaction-cost motivation aims to achieve transaction economies and asset efficiencies, while resource-based motivation aims to supplement existing resources or secure missing resources. Strategic alliances are an efficient method for sharing resources without having to develop a new ownership structure (Aaker, 1995) while still capitalizing on the firm's core competencies (Lin & Darling, 1999; Webster, 1992). Strategic-positioning motivation is when a firm is willing to strengthen its strategic competitive positioning in the industry through strategic alliances. Strategic alliances allow firms to overcome market access difficulties (Lei & Slocum, 1991; B. Lin & Darling, 1999) and reposition themselves in different market segments (Sadowski & Duysters, 2008). Learning motivation is when the goal of a firm's strategic alliance is formal and implicit learning. Other motivations include risk reduction/management, first-mover advantage, increased speed-to-market, increased flexibility, and reduced uncertainty.

Accordingly, strategic alliances can be implemented for many reasons, but all are related to enhancing firm capabilities and management efficiency. From the resource-based perspective, strategic alliances allow firms to access the unique resources and competencies of their partners (J. Barney, 1991) as it contributes to the combination of complementary assets belonging to them. By allowing the flow of knowledge and opportunities, a firm can increase its ability to recognize and evaluate technological innovations in the marketplace (H. Lin, 2012). Therefore, strategic alliances encompass a means of exchanging, sharing, and co-developing products, technologies, and services with other organizations (Gulati, 1998). The broader concept of a strategic alliance includes, for instance, joint ventures, partnerships, contracts, licenses, and agreements (P Kale & Singh, 2009).

2.3.2 Alliance portfolio management capability (APMC)

2.3.2.1 Alliance portfolio

The concept of an alliance portfolio was defined by various researchers in previous studies (Table 2-1). The most general approach describes an alliance portfolio as “a firm’s collection of direct alliances with partners” (Dovev Lavie, 2007, p. 1188). The key concept of an alliance portfolio is that the point of interest lies on the focal firm’s set of alliances with its partners. Compared to a single alliance, an alliance portfolio requires additional considerations as the focal firm deals with different collaborations of varying governance structures and at different stages of their life cycles (Sarkar, Aulakh, & Madhok, 2009). As more firms begin to conduct strategic alliances more frequently, the alliance portfolio is becoming an important unit of analysis (Jiang, Tao, & Santoro, 2010; Wassmer, 2010).

Table 2-1. Conceptualizations of alliance portfolio

Conceptualization	Reference
The set of alliances in which a firm is involved	Bae & Gargiulo (2004)
A focal firm’s egocentric alliance network (i.e., all direct ties with partner firms)	Baum, Cowan, & Jonard (2010), Rowley, Behrens, & Krackhardt (2000)
The set of bilateral alliances maintained by a focal firm	Doz & Hamel (1998)
A firm’s portfolio of strategic agreements or relationships	George, Zahra, Wheatley, & Khan (2001)
All alliances of a focal firm	Hoffmann (2005, 2007)
A firm’s collection of direct alliances with partners	Dovev Lavie (2007)
A firm’s collection of immediate alliance partners	Dovev Lavie & Miller (2008)
A firm’s network of business-partner relationships	Parise & Casher (2003)
All international joint ventures of a focal firm	Reuer & Ragozzino (2006)

Reference: Wassmer (2010)

2.3.2.2 Alliance portfolio management capability

Sarkar, Aulakh, & Madhok (2009) proposed a concept of a firm's capability for managing its own alliance portfolio called APMC. APMC was first introduced in relation to network resources (Gulati & Kellogg, 1999) and social capital (Nahapiet & Ghoshal, 1998). Network resources highlight the strategic nature of information that a firm can access through its connected ties (Gulati & Kellogg, 1999); social capital emphasizes one's degree of linkage to others for access to resources and capabilities and for creating a cohesiveness that facilitates the pursuit of common goals (Adler & Kwon, 2002). Koohborfardhaghighi & Altmann (2017) argued that the richer the knowledge base within an enterprise with respect to its human and social capital, the more it can empower its employees to be creative and innovative during group work. In a similar sense, a firm's APMC can be understood as a firm's capability to manage a diverse portfolio while managing its resources and pursuing its of goals.

APMC consists of three different components (Table 2-2): partnering proactiveness, portfolio coordination, and relational governance. Partnering proactiveness is defined as "an organization's deliberate efforts to discover and act on new alliance opportunities." Firms can take first-mover advantage if they are able to sense or preempt promising partnering opportunities. Portfolio coordination is defined as "an organization's engagement in integrating and synchronizing knowledge and activities across their alliances." If a firm has advantages in transferring knowledge and activities, it will benefit from increasing knowledge flows by brokering information across the alliance portfolios. Lastly, the definition of relational governance is "an organization's engagement in activities for the development of informal self-enforcing safeguards in their collaborative relationships." Thus, a firm with strong relational governance can lower contracting and monitoring costs and increase incentives for value-creating initiatives.

Table 2-2. Alliance Portfolio Management Capability Properties

	Definition	Source of strategic advantage
Partnering proactiveness	An organization's deliberate efforts to discover and act on new alliance opportunities	First-mover advantages in imperfect factor market for partners
Portfolio coordination	An organization's engagement in integrating and synchronizing knowledge and activities across their alliances	Increasing knowledge flows and brokering information across the portfolio of alliances
Relational governance	An organization's engagement in activities for the development of informal self-enforcing safeguards in their collaborative relationships	Lowering contracting and monitoring costs and increasing incentives for value-creating initiatives by alliance partners

Reference. Sarkar et al. (2009)

Due to the increased complexity, a firm's APMC is needed to examine alliance portfolios (Castro & Roldán, 2015a; P Kale & Singh, 2009; Schreiner, Kale, & Corsten, 2009). Whether a firm can successfully manage its various alliance portfolios depends on its portfolio management skills. Accordingly, APMC must reflect the value of a portfolio as a whole rather than focus on its individual components; a holistic and inclusive approach towards alliance portfolios is suitable for the understanding of APMC.

Chapter 3. Which diversification index should be selected?: Insights for diversification perspectives

3.1 Introduction

Diversification has been discussed in various areas such as biology (Macarthur, 1965; Solow, Polasky, & Broadus, 1993) and ecology (Morris et al., 2014). With the increasing frequency of convergence among different industries and technologies, diversification has been found to be a prevailing phenomenon in various areas and scopes. In management and economics, diversification has been discussed in the context of research (Abramo, D'Angelo, & Di Costa, 2018; Dranev, Kotsemir, & Syomin, 2018; Herron, Mehta, Cao, & Lenoir, 2016), business (Geringer, Tallman, & Olsen, 2000; Singh, Gaur, & Schmid, 2010; Stephan, 2002; Woerheide & Persson, 1992), technology (Bart, Rene, & Bart, 2007; Breschi et al., 2003; Cohendet, Llerena, & Sorge, 1992; Garcia-Vega, 2006; H. Kim, Lim, & Park, 2009; Kook, Kim, & Lee, 2017; S. U. Lee & Kang, 2015; C. Lin & Chang, 2015; Luan, Hou, Wang, & Wang, 2014; Quintana-García & Benavides-Velasco, 2008; Zhang & Tang, 2018), and geography (Geringer et al., 2000; Stephan, 2002).

Along with the importance of diversification, various diversification measurements were introduced and used in previous studies. The variety of available diversification indices provides a wide range of selection opportunities to researchers. At the same time, it implies the lack of a rigorous consensus for choosing an appropriate diversification index either in general or specific situations. In the case of ecology, Morris et al. (2014) pointed out the difficulty of quantifying biodiversity due to the multitude of proposed indices. The absence of consensus on the selection of a diversification index may lead to justified allegations of a lack of objectivity. Since both interpretation and consequences can differ depending on the characteristics of the index used, the validity of diversification measures should be considered prior to the selection of a diversification index.

There were few attempts to address this problem, but they were limited to certain situations and not of general application. To prove the content validity of the selection of a diversification index, the analytical perspective should not be restricted to limited cases. In order to obtain the content validity of a diversification index, the evaluation of diversification indices should be considered more rigorously in the context of various cases. For instance, the result of diversification can differ according to the measurement, the analytic sample, and the target of interest. A more generalized understanding of diversification indices, therefore, can contribute to the various research areas where diversification is a point of interest.

Therefore, in this study, the empirical implications of selecting a suitable diversification index are derived, focusing on the case of technological diversification using patents. Due to the reliability and usability of patents, various cases can be studied and comparisons among them can be made to obtain a more generalized understanding. Here, the three cases include cross-section, single time period, and multiple time periods, with comparisons among six countries. In addition, the list of technological diversification indices that are frequently used in previous studies are examined to determine which are better suited for measuring technological diversity. To prove the content validity of the selection of a technological diversification index, a comparison of the three cases with different time sets and six different countries is included. PCA is conducted to determine distinctive relations among the variables and derive the dominant variable of each principal component. Since the relationships between diversification indices do not always satisfy the mathematically predicted patterns (Nagendra, 2002; G. Stirling & Wilsey, 2001), performing PCA on real data can ensure that the conclusions are valid (Andy Stirling, 2007).

The remainder of this chapter is laid out as follows. Section 2 reviews the content validity of diversification and technological diversification and its related indices in detail. Section 3 describes the data and methods used in this study. Lastly, the results and conclusions are set out in Sections 4 and 5.

3.2 Literature review

3.2.1 The content validity of diversification index

The validity of an index can be studied from the perspective of either face or content validity. Face validity observes whether a test measures what it is supposed to measure while content validity observes whether a measure represents what it superficially appears to measure. Simply put, monthly income indicates face validity of one's financial ability per month. Compared to face validity, however, content validity requires a rigorous evaluation of the measure. In general, content validity requires either recognition by an expert or statistical testing as it deals with superficial measurements. Robins & Wiersema (2003) pointed out the importance of using an appropriate diversification index by emphasizing the content validity of a diversification measure.

The main reason for the content validity of a diversification index is that the lack of a prior assessment of content validity may cause problems in obtaining consistent results due to the sensitivity of using each index. Although the result can differed as a result of the diversity measurement (Morris et al., 2014), there is no sufficient consensus on the selection of a diversification measure (Robins & Wiersema, 1995, 2003); the sensitivity of diversification measurements may cause contradictory results and unexpected confusion depending on the choice of a diversification index. Robins & Wiersema (2003) examined the content validity of an entropy index and a concentric index to see whether these indices are suitable for use as indicators of portfolio relatedness. Their results show that the concentric index positively influenced dominant business focus (the relative size of dominant businesses) and negatively influenced pure diversification (the number of businesses); the entropy index exhibited the opposite characteristics. From these findings, they concluded that these sorts of sensitivities can create ambiguities in strategy research. Woerheide & Persson (1992) evaluated five diversification indices for measuring unevenly distributed stock portfolios. Among the five indices—the complement of the Herfindhal index, Rosenbluth's index, the exponential of entropy index (Marfels, 1971), the comprehensive concentration index (Marfels, 1971), and the entropy index (Hart, 1971)—

the first was found to be the most adequate for general use.

Therefore, rather than simply adopting one of the diversification indices, their prior assessment is needed.

3.2.1 Technology diversification

Technological diversification refers to the degree of a firm's technological diversity. Although there is consensus on the definition and components of technological diversification, there has not been an in-depth discussion on the diversification index. In case of technological diversification, Variety, the Herfindahl-Hirschman index (HHI), the modified HHI, and Entropy are some of the generally used indices (Table 3-1). These indices are widely used in various areas of research and detailed explanations of them will be provided in the following section.

Table 3-1. Technology diversification targets and indices

Material	Diversification Target	Index	Reference
Patent	Primary technology class (sub-class)	Variety	(S. U. Lee & Kang, 2015; Wadhwa & Kotha, 2006)
		1-HHI	(C. Lin & Chang, 2015; Quintana-García & Benavides-Velasco, 2008)
	Technology field	Entropy	(Stephan, 2002)
		Joint occurrence of possible pairs	(Breschi et al., 2003)
		1/HHI	(Bart et al., 2007)
		1-HHI	(Bas & Patel, 2005; Garcia-Vega, 2006)
		HHI	(Fan, Li, & Yang, 2017; Gambardella & Torrisi, 1998; H. Kim et al., 2009)

As described in Table 3-1, patent data are used as analytic material for measuring technological diversification. Patents can be used to observe a firm's technological diversification and concentration strategy (Kim et al., 2009). As an effective and valid indicator for firm-level technological activities, patents allow the grasping of a firm's technological activities rooted in a formal R&D organization (Pavitt, 1988). In relevant studies, it is regarded as a form of technological output that explains a firm's innovative capabilities (Ahuja, 2000; H. Kim et al., 2009; Lee & Kang, 2015). Since patent data spans 80 patent offices worldwide from the 1970s, comparisons across countries and over a wide range of time periods are available.

In general, the IPC is used as a target of technological diversification. Argyres (1996) suggested that patents assigned to different areas of technology can be observed as different technological applications. Instead, the technological classification assigned to a patent can be used to distinguish a firm's technological applications. Jaffe (1989) viewed technology as consisting of a number of distinct "technological areas" and used this approach to characterize a firm's technological position. Technological classifications provided by patents offer detailed information on the relevant area of technology, which is relevant for assessing a firm's technological activities (Stephan, 2002). In this sense, a patent is acceptable material as it includes the IPC, which is a type of technological classification that distinguishes different technologies in a hierarchical order. Even though the IPC is selected as a diversification target, its measurement level has to be determined. As described in Table 3-1, technological diversification is measured either with reference to a sub-class or technology field. The sub-class refers to the hierarchical level of the IPC and technology field refers to a bundle of related industry classifications from the IPCs. Accordingly, the criteria for the technology field may differ as a result of either references or countries. Since the sub-class level of the IPC can be used without restrictions across different countries, it is adopted as a diversification target instead of the technology field.

3.2.2 Diversification perspectives and indices

The main reason that the values measured by each diversification index differ is due to differences in their points of interest. In this vein, Stirling (2007) proposed a general framework for diversity that can be applied in the field of science, technology, and society. He classified three basic properties of diversity: the number of elements (Variety), the distribution of elements (Balance), and the difference between the elements (Disparity). All these properties are necessary but individually insufficient as each property constitutes other two (Andrew Stirling, 1998; Andy Stirling, 2007). Thus, it is more likely to assume that the selection of a diversification index should consider multiple aspects rather than only one particular index. In this study, a total of six diversity indices that are widely used in technological diversification studies are selected: Variety, HHI, 1-HHI, 1/HHI, Entropy, and Rao-Stirling (Table 3-2). Although it was not mentioned in the previous section, Rao-Stirling is included to cover the disparity of diversification.

Variety, which is the simplest and the most intuitive diversification index, counts the number of entities (Macarthur, 1965). As already described in its title, it only considers the variety of diversification. In economics, it is often used as a simple enumeration of firms or products (Cohendet et al., 1992; Kauffman, 1992; Saviotti & Mani, 1995). For example, the kinds of IPC sub-classes owned by a firm represents the richness of its technological diversification.

Instead of counting a total number, using the proportion of each target of diversification is a more general approach used by most indices. The HHI is one of the most widely adopted indices for the measurement of technological concentration or diversification (Berry, 1971). Stirling's framework (2007) covers the variety and balance properties of diversification. This index was initially adopted in management literature to observe firms' diversification (Geringer et al., 2000; Sambharya, 1995), but has also been adopted to study technological diversification (Gambardella & Torrisi, 1998). The results of the HHI are quite intuitive as its formula is designed to treat proportions equally using a square root. For example, an applicant with an equally distributed proportion of IPC sub-classes has a lower HHI compared to one with concentrated technologies.

Rather than simply adopting the HHI, modified HHIs are introduced. 1-HHI has been used in previous studies (Bas & Patel, 2005; Garcia-Vega, 2006; Lin & Chang, 2015; Quintana-García & Benavides-Velasco, 2008). It is obvious that a concentrated firm's value is low while diversified firms require higher values of diversification. A firm with a higher diversification value is assumed to be diversified. Another modification of the HHI is measuring diversification by taking its inverse (Bart et al., 2007). The implications of inversed HHI results are similar to those of the 1-HHI, but it emphasizes the apparent differences in diversification. For instance, a comparison between HHI values of 1/4 and 5/8 becomes 6/8 and 3/8 when transformed into the 1-HHI. When they are converted into the inverse HHI, they become 4 and 5/8; the difference between them is greater than in the previous indices.

Similar to the HHI, Entropy also covers the variety and balance of diversification. It was first introduced in thermodynamics and used in the second law of thermodynamics, which explains the flow of energy. In thermodynamics, entropy represents the amount of energy that can no longer be reused. An increase in entropy represents chaos at the molecular level where the possibility of transforming energy into work is low. The concept of entropy used in diversification is somewhat similar, but more related to information theory. In information theory, entropy, also known as the Shannon index, deals with the uncertainty (or imbalance) of information (Shannon, 1948). An increased value of entropy indicates an increase in information uncertainty. For instance, if a firm obtains new information, it means that the understanding of its own overall information decreases. Here, the degree of information uncertainty depends on the proportion of new information to overall information. In the case of diversification, an increased value of entropy implies an increase in diversification in the sense of information uncertainty. Unlike the HHI, however, entropy gives more weight to lower values so that it can highlight the imbalance among components.

Lastly, the Rao-Stirling index not only measures the proportion of each entity, but also the Euclidean distance between them (Stirling, 2007). Unlike previous indices, it considers disparity in addition to variety and balance. In order to determine the disparity among elements, it conceives of the distance between them in a so-called disparity space (Solow et al., 1993). Disparity space is a unique n-dimensional space where n refers to the number of attributes of elements. Here, the attributes of elements can either be cardinal, interval, or binary terms. In this case, the attributes of elements are obtained by the cardinal terms of an applicant’s IPC classes. After normalization and weighting, the Euclidean distance between elements can be scaled to reflect distances in disparity space (Kruskal, 1964).

Table 3-2. Formulas of diversification indices

Diversity property	Diversification index	Formula
Variety	Variety (or Richness)	$\sum_i (p_i^0)$
Variety + Balance	Herfindhahl-Hirschman (or Simpson)	$\sum_i (p_i^2)$
Variety + Balance	1 - Herfindhahl-Hirschman (or Gini-Simpson)	$1 - \sum_i (p_i^2)$
Variety + Balance	1 / Herfindhahl-Hirschman	$\frac{1}{\sum_i (p_i^2)}$
Variety + Balance	Entropy (or Shannon)	$-\sum_i (p_i log p_i)$
Variety + Balance+ Disparity	Rao-Stirling	$\sum_{ij} d_{ij}(p_i p_j)$

(i: IPC, p_i: proportion of sub-class IPC i, d_{ij}: distance between IPC i and j)

3.3 Data and methodology

3.3.1 Data

For the empirical analysis, Worldwide Patent Statistical Database of the European Patent Office (EPO) is used. The EPO patent data have the advantage of minimizing home-country bias as firms' are headquartered in different countries (Schmoch, 1999). From previous studies, technological diversification has been discussed in three different cases: cross-section, single period, and multiple period (Table 3-3). The cross-sectional case observes technological diversification at a certain time period. The single-period case observes technological diversification within a specified time period. The multiple-period case separates the time periods. For comparison, three data sets are constructed for the three cases including the three groups of countries (high-, mid-, and low-level) classified by their level of patent applications. For the high-level patent application group, the top-six patent application countries—the United States (US), Germany (DE), China (CN), Spain (EP), Japan (JP), and Korea (KR)—are included. For the mid-level patent application group, Sweden (SE), the Russian Federation (RU), Italy (IT), Brazil (BR), and the Netherlands (NL) are selected. For the low-level patent application group, Bulgaria (BG), Malaysia (MY), Serbia and Montenegro (YU), the Eurasian Patent Organization (EA), Slovenia (SI), and the Philippines (PH) are included. Here, YU is intentionally included to see how diversification indices are observed where the number of patent applications dramatically decreases. Case 1 uses cross-sectional data in 2015 and 10,000 applicants are randomly selected from each country. Case 2 covers a single time period of ten years. Case 3 covers multiple five-year time periods. Here, the empirical cases of the US, the NL, and the PH are chosen. For the latter two cases, applicants who have patents in the beginning and end years are selected. Overall descriptions of the sample data for each case are set out in Table 3-4.

Table 3-3. Summary of the empirical studies on technology diversification

Target	Time		Country	Reference
Organization	Single period	1976-2006	Korea	Kim et al. (2009) *
Firm	Cross-section	2008	US	Lin and Chang (2015)
	Single period	2004-2012	China	Fan et al. (2017)
		1976-2002	US	Quintana-García and Benavides-Velasco (2008)
		1990-2010	US	Lee and Kang (2015)
		1989-1999	US	Wadhwa and Kotha (2006)
		1978-1993	France, Germany, Italy, Japan, UK, US	Breschi et al. (2003)
		1995-2003	US, Europe, Japan	Leten et al. (2007)
		1995-2000	15 European countries	Maria Garci-Vega (2006)
		1984-1991	US and Europe	Gambardella and Torrisi (1998)
	Multiple periods	1983-1987, 1988-1992, 1993-1997	US, Europe, Japan	Stephan (2002)
		1988-1990, 1994-1996	Europe	Bas and Patel (2005)

* Excluding public-owned organizations, university foundations, acquired firms, and foreign firms

Table 3-4. Description of sample data for the three different cases

Case	Data set	Country	Year
Case 1	Cross-section	(High) US, JP, KR, DE, CN, EP;	2015
Case 2	Longitudinal	(Mid) SE, RU, IT, BR, BE, NL; (Low) BG, MY, YU, EA, SI, PH	1996-2015
Case 3	Longitudinal	US, NL, PH	1996-2000; 2001-2005; 2006-2010; 2011-2015

3.3.2 Methodology

3.3.2.1 Diversification calculation

In this study, two different methodologies are used: diversification calculation and PCA. Since the main point of interest of this research is firm-level technological diversification, data is organized by each firm's IPC sub-class assigned to the patent. In order to remain consistent among countries, technological diversification is measured with IPC sub-classes for all cases. The sub-class level of the IPC is considered as units of technology for the selection of new technologies (Kim, 2013). Basically, technology diversification is measured annually and its accumulated form is used for cases with multiple time periods (Figure 3-1). One of the requirements for a technological diversification index is that it should be capable of capturing either changes or variations. With this rule, changes in firm-level technological diversification can be observed while the overall technological information is secured. Under this condition, diversification indices are derived with the equations mentioned in the previous section.

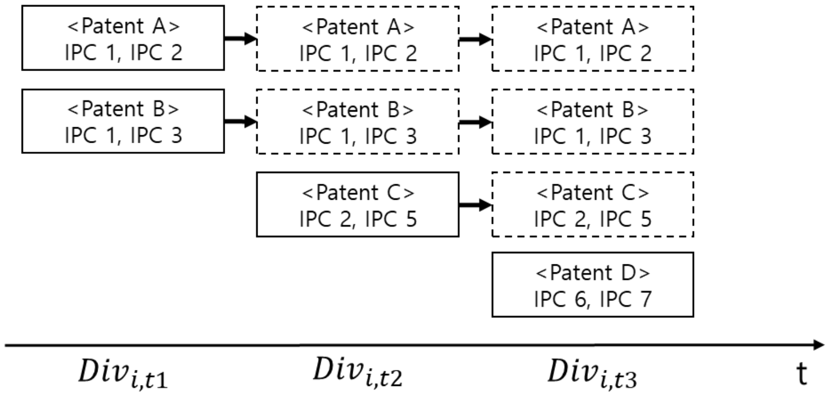

Figure 3-1. Firm-level annual technology diversification

3.3.2.2 Principal component analysis

PCA is a statistical procedure for reducing the dimensions of a data set. Here, the dimensions of a data set refer to the measurement type. It uses orthogonal transformation to convert a set of possibly correlated variables into new set of linearly uncorrelated variables. By doing so, the following goals can be achieved (Abdi & Williams, 2010). First of all, the most important information from the data table can be extracted. In addition, the size of the data can be compressed while retaining important information. Lastly, patterns of similarity in the observations and variables can be analyzed. Given these advantages, PCA has been widely used in big data analysis and in index studies (Morris et al., 2014).

In general, data pre-processing is required prior to the main analysis. Let us assume a data matrix X consists of i observations and j variables (Eq. (1)). Firstly, the data is normalized to the zero mean of each variable ($\mathrm{X}^T 1 = 0$). Then, z_1 that maximizes the variance of $z_1^T X$ under normalized conditions is calculated (Eq. (2)). Here, z_1 refers to the eigenvalue of principal component 1 and the result of Eq. (2) represents the first principal component. After this, the second principal component, which is uncorrelated to the first principal component, is derived. As can be seen in Eq. (3), z_2 that maximizes the variance of $z_2^T X$ should be independent from z_1.

$$\mathrm{X} = \begin{pmatrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{pmatrix} \text{ Eq (1)}$$

$$\max_{z_1} var[z_1^T X] = z_1^T \sum z_1 \quad \mathrm{s.t} \quad z_1^T z_1 = 1 \quad \text{Eq (2)}$$

$$\max_{z_2} var[z_2^T X] = z_2^T \sum z_2 \quad \mathrm{s.t} \quad z_2^T z_2 = 1 \ \text{ and } \ z_1^T \sum z_2 = 0 \quad \text{Eq (3)}$$

Geometrically, the concept of PCA is more comprehensive (Figure 3-2). For instance, data with two variables can be described with two dimensions using two different axes. As mentioned earlier, the average of each variable is transformed to zero so that the mean of the data can be located in the center. Observation points projected to an imaginary line that goes through the center are created and one that maximizes the sum of the squared distances between the projected data points and the origin is selected for principal component 1 (PC1). The second principal component is created by simply drawing a line perpendicular to principal component 2 (PC2). Finally, new axes with PC1 and PC2 are created.

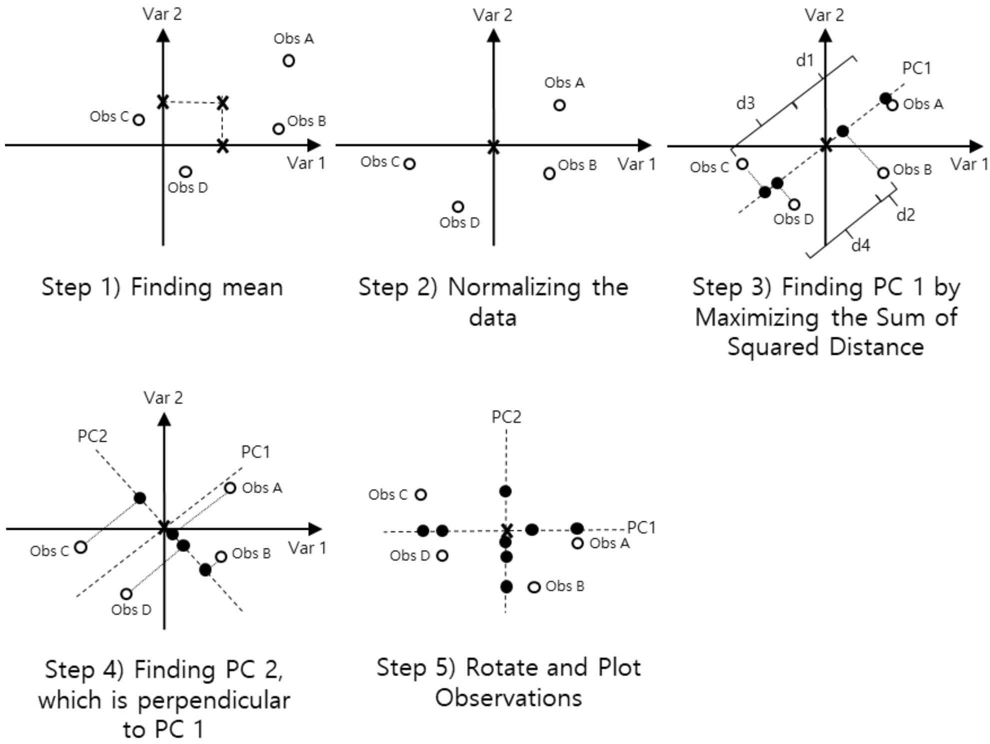

Figure 3-2. Geometric Description of PCA

In index studies, PCA was used for two different purposes. The first is to directly propose a new index using the results of the PCA (Chao & Wu, 2017; Filmer & Pritchett, 2001; Vyas & Kumaranayake, 2006). The outcome of the PCA—the principal component—is a linear combination of variables where the coefficient of each variable indicates its importance or weight with respect to a given principal component. By summing the products of the input variables and the PCA coefficients, a PCA-based index is proposed. This is one of the data-driven procedures of index mining or a systematic search for optimal variable aggregation (Chao & Wu, 2017).

Secondly, PCA is used to provide a guideline for selecting indices taking into consideration their similarities and differences (Godshalk & Timothy, 1988; Morris et al., 2014). As indices that are designed for certain purposes share a certain level of similarity, determining the difference among actual measurements can provide a considerable amount of information in selecting a diversification index. Compared to using a simple correlation test, PCA has the advantages of dealing with a large number of variables and comparing in hierarchical order with respect to the relative importance of principal components. In this sense, principal components obtained from PCA can address the problem of collinearity (Chao & Wu, 2017). In this study, PCA is used to select a diversification index by analyzing their similarities and differences.

3.3.2.3 Selecting diversification index

Once principal components are derived, diversification indices are classified into either PC1 or PC2. In previous studies, the importance value (IV) of each index is measured to determine which is best able to differentiate principal components (Wilsey, Chalcraft, Bowles, & Willig, 2005). Here, IV synthesizes information based on the importance of each principal component and generates a value representing the overall ability of each diversification index to distinguish principal components (Morris et al., 2014). Previous studies, however, proposed using at least two measures; they failed in deriving an ideal index (Heino, Mykrä, & Kotanen, 2008; Stirling & Wilsey, 2001; Whittaker, 1972) as selecting a proper index requires the consideration of diverse situations and conditions. Thus, a comparison between principal components precedes index selection.

Following previous studies, the comparison among principal components is limited to PC1 and PC2 as they are the components that explain the data well. Between PC1 and PC2, the absolute value of the coefficient of each diversification index is compared. The coefficient of each principal component's variable is also regarded as the weight of the variable. In other words, the coefficient of a diversification index shows its level of importance with respect to that principal component. In this sense, the coefficients of a diversification index can be used to determine the principal component that diversification most affects. For instance, if the absolute value of PC1's variety is greater than that of PC2, it is assumed that PC1 is more influenced by variety than PC1. In this manner, each diversification index can be classified. One of the most important features of an index is whether it can show differences well. Among the list of diversification indices for each principal component, the one with the largest standard deviation (SD) is selected as the representative index; as a larger SD implies a wider spread of values, this can be seen as a reasonable approach.

3.4 Result

3.4.1 Case 1: Cross-section

In case 1, applicant-level technological diversifications in 2015 are measured and those of six different countries are compared. Tables 3-5, 3-7, and 3-9 show the descriptive statistics of the randomly selected 10,000 applicants in each country and Tables 3-6, 3-8, and 3-10 show the normalized SD of all indices; the principal component that each index is highly dependent on is described in parentheses. For countries in the low-level patent application groups that do not have sufficient applicants, the full sample is used. Here, YU is excluded as there were no patent applications in 2015 due to their separation in 2006. The bold values indicate the biggest SDs for both PC1 and PC2. The result is somewhat interesting because the results of the PCA among the six countries in each of the three groups are very alike. In this cross-sectional 2015 data set, the Gini-Simpson and the Rao-Stirling are shown to be the representative indices for PC1 and PC2, respectively. In the high-level patent application group, the 1/HHI is more affected by PC2 in CN. This may be due to the relatively higher average number of IPC sub-classes per applicant and active IPC sub-classes in CN, as the 1/HHI is more correlated to the Variety and the Rao-Stirling. Although the separation between PC1 and PC2 is apparent in the high-level patent application groups, the mid- and low-level patent application groups show few differences in their results as Variety is allocated to PC1 in BE, IT, the NL, the RU, the EA, the PH, and SI. However, these small differences do not influence the overall result as the representative indices are the same for all groups.

Table 3-5. Descriptive statistics of case 1 (High-level patent application group)

	US	JP	KR	DE	CN	EP
Total number of patents	17,523	20,438	22,337	15,760	70,872	14,315
Total number of applicants	10,000	10,000	10,000	10,000	10,000	10,000
Total number of IPCs	58,142	79,578	77,154	43,499	147,590	45,876
Average number of patent per applicant	1.80	2.22	2.60	1.91	7.31	1.57
Average number of IPC per applicant	5.81	7.96	7.71	4.35	15.76	4.59
Number of activated IPC	533	539	557	549	592	560

Table 3-6. Summarized result of case 1 (High-level patent application group)

	US	JP	KR	DE	CN	EP
Variety	0.03 (PC2)	0.032 (PC2)	0.027 (PC2)	0.03 (PC2)	0.033 (PC2)	0.023 (PC2)
HHI	0.28 (PC1)	0.293 (PC1)	0.299 (PC1)	0.287 (PC1)	0.331 (PC1)	0.281 (PC1)
Gini-Simpson	**0.29 (PC1)**	**0.303 (PC1)**	**0.31 (PC1)**	**0.297 (PC1)**	**0.335 (PC1)**	**0.29 (PC1)**
1/HHI	0.04 (PC1)	0.048 (PC1)	0.06 (PC1)	0.041 (PC1)	0.04 (PC2)	0.033 (PC1)
Entropy	0.139 (PC1)	0.151 (PC1)	0.155 (PC1)	0.138 (PC1)	0.157 (PC1)	0.129 (PC1)
Rao-Stirling	**0.216 (PC2)**	**0.202 (PC2)**	**0.193 (PC2)**	**0.142 (PC2)**	**0.162 (PC2)**	**0.202 (PC2)**

Table 3-7. Descriptive statistics of case 1 (Mid-level patent application group)

	BE	BR	IT	NL	RU	SE
Total number of patents	59	3,899	262	1,608	10,339	1,972
Total number of applicants	135	10,000	553	4,033	10,000	3,670
Total number of IPCs	462	33,460	1,754	13,441	31,011	19,377
Average number of patent per applicant	1.36	1.28	1.13	1.32	1.43	1.73

Average number of IPC per applicant	3.42	3.33	3.17	3.33	2.78	5.28
Number of activated IPC	60	200	200	391	496	412

Table 3-8. Summarized result of case 1 (Mid-level patent application group)

	BE	BR	IT	NL	RU	SE
Variety	0.13 (PC1)	0.022 (PC2)	0.138 (PC1)	0.027 (PC1)	0.056 (PC1)	0.024 (PC2)
HHI	0.307 (PC1)	0.282 (PC1)	0.262 (PC1)	0.275 (PC1)	0.271 (PC1)	0.287 (PC1)
Gini-Simpson	**0.336 (PC1)**	**0.291 (PC1)**	**0.322 (PC1)**	**0.29 (PC1)**	**0.291 (PC1)**	**0.308 (PC1)**
1/HHI	0.121 (PC1)	0.034 (PC2)	0.147 (PC1)	0.047 (PC1)	0.06 (PC1)	0.074 (PC1)
Entropy	0.223 (PC1)	0.125 (PC1)	0.245 (PC1)	0.134 (PC1)	0.162 (PC1)	0.165 (PC1)
Rao-Stirling	**0.256 (PC2)**	**0.213(PC2)**	**0.226 (PC2)**	**0.217 (PC2)**	**0.044 (PC2)**	**0.223 (PC2)**

Table 3-9. Descriptive statistics of case 1 (Low-level patent application group)

	BG	EA	MY	PH	SI	YU
Total number of patents	36	13	223	3,001	165	-
Total number of applicants	93	49	643	10,000	395	-
Total number of IPCs	1,140	164	2057	49,543	822	-
Average number of patent per applicant	1.28	1.04	1.38	1.28	1.17	-
Average number of IPC per applicant	12.3	3.35	3.20	4.94	2.08	-
Number of activated IPC	39	16	125	395	127	-

Table 3-10. Summarized result of case 1 (Low-level patent application group)

	BG	EA	MY	PH	SI	YU
Variety	0.285 (PC2)	0.215 (PC1)	0.055 (PC2)	0.081 (PC1)	0.115 (PC1)	-
HHI	0.262 (PC1)	0.215 (PC1)	0.266 (PC1)	0.272 (PC1)	0.271 (PC1)	-
Gini-Simpson	**0.349 (PC1)**	**0.323 (PC1)**	**0.293 (PC1)**	**0.316 (PC1)**	**0.325 (PC1)**	-
1/HHI	0.179 (PC1)	0.198 (PC1)	0.096 (PC1)	0.112 (PC1)	0.136 (PC1)	-
Entropy	0.333 (PC1)	0.31 (PC1)	0.174 (PC1)	0.213 (PC1)	0.23 (PC1)	-
Rao-Stirling	**0.352 (PC2)**	**0.312 (PC2)**	**0.229 (PC2)**	**0.338 (PC2)**	**0.24 (PC2)**	-

3.4.2 Case 2: Single Time Periods

In case 2, applicant-level technological diversification between 1996 and 2015 is measured. For each group, 10,000 applicants are randomly selected within this time period (Tables 3-11, 3-13, and 3-15). Among the high-level patent application group, the total number of patents and IPC sub-classes in JP are remarkably higher than in other countries. Here, the PCA result is consistent to case 1; the same indices are allocated to the same principal components. In case of the mid-level (low-level) patent application group, the result is almost similar except the 1/HHI (Variety) of IT (the PH) is classified to PC2 (PC1). However, this can be regarded as a minor difference as the representative indices for each principal component remain the same. In summary, the PCA results of case 2 are similar to case 1; the Gini-Simpson and the Rao-Stirling are the most important indices for each principal component (Tables 3-12, 3-14, 3-16). Therefore, applicant-level technological diversification in single time periods can be conducted from two different perspectives.

Table 3-11. Descriptive statistics of case 2 (High-level patent application group)

	US	JP	KR	DE	CN	EP
Total number of patents	39,258	82,227	22,782	27,095	14,723	12,556
Total number of applicants	10,000	10,000	10,000	10,000	10,000	10,000
Total number of IPCs	222,151	405,157	145,354	141,865	168,455	74,831
Average number of patent per applicant	2.21	3.42	2.23	1.93	2.91	1.36
Average number of IPC per applicant	10.99	12.97	7.22	7.78	8.99	5.95
Number of activated IPC	600	611	594	602	611	582

Table 3-12. Summarized result of case 2 (High-level patent application group)

	US	JP	KR	DE	CN	EP
Variety	0.038 (PC2)	0.047 (PC2)	0.035 (PC2)	0.045 (PC2)	0.028 (PC2)	0.037 (PC2)
HHI	0.298 (PC1)	0.295 (PC1)	0.316 (PC1)	0.306 (PC1)	0.328 (PC1)	0.295 (PC1)
Gini-Simpson	**0.308 (PC1)**	**0.301 (PC1)**	**0.323 (PC1)**	**0.313 (PC1)**	**0.331 (PC1)**	**0.311 (PC1)**
1/HHI	0.053 (PC1)	0.073 (PC1)	0.066 (PC1)	0.053 (PC1)	0.043 (PC1)	0.072 (PC1)
Entropy	0.163 (PC1)	0.194 (PC1)	0.168 (PC1)	0.165 (PC1)	0.161 (PC1)	0.163 (PC1)
Rao-Stirling	**0.227 (PC2)**	**0.153 (PC2)**	**0.163 (PC2)**	**0.212 (PC2)**	**0.22 (PC2)**	**0.234 (PC2)**

Table 3-13. Descriptive statistics of case 2 (Mid-level patent application group)

	BE	BR	IT	NL	RU	SE
Total number of patents	8,013	18,361	15,974	16,877	23,745	22,162
Total number of applicants	10,000	10,000	10,000	10,000	10,000	10,000
Total number of IPCs	53,494	80,658	41,408	54,591	60,949	80,647
Average number of patent per applicant	1.25	1.39	1.33	1.394	1.59	1.61
Average number of IPC per applicant	4.29	5.98	3.18	3.73	3.96	5.22

Number of activated IPC	557	586	599	580	585	580

Table 3-14. Summarized result of case 2 (Mid-level patent application group)

	BE	BR	IT	NL	RU	SE
Variety	0.045 (PC2)	0.046 (PC2)	0.032 (PC2)	0.033 (PC2)	0.048 (PC2)	0.04 (PC2)
HHI	0.299 (PC1)	0.301 (PC1)	0.296 (PC1)	0.298 (PC1)	0.303 (PC1)	0.3 (PC1)
Gini-Simpson	**0.314 (PC1)**	**0.31 (PC1)**	**0.302 (PC1)**	**0.306 (PC1)**	**0.316 (PC1)**	**0.312 (PC1)**
1/HHI	0.007 (PC1)	0.055 (PC1)	0.036 (PC2)	0.034 (PC1)	0.06 (PC1)	0.064 (PC1)
Entropy	0.168 (PC1)	0.162 (PC1)	0.134 (PC1)	0.142 (PC1)	0.169 (PC1)	0.167 (PC1)
Rao-Stirling	**0.197 (PC2)**	**0.252 (PC2)**	**0.14 (PC2)**	**0.173 (PC2)**	**0.177 (PC2)**	**0.169 (PC2)**

Table 3-15. Descriptive statistics of case 2 (Low-level patent application group)

	BG	EA	MY	PH	SI	YU
Total number of patents	9,776	11,905	13,372	5,624	13,753	4,826
Total number of applicants	10,000	10,000	10,000	10,000	10,000	10,000
Total number of IPCs	172,308	100,316	74,641	52,722	114,314	179,565
Average number of patent per applicant	1.44	1.32	1.33	1.26	1.38	1.23
Average number of IPC per applicant	13.77	7.93	5.96	5.08	8.40	15.52
Number of activated IPC	543	540	533	488	559	489

Table 3-16. Descriptive statistics of case 2 (Low-level patent application group)

	BG	EA	MY	PH	SI	YU
Variety	0.054 (PC2)	0.048 (PC2)	0.048 (PC2)	0.08 (PC1)	0.042 (PC2)	0.077 (PC2)
HHI	0.283 (PC1)	0.27 (PC1)	0.3 (PC1)	0.279 (PC1)	0.278 (PC1)	0.253 (PC1)
Gini-Simpson	**0.307 (PC1)**	**0.289 (PC1)**	**0.315 (PC1)**	**0.316 (PC1)**	**0.292 (PC1)**	**0.276 (PC1)**

1/HHI	0.093 (PC1)	0.073 (PC1)	0.062 (PC1)	0.104 (PC1)	0.061 (PC1)	0.083 (PC1)
Entropy	0.196 (PC1)	0.163 (PC1)	0.174 (PC1)	0.216 (PC1)	0.155 (PC1)	0.183 (PC1)
Rao-Stirling	**0.3 (PC2)**	**0.285 (PC2)**	**0.174 (PC2)**	**0.31 (PC2)**	**0.302 (PC2)**	**0.301 (PC2)**

3.4.3 Case 3: Multiple Time Periods

In case 3, technological diversifications are measured across four different time periods. Among the 18 countries, the US, the NL, and the PH are selected for each group. Here, PCA is conducted on the same sample from case 2, but separated by time periods. Among the six principal components, PC1 and PC2—which explain the majority of the data's characteristics (Tables 3-17, 18, 19)—are compared. Similar to the previous cases, a clear distinction between PC1 and PC2 is observed (Figures 3-3, 3-4, 3-5). In most cases, the HHI, the Gini-Simpson, the 1/HHI, and Entropy are spread along PC1 while mainly only Variety and the Rao-Stirling change with PC2. This indicates that for analyzing diversification within a single country with multiple time periods, two different aspects of diversification indices can be used.

Table 3-17. Summarized result of case 3 (US)

	1996-2000	2001-2005	2006-2010	2011-2015
Variety	0.057 (PC2)	0.039 (PC2)	0.047 (PC2)	0.05 (PC2)
HHI	0.289 (PC1)	0.294 (PC1)	0.3 (PC1)	0.302 (PC1)
Gini-Simpson	**0.31 (PC1)**	**0.304 (PC1)**	**0.319 (PC1)**	**0.314 (PC1)**
1/HHI	0.082 (PC1)	0.048 (PC1)	0.092 (PC1)	0.068 (PC1)
Entropy	0.18 (PC1)	0.155 (PC1)	0.203 (PC1)	0.19 (PC1)
Rao-Stirling	**0.241 (PC2)**	**0.237 (PC2)**	**0.229 (PC2)**	**0.248 (PC2)**

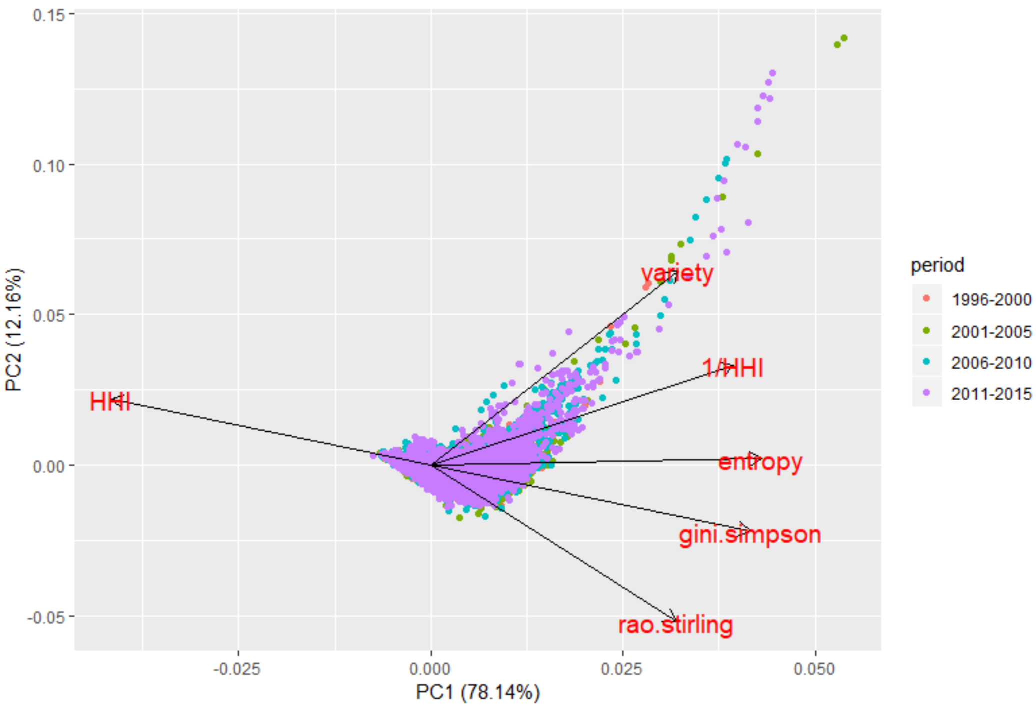

Figure 3-3. PCA result of case 3 (US)

Table 3-18. Summarized result of case 3 (NL)

	1996-2000	2001-2005	2006-2010	2011-2015
Variety	0.058 (PC2)	0.07 (PC2)	0.061 (PC2)	0.042 (PC2)
HHI	0.293 (PC1)	0.302 (PC1)	0.3 (PC1)	0.295 (PC1)
Gini-Simpson	**0.315 (PC1)**	**0.322 (PC1)**	**0.322 (PC1)**	**0.303 (PC1)**
1/HHI	0.083 (PC1)	0.089 (PC1)	0.09 (PC1)	0.04 (PC2)
Entropy	0.194 (PC1)	0.204 (PC1)	0.195 (PC1)	0.141 (PC1)
Rao-Stirling	**0.147 (PC2)**	**0.163 (PC2)**	**0.195 (PC2)**	**0.203 (PC2)**

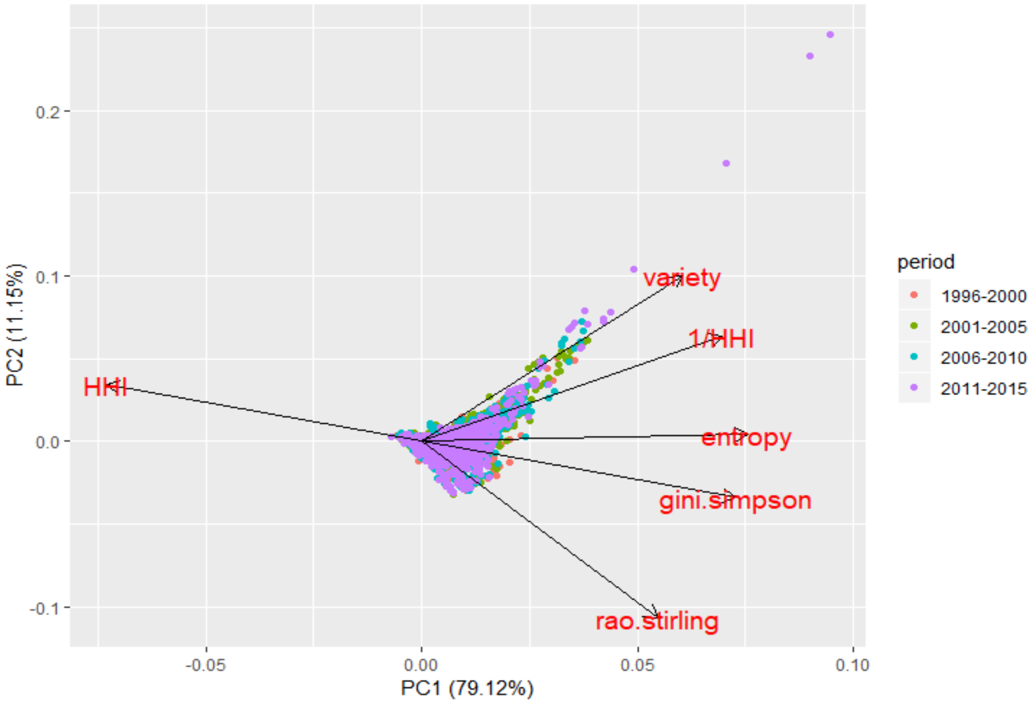

Figure 3-4. PCA result of case 3 (NL)

Table 3-19. Summarized result of case 3 (PH)

	1996-2000	2001-2005	2006-2010	2011-2015
Variety	0.17 (PC1)	0.162 (PC1)	0.19 (PC1)	0.077 (PC1)
HHI	0.277 (PC1)	0.278 (PC1)	0.267 (PC1)	0.279 (PC1)
Gini-Simpson	**0.323 (PC1)**	**0.338(PC1)**	**0.354 (PC1)**	**0.316 (PC1)**
1/HHI	0.167 (PC1)	0.156 (PC1)	0.189 (PC1)	0.103 (PC1)
Entropy	0.251 (PC1)	0.279 (PC1)	0.291 (PC1)	0.215 (PC1)
Rao-Stirling	**0.337 (PC2)**	**0.253 (PC2)**	**0.204 (PC2)**	**0.311 (PC2)**

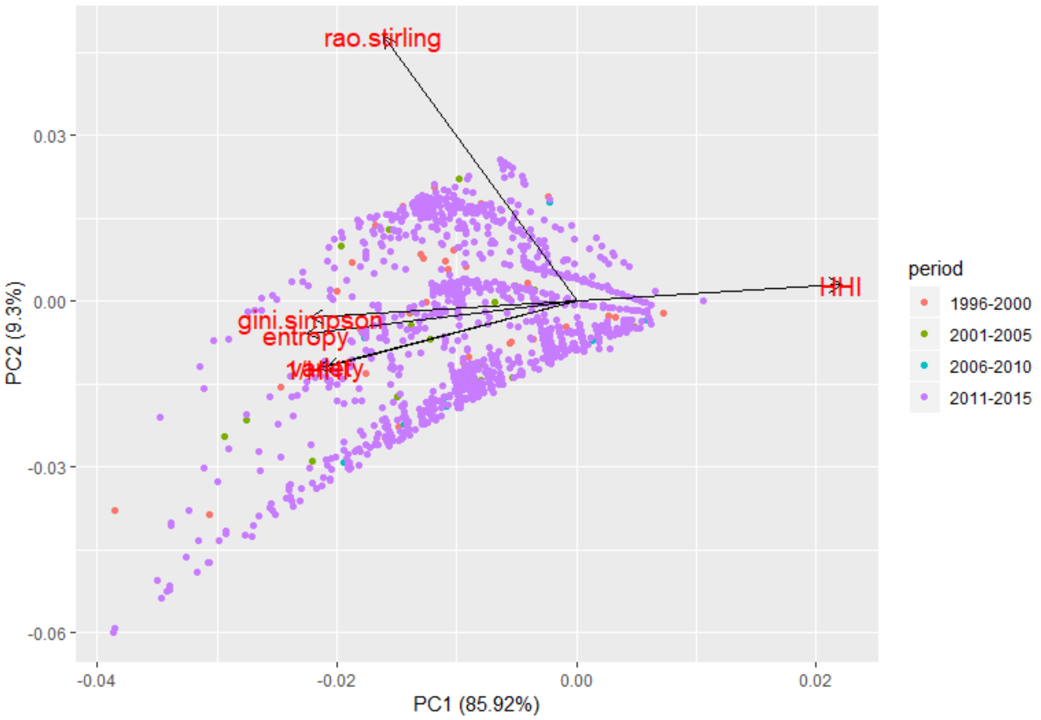

Figure 3-5. PCA result of case 3 (PH)

3.5 Conclusion

Although diversification has been discussed in various studies, a prior assessment for the selection of a diversification index has not yet been discussed. Since all diversity indices were designed to measure diversity with respect to its own interest, it may cause inconsistent results when used in empirical studies. In this study, the selection of a diversification index has been empirically analyzed with technological diversity indices using patent data taking into consideration three cases. One of the key issues in using PCA for testing indices is the sample size of the databases (Chao & Wu, 2017). For instance, if the number of observations is less than the number of variables, PCA can be influenced by the outliers in the database and the results will not be consistent (Hastie, Tibshirani, & Jerome, 2009). By using a large sample size of quality, universally accessible patent data, the PCA result is stabilized and reliable (Hastie et al., 2009). By covering the most frequently used cases in previous studies, the results of this study can be implemented in subsequent studies. As a result, the interesting findings are those related to improving the understanding of diversity.

Firstly, a clear distinction among diversification indices is observed in all cases. As a result of the PCA, the diversification indices are separated into two groups based on principal components: the HHI, the Gini-Simpson, the 1/HHI, and Entropy for PC1 and Variety and the Rao-Stirling for PC2. This is somewhat consistent with Stirling's (Stirling, 2007) framework as PC1 represents balance and PC2 represents both variety and disparity. Since theories or existing evidence supporting index outcomes are important (Chao & Wu, 2017), proposing two diversification perspectives is reliable and supported by Stirling's (Stirling, 2007) framework. In this context, diversification can be explained using two perspectives of diversification: balance-centered and hetero-centered diversification (Figure 3-6). Balance-centered diversification refers to the balance of diversification where the proportions of elements are the targets of interest. On the other hand, hetero-centered diversification refers to the variety and disparity of diversification, which focuses on the degree of differentiation among elements. In addition, the variables with the biggest SD are shown to be the Gini-Simpson and the Rao-Stirling. A bigger SD implies that the variations in the indices are more observable. In this respect, the Gini-Simpson and the Rao-Stirling are recommended for observing PC1 and PC2.

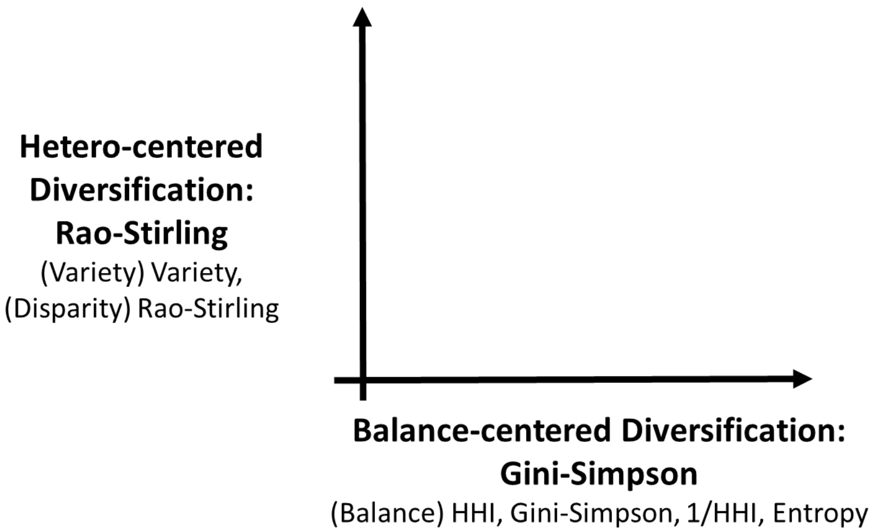

Figure 3-6. Two diversification perspectives

To supplement the selection of these two indices, a comparison among diversification indices for each diversification perspective is conducted. Figure 3-7 shows the time-series graph of balance-centered diversification in the US. Here, the size of each dot indicates the average number of IPC sub-classes used for patent applications. Although all these diversification indices show similar variations, the Gini-Simpson appears to accurately reflect diversification changes and reality. From 2000 to 2001, a great shift in technological diversification occurred, incrementing the use of numerous IPC sub-classes. Compared to other indices, the Gini-Simpson increased by a greater value, indicating that it detects diversification changes more clearly. Another interesting point is between 2008 and 2009 when the financial crisis occurred; the Gini-Simpson showed a more reasonable outcome as it shows the smallest changes in that time period. In the case of hetero-centered diversification, Figure 3-8 shows the time-series graph of hetero-centered diversification where the size of each dot indicates the total number of unique IPC sub-classes. Compared to Variety, the Rao-Stirling describes hetero-centered diversification more clearly. For instance, the Rao-Stirling experienced a greater increase between 2000 and 2001 and no changes between 2008 and 2009. Since Variety can only determine the number of IPC sub-classes used for a patent application, the level of heterogeneity for diversification is underestimated, a characteristic which is highlighted by the Rao-Stirling. In addition, although lesser or no diversification increment was expected in 2008 and 2009, Variety increased while the Rao-Stirling remained the same. This shows that the two representative diversification indices for each diversification perspective not only captures the variation well, but also reflects reality in a more reasonable sense.

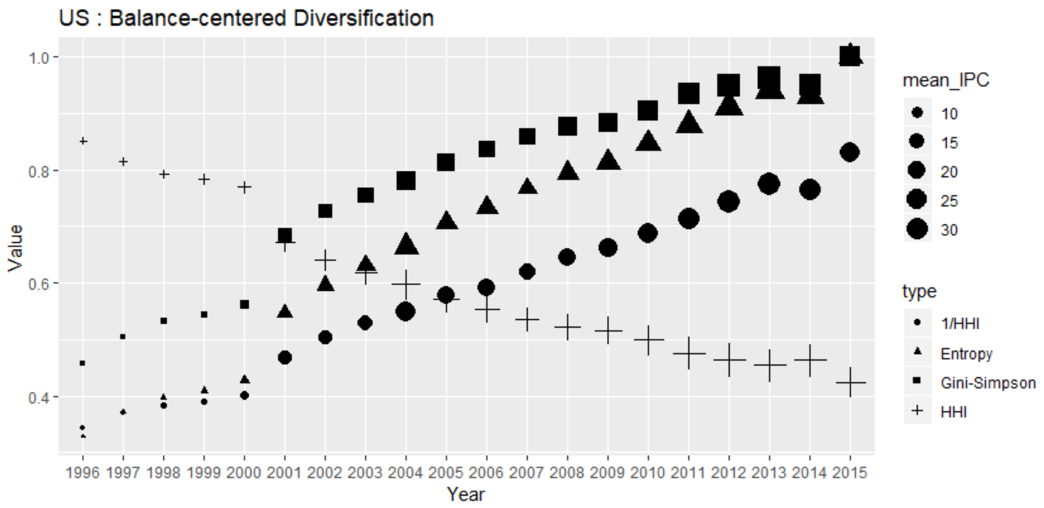

Figure 3-7. Balance-centered diversification indices (US)

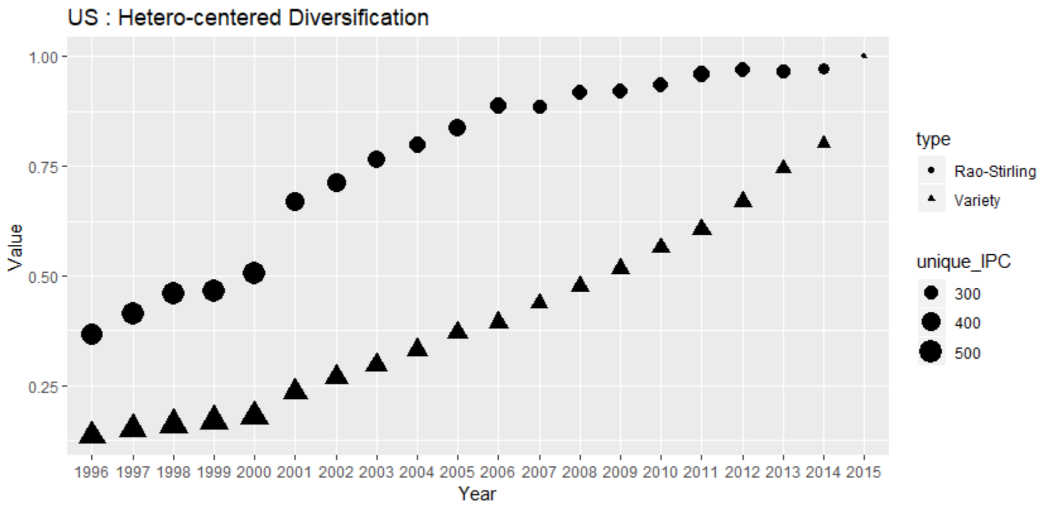

Figure 3-8. Hetero-centered diversification indices (US)

With these two perspectives of diversification indices, interesting findings can be obtained. If diversification is discussed with a single diversification index, only limited information about diversification is used. For instance, comparing the diversification of applications in each country only tells us the degree to which it either increases or decreases. Two perspectives of diversification clarify how the applicants in each country achieved diversification either in balance or heterogeneity. Figures 3-9, 3-10, and 3-11 show the result of the empirical analysis based on two perspectives of diversification indices. These figures show the average normalized diversification perspective for each five-year time period. Here, the size of each point indicates the average usage of IPC sub-classes per patent application. As diversification is measured with reference to each country, only comparisons of both increases or decreases in values are allowed.

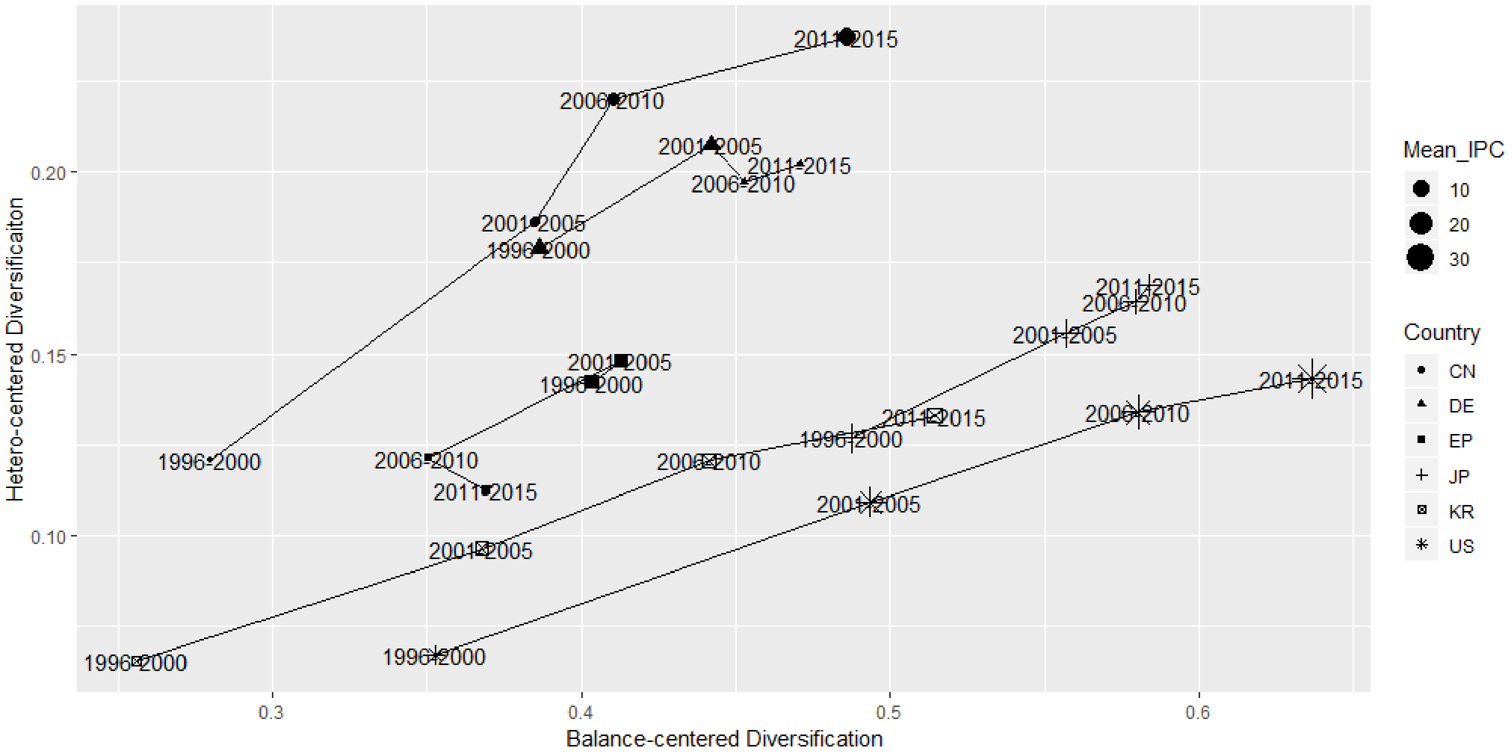

Figure 3-9. Comparison among countries using two diversification perspectives (High-level patent application group)

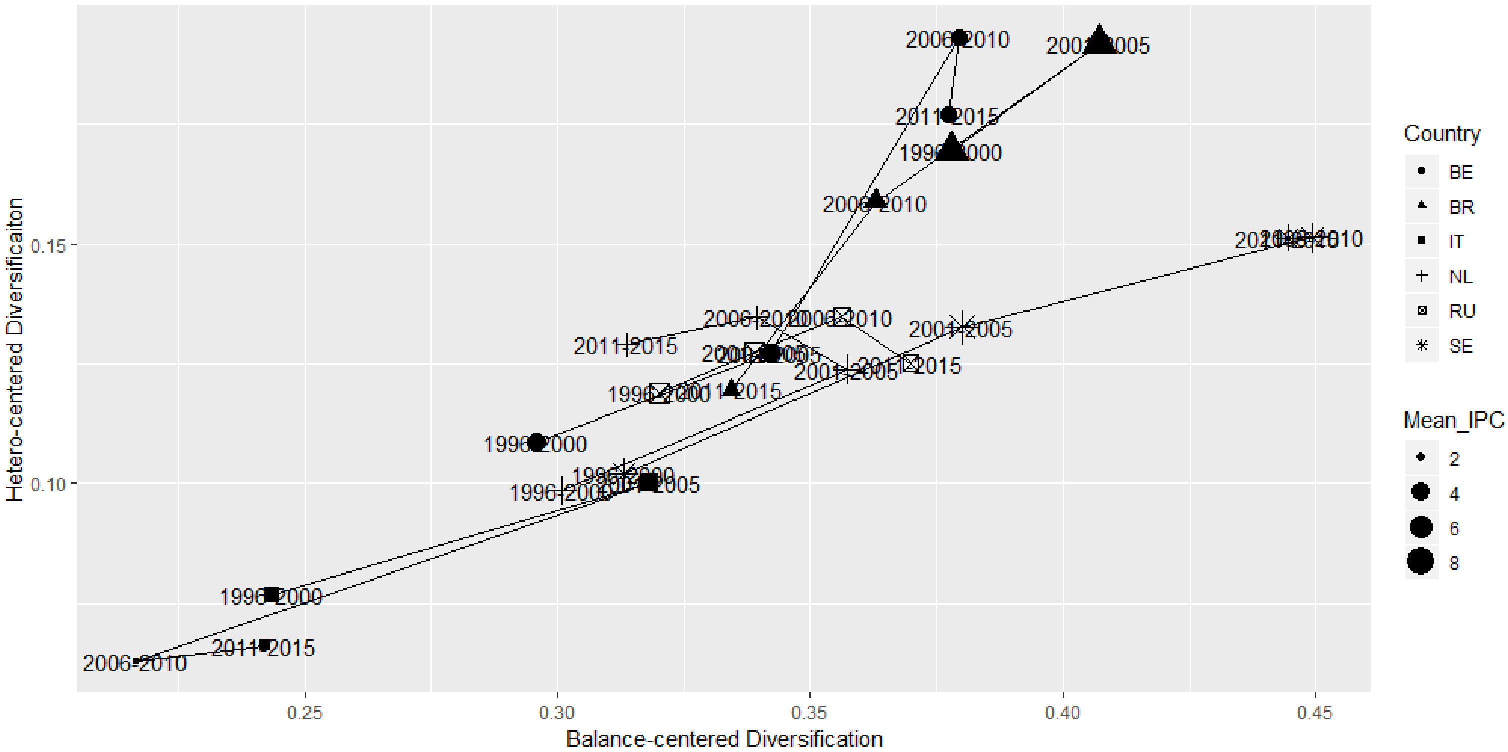

Figure 3-10. Comparison among countries using two diversification perspectives (Mid-level patent application group)

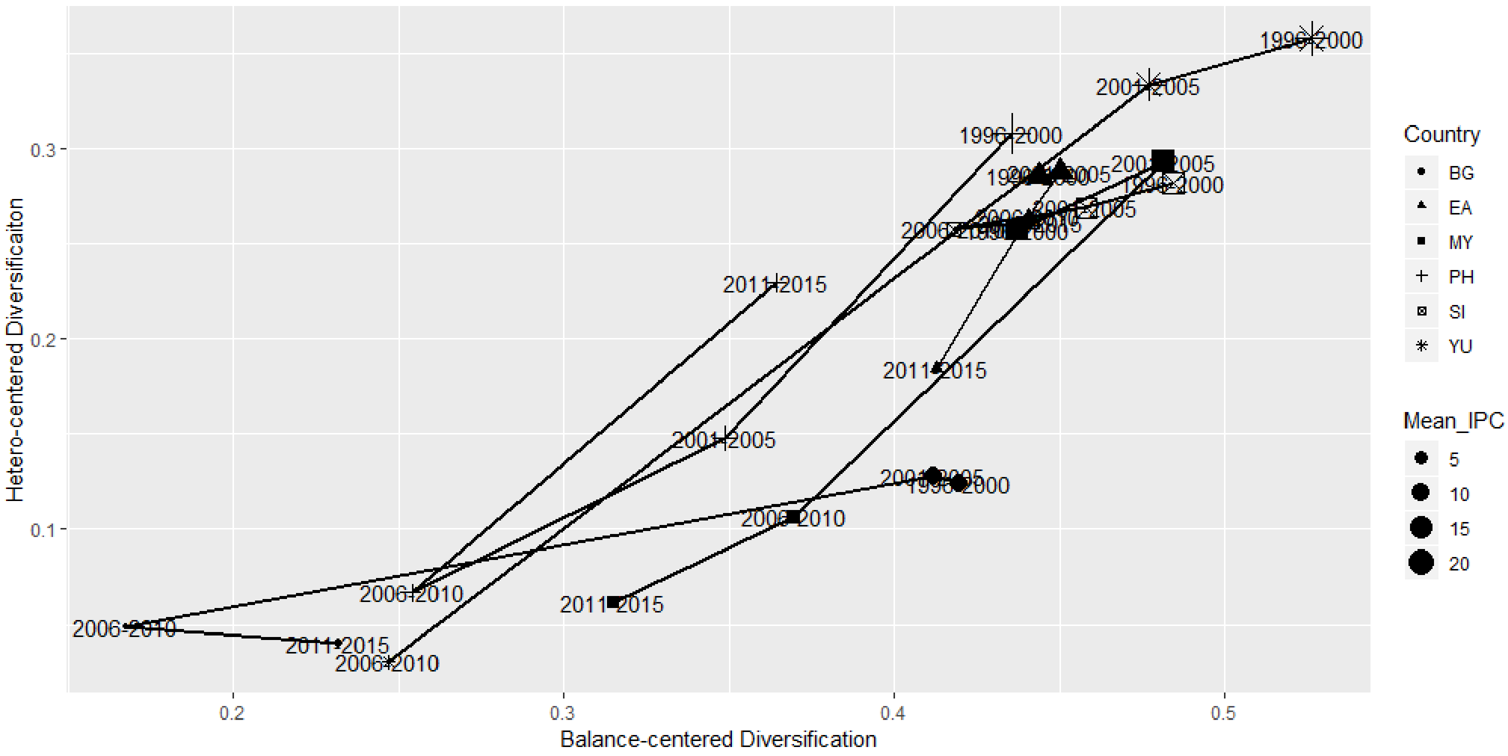

Figure 3-11. Comparison among countries using two diversification perspectives (Low-level patent application group)

For the high-level patent application group, a clear increase in both diversification perspectives are observed (Figure 3-9). In the case of DE and EP, slight decreases in 2006–2010 and 2011–2015 are observed as a consequence of the financial crisis. The countries (all except CN) familiar with applying for numerous IPC sub-classes for patent applications tend to move more horizontally, seeking balance-centered diversification. On the other hand, CN's technological diversification is more focused on hetero-centered diversification. This is a reasonable finding as CN is known to achieve dramatic increases in technological development in a very short period of time. From these findings, the differences in the trajectories of technological diversification regarding the maturity of technological application are observed.

For the mid-level patent application group, more dynamic fluctuations in both diversification perspectives are observed (Figure 3-10). As observed from the high-level patent application group, most European countries show decreases around the financial crisis. SE tended to maintain technological diversification with a smaller decrease. SE is one of the countries with the highest number of patent applications per person and is also known as a leader in information technology; they were ranked second place in the world IT report in 2008. SE's accumulated strength in technological potential and competitiveness in information technology seem to contribute to the maintenance of technological diversification. On the other hand, BR's diversification started to decrease after 2001–2005 as a consequence of the financial crisis in 1999.

For the low-level patent application group, the fluctuation is much more dynamic (Figure 3-11). Save for the PH, the decrease in technological diversification is an acceptable outcome as it can be interpreted with reference to their economic situation. Here, the interesting point is the case of the PH. As a result of the financial crisis in 1997, the PH's technological diversification decreased dramatically. Following the stabilization of both its politics and economy, however, the PH maintained an average of 6% in economic growth since 2010. Since diversification activities can be strengthened with stabilized economic conditions, this result can be regarded as a reliable outcome.

Lastly, the implications of two diversification perspectives can be extended to the level of industry effects. Figures 3-12, 3-14, 3-16, and 3-18 show the time-series graphs of representative diversification indices in the US, DE, CN, and KR while Figures 3-13, 3-15, 3-17, and 3-19 show the industry proportion of diversification classified by IPC sub-class. These countries show a steady growth in diversification with slight differences in variations. Here, interesting findings are observed as variations in technological diversification are closely related to changes in industry proportion. Especially for the US and KR, the influence of information and communication technologies (ICT) (Sections G and H) seems to be greater than others. Since technological convergence occurs more frequently using ICT technologies, these technologies can be regarded as a driving force for technological diversification. This tells us that in order to maintain a consistent growth of diversification, continuous investment on certain industries is needed. Overall, the contributions of this study can be implemented in further studies. Firstly, the two perspectives of diversification are proposed. It not only proves Stirling's (Stirling, 2007) framework empirically, but also provides generalized insights by covering most frequently used cases. Secondly, it can be used as a reference for the selection of a diversification index. As mentioned earlier, the selection of a diversification index is necessary as the results of the analysis can differ depending on the characteristics of the index. Since this result is derived from the empirical analysis, it can provide reliable evidence for this matter. This study can also be used as a reference for a more systematic mode of index selection, in particular for those interested in the quantitative aspects of science.

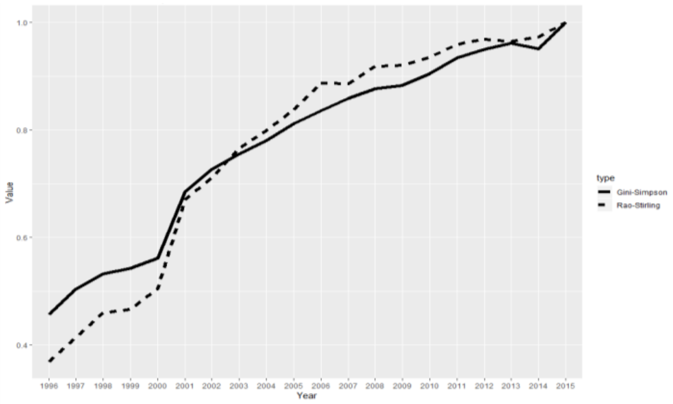

Figure 3-12. Representative diversification indices (US)

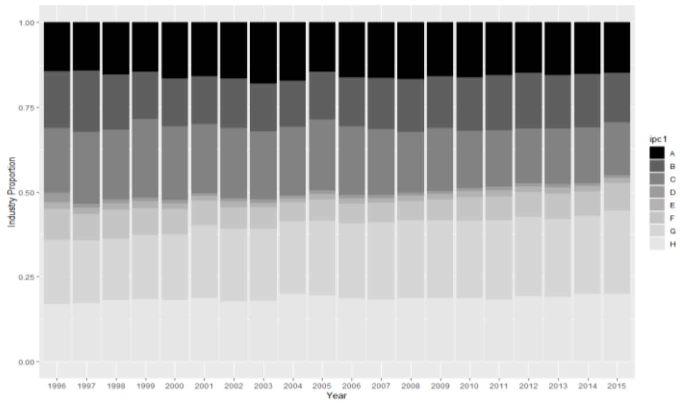

Figure 3-13. Industry proportion on diversification (US)

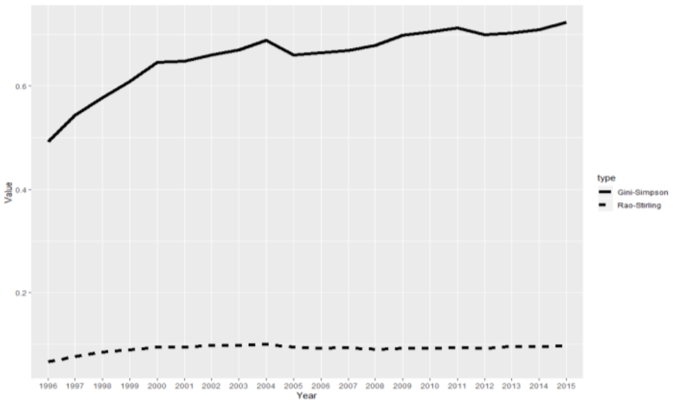

Figure 3-14. Industry proportion on diversification (DE)

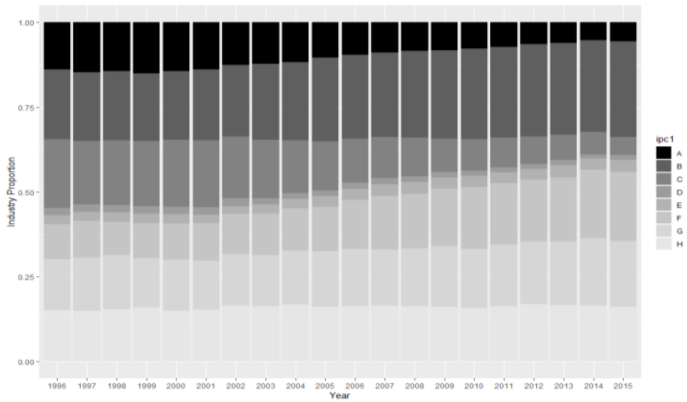

Figure 3-15. Industry proportion on diversification (DE)

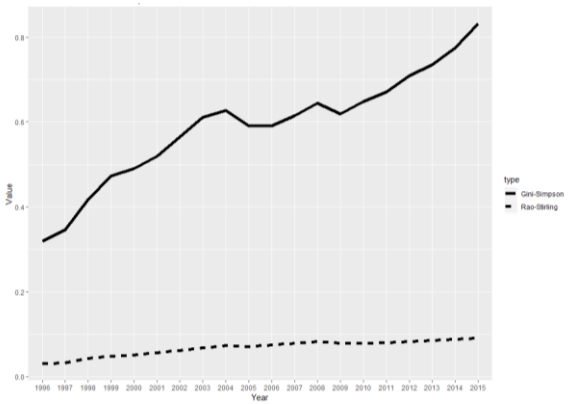

Figure 3-16. Representative diversification indices (CN)

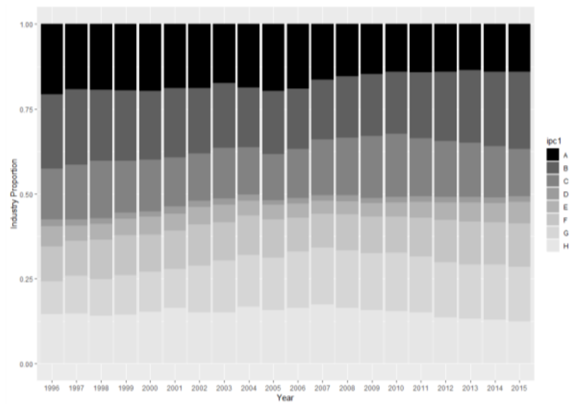

Figure 3-17. Industry proportion on diversification (CN)

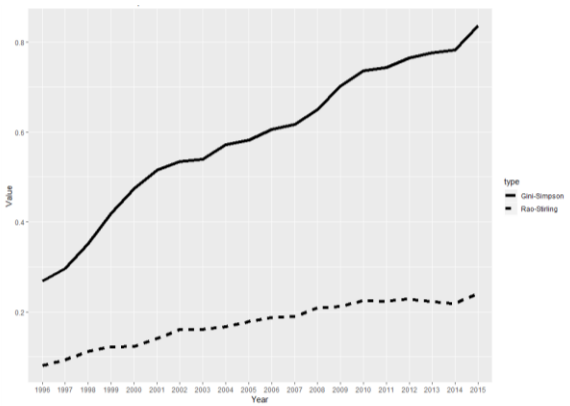

Figure 3-18. Industry proportion on diversification (KR)

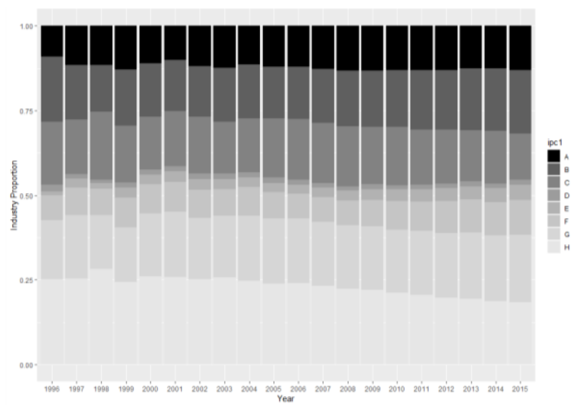

Figure 3-19. Industry proportion on diversification (KR)

Chapter 4. Effects of firm-level diversifications of market, product, and technology on performance: Focused on diversity property

4.1 Introduction

Diversification is an important issue in strategic management (Montgomery, 1994; Palepu, 1985; Penrose, 1995; Zander & Zander, 2005). Although there are some debates concerning the effect of diversification, it is continuously discussed alongside the development of new and diverse markets. The reasons for diversification can be explained by following two theoretical perspectives (Wan et al., 2011). In the field of industrial organization, the importance of diversification was investigated by its relation to market power (Berry, 1971; Gort, 1962; Utton, 1979). Here, agency theory explains that diversification is implemented to lower risk (Amihud & Lev, 1981) and secure a market position (Shleifer & Vishny, 1989).

On the other hand, strategic management researchers focused on the relationship between diversification and firm performance. The central premise of the resource-based view is that a firm’s competitiveness relies on its resources and capabilities (Peteraf & Barney, 2003). Firm resources, not market factors, limit a firm’s potential growth and choice of business (Penrose, 1995). Through the diversification of resources, a firm can achieve economies of scope (Penrose, 1995), which can lead to the enhancement of the firm’s competitive advantage. In this sense, if a firm possesses the necessary resources to make diversification economically feasible, diversification can be adopted in its strategy (Teece, 1982; Wan et al., 2011; Wernerfelt, 1984).

From a managerial standpoint, however, diversification is a complex and risky task as it requires new skills, technologies, and facilities (Ansoff, 1957). In addition, a firm’s strategic decisions are not always unified across its value chains. For instance, a firm’s diversification strategy for R&D and commercialization may not the same depending on its business circumstances. Based on previous studies, the focus of a firm’s diversification activities are aimed at either the firm’s market/product (Chavas & Kim, 2010; Gemba & Kodama, 2001; Michael Gort, 1962) or technology (Breschi et al., 2003; Garcia-Vega, 2006; Quintana-García & Benavides-Velasco, 2008).

Previous studies, however, also showed the following limitations when analyzing a firm’s diversification activities. Firstly, market and product diversifications are not clearly distinguished. In previous studies, a firm’s diversification is measured using sales information depending on the Standard Industrial Classification (SIC). By definition, using the SIC is more likely to refer to industry diversification, which is defined as a firm’s activity in more than one kind of product segment or market (Sirmon et al., 2007). However, it is the most general approach as it reflects the overall outcome of a firm’s diversification and can be easily implemented using product financial data (Chavas & Kim, 2010; Gemba & Kodama, 2001; Gort, 1962). Since a firm’s diversification strategies with respect to its market and product may not be consistent, the separation of market and product diversification can provide more meaningful implications. Secondly, diversification indices are measured from a simple perspective. In diversification studies, the role of the index is crucial as the result can differ due to the method of measurement (Morris et al., 2014). The problem is that diversification cannot be simply defined as it contains three different properties: variety (the number of unique elements), balance (the proportion of elements), or disparity (the difference between elements) (Stirling, 2007). Therefore, the result may be biased due to the properties of diversification it focuses on if a certain diversification index is selected for measurement.

This study investigates the effects of firm-level diversification on business and innovation performance. Here, firm-level diversification contains market, product, and technological diversification. In previous studies, market, product, and technological diversification are analyzed separately as distinctive phenomena or alternative routes to growth (Stephan, 2002). This study considers all three diversification activities; instead of adopting a previous approach, market and product diversification are measured by the actual number of markets entered into and products developed by a firm. By doing so, a firm's diversification from the resource-based view can be clarified and separate implications can be derived. In addition, firm-level diversification is measured with two different diversification perspectives: balance-centered (Gini-Simpson) and hetero-centered (Rao-Stirling) diversification. With these two diversification models, the understanding of firms' diversification with respect to the properties of diversity can be enhanced. For the empirical analysis, the case of the US pharmaceutical industry is selected and an integrated data set comprising three different data sets is used: product data from Medtrack and the Orange Book, firm data from Compustat, and patent data from the LexisNexis Total Patent database.

In the remainder of this chapter, Section 2 reviews the theoretical backgrounds for firm-level diversification effects and diversification measurements. Section 3 describes the data and methods used in this study. Lastly, the results and conclusions are set out in Sections 4 and 5.

4.2 Literature review

4.2.1 Diversification perspectives

From previous studies, a single diversification index was selected to measure diversification. In most cases, the interpretation of a selected diversification measurement leads to the straightforward conclusion as to whether there is diversification or not. Diversification, however, is not a subject capable of simple interpretation as it can be interpreted with different properties. In this respect, this study adopts Stirling's (2007) diversity framework to consider the three different properties of diversification (variety, balance, and disparity). Variety refers to the number of entities measured (Macarthur, 1965). Simply put, it measures the number of unique entities. Balance refers to the proportion of elements across categories. Like the meanings of "evenness" in ecology (Pielous, 1977) and “concentration” in economics (Finkelstein & Friedberg, 1967), it captures the distribution of elements. Disparity measures the distance between elements and highlights both the variety and disparity of diversification.

These properties do not exist independently and more importantly, there is no such index that can be clearly defined with a single property (Stirling, 1998). In other words, any diversification index can be used in diversification studies but the differences between the points of interest of each property of diversification remains. Instead of selecting a single diversification index, thus, this study categorizes diversification into two perspectives: balance-centered and hetero-centered. Balance-centered diversification reflects the balance of diversification. It is the most widely used concept of diversification as it indicates whether only certain elements are diversified or if the diversification is equally balanced (Bas & Patel, 2005; Garcia-Vega, 2006; Lin & Chang, 2015; Quintana-García & Benavides-Velasco, 2008). Among various diversification indices such as the HHI, the Gini-Simpson, and Entropy, the Gini-Simpson is adopted to measure balance-centered diversification. On the other hand, hetero-centered diversification highlights the variety and disparity of diversification. As variety and disparity strongly depend on the uniqueness of elements, the Rao-Stirling, the only measurement that considers disparity, is chosen. Hetero-centered diversification captured by the Rao-Stirling tells us the level of heterogeneity in diversification by highlighting the differences between each of the elements.

Referring to previous studies, the interpretation of these two diversification perspectives should be clarified in relation to existing expressions of diversification. As mentioned earlier, the most generally adopted diversification property is balance and its existing expression is classified into two types: diversification or less diversification. In terms of balance, diversification implies a concentrated proportion while less diversification reflects a balanced proportion. In this sense, greater (less) diversification in previous studies indicates less (greater) balance-centered diversification. In the case of hetero-centered diversification, a similar approach can be implemented. Basically, hetero-centered diversification shows whether diversification is accomplished with heterogeneity or less heterogeneity. Based on the previous approach, concentration implies not only a concentration of elements, but also the presence of new elements. This is because the proportion of a heterogeneous element must be small compared to existing elements, making diversification appear concentrated. However, this may not always be consistent with the measurement of hetero-centered diversification, because the proportion of elements is also included in the calculation. Since hetero-centered diversification has not been proposed in previous studies, both interpretations of the concentration and balance of diversification are allowed for hetero-centered diversification. A summary of the interpretation of diversification perspectives is set out in Table 4-1.

Table 4-1. Interpretation of diversification perspectives

Previous approach	Balance-centered diversification	Hetero-centered diversification
Diversification ↑ = Concentrated	Balance-centered diversification ↓ = Concentrated	Hetero-centered diversification ↑ = Heterogeneous = Concentrated or Balanced
Diversification ↓ = Balanced	Balance-centered diversification ↑ = Balanced	Hetero-centered diversification ↓ = Less heterogeneous = Balanced or Concentrated

4.2.2 Market/product diversification

Market diversification refers to firms entering different markets by leveraging their own resources or capabilities (Wan et al., 2011) while product diversification refers to the production of different products. In the case of market/product diversification, diversification can be measured by either geography or type. The geographical aspect of market/product diversification, also known as international diversification, focuses on where the product is merchandized (Lee, Hooy, & Hooy, 2012; Oh et al., 2015; Singh et al., 2010). For instance, a firm's attempt to do business in other countries or regions is a geographical market diversification. However, as more firms become globalized, the barriers to entry of the international market become lower than before and, more importantly, customers begin to expect higher quality and lower cost in the global market. In other words, competition has shifted from global markets or international businesses to new product development (Hitt et al., 1997).

The effects of type-based market/product diversification are widely investigated (Fukui & Ushijima, 2007). Type-based market/product diversification refers to a firm's possession of various market or product types. In order to analyze market/product diversification, a closer consideration of the types of diversification and industry structures is needed. In previous studies, market and product diversification are measured with reference to the SIC without separating the two, although each of them refers to a different aspect (Chavas & Kim, 2010; Gemba & Kodama, 2001; Gort, 1962). For instance, let us assume that there are two firms, firm A and firm B. Firm A enters into two different markets with the same products and firm B enters into a single market with different products. In this case, both firms' methods of approaching diversification are different as each of them pursue different diversification activities. If the existing approach is adopted for this case, however, this difference cannot be observed. With the existing approach, there are always limitations in deriving the strategic implications for a firm's actual activities.

In this study, market and product diversification are measured separately by following their definitions. Market diversification indicates the degree of diversification in the market type where a firm's product is merchandized and product diversification refers to the degree of diversification in the function of a firm's developed products. For measuring market and product diversification, a firm's product information is used instead of overall sales classified by industry classification. A firm's merchandized products are a good yardstick by which a firm's capability or strategy can be observed, as it is an outcome of the firm's overall activity. In addition, a firm's involvement in both market and product diversification can be observed with reference to the firm's merchandized products because they tell us where it is merchandized and what functions or components it has.

4.2.2.1 Market/product diversification and business performance

According to the resource-based view, a firm's diversification strategy can enhance a firm's efficiency through synergistic resource sharing or economies of scope (Penrose, 1995; Teece, 1982; Wan et al., 2011; Wernerfelt, 1984). Through the coordination or allocation of its core resources, a firm can enhance its competitive advantage (Borda, Geleilate, Newburry, & Kundu, 2017; Chang & Wang, 2007; Lee, Huang, & Chang, 2017; Li & Greenwood, 2004). From this perspective, a market/product diversification strategy has a significant influence on the performance of firms (Geringer, Beamish, & DaCosta, 1989; Hitt et al., 1997; Kim, Hwang, & Burgers, 1989). In the case of multinational firms, international diversification allows flexibility in diversity and complexity (Chang & Wang, 2007). By diversifying positions or sales in different industries or markets, diversified firms can secure stronger market power than non-diversified firms (Gemba & Kodama, 2001).

On the other hand, diversification negatively influences performance as the divergence from a firm's core business makes firms face increased risks and transaction costs (Hitt, Hoskisson, & Ireland, 1994; Jones & Hill, 1988). Fukui & Ushijima (2007) used the Herfindhal index to measure diversification and found that diversification has a negative effect on firm performance. This negative effect may be mitigated by diversifying to closely related industries. On the contrary, Singh et al. (2010) investigate the effect of product and geographic diversification, measured using the 1-HHI (or the Gini-Simpson), on the performance of small and medium enterprises. This is consistent with the work of Fukui & Ushijima (2007), as a positive measure of the Gini-Simpson implies a less diverse or more balanced diversification. Chang and Wang (2007) showed that multinational firms' related-product diversification, measured by Entropy, causes performance gains and unrelated-product diversification negatively moderates the international-diversification–performance relationship. Oh et al. (2015) found that product diversification, measured by Entropy, negatively moderates the effect of inter-regional diversification on performance. In other words, developing diverse products can hinder the regional effects of diversification. With respect to markets and products, therefore, the positive effects of hetero-centered diversification and the negative effects of balance-centered diversification on business performance can be assumed.

H1. Balance-centered market/product diversification positively influences business performance.

H2. Hetero-centered market/product diversification negatively influences business performance.

4.2.2.2 Market/product diversification and innovation performance

Market diversification refers to a firm pursuing more markets with different demand characteristics. International diversification allows firms to achieve greater returns on innovation and lowers the risk of R&D investment (Hitt et al., 1994). From the work of Kotabe & Murray (1990), US multinational firms with higher levels of production and marketing on a global basis are shown to be better at retaining innovative capabilities. Firms operating in a single market find investing difficult because it takes a longer time to recover the original investment before the technology becomes obsolete (Hitt et al., 1994; Kotabe & Murray, 1990). Therefore, market diversification motivates firms to innovate to adapt to a new market, thus leading to more innovation. For these reasons, a negative (positive) effect of balance-centered (hetero-centered) diversification on innovation performance is assumed.

H3. Balance-centered market/product diversification negatively influences innovation performance.

H4. Hetero-centered market/product diversification positively influences innovation performance.

4.2.3 Technology diversification

Technological diversification indicates the level of diversification of technology. In previous studies, technological diversification is measured with reference to patents. Patents are a reliable indicator for measuring a firm's level of technological diversification. In addition to the various information provided by a patent, the IPC is used as a target of measurement. Since the IPC represents the technological component of a patent (Strumsky et al., 2012), measuring diversification with reference to the IPC can show more specific levels of a firm's technological diversification. Measuring technological diversification with the IPC may differ depending on the level of the IPC used. In this study, IPC sub-classes are used as they designate an intuitive and representative level of technology (Kim, Jung, Hwang, et al., 2018).

4.2.3.1 Technology diversification and business performance

In the case of technology, firms can choose a specialization strategy for either a technological competitive advantage or a diversification strategy for an advantage in competitive markets (Garcia-Vega, 2006). The significant influence of technological diversification on business performance is expected. Breschi et al. (2003) emphasized the importance of technological diversification because a firm needs to manage a wider number of technologies for product development. By promoting product diversification, technological diversification contributes to improved business performance. Miller (2006) found a positive relationship between technological diversification and a market-based measure of performance. Rather than concentrating on certain technologies, firms can prevent the lock-in effect when focusing on certain technologies and seek the renovation of their businesses (Suzuki & Kodama, 2004). In a similar sense, concentrated diversification enhances firm innovation by emphasizing accumulated technological competence in core fields and high learning effects (Chen, Yang, & Lin, 2013; Garcia-Vega, 2006; Lin, Chen, & Wu, 2006; Vila, Perez, & Morillas, 2012).

H5. Balance-centered technological diversification negatively influences business performance.

H6. Hetero-centered technological diversification positively influences business performance.

4.2.3.2 Technology diversification and innovation performance

Gort (1966) insisted that R&D is an area where diversification is likely to achieve economies of scale. By diversifying its technologies, a firm can increase the possibility of meeting new technological needs (Nelson, 1959) and cross-fertilization between different technologies (Granstrand, 1998; Suzuki & Kodama, 2004). Chen, Shih, & Chang (2012) investigated the effect of technological diversification on innovation performance and found that related technological diversification exerts a positive influence on innovation performance. Here, "related diversification" refers to concentrated diversification and "unrelated diversification" refers to balanced diversification. As they measured innovation performance by the total number of patent applications, their results imply a preferential attachment effect (Barabási & Albert, 1999). In other words, a firm developing similar technologies is more likely to develop a more comprehensive patent application (Kim, Jung, & Hwang, 2018). In this sense, concentrated diversification is preferred for the creation of valuable patents as it leads to more specialized technological development. Thus, concentrated diversification and heterogeneous diversification effects are assumed.

H7. Balance-centered technological diversification negatively influences innovation performance.

H8. Hetero-centered technological diversification positively influences innovation performance.

4.3 Data and Methodology

4.3.1 Data

In this study, the firm-level product and technology data of pharmaceutical firms that have approved and merchandized products and patent applications in the US are included. The pharmaceutical industry is characterized by huge R&D costs, long commercialization periods, and complex and lengthy approval procedures. These conditions make pharmaceutical products a reliable indicator for the outcome of firms' investments and efforts. For the definitions of market and product diversification, market and product types are classified by therapeutic category based on the third level of the 2018 Anatomical Classification of Pharmaceutical Products (ATC) maintained by the European Pharmaceutical Market Research Association (EphMRA). In the pharmaceutical industry, products are classified by their therapeutic usage, which refers to the treatment of a patient's condition. It not only determines where the products are used, but also the type of market by defining its potential patients. In this sense, therapeutic categories are considered to be the relevant economic markets and used as indicators for market diversification in the pharmaceutical industry (Hanusch & Pyka, 2007). In addition, the ATC is another classification used in products. It comprises a total of 16 principal groups and four levels. Among them, the third-level classification is used to distinguish each product's functional type as it classifies pharmaceutical products by chemical structure or indication or method of action. Since chemical structure is a key component of differentiating pharmaceutical products—mostly drugs—the ATC EphMRA drug classification is acceptable as an indicator for product type.

In order to consider the three domains of the firm-level diversification framework, three different data sets are integrated based on the name of the firm. To add the products' approval dates, commercialized product information from the Medtrack database is merged with the product classification from the Orange Book (also known as "Approved Drug Products with Therapeutic Equivalence Evaluations"), which identifies pharmaceutical products approved by the Food and Drug Administration. In addition to this, US patent data from the LexisNexis Total Patent database of listed firms and their characteristics from Compustat are added.

As a result, an integrated data set comprising 124 firms that have both approved and commercialized products and firm-level characteristics of revenue totals, employees, R&D investments, and patent applications in the US from 2001 to 2016 is constructed. For product and market diversification, a total of 2,133 products containing market and product information are used. One of the advantages of using Medtrack data is that it provides overall and detailed information about pharmaceutical products. For technological diversification, a total of 72,549 patents belonging to pharmaceutical firms are used. Lastly, an integrated data set is constructed to conduct structural equation modelling. In order to conduct firm-level analysis, these two data sets are combined with reference to the names of firms. In this study, a total of 22 market types, 237 product types, and 607 patent types are used; a list of them is set out in Appendix 2. Table 4-2 provides the descriptive statistics of the variables for the full sample.

Table 4-2. Descriptive statistics

Variable	Definition	Mean	St. Dev.
Diversification Indices			
Balance-centered MDI	Market diversification measured by Gini-Simpson	0.41	0.01
Hetero-centered MDI	Market diversification measured by Rao-Stirling	52.63	0.85
Balance-centered PDI	Product diversification measured by Gini-Simpson	0.32	0.01
Hetero-centered PDI	Product diversification measured by Rao-Stirling	15.06	0.23
Balance-centered TDI	Technology diversification measured by Gini-Simpson	0.31	0.01
Hetero-centered TDI	Technology diversification measured by Rao-Stirling	27,817.99	306.17
Control variables			
R&D	Annual R&D investment	9,835.96	679.18
Firm size	Annual number of employee	14.73	0.74
Firm age	Firm age	52.60	1.08
Dependent variables			
Business performance	Annual revenue	145,975.88	14,925.30
Innovation performance	Annual total number of patent citation	1,101.40	97.12

4.3.2 Variables

4.3.2.1 Dependent variables

In this study, two econometric models with different dependent variables are constructed to investigate the effects of firm-level diversification domains on firm performance. From the study of Shim, Kim, & Altmann (2016), three factors were used to investigated the effects of the integration of R&D and marketing on the success of new product development (NPD): time to market, product sales, and technological innovation. Firm performance also can be similarly categorized by differentiating the stages of commercialization and R&D. The first dependent variable is business performance, which indicates performance during the commercialization stages. In order to identify the firm's business performance, the natural logarithm of the total revenue acquired in a given year is used. As business performance is regarded as short-term performance (Xu & Liu, 2017), a shorter time lag than in the case of innovation performance is reasonable. Thus, a time lag of a year between the dependent variable and all explanatory variables (i.e., independent and control variables other than firm age) is added (Su & Tsang, 2015).

Another dependent variable is innovation performance, which refers to the outcome of the R&D stage, measured by the natural logarithm of a firm's annual number of citations created from its patent pool. Patent citations are widely used as an indicator for firms' knowledge performance because it indicates the value of the technology itself (Hall, Jaffe, & Trajtenberg, 2005; Trajtenberg, 1990) and plays an important role in knowledge transfer (Griliches, 1990). In order to give weight to the minimum period of two years required for patent publication, a time lag of two years is added.

4.3.2.2 Independent variables

The diversification indices of three firm-level diversification domains are used as independent variables. Each diversification domain is measured by a different target based on the relevant aspect of each diversification domain: the market diversification index (MDI), product diversification index (PDI), and technological diversification index (TDI). As mentioned previously, the MDI and the PDI are measured by a product's merchandized market and product type and the TDI is captured from the technological component of a firm's patents (Figure 4-2). In order to avoid misinterpretation, all diversification indices are measured annually and are accumulative. For instance, if firm A diversified its markets (or products or technologies) in t1 and t3, no diversification occurred in t2. However, unless firm A decided to stop selling its products (or possessing its technology), the level of diversification should be maintained in t2.

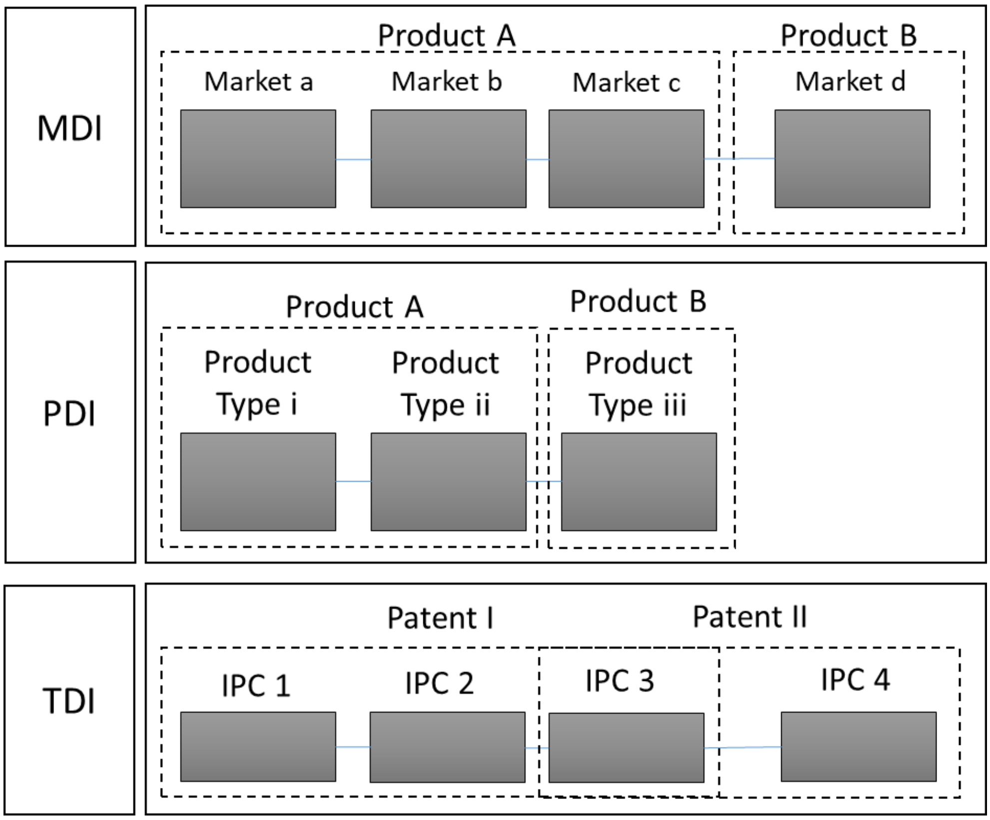

Figure 4-1. Concept of firm-level diversification framework

Each diversification domain is measured from two different perspectives: balance-centered and hetero-centered diversification. As mentioned in the literature review, balance-centered diversification is measured using the Gini-Simpson (Eq. (1)) and hetero-centered diversification is measured using the Rao-Stirling (Eq. (2)).

$$\text{Balance} - \text{centered Diversification} = \text{Gini} - \text{Simpson} = 1 - \sum_{\mathrm{j}} (p_{\mathrm{j}}^2) \quad \text{Eq. (1)}$$

$$\text{Hetero} - \text{centered diversification} = \text{Rao} - \text{Stirling} = \sum_{\mathrm{jk}} d_{\mathrm{jk}}(p_{\mathrm{j}} p_{\mathrm{k}}) \quad \text{Eq. (2)}$$

4.3.2.3 Control variables

Beyond firm-level diversification indices, various factors may influence firm performance. Since the role of R&D in the pharmaceutical industry is critical, each firm's R&D factors should be controlled. R&D expenditure, measured by its natural logarithm, is viewed as barrier to risk as it has a negative correlation with risk (Miller & Bromiley, 1990). Firm age, measured as the number of years since the formation or incorporation of the firm, is included to control for business experience (Du, Lu, & Guo, 2015). While a firm with a longer history is more likely to use its experience to innovate (Huergo & Jaumandreu, 2004; Sun & Govind, 2017), one with a shorter history is likely to be more creative (Klepper, 1996). Firm size is also an important indicator as it affects a firm's innovation, performance (Ahuja, 2000; Du et al., 2015; Pavitt, Robson, & Townsend, 1987) and growth (Delmar, Davidsson, & Gartner, 2003; Orlando, Renzi, Sancetta, & Cucari, 2018). The natural logarithm of the number of employees is used to measure firm size (Delmar et al., 2003; Du et al., 2015; Orlando et al., 2018).

4.3.3 Methodology

For the empirical analysis, a panel regression is conducted. The theoretical econometric model for panel data is characterized as Eq. (3) where i is the agent, t is the time, x_{it} is the vector of independent variables, u_i is the unobserved effects, and v_{it} is the idiosyncratic error.

$$y_{it} = \beta_0 + \beta_1 x_{it} + u_i + v_{it}, i \in N, t \in T \qquad \text{Eq. (3)}$$

In order to derive a consistent estimator of β, both u_i and v_{it} should be controlled. For instance, if a correlation between x_{it} and either u_i or v_{it} exists, the estimator is in a heterogeneity bias or a bias caused by omitting a time-constant variable. Accordingly, a panel regression is conducted either by fixed or random effects. Firstly, a fixed effects (FE) model assumes the unobserved factors are correlated to the dependent variables. Here, unobserved factors refer to time-invariant variables that may influence the dependent variable. Since this unobserved factor may or may not influence the estimation, it has to be controlled. To do so, the time-mean value is subtracted from Eq. (3) and time-demeaned data is collected (Eq. (4)). Although $cov(x, u_i) = 0$ is not satisfied, a consistent estimator can be derived.

$$y_{it} - \overline{y_t} = \beta(x_{it} - \overline{x_t}) + v_{it} - \overline{v_t} \quad \text{Eq. (4)}$$

A random effects (RE) model is built under the assumption that u_i is random and uncorrelated with x_{it}. Since $\mathrm{cov}(x_{it}, u_i) = 0$ is satisfied, time-invariant factors are now included. For instance, if the difference among the entities is assumed to have some influence on the dependent variable, an RE model is preferable to an FE model. In order to make a selection between the FE and RE models, the correlation between u_i and x_{it} should be determined. Since the Hausman test shows whether a certain model is suitable for either an FE or an RE model, it is conducted prior to the panel regression.

4.4 Results

The correlations between the variables used in each of the estimated models are set out in Appendix 2. For the multicollinearity check, a variation inflation factor (VIF) test on all the variables is conducted. Since the value of the VIF for all variables is below 10, no multicollinearity issues are present in the result (Chatterjee, Hadi, & Price, 2000; Kutner, Nachtsheim, Neter, & Li, 2005).

Table 4-3. Panel regression result of the full sample

	Dependent variable: Business performance Random-effects model		Dependent variable: Innovation performance Random-effects model	
	(1) Balance-centered	(2) Hetero-centered	(3) Balance-centered	(4) Hetero-centered
Independent variable				
MDI	5.292	0.036**	2.65	0.013
	(-3.728)	(-0.017)	(-5.877)	(-0.028)
PDI	114.917**	-0.467**	428.001***	-1.145***
	(-56.66)	(-0.182)	(-79.479)	(-0.271)
TDI	-17.763*	0.0001*	-85.900***	-0.00004
	(-10.6)	(-0.00005)	(-14.585)	(-0.0001)
Control variable				
Firm size	0.063***	0.062***	0.060***	0.062***
	(-0.008)	(-0.008)	(-0.009)	(-0.009)
R&D investment	-0.627	-0.61	1.189	0.884
	(-0.583)	(-0.473)	(-0.822)	(-0.669)
Firm Age	-0.348**	-0.320**	-0.668***	-0.411**
	(-0.145)	(-0.127)	(-0.213)	-0.187)
Constant	-92.872**	12.649***	-349.630***	24.070***
	(-47.121)	(-3.805)	(-66.895)	(-5.257)
Observations	1,323	1,323	1,266	1,266
Time-lag	t+1	t+1	t+2	t+2
R2	0.072	0.074	0.123	0.120
Adjusted R2	0.068	0.070	0.119	0.116
F Statistics	16.867***	17.376***	29.140***	28.183***

Table 4-3 reports the estimation results of panel regression on the effects of the firm-level diversification domains on firms' business (columns (1) and (2)) and innovation performance (columns (3) and (4)). For each dependent variable, the effects of the balance-centered (columns (1) and (3)) and hetero-centered (columns (2) and (4)) perspectives of diversification are separated. Prior to estimation, the Hausman test is conducted on all equations to test the validity of the assumptions on the uncorrelation of missing observations in an unbalanced panel data set. The results of the Hausman test strongly indicate that the RE model is preferable to the FE model. Accordingly, for estimation, all models are estimated using the RE model.

For all cases, the coefficient of firm size is positive at a statistically significant level. It implies that bigger firms have greater resources to achieve better performance. On the other hand, the coefficient of firm age is negative at a statistically significant level. This may be explained on the basis that the creativity and less risk-averse behavior of younger firms help to promote performance (Klepper, 1996).

In columns (1) to (2) of Table 4-3, the results of business performance are described. For firms' business performance, all independent variables showed a significant influence except balance-centered MDI. The effects of both balance-centered and hetero-centered MDI are positive, but only the latter is statistically significant. This result implies that entering heterogeneous markets enhances a firm's business performance. The balance-centered PDI showed a positive effect while the coefficient of the hetero-centered PDI is negative, both at a statistically significant level. The positive coefficient of the balance-centered PDI implies that a balanced proportion of product types promotes business performance. On the other hand, the negative coefficient of the hetero-centered PDI suggests that heterogeneous product development hinders business performance. The coefficients for both TDIs are statistically significant, but in different directions with respect to PDI. In the case of TDI, the coefficient of the balance-centered TDI is negative while the coefficient of the hetero-centered TDI is positive. Obviously, this result indicates that heterogeneous (balanced) technological diversification promotes (hinders) business performance.

The effects of firm-level diversification activities on innovation performance are presented in columns (3) to (4) of Table 4-2. In this case, only the balance-centered and the hetero-centered PDI and the balance-centered TDI showed significant effects. However, an interesting observation is that the sign of each parameter is consistent with the business performance model. Although it failed to attain a significant level, the signs of both MDIs were equal to the results of business performance. Both the balance-centered and hetero-centered PDIs showed statistically significant effects on innovation performance. More interestingly, the sign of both PDIs are shown to be consistent. Hence, balanced (less heterogeneous) product diversification is beneficial to innovation performance. In addition, the coefficient of the balance-centered TDI is negative at a statistically significant level. This result is also consistent to business performance as balanced, concentrated technological diversification hinders innovation performance.

4.5 Discussion

This study investigates the effects of firm-level market, product, and technological diversification activities on business and innovation performance from two perspectives of diversification: balance-centered and hetero-centered. Basically, this diversification approach is consistent with the concept of intra-industry diversification (also known as related inter-industry diversification), which indicates a firm's presence in more than one market niche or product line within a single industry (Li & Greenwood, 2004; Stern & Henderson, 2004; Zahavi & Lavie, 2013). An empirical analysis is conducted using this approach with reference to the case of pharmaceutical firms operating in the US. From these findings, both theoretical and managerial implications are discussed.

4.5.1 Managerial discussion

Table 4-4. Managerial implication for business performance

	Balance-centered diversification	Interpretation	Hetero-centered diversification	Interpretation
Market diversification			+	Heterogeneous market
Product diversification	+	Balanced product	-	Less heterogeneous product
Technology diversification	-	Concentrated technology	+	Heterogeneous technology

Table 4-5. Managerial implication for innovation performance

	Balance-centered diversification	Interpretation	Hetero-centered diversification	Interpretation
Market diversification				
Product diversification	+	Balanced product	-	Less heterogeneous product
Technology diversification	-	Concentrated technology		

This study suggests three different diversification strategies for markets, products, and technology (Tables 4-4 & 4-5). For market diversification, heterogeneous market diversification is recommended. Although entering a heterogeneous market requires greater investment, diversifying into a heterogeneous market can provide better opportunities for firms. In the case of product diversification, a balanced and less heterogeneous product diversification is recommended. Products are better diversified within existing products to strengthen existing characteristics or traits. This result reflects the case of the pharmaceutical industry where product development requires a tremendous amount of investment comprising average development periods of 10 years. As developing a pharmaceutical product is a huge risk for firms, it is important for pharmaceutical firms to continuously seek product diversification as a way of strengthening their market position.

In addition to this, pharmaceutical firms should consider entering new markets to increase their market power.

For technological diversification, concentrated and heterogeneous diversification is suggested. In the case of patent citations, a greater number of patent citations implies that firms' technologies are valuable enough to be likely to be implemented in other technologies. A firm that focuses on a certain type of technology is more likely to specialize and have higher-quality technology that others do not have. In addition, seeking disparity in technological development allows firms to have a relative advantage in achieving innovation performance. Although developing heterogeneous technology may require a larger investment, it is important for a firm to increase the value of its technology. In particular, for those industries where the role of intellectual property or technology is highly valued, firms should conduct technological diversification to strengthen their technological advantages. As the attitudes of business managers on the acceptance of innovation relies on their perceptions of the potential benefits (Haile & Altmann, 2015), this finding can be used as a reference for a diversification strategy.

4.5.2 Theoretical discussion

In this study, the following theoretical contributions are made. First of all, these results advance diversification research by classifying the market based on merchandizing and the product based on functional types. In the case of market diversification, this result partially supports the results of previous diversification studies as it is aligned with the positive effects of diversification on business performance. Therefore, the market diversification described in previous studies is more closely related to heterogeneous market diversification. The result of product diversification is supported by the diversification discount as balanced and less-heterogeneous product development is recommended. It implies that the diversification discount effects discussed in previous studies are more related to product diversification. The result of technological diversification is supported by the resource-based view as concentrated and heterogeneous diversification is proposed. In the case of technological diversification, a competitive advantage can be realized through diversification.

This result, however, is inconsistent to the result of Gambardella & Torrisi (1998), where the business and technological diversification of electronic firms in the 1980s are examined. They found that business diversification positively influences business diversification while technological diversification has a negative effect on business diversification. In the case of the electronics industry, market entry and product development occurs more frequently as it requires less investment and fewer approvals compared to the pharmaceutical industry. Based on the findings, the differences between the industries and the time periods of the studies are observed. In the 1980s, technological convergence did not occur as easily or quickly as it does now, so it may have been more important for firms to secure what they already had. Thus, the empirical result that suggest heterogeneous market diversification and a balanced and less-heterogeneous product diversification can still be recommended, particularly to knowledge-intensive manufacturing industries.

Secondly, the importance of the properties of diversity has been discussed in the context of diversification measurements. Previously, diversification was discussed in a simple manner, although its perspectives could be verified. The selection of a diversification index is crucial because it not only affects the result but also its interpretation. Kim & Pantzalis (2003) used the number of business segments as an indicator of diversification. If diversification is measured in this manner, an increase or decrease in diversification can only indicate whether the number of business components changed. The study of Stephan (2002) is somewhat similar to this approach; he analyzed the relationship between product, geographical (geography-based markets), and technological diversification. This study differs from the existing studies not only because it adopts a type-based market, but also utilizes two different diversification perspectives. Rather than simply adopting one of the diversification indices, adopting two perspectives of diversification measurement is proposed. With this approach, the understanding of diversification and its analytical implications can be strengthened.

For further studies, more interesting findings about the relationship between two diversification perspectives for each activity can be discussed. From the results of the analysis, both balance-centered and hetero-centered diversification perspectives showed different results for each case. To obtain a better understanding, the findings from the relationship between these two diversification perspectives are set out in Figures 4-2, 4-3, and 4-4. These figures show the relationship between the two diversification perspectives for each of the diversification activities. As panel data is used in this study, each firm's diversification level is calculated as an average. Here, the size of the circle indicates the firm size and the color of the circle indicates whether it is an experienced or a creative firm determined with reference to whether the firm age is above (circle) or below the median (triangle) of firm age. The black-dotted (gray full-line) circle refers to firms at the top levels of business (innovation). To see the relationship between balance-centered and hetero-centered perspectives, a regression line is also plotted in blue.

For the MDI and the PDI, a positive and linear relationship is observed. This is an intuitive result as the natures of the Gini-Simpson and the Rao-Stirling show positive correlations. Given that the group of firms with a high firm size and firm age are located at the top-right side of the graph, it can be seen that higher levels of heterogeneity and balance in diversification are achieved by those leading firms. The TDI, however, showed different results because an inverted U-shape relationship is observed. It implies that there exists an optimal value of the balance-centered TDI that maximizes the hetero-centered TDI. In other words, the maximum technological heterogeneity is not simply obtained by maximizing the balance of technologies, but by attaining the required amount of balance in diversification. At the same time, top innovation groups are located near the maximum value of the hetero-centered TDI. Unlike market and product diversification, securing a specialty or expertise in a certain area of technology is important as it relates to the value of technology due to the nature of intellectual property. Thus, the importance of possessing the technological strength in a specialized area has to be considered. This finding reminds us of the study by Bart et al. (2007) where the relationship between technological diversification and technological performance in conjunction with the technological coherence of firms’ technology portfolios is examined. They insisted that technological diversification at the firm level is reported to show an inverted U-shaped relationship with technological performance (Bart et al., 2007; Huang & Chen, 2010). Their result is somewhat similar to this as high-performance firms are not located at the maximum level of diversification, but lie near the threshold that maximizes balance-centered diversification. It reminds us that there exists an optimal value of hetero-centered diversification that maximizes balance-centered diversification and firm performance. Finding an optimal diversification strategy, therefore, can be another potential research question for future research. Particularly in the case of technological diversification, a discussion on the optimal diversification strategy can provide more insight into a firm’s diversification activities.

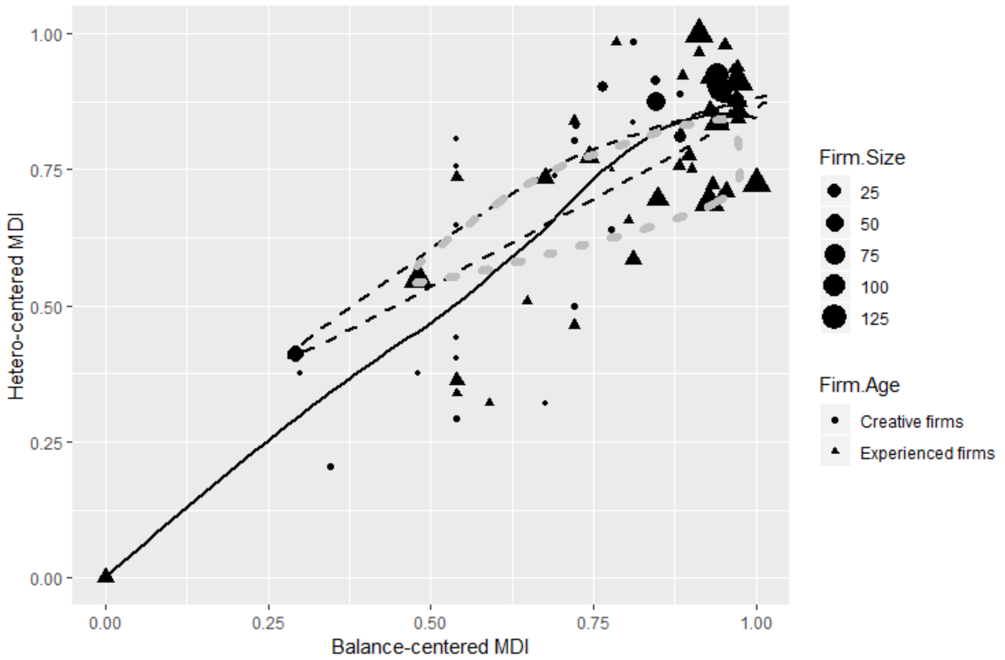

Figure 4-2. Market diversification perspectives

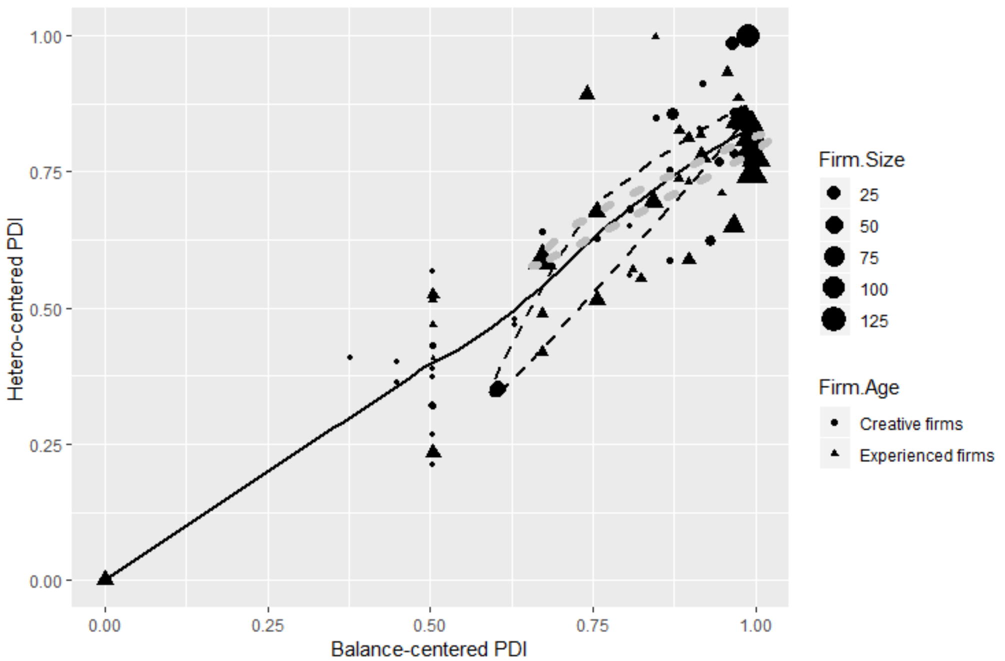

Figure 4-3. Product diversification perspectives

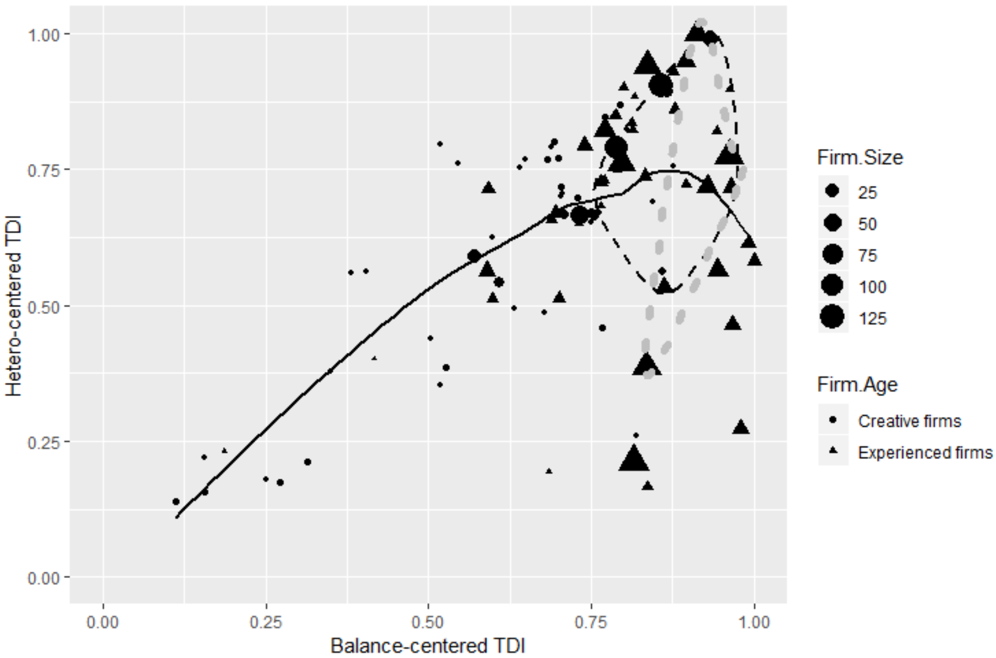

Figure 4-4. Technology diversification perspectives

Chapter 5. Effects of open innovation on firm-level diversification: The moderating role of alliance portfolio management capability

5.1 Introduction

Along with the appearance of the convergence phenomenon, a firm's diversification strategy increased in importance in order to respond to rapid technological changes. From the product/market matrix proposed by Ansoff (1957), diversification is described as one of a firm's four main growth strategies. Here, diversification is understood as the most difficult and risky strategy as it requires new skills, technologies, and facilities. Diversification, however, allows efficient resource allocation (Weston, 1970), tax reductions through reductions in earnings volatility (Lewellen, 1971), and economies of scale (Teece, 1982).

Due to limited resources, however, it is not easy for firms to achieve diversification by themselves. Accordingly, firms try to access external resources rather than participating in standalone activities. In this sense, an open innovation model can either complement or supplement a firm's internal innovation efforts. From a process perspective, the open innovation model is divided into three types (Gassmann & Enkel, 2004): coupled, outside-in, and inside-out activities. Open innovation is regarded as an effective driver of innovation as it encompasses firms' activities to increase the number of available opportunities for the external use of innovation (Chesbrough, Vanhaverbeke, & West, 2008; Gassmann et al., 2010). The open innovation model, therefore, can contribute to understanding the relationship between external collaboration and firm-level diversification.

While open innovation considers the types of processes in collaboration, a strategic alliance comprises the actual method of doing so. In the current business landscape, strategic alliances have become a ubiquitous phenomenon (Gulati, 1998). The effect of a single alliance on a firm's governance, performance, evolution, and formation has been discussed in the majority of the existing research on traditional alliances (Gulati, 1998). A single alliance, however, relies on the weak assumption that a firm's alliances are independent of one another (Gulati, 1998; Sarkar et al., 2009). In practice, the achievements of current alliances are related to both previous and future alliances. An alliance portfolio, therefore, seems to be more suitable for understanding the effects of a firm's partnership activities and is considered an important unit of analysis (Jiang et al., 2010; Wassmer, 2010).

As a reflection of the importance of an alliance portfolio, the effects of APMC were discussed in various studies (Castro & Roldán, 2015b; Luvison & De Man, 2015; Sarkar et al., 2009; Schreiner et al., 2009). APMC reflects a focal firm's ability to manage, coordinate, and control the portfolio as a whole (Hoffmann, 2005). Unfortunately, the role of APMC as an important factor in moderating a firm's collaboration activities has not been explored in open innovation literature. Accordingly, the purpose of this study is to find the moderating role of APMC in the relationship between open innovation activities and firm-level diversification. In conclusion, greater APMCs play a positive modeating role in the relationship between open innovation activities and firm-level diversification.

The contribution of this study is to enhance the understanding of the relationship between the open innovation model and firm-level diversifications (market, product, and technological) by highlighting the role of APMCs. To the best of my knowledge, this study is the first to provide evidence that APMC plays a critical role in enhancing diversification when firms pursue an open innovation model. In addition, this study tries to evaluate the effects of open innovation activities through records of individual deals. Furthermore, this study implements network theory to measure a firm's APMCs. In order to do so, the properties of APMCs are discussed in the context of an alliance network and as a result, APMC is measured from firms' alliance network indices that are relevant to its properties.

For empirical studies, pharmaceutical firms that are operating in the US are selected and two different data sets are constructed: markets/products and technology. The market/product data set includes Medtrack product data, Orange book classifications, and Compustat data; the technology data set includes LexisNexis Total Patent data and Compustat data. Each data set is integrated using Medtrack's deal data, which offers the overall alliance information of pharamaceutical firms. In the remainder of this chapter, Section 2 reviews the theoretical backgrounds for the open innovation model and APMCs. Section 3 describes the data and methods used in this study. Lastly, the results and conclusions are described in Sections 4 and 5.

5.2 Literature review

5.2.1 Open innovation

Access to external resources through open innovation is regarded as a critical source of a firm's innovation (Duysters & Lokshin, 2011). Open innovation is defined as "… the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough et al., 2008). Given its nature, open innovation can be explained using various perspectives, but this study mainly deals with the process perspective, which is the most frequently adopted one. According to the process perspective of open innovation, this study classifies a firm's open innovation activities into three parts (Gassmann & Enkel, 2004): outside-in (or inbound), inside-out (or outbound), and coupled.

Inside-out activities are activities that earn profits by selling or transferring firms' resources to the market or outside environment. Through inside-out activities, firms make profits by commercializing their knowledge through external parties (Lichtenthaler, 2005). Inside-out activities involve major risks as it may weaken the firm's competitive advantage by transferring the firm's knowledge to the market. Compared to closed innovation strategies, however, inside-out activities can contribute in two ways. Firstly, firms can increase their licensing revenues, which bring high profit margins (Fosfuri, 2006). Secondly, it allows firms to enhance their influence in the market. Due to the indirect network effects, the value of a firm's technology can be increased when it is adopted by other firms (Kim, Jung, Hwang, et al., 2018). Accordingly, firms can not only increase their benefits from licensing revenues, but also strengthen their influence in the market. Lastly, inside-out activities allow access to diverse sources of innovation (Bianchi, Cavaliere, Chiaroni, Frattini, & Chiesa, 2011). For instance, bio-pharmaceutical firms actively exploit the results of their innovation with external organizations especially at the latter stages of development including clinical testing and post-approval activities. By doing so, they can ensure quicker and wider access to the market. Inside-out activities, therefore, are complementary to internal development (Michelino, Caputo, Cammarano, & Lamberti, 2014).

It is accordingly apparent that inside-out activities contribute to a firm's innovation activities. However, the effects of inside-out activities on diversification are not guaranteed. The important difference is the type of innovation achieved through inside-out activities. Creating innovation through inside-out activities focuses on converting its resources directly to commercialized value rather than diversifying its resources. In addition, access to diverse innovation is more akin to requesting other firms to do certain development processes for quicker entry. From a diversification perspective, therefore, the connection between inside-out activities and diversification is weak. As diversification is already determined by the nature of a firm's resources, it can be hardly being assumed that inside-out activities influence diversification.

An outside-in process refers to the integration of an external knowledge source through the integration of suppliers and customers to increase firms' innovation. Simply put, firms can access and integrate external knowledge sources through the outside-in process. The external knowledge source provides the not only access to new and complementary knowledge, but also the potential to generate new knowledge (Coombs & Hull, 1998). In the case of the bio-pharmaceutical industry, for example, outside-in activities are likely to take place mainly in the initial stages of development such as during the drug discovery and development processes (Bianchi et al., 2011). In case of bio-the pharmaceutical industry, more than 60% of firms' open innovation activities are reported to be outside-in processes (Bianchi et al., 2011; Chiaroni, Chiesa, & Frattini, 2009). Outside-in activities, therefore, are substitutive to internal R&D activities (Michelino et al., 2014). In this sense, outside-in activities can be adopted to promote a firm's innovation activities. From a diversification perspective, the significant influence of outside-in activities is unsurprising as it supplements a firm's resources not only temporarily but also permanently.

Coupled activities refer to the integration of outside-in and inside-out processes. As a type of co-innovation with partnering firms, it involves inter-firm relationships and the recombination of external knowledge with existing knowledge (Mazzola, Bruccoleri, & Perrone, 2012). Coupled activities allow firms to develop new knowledge and enrich their knowledge base (Katila & Ahuja, 2002). Coupled activities are not only positively related to innovation (Chou, Yang, & Chiu, 2016), but also can promote the market adaptability of innovation output (Mazzola et al., 2012). Co-patents, one of possible outcomes of coupled activities, reduce costs and produce new products with advanced technologies. Using co-patents, firms may achieve new business possibilities and encounter new growth options

(Chesbrough & Garman, 2012). Therefore, coupled activities are likely to influence a firm's innovation activities and diversification. Coupled activities indicate the direct involvement of a firm in the creation of new innovative value. From this perspective, the effect of coupled activities on diversification can be assumed.

5.2.2 APMC and performance

From previous studies, various researchers explored the effects of APMC on market performance (Sarkar et al., 2009), performance (Luvison & De Man, 2015), performance satisfaction (Castro & Roldán, 2015a), or innovation (Oerlemans, Knoben, & Pretorius, 2013). For market performance, Sarkar, Aulakh, & Madhok (2009) conducted empirical study targeting 235 firms to validate their proposed concepts of APMC. They showed that APMC causes significant and positive influence on firm's market performance. Portfolio outcome indicates any desired outcomes achieved by alliance portfolio. Castro & Roldán (2015a) investigated the effect of APMC on alliance performance, referring to performance satisfaction. They not only showed that they exert significant influence on the alliance portfolio performance, but also explored that relational governance and portfolio coordination partially mediate the effect of partnering proactiveness on the alliance portfolio performance. It not only supports the conceptualization of APMC, but also relationship among three components. The work of Luvison & De Man (2015) also supported this positive relation APMC on firm performance. In addition to this, they found out that alliance supportive culture, which indicates a culture that induces firms to apply alliance mechanism in an effective manner, mediates this relationship. Schreiner et al. (2009) diversified alliance outcomes including joint action, customer knowledge, firm performance, and status in network and showed positive and significant effect of APMC.

As diversification regarded as a type of innovation activity, it is reasonable to assume the positive relation between APMC and firm-level diversification is expected. As it is so, the role of APMC on firm-level activities should be considered as an indicator for firm's competitive capability. Oerlemans, Knoben, & Pretorius (2013) analysed the influence of using technology management tools (TM-tools), a specification of APMC, on the relationship between alliance portfolio diversity and innovation outcome, and detected strong positive moderating effect. Moreover, intensive usage of TM-tools turned out to convert negative effect of alliance portfolio diversity into a positive effect. It shows that APMC is beneficial for the management of diverse alliance portfolios. Similar to this, firm's APMC may act as a positive moderator on the relation between open innovation process and firm-level diversification, which is considered as alliance outcome. Due to the above line of reasons, the influence of open innovation process on firm-level diversification is expected to positively and significantly being moderated by APMC.

5.3 Data and methodology

For the empirical study, the analytic procedure comprises four different stages (Figure 5-1). In the first stage, two different data sets are constructed. For each data set, diversification indices with balance-centered and hetero-centered perspectives are measured. In addition, APMCs are measured from the alliance network. With these measured values, a panel analysis is conducted.

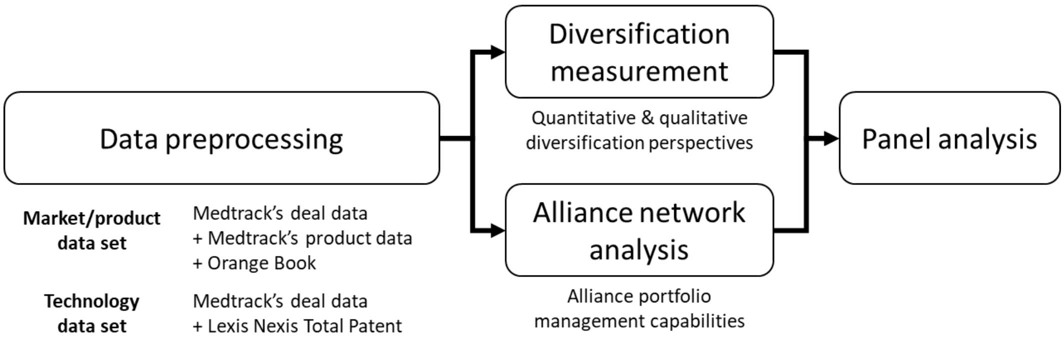

Figure 5-1. Research process of chapter 5

5.3.1 Data

In this study, the case of pharmaceutical firms operating in the US is selected. In the pharmaceutical industry, firms develop drugs and exclusively take advantage of their intellectual property (Ahn, Meeks, Davenport, & Rebecca, 2010). More importantly, pharmaceutical firms have to manage huge R&D costs, long commercialization periods, and complex regulatory approval procedures. Under these conditions, strategic alliances have become frequent phenomena in the pharmaceutical industry (Diestre & Rajagopalan, 2012). Pharmaceutical firms conduct collaborations with other firms for their product development processes (Baum, Tony, & Silverman, 2000; Bianchi et al., 2011; Niosi, 2003; Salman & Saives, 2005) to overcome the complex and risky obstacles. Accordingly, the pharmaceutical industry provides a good sample space because it is characterized by a high alliance frequency (Baum et al., 2000; Gay & Dousset, 2005; Hagedoorn, 1993).

The data sample is collected from three different data sets: Medtrack, a commercially provided database of bio-pharmaceutical firm deal and product data; LexisNexis Total Patent data; and Compustat firm data each from 2001 to 2016. Due to the nature of the study, only partnership deals are included; mergers and acquisitions and joint ventures are excluded as they have different ownership structures. In addition, the integrated data set is divided into two parts (a market/product set and a technology set) to reflect differences in the purpose of the alliance. In the market/product set, a total of 182 firms and 1,987 products with 22 market types and 234 product types are used. In the technology set, a total of 403 firms and 104,134 patents with 502 IPC sub-classes are used.

5.3.2 Variables

5.3.2.1 Dependent variables

In this study, firm-level diversification includes market, product, and technological diversification. Each type of diversification is measured with reference to a different target based on the aspect of each diversification domain: the MDI, the PDI, and the TDI. While the MDI and the PDI are measured with reference to a product's merchandized market and product type, the TDI is captured from the technological component of a patent. In order to avoid misinterpretation, all diversification indices are measured annually and accumulatively. Moreover, each type of diversification is measured from two different perspectives: balance-centered and hetero-centered. Balance-centered diversification highlights the proportion of elements owned and hetero-centered diversification emphasizes the heterogeneity of elements. Balance-centered diversification is measured by the Gini-Simpson (Eq. (1)) and hetero-centered diversification is measured by the Rao-Stirling.

$$\mathrm{Balance-centered\ \ Diversification = Gini-Simpson} = 1 - \textstyle\sum_{\mathrm{j}} \left(p_{\mathrm{j}}^{2}\right) \quad \text{Eq. (1)}$$

$$\mathrm{Hetero-centered\ \ diversification = Rao-Stirling} = \textstyle\sum_{\mathrm{jk}} \mathrm{d_{jk}}(\mathrm{p_j p_k}) \quad \text{Eq. (2)}$$

5.3.2.2 Independent variables

Two open innovation activities are used as independent variables: coupled and outside-in. Based on the definition of each open innovation activity, this study classifies a firm's alliance activities based on a firm's deal category. Detailed information is presented in Appendix 4. To measure a firm's openness, previous studies used either partner numbers (Laursen & Salter, 2006) or subjective evaluation (Hung & Chou, 2013). In this study, a firm's annual open innovation activities are measured with reference to the total number of open innovation activities.

5.3.2.3 Moderators

Although the original idea of APMCs was derived from the network perspective, previous studies used survey material to measure APMC. In addition, cross-sectional survey material cannot convey the additive perspective of an alliance portfolio as it only focuses on certain periods of time. This study, therefore, measures APMC with relevant network indices measured from an alliance network. The use of network analysis not only meets the conditions of APMCs, but can also be implemented in general innovation research (Kim, Lee, & Altmann, 2015). Prior to measurement, an alliance network is constructed. Here, each node is a firm and each edge is a partnership relationship. In order to capture a focal firm's management capability with respect to various alliances, a focal firm's alliance network is built in a non-directional, weighted, and accumulated form (Figure 5-2). This is because an edge does not represent the direction of a relationship but the frequency of partnership (Kim et al., 2015).

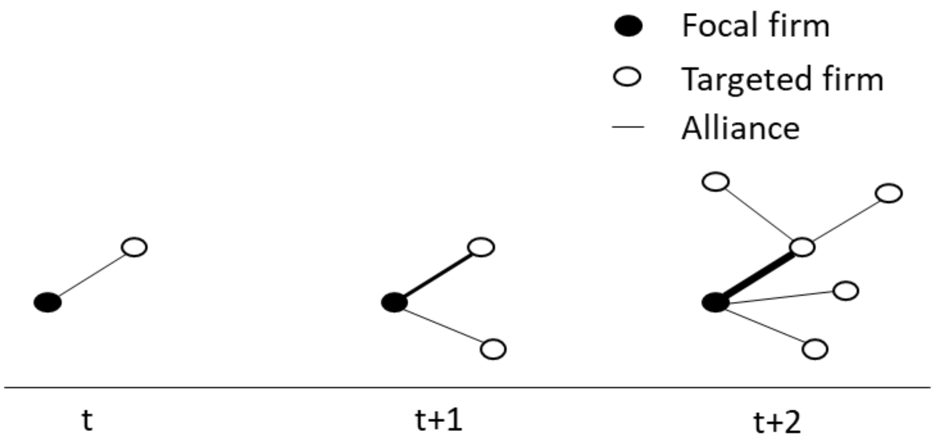

Figure 5-2. Alliance portfolio network

From this network, a firm's APMC is measured through a combination of partnering proactiveness, portfolio coordination, and relational governance. By adopting the original definition of each component and its theoretical foundations in social capital theory, related network indices are measured from the alliance portfolio network. Partnering proactiveness is defined as "an organization's deliberate efforts to discover and act on new alliance opportunities” and offers partners first-mover advantages in an imperfect factor market (Sarkar et al., 2009). In this sense, degree centrality is a suitable measurement (Eq. (3)): degree centrality shows whether a certain node is likely to be positioned at the center of a network by measuring the total number of connected edges (Freeman, 1978; Kim & Altmann, 2013). In social capital theory, degree centrality is used as an important factor of information diffusion and innovation as it represents the resources available to an individual (Abbasi, Wigand, & Hossain, 2014). In this sense, a firm that has more alliances with other firms is more likely to enter into new alliances. Since partnering proactiveness refers to a firm’s ability to discover and act on new alliance opportunities (Sarkar et al., 2009), degree centrality meets this condition.

Sarkar et al. (2009) defined portfolio coordination as “an organization’s engagement in integrating and synchronizing knowledge and activities across their alliances.” Its strategic advantage is increasing knowledge flows and brokering information across alliance portfolios. Accordingly, betweenness centrality can be used as an indicator for portfolio coordination (Eq. (4)). Previously, betweenness centrality was used for measuring the social cohesion of social capital as it represents the bridging dimension of a network (Abbasi et al., 2014). A higher betweenness centrality implies that a firm has a greater influence on resource or knowledge transfers within an alliance portfolio network. Since portfolio coordination implies a firm’s ability to increase knowledge flows (Sarkar et al., 2009), betweenness centrality can reflect this property.

Lastly, the total number of alliances with firms with prior alliance experience measures relational governance (Eq. (5)). A firm with a higher level of relational governance is assumed to have lower contracting and monitoring costs and higher incentives for value-creating initiatives (Sarkar et al., 2009). In social capital theory, higher levels of trust allow an agent to take greater advantage of its partners compared to lower levels of trust because the agent has stronger ties with its partners. From previous studies, prior alliance experience was shown to be influential to a firm's future alliances or performance (Anand & Khanna, 2000; Child & Yan, 2003; Lyles, 1988). Zollo, Reuer, & Singh (2002) found that the performance of strategic alliances in biotechnology depended on the partners' experience, especially the smaller ones. A firm with more alliance experience may have the tacit capability to spot alliance opportunities, select better partners, and achieve greater success (Child & Yan, 2003; Kale, Dyer, & Singh, 2001; Lyles, 1988). In addition, stock markets and investors react more favorably to firms with more alliance experience (Anand & Khanna, 2000). Accordingly, additional alliances with the same partner can indicate the relational governance of the focal firm.

$partering\ \ proactiveness_{i,t} = \sum_{k=1}^{K} \mathrm{deg}_{i,t,k}(v)$ Eq. (3)

$portfolio\ \ coordniation_{i,t} = \sum_{s \neq v \neq t \in V} \frac{\sigma_{i,t,st}(v)}{\sigma_{i,t,st}}$ Eq. (4)

$relational\ \ governance_{i,t} = \sum_{t=1}^{t-1} 1 +$

$\#\ \ of\ \ alliances\ \ with\ \ previous\ \ partners$ Eq. (5)

$\mathrm{APMC}_{i,t} = \sum\ \ (partering\ \ proactiveness_{i,t} + portfolio\ \ coordination_{i,t}) *$

$relational\ \ governance_{i,t}$ Eq. (6)

With these measurements, a firm's APMC can be derived (Eq. (6)). Rather than a simple summation or multiplication of all three components, the sum of partnering proactiveness and portfolio coordination is multiplied by relational governance. The sum of partnering proactiveness and portfolio coordination implies the consideration of the two with equal weight. The multiplication of relational governance works as a weight to distinguish differences in the result.

5.3.2.4 Control variables

This study employed control variables to account for other potential effects on firm-level diversification, open innovation processes, and APMCs, to reduce the possibility of bias due to unobserved heterogeneity. Beyond firm-level diversification indices, various factors may influence a firm's performance. Since the role of R&D in the pharmaceutical industry is critical, each firm's R&D factors should be controlled for. The natural logarithm of R&D expenditure is viewed as a barrier to risk as it has a negative correlation with risk (Miller & Bromiley, 1990). Firm age, measured as the number of years since the formation or incorporation of the firm, is included to control for business experience (Du et al., 2015). While a firm with a longer history is more likely to use its experience to innovate (Huergo & Jaumandreu, 2004; Sun & Govind, 2017), one with a shorter history is likely to be more creative (Klepper, 1996). Firm size, measured as the natural logarithm of the number of employees (Delmar et al., 2003; Du et al., 2015; Orlando et al., 2018), is included to control its effect on firm innovation, performance (Ahuja, 2000; Du et al., 2015; Pavitt et al., 1987) and growth (Delmar et al., 2003; Orlando et al., 2018).

5.4 Results

Prior to the panel regression, mean centering is conducted for the independent variables and the control variables. When the interaction term is included in the regression model, multicollinearity issues may arise. Mean centering—subtracting the mean value from each of the observed variables—can reduce the possibility of multicollinearity (Bohrnstedt & Goldberger, 1969). Eq. (7) shows the correlation between X and the correlation term XZ in the case of a bivariate distribution where E() implies the expectation value, Var() refers to variance, and Cov() indicates covariance. Theoretically, both E(X) and E(Z) become zero after mean centering, which will make both the numerator and the correlation between X and XZ zero.

$$\mathrm{corr}(\mathrm{X},\mathrm{XZ}) = \frac{E(Z)Var(X)+E(X)Cov(X,Z)}{\sqrt{Var(X)[(E(X))^2 Var(Z)+(E(X))^2 Var(X)+2E(X)E(Z)Cov(X,Z)+Var(X)Var(Z)+(Cov(X,Z))^2}} \quad \text{Eq. (7)}$$

The correlations between the variables used in each of the estimated models are described in Tables 5-1 and 5-2. For the multicollinearity check, the VIF test was conducted on all variables. Since the value of the VIF for all the variables is below 10, no multicollinearity issues are present in the result (Chatterjee et al., 2000; Kutner et al., 2005). The Hausman test is then conducted to determine whether an FE or an RE model is suitable for the analysis. The results show that the relationships between the property effects of each variable and the dependent variable of this study were statistically significant; thus, FE estimation is more suitable for the panel data.

Table 5-1. Descriptive statistics and Pearson correlation coefficients of market/product data set.

	Mean	s.d.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	VIF
(1) Balance-centered MDI	0.54	0.37												
(2) Hetero-centered MDI	61.58	45.86	**0.89**											
(3) Balance-centered PDI	0.62	0.40	**0.94**	**0.84**										
(4) Hetero-centered PDI	12.82	8.60	**0.9**	**0.81**	**0.96**									
(5) Coupled	13.90	27.75	**0.22**	**0.22**	**0.23**	**0.17**								2.88
(6) Outside-in	1.08	1.58	**0.39**	**0.32**	**0.4**	**0.35**	**0.4**							3.12
(7) R&D	2086.43	8288.48	**0.13**	**0.22**	**0.12**	**0.13**	0.04	**0.09**						3.71
(8) Firm age	39.00	45.30	**0.38**	**0.38**	**0.37**	**0.35**	**0.15**	**0.25**	**0.2**					1.36
(9) Firm size	13.90	27.75	**0.38**	**0.33**	**0.37**	**0.3**	**0.55**	**0.55**	**0.2**	**0.32**				3.84
(10) APMC	9.76	3.36	**0.43**	**0.34**	**0.42**	**0.35**	**0.38**	**0.52**	**0.11**	**0.38**	**0.56**			2.19
(11) APMC*Coupled	10.30	20.12	**0.15**	**0.17**	**0.17**	**0.13**	**0.77**	**0.43**	0.05	0.06	**0.53**	**0.2**		2.98
(12) APMC*Outside-in	13.25	22.82	**0.18**	**0.17**	**0.19**	**0.14**	**0.45**	**0.73**	0.06	**0.11**	**0.54**	**0.21**	**0.56**	2.84

Notes: Correlation in bold denote statistical significance at the 5% levels.

Table 5-2. Descriptive statistics and Pearson correlation coefficients of technology data set

	Mean	s.d.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	VIF
(1) Balance-centered TDI	6.59	3.29										
(2) Hetero-centered TDI	193.33	117.90	**0.52**									
(3) Coupled	0.61	1.04	0.04	-0.01								1.89
(4) Oustside-in	0.39	0.66	**0.05**	0.04	0.02							1.21
(5) R&D	1479.14	6613.08	**0.16**	0.02	-0.01	**0.06**						3.25
(6) Firm age	33.34	37.77	**0.2**	**0.09**	0.01	**0.14**	**0.27**					1.43
(7) Firm size	9.75	23.23	**0.14**	**0.18**	**0.16**	**0.3**	**0.25**	**0.46**				3.58
(8) APMC	8.50	3.38	**0.22**	**0.17**	**0.25**	**0.17**	**0.07**	**0.18**	**0.33**			1.35
(9) APMC*Coupled	6.10	12.26	0	-0.01	**0.63**	**0.09**	-0.01	0.01	**0.12**	0.01		1.76
(10) APMC*Outside-in	3.71	6.92	**0.07**	**0.06**	**0.1**	**0.32**	0.04	**0.11**	**0.28**	0	**0.07**	1.17

Notes: Correlation in bold denote statistical significance at the 5% levels.

Table 5-3. Panel regression result of balance-centered diversification

	Dependent variable: Balance-centered MDI			Dependent variable: Balance-centered PDI			Dependent variable: Balance-centered TDI		
	Fixed effect model			Fixed effect model			Fixed effect model		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Control variable									
R&D investment	-0.017***	-0.016***	-0.016***	-0.00	-0.009	-0.008	0.0002	-0.002	-0.001
	(-0.006)	(-0.006)	(-0.006)	(-0.007)	(-0.007)	(-0.007)	(-0.004)	(-0.004)	(-0.004)
Age	0.010***	0.011***	0.012***	0.011***	0.012***	0.013***	0.010***	0.008***	0.008***
	(-0.001)	(-0.001)	(-0.001)	(-0.001)	(-0.002)	(-0.002)	(-0.001)	(-0.001)	(-0.001)
Firm size	0.017**	0.018**	0.018**	0.008	0.009	0.008	-0.002	-0.002	-0.001
	(-0.008)	(-0.008)	(-0.008)	(-0.009)	(-0.009)	(-0.009)	(-0.006)	(-0.006)	(-0.006)
Independent variable									
Coupled	0.007**	0.007**	0.011**	0.007*	0.007*	0.011**	0.002	-0.001	-0.005
	(-0.003)	(-0.003)	(-0.004)	(-0.004)	(-0.004)	(-0.005)	(-0.003)	(-0.003)	(-0.004)
Outside-in	0.001	0.001	0.008**	0.002	0.002	0.013***	0.003	0.003	0.003
	(-0.003)	(-0.003)	(-0.004)	(-0.003)	(-0.003)	(-0.004)	(-0.004)	(-0.004)	(-0.005)
Moderator									

APMC		-0.002	-0.005*		-0.002	-0.006*		0.007***	0.007***
		(-0.003)	(-0.003)		(-0.003)	(-0.003)		(-0.002)	(-0.002)
APMC*Coupled			-0.001			-0.001			0.002**
			(-0.001)			(-0.001)			(-0.001)
APMC*Outside-in			-0.002**			-0.004***			-0.0002
			(-0.001)			(-0.001)			(-0.002)
Observation	817	817	817	817	817	817	1,621	1,621	1,621
R2	0.130	0.131	0.141	0.130	0.130	0.145	0.121	0.135	0.138
Adjusted R2	0.125	0.125	0.132	0.124	0.124	0.137	0.120	0.133	0.135
F Statistic	20.075***	16.842***	13.637***	19.906***	16.672***	14.146***	33.532***	31.563***	24.298***

Table 5-4. Panel regression result of hetero-centered diversification

	Dependent variable: Hetero-centered MDI			Dependent variable: Hetero-centered PDI			Dependent variable: Hetero-centered TDI		
	Fixed effect model			Fixed effect model			Fixed effect model		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Control variable									
R&D investment	-3.893***	-3.870***	-3.735***	-0.279*	-0.269*	-0.254*	-445.319	-649.079	-632.055
	(0.866)	(0.869)	(-0.866)	(-0.153)	(-0.153)	(-0.152)	(-741.576)	(-742.464)	(-743.646)
Age	1.002***	1.070***	1.173***	0.222***	0.250***	0.275***	1,305.335***	1,056.658***	1,060.030***
	(0.15)	(0.205)	(-0.21)	(-0.027)	(-0.036)	(-0.037)	(-139.327)	(-162.506)	(-162.605)
Firm size	4.806***	4.843***	4.852***	-0.077	-0.062	-0.063	-806.532	-752.207	-718.919
	(1.11)	(0.869)	(-1.111)	(-0.196)	(-0.196)	(-0.195)	(-1050.136)	(-1046.989)	(-1049.632)
Independent variable									
Coupled	0.838*	0.860*	0.75	0.152*	0.161*	0.216*	23.174	-227.277	-555.727
	(0.479)	(0.481)	(-0.632)	(-0.084)	(-0.085)	(-0.111)	(-447.793)	(-454.398)	(-590.431)
Outside-in	0.214	0.224	1.379**	0.035	0.039	0.265***	793.564	795.376	879.738
	(0.402)	(0.403)	(-0.553)	(-0.071)	(-0.071)	(-0.097)	(-663.762)	(-661.671)	(-761.741)
Moderator									

APMC		-0.190	-0.541		-0.07	-0.155**		766.903***	760.314***
		(0.375)	(-0.399)		(-0.066)	(-0.07)		(-260.193)	(-263.474)
APMC*Coupled			0.06			-0.015			147.12
			(-0.142)			(-0.025)			(-158.205)
APMC*Outside-in			-0.420***			-0.078***			-95.247
			(-0.133)			(-0.023)			(-250.735)
Observation	817	817	817	817	817	817	1,621	1,621	1,621
R2	0.088	0.088	0.102	0.095	0.096	0.112	0.078	0.084	0.085
Adjusted R2	0.082	0.081	0.093	0.089	0.090	0.103	0.076	0.082	0.081
F Statistic	12.859***	10.746***	9.424***	13.988***	11.891***	10.475***	20.457***	18.604***	14.074***

In order to observe the moderating effect, the regression is conducted in a hierarchical form. First, the baseline models without moderators and interaction terms are estimated (models 1, 4, and 7). Secondly, APMC is included in the models (models 2, 5, and 8). Lastly, the moderating effect of APMC is introduced to the models (models 3, 6, and 9). The results of the balance-centered and hetero-centered diversifications are similar save for a few points (Tables 5-4 & 5-5). For ease of explanation, the results are described as a comparison between the two data sets: market/product and technology. For market and product diversification, all baseline models (models 1, 4, and 7) are highly consistent. In the case of control variables, firm age and firm size positively influenced balance-centered and hetero-centered diversification. Although younger firms have the advantage of greater creativity (Klepper, 1996), the experience of older firms is more likely to benefit diversification. Similarly, the positive effect of firm size implies that bigger firms are easier to diversify due to the availability of resources compared to smaller ones. The negative influence of R&D investment is also understandable as it is regarded as a sunk cost regarding firm performance.

For market and product diversifications, the effects of coupled activities are shown to be positive and significant while the effects of outside-in activities are not significant. This result partially supports previous studies as the effects of both open innovation activities are known to be significant. The effect of open innovation activities was examined in previous studies using cross-sectional, not panel, data. Using panel data, the evaluation of open innovation activities is conducted accumulatively, rather than with reference to individual activities. This leads to a different result as the results of this study are derived from panel data analysis using an integrated data set of all individual records of firms' alliances.

Although the effects of APMC are not significant (models 2, 5, and 8), the interaction terms showed interesting results (models 3, 6, and 9) for market and product diversification. The coefficients of the interaction terms between APMC and outside-in activities are negative and significant for market and product diversification. As mentioned earlier, a negative value of balance-centered (hetero-centered) diversification indicates concentration (less-heterogeneity) in diversification. This result implies that APMC has a significant influence on the relationship between outside-in activities and market/product diversification. In other words, with greater APMCs, a firm can promote market and product diversification by conducting outside-in activities.

In case of technological diversification, the effects of APMC are shown to be positive and significant. The moderating effect of APMCs on the TDI, however, is slightly different for the MDI and the PDI. For balance-centered technological diversification, the coefficient of the interaction term between APMC and coupled activities is positive at the statistically significant level. It implies that coupled activities enhance balance-centered technological diversification with the existence of APMCs. Simply put, a firm with higher APMC is more likely to promote balance-centered technological diversification through coupled activities. On the other hand, the interaction term between APMC and outside-in activities is shown to be insignificant.

5.5 Discussion

This study investigates the effects of open innovation activities (coupled and outside-in) on firm-level diversification activities taking into consideration the moderating effect of APMCs. Using this approach, an empirical analysis is conducted using the case of pharmaceutical firms. The theoretical and managerial implications of our findings are discussed.

5.5.1 Managerial discussion

Engagement in various strategic alliances has become a ubiquitous phenomenon in the business landscape (Contractor & Lorange, 2002; Gulati, 1998). Compared to strategic alliances, however, an alliance portfolio is more complicated because it requires the consideration of additional aspects regarding the firm itself and its partners and relationships. Our results provide firm-specific managerial implications, in particular for pharmaceutical firms.

First of all, a firm’s APMCs are important to realize the effect of open innovation activities. The result of this study shows that the effect of a firm’s innovation activities becomes significant when it is considered with APMCs. As more firms engage in simultaneous partnerships with various organizations, the ability to manage alliance portfolios is important. Accordingly, a greater value of APMC indicates that firms have an advantage in discovering new partners (partnering proactiveness) and promoting information flow (portfolio coordination) and trust (relational governance). In order to enhance the effects of alliance activity, firms should strengthen their APMCs with respect to partnering proactiveness, portfolio coordination, and trust.

In addition, the implications of open innovation activities for the pharmaceutical industry should differ depending on the type of diversification needed. For firms with high levels of APMCs entering into alliances for the purpose of market and product diversification, their interest is in either entering the market or developing a product using their technologies. From the firm's perspective, outside-in activities allow them to enrich resources that they do not have. In this sense, the intention of outside-in activities should be understood in the context of a focal firm's product development. As pharmaceutical product development requires a huge investment over a long period of time, outside activities are more likely to contribute to the diversification of existing market and product resources. On the other hand, firms that are aiming to develop technology through alliances should consider using coupled activities. Technology alliances are somewhat different from market and product alliances due to the existence of a synergistic effect. Through coupled activities, it is possible for participating firms to create a synergistic effect as the two different technological components belonging to the partnered firms can be combined. Since the role of technology is highly valued in the pharmaceutical industry, coupled activities are recommended for the creation of a better technological outcome.

5.5.2 Theoretical discussion

Due to its importance in both theoretical and practical aspects, open innovation has been widely discussed by various researchers. This study advances the open innovation model as follows.

Firstly, this study investigated the effect of open innovation activities from the alliance portfolio perspective. In practice, firms enter into various types of alliances with different partners simultaneously. For instance, firm A can have a partnership with firm B and C with different open innovation activities in 2018. In previous studies, however, firms' open innovation activities are mostly discussed with reference to a certain type of activity or over a certain time period. Consequently, the evaluation of open innovation activities is done from an overall perspective. The outcome of this approach is still powerful as it provides an overall understanding of open innovation activities. However, this approach is vulnerable as it may either over- or under-emphasize the result. In contrast, this study measures firms' open innovation activities with reference to all their alliance records. It not only allows us to consider all open innovation activities, but also guarantees the objectivity of the classification as it is distinguished by each alliance's deal category.

In addition, this study proposed a measurement for APMCs based on network theory. In previous studies, APMC is measured using survey materials including relevant questionnaires that reflect the definition of each component (Castro & Roldán, 2015a; Luvison & De Man, 2015; Oerlemans et al., 2013; Sarkar et al., 2009; Schreiner et al., 2009). In contrast, this study addressed the connection between network indices and APMC components. Since the original idea of APMC is based on social capital theory, this approach is more effective in maintaining the objectivity and consistency of its measurements. With this proposed calculation, this study contributes to future studies on APMC and the expansion of the application of network theory.

Lastly, contributions to open innovation theory are made by investigating the moderating effect of APMC. In open innovation studies, individual effects were mostly focused on a firm's internal capacities. As mentioned earlier, however, firms' alliance activities are becoming more diverse and frequent. Thus, a consideration of a firm's ability to manage alliance portfolios can reflect these phenomena. In subsequent studies, the moderating effect of APMCs can be investigated in various research on firms' collaboration activities including mergers and acquisitions and joint ventures.

Chapter 6. Conclusion

6.1 Summary

This study aims to propose a firm-level diversification framework that addresses the limitations of existing studies and derives insights and implications for strategic management. For this purpose, this study is constructed with three articles, which are summarized as follows.

In the first article, the issue of selecting a diversification index is discussed, taking into consideration the properties of diversity. Along with the importance of diversification, various diversification measurements are introduced and used in previous studies. The list of diversification indices affords a wide selection to researchers; however, the absence of consensus on the selection of a diversification index may lead to justified allegations of a lack of objectivity. This study focuses on the case of technological diversification to derive empirical implications for selecting a suitable diversification index. In order to do so, the technological diversification indices (Variety, the HHI, the Gini-Simpson, the 1/HHI, Entropy, and the Rao-Stirling) that are frequently used in previous studies are examined to determine which are better suited for measuring applicant-level technological diversification. To obtain the content validity of the diversification index, three cases were tested: cross-sectional and single and multiple time periods. The diversification indices were separated into two groups: the HHI, the Gini-Simpson, the 1/HHI, and Entropy for

PC1 and Variety and the Rao-Stirling for PC2. In this context, diversification can be explained from two perspectives of diversification: balance-centered and hetero-centered. Balance-centered diversification refers to the balance of diversification where the proportion of elements is the target of interest. Hetero-centered diversification refers to the variety and disparity of diversification, which focuses on the degree of differentiation among elements. Accordingly, the balance-centered and hetero-centered diversification perspectives are recommended for use in applicant-level technological diversification studies.

The second article examines the relationship between firm-level diversification activities and performance with respect to diversification perspectives. Due to the importance of the effects of diversification, a firm’s diversification was discussed with reference to the different value chains: market, product, and technological. However, the existing approach for measuring a firm’s product/market diversification using sales information distinguished using the SIC cannot provide direct implications as different strategies are constructed for market and product diversification. In addition, diversification itself was studied in a simple manner although it comprises different aspects and the results vary depending on the property of diversification the selected index emphasizes. In this sense, this study takes firm-level diversification research to a new level of analysis by considering firm-level diversification with a clear separation between markets and products and two diversification perspectives: balance-centered (the Gini-Simpson) and hetero-centered (the Rao-Stirling). To determine the effects of firm-level diversification activities on business and innovation performance, an empirical analysis for pharmaceutical firms is conducted. In the case of market diversification, market heterogeneity enhances business performance. For product (technological) diversification, a balanced (concentrated) form of diversification involving less product (greater technological) heterogeneity is suggested. This result not only suggests the importance of differentiated strategies for product and technological diversification, but also the consistency of a diversification strategy regardless of the stage of development.

In the third article, the effect of open innovation activities on diversification is investigated taking into consideration the moderating effect of APMC. Strategic alliances are now becoming a ubiquitous phenomenon in business as it can reduce transaction costs, provide access to new resources, reduce uncertainty, and improve competitive advantages. Due to the complexity of diversification, entering into strategic alliances with other organizations became an efficient method of diversification. As more firms enter into multiple alliances with various partners, a firm's ability to manage multiple alliances caught the attention of various researchers. This study examines a firm's alliance strategy to promote diversification by adopting an open innovation model and APMC. The open innovation model represents a way of conducting alliances with other organizations, while APMC indicates a firm's ability to manage various alliances. For this purpose, panel data is constructed and network analysis used to measure APMC. As a result, the moderating effect of APMC on the relationship between open innovation activities and diversification is observed. This demonstrates the importance of APMC in realizing the effects of open innovation activities and differentiates the consequences of open innovation activities depending on the goals of diversification.

6.2 Contribution

Through Chapters 2 and 3, this study proposes a firm-level diversification framework including market, product, and technological diversification with two diversification perspectives (balance-centered and hetero-centered) that can overcome and address the limitations of previous studies. This framework can be used to derive more specific implications for market and product diversification. Firstly, by differentiating market and product diversification, this framework can contribute to the derivation of strategic implications for each market and product. Compared to previous approaches that measured diversification with sales data classified using the SIC, this approach can be much more beneficial to firms as it directly links to a firm’s actual strategic decision making for its markets and products. Secondly, this framework provides an overall consideration of a firm’s diversification activities. In most cases, a firm’s diversification efforts are focused on one of the activities. A firm’s activities, however, are not irrelevant to one another as they are all part of the firm’s activities. The framework proposed in this study integrates proposals for market, product, and technological diversification, and also emphasizes the importance of a holistic consideration of a firm’s diversification activities. Lastly, adopting two diversification perspectives broadens our understanding of diversification. The absence of a consensus on a diversification index may lead to a lack of objectivity and inconsistent results. Since diversification indices contain different properties of diversity, examining diversification from two different perspectives is more suitable. By doing so, not only is the meaning of diversification clarified, but more specific implications for diversification can also be derived.

As a result of Chapters 4 and 5, this study provides managerial implications for diversification strategies with respect to the properties of diversity. As mentioned earlier, the two diversification perspectives refer to different properties of diversification. Balance-centered diversification indicates whether diversification is balanced or unbalanced while hetero-centered diversification indicates whether diversification is heterogeneous or otherwise. These proposed diversification perspectives can be used to classify a firm's diversification behavior into four types: generalist, specialist, pioneer, and conservative. If a firm's diversification is well balanced, it is assumed that this firm prefers to obtain various elements in equal proportions. On the other hand, concentrated diversification implies that a firm's activities are concentrated on certain elements. Hence, a firm with a well-balanced approach to diversification can be described as a generalist while one with a concentrated approach can be described as a specialist. In the case of hetero-centered diversification, a firm with a greater heterogeneity of elements is one that would pursue something new and different from what it has. If a firm's diversification is less heterogeneous, then the firm diversifies within its boundary of elements.

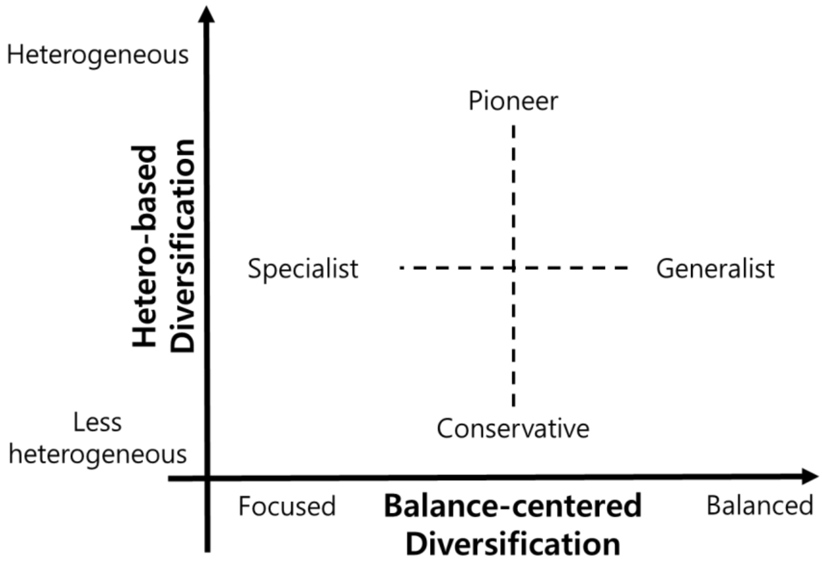

Figure 6-1. Diversification strategy types

Based on this classification, the resulting diversification effects can be redefined to diversification strategy types (Figure 6-1). For instance, the positive effect of hetero-centered market diversification on business performance indicates that a pioneer-type firm is more likely to achieve better business performance. In the case of product diversification, a generalist- or conservative-type firm is more likely to obtain better business and innovation performance. In this way, managerial implications for a firm's diversification activities can be distinguished with respect to the properties of diversity and, more importantly, industry-specific features can be obtained. Due to the highly knowledge-intensive nature of the pharmaceutical industry, the dominant players in each product category have remained almost unchanged. However, firms continuously invest into R&D not only to explore for blue oceans, but also retain their technological specialty. As the empirical results of Chapter 4 reflect the conditions of the pharmaceutical industry, this approach can be similarly implemented to examine different industries.

Lastly, this study bridges open innovation activities and APMC to understand firm-level diversification. Due to the complexity of diversification, entering into strategic alliances with other organizations has been an alternative solution for firms. This contributes to understanding a firm's alliance portfolio activity by investigating its method of collaboration and APMC. With this approach, certain trends for each of the diversification activities can be observed.

From the results of Chapter 5, for example, the average levels of the top 100 firms' diversification perspectives categorized by open innovation activities and APMC are shown in Figures 6-2, 6-3, and 6-4. From the case of market and product diversification, a group of firms with higher levels of APMCs are located at the top-right corner of the graph. In addition, most of them conduct outside-in activities instead of coupled activities. This implies that firms with higher market/product balance-centered and hetero-centered diversification are likely to have greater APMCs and choose to focus on outside-in activities. In this context, a firm with the ability to manage diverse alliance portfolios seems to prefer outside-in activities for product and market diversification.

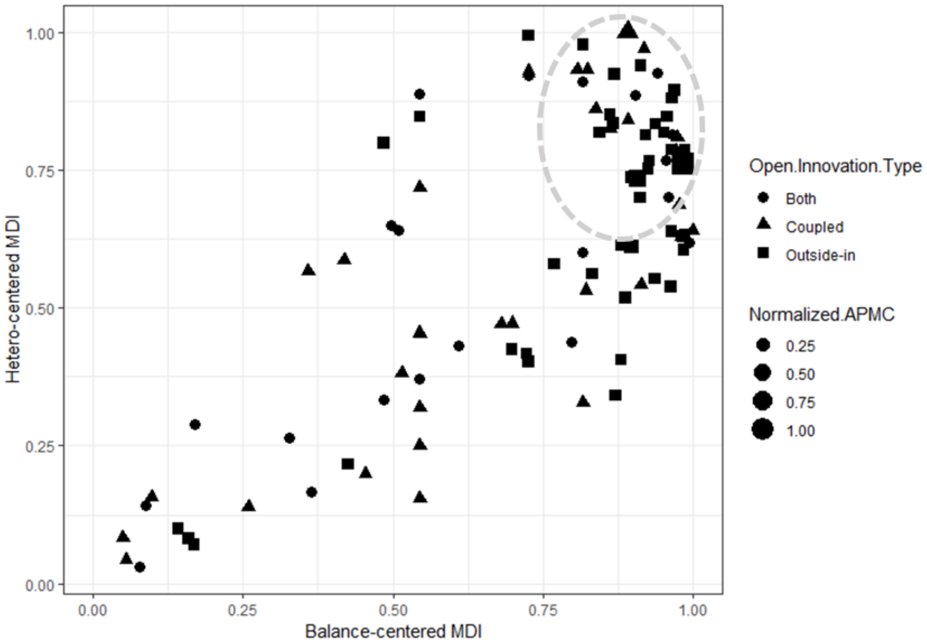

Figure 6-2. Market diversification and APMC

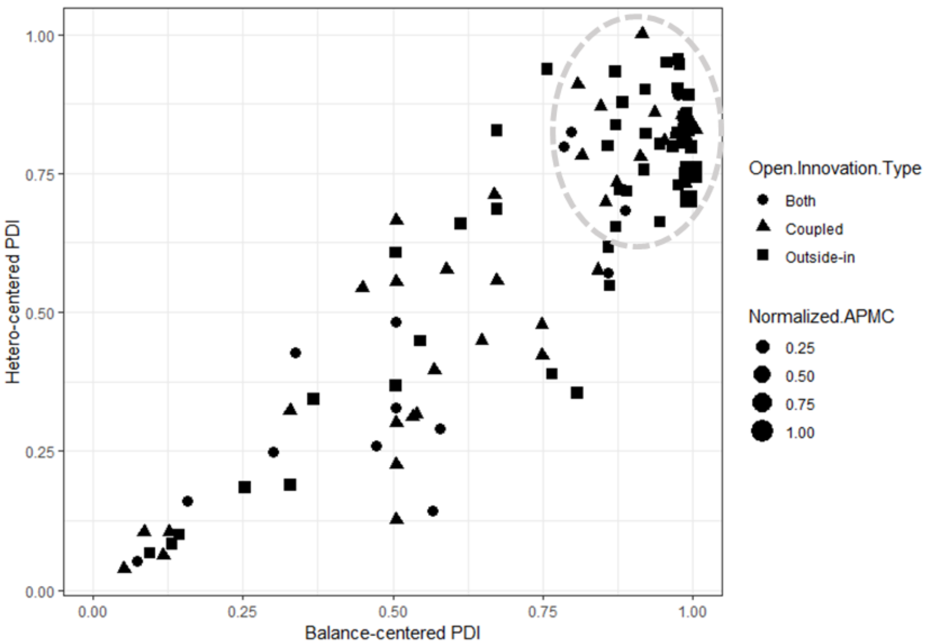

Figure 6-3. Product diversification and APMC

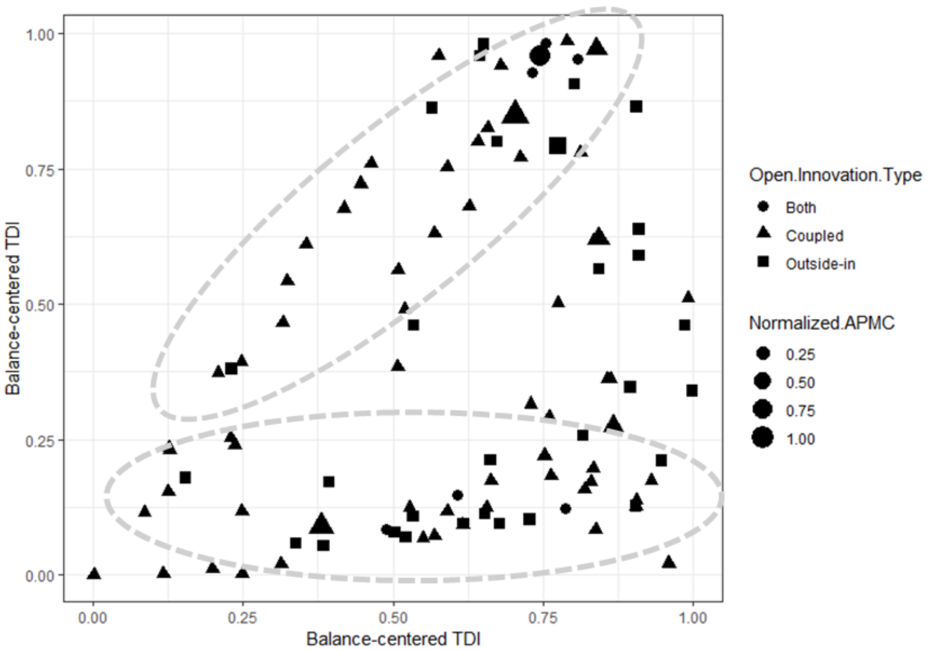

Figure 6-4. Technology diversification and APMC

In the case of technological diversification, no trend was observed regarding the level of APMC. Instead, coupled activities are observed more frequently than outside-in activities especially for groups with high levels of APMCs. Unlike market and product diversification, this result shows that a firm with the ability to manage diverse alliance portfolios prefers coupled activities. In addition, two types of trends are observed in technological diversification: one goes to the top-right corner and one moves horizontally. The former trend implies the pursuit of both balance-centered and hetero-centered diversification while the latter only focuses on balance-centered diversification with hetero-centered diversification remaining unchanged. This result shows that a firm's alliance portfolio for technological diversification can pursue either both types of diversification or only balance-centered diversification. By bridging firm-level diversification, open innovation activities, and APMCs, certain trends are observed. The contributions of this study are not restricted to this empirical study but are expected to be capable of implementation in various cases.

6.3 Limitations and future research

This study proposes a firm-level diversification framework consisting of market, product, and technological diversification activities taking into consideration two diversification perspectives. In order to achieve this, this study not only examined the properties of diversity and clarified the diversification activities, but also tried to derive strategic implications for diversification regarding diversification itself and alliance portfolio management. Unfortunately, this study exhibits a few limitations that are left for further studies.

In the first article, the content validity of the diversification index was only focused on technological diversification. Since the goal of this study targets the investigation of a firm's diversification activities, the initial intention was to cover both market and product diversification. As already described in the first article, however, the data should be transferable to various structures and applicable to different cases. Due to the limitations of market and product data, the content validity of the diversification index was only tested in the case of technological diversification using patent data. Since diversification measurements may differ depending on the data source, this remains a limitation of this study.

The second and third article also contain limitations. Firstly, the empirical analysis is only limited to pharmaceutical firms. The pharmaceutical industry itself is suitable for the purpose of this study as they are knowledge-based, have a clear distinction between markets and products, and are frequently involved in diversification activities and strategic alliances. In other words, the empirical analysis conducted on the case of the pharmaceutical industry is reasonably applicable to the main context of this study. The inclusion of other industries, however, may contribute to the generality of the framework. In addition, the individual characteristics of each industry can be observed by comparison.

In addition, the relationship between each diversification activity was not considered. The three firm-level diversification activities introduced in this study reflect a firm's major activities in a product-development process. As these activities are not standalone, the inter-relationship among them can provide interesting findings to aid in the understanding of diversification activities. The structural relationship between diversification activities can be investigated in further studies.

Lastly, diversification among various industries can be implemented. One of the remarkable phenomena occurring around us as a result of the so-called the fourth industrial revolution is convergence. Convergence is defined as "a blurring of boundaries between at least two hitherto disjoint areas of science, technology, markets, or industries" (Curran & Leker, 2011, p. 258). As a result of convergence, the boundaries between heterogeneous industries, products, and technologies have become meaningless. As convergence among different industries and technologies begins to occur more frequently, diversification is found to be a prevailing phenomenon in various areas and scopes. Accordingly, an investigation of a firm’s diversification into various industries can be a timely research subject.

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Appendix 1: Correlation matrix (Chapter 4)

Table A1-1. Correlations coefficient matrix for business performance model (1)

	VIF	1	2	3	4	5	6
1 Business Performance$_{t+1}$	-						
2 Balance-centered MDI$_t$	3.58	0.03					
3 Balance-centered PDI$_t$	3.72	-0.01	**0.84**				
4 Balance-centered TDI$_t$	1.34	**-0.2**	**0.1**	0.01			
5 Employee $_t$	1.34	**0.13**	**-0.32**	**-0.33**	**-0.33**		
6 R&D investment$_t$	1.06	**0.53**	**-0.12**	**-0.11**	**-0.2**	0.07	
7 Age$_t$	1.49	0.04	**-0.37**	**-0.37**	**-0.4**	**0.42**	**0.13**

Notes: Correlation in bold denote statistical significance at the 5% levels.

Table A1-2. Correlations coefficient matrix for innovation performance model (2)

	VIF	1	2	3	4	5	6
1 Business Performance$_{t+1}$	-						
2 Hetero-centered MDI$_t$	3.58	0					
3 Hetero-centered PDI$_t$	3.72	-0.03	**0.83**				
4 Hetero-centered TDI$_t$	1.34	**0.11**	**0.14**	**0.15**			
5 Employee$_t$	1.34	**0.13**	**0.29**	**0.27**	**0.15**		
6 R&D investment$_t$	1.06	**0.53**	**0.13**	**0.1**	**0.16**	**0.07**	
7 Age$_t$	1.49	0.04	**0.3**	**0.31**	**0.24**	**0.42**	**0.13**

Notes: Correlation in bold denote statistical significance at the 5% levels.

Table A1-3. Correlations coefficient matrix for business performance model (3)

	VIF	1	2	3	4	5	6
1 Innovation Performance$_{t+2}$	-						
2 Balance-centered MDI$_t$	3.59	0.01					
3 Balance-centered PDI$_t$	3.75	-0.01	**0.84**				
4 Balance-centered TDI$_t$	1.34	**-0.25**	**0.09**	0.01			
5 Employee$_t$	1.35	**0.38**	**-0.32**	**-0.33**	**-0.33**		

6 R&D investment$_t$	1.06	**0.07**	**-0.12**	**-0.11**	**-0.21**	**0.07**	
7 Age$_t$	1.49	**0.24**	**-0.36**	**-0.37**	**-0.39**	**0.43**	**0.13**

Notes: Correlation in bold denote statistical significance at the 5% levels.

Table A1-4**.** Correlations coefficient matrix for business performance model (4)

	VIF	1	2	3	4	5	6
1 Innovation Performance$_{t+2}$	-						
2 Hetero-centered MDI$_t$	3.37	0.02					
3 Hetero-centered PDI$_t$	3.33	0.01	**0.83**				
4 Hetero-centered TDI$_t$	1.09	-0.02	**0.14**	**0.15**			
5 Employee$_t$	1.28	**0.38**	**0.3**	**0.27**	**0.15**		
6 R&D investment$_t$	1.05	0.07	**0.13**	**0.11**	**0.16**	**0.07**	
7 Age$_t$	1.34	**0.24**	**0.3**	**0.31**	**0.24**	**0.43**	**0.13**

Notes: Correlation in bold denote statistical significance at the 5% levels.

Appendix 2: Diversification category

Table A2-1. Diversification types for each domain

Diversification Domain	Diversification Target	Types
Market Type	Therapeutic Category (22)	Infectious Diseases; Cardiovascular; Oncology; Central Nervous System; Endocrine, Metabolic and Genetic Disorders; Dermatology; Immunology and Inflammation; Ophthalmology; Surgery; Genitourinary Disorders; Gastroenterology; Respiratory; Musculoskeletal; Hematology; Nutritional Deficiency; Fever; Poisoning; Edema; Dental; Diagnostics; Others; Trauma
Product Type	ATC EphMRA Drug Class Third Level (233)	A10; A10C; A10H; A10J; A10K; A10L; A10M; A10N; A10S; A10X; A11; A11B; A11C; A11F; A12A; A12B; A12C; A14A; A15; A16; A1A; A1B; A2A; A2B; A3A; A3C; A3F; A3G; A4A; A5A; A5B; A6A; A7A; A7E; A7H; A7X; A8A; A9A; B1A; B1B; B1C; B1D; B1E; B2A; B2B; B2C; B3A; B3X; B6C; C10A; C10B; C10C; C11A; C1A; C1B; C1C; C1D; C1E; C1F; C1X; C2A; C2B; C2D; C3A; C4A; C5A; C5C; C6X; C7A; C8A; C9A; C9B; C9C; C9D; D10; D10A; D10B; D1A; D2A; D3A; D4A; D5A; D5B; D5X; D6A; D6D; D7A; D7B; D8A; G1A; G1B; G1C; G1D; G2A; G2B; G2D; G2E; G2F; G2X; G3A; G3B; G3C; G3D; G3E; G3F; G3G; G3J; G3X; G4A; G4C; G4D; G4E; G4X; H1A; H1C; H2A; H3A; H3B; H4A; H4C; H4D; H4E; J1A; J1B; J1C; J1D; J1E; J1F; J1G; J1H; J1K; J1M; J1P; J1X; J2A; J3A; J4A; J4B; J5B; J5B4; J5C; J5D; J8X; K1B; K6B; L1A; L1B; L1C; L1F; L1G; L1H; L1X; L2A; L2B; L4B; L4X; M1A; M1C; M2A; M3A; M3B; M4A; M5B; M5X; N1A; N1B; N2A; N2B; N2C; N3A; N4A; N5A; N5B; N5C; N6A; N6B;

		N6C; N6D; N7B; N7D; N7E; N7F; N7X; P1A; P1B; P1D; P1G; P3A; R01A; R1A; R1B; R3A; R3B; R3C; R3D; R3F; R3J; R3K; R3X; R5B; R5C; R5D; R5F; R6A; R7A; R7C; R7X; S1A; S1B; S1C; S1D; S1E; S1G; S1H; S1K; S1P; S1R; S1T; S1X; S2A; S2C; T1E; T1G; T1X; T2X; V3C; V3D; V3E; V3F; V3G; V3H; V3X; V6D
Technology Type	International Patent Classification Sub-class (556)	A01B; A01C; A01D; A01F; A01G; A01H; A01J; A01K; A01M; A01N; A01P; A16K; A16N; A21B; A21C; A21D; A21K; A22B; A22C; A23B; A23C; A23D; A23F; A23G; A23J; A23K; A23L; A23P; A24B; A24C; A24D; A24F; A41B; A41D; A41F; A42B; A43B; A45C; A45D; A45F; A46B; A46D; A47B; A47C; A47D; A47F; A47G; A47H; A47J; A47K; A47L; A51K; A61B; A61C; A61D; A61F; A61G; A61H; A61J; A61K; A61L; A61M; A61N; A61P; A61Q; A61R; A61U; A61V; A62B; A62C; A62D; A63B; A63C; A63D; A63H; A66K; A67B; A67K; A69K; A81K; B01D; B01F; B01J; B01K; B01L; B02B; B02C; B02L; B03B; B03C; B03D; B04B; B04C; B04D; B05B; B05C; B05D; B05H; B06B; B07B; B07C; B07D; B08B; B09B; B09C; B21B; B21C; B21D; B21F; B21G; B21H; B22C; B22D; B22F; B23B; B23C; B23D; B23H; B23K; B23P; B23Q; B24B; B24C; B24D; B25B; B25C; B25F; B25G; B25J; B26B; B26D; B26F; B27B; B27C; B27G; B27K; B27L; B27N; B28B; B29B; B29C; B29D; B29F; B29H; B29J; B29K; B29L; B30B; B31B; B31C; B31D; B31F; B32B; B41B; B41C; B41D; B41F; B41J; B41L; B41M; B41N; B42D; B42F; B43K; B43L; B44C; B44D; B44F; B60B; B60C; B60D; B60J; B60K; B60L; B60N; B60R; B60T; B61B; B61C; B61K; B61L; B61N; B62B; B62C; B62D; B62M; B63B; B63C; B63G; B63H; B64D; B64H; B65B; B65C; B65D; B65G; B65H; B65O; B66C; B66F;

	B67B; B67C; B67D; B68G; B81B; B81C; B82B; B82Y; C01B; C01C; C01D; C01F; C01G; C01L; C01N; C02B; C02C; C02D; C02F; C03B; C03C; C04B; C05B; C05C; C05D; C05F; C05G; C06B; C06D; C06G; C06P; C07B; C07C; C07D; C07F; C07G; C07H; C07I; C07J; C07K; C07L; C07M; C07P; C07R; C08B; C08C; C08D; C08F; C08G; C08H; C08J; C08K; C08L; C08Q; C08R; C08V; C09B; C09C; C09D; C09F; C09G; C09H; C09J; C09K; C09L; C10B; C10C; C10G; C10H; C10J; C10K; C10L; C10M; C10N; C11B; C11C; C11D; C12B; C12C; C12D; C12G; C12H; C12K; C12M; C12N; C12P; C12Q; C12R; C12S; C13B; C13K; C14C; C21B; C21C; C21D; C22B; C22C; C22D; C22F; C23B; C23C; C23D; C23F; C23G; C25B; C25C; C25D; C25F; C30B; C40B; C61K; C67D; D01B; D01D; D01F; D01G; D01H; D02G; D02J; D03C; D03D; D03J; D04B; D04C; D04D; D04G; D04H; D05B; D05C; D06B; D06F; D06H; D06L; D06M; D06N; D06P; D06Q; D07B; D21C; D21F; D21H; D21J; D61N; E01C; E01F; E02B; E02D; E02F; E03B; E03C; E03D; E04B; E04C; E04D; E04F; E04G; E04H; E05B; E05C; E05D; E06B; E07D; E21B; E21D; E21F; E25D; F01B; F01C; F01D; F01K; F01L; F01N; F02B; F02C; F02D; F02F; F02G; F02M; F03C; F03D; F03G; F04B; F04C; F04D; F04F; F15B; F15C; F15D; F16B; F16C; F16D; F16F; F16G; F16H; F16J; F16K; F16L; F16M; F16N; F16P; F16R; F16S; F17C; F17D; F21I; F21K; F21L; F21S; F21V; F21Y; F22B; F23B; F23C; F23D; F23G; F23J; F23K; F23L; F23Q; F24C; F24F; F24H; F24J; F25B; F25C; F25D; F25J; F26B; F27B; F27D; F28B; F28D; F28F; F41G; F41H; F42B; G01B; G01C; G01D; G01F; G01G; G01H; G01J; G01K; G01L; G01M; G01N; G01P; G01Q; G01R; G01S; G01T; G01V; G02B; G02C; G02F; G03B;

	G03C; G03D; G03F; G03G; G03H; G04B; G04F; G04G; G05B; G05D; G05F; G05G; G06F; G06G; G06J; G06K; G06M; G06N; G06Q; G06T; G07C; G07D; G07F; G07H; G08B; G08C; G09B; G09C; G09F; G09G; G10H; G10K; G10L; G11B; G11C; G12B; G21C; G21F; G21G; G21H; G21K; G23F; G30B; G60F; G61K; G61N; H01B; H01C; H01F; H01G; H01H; H01J; H01K; H01L; H01M; H01N; H01P; H01Q; H01R; H01S; H01T; H02B; H02G; H02H; H02J; H02K; H02M; H02N; H02P; H02S; H03B; H03C; H03D; H03F; H03G; H03H; H03K; H03L; H03M; H04B; H04H; H04J; H04K; H04L; H04M; H04N; H04Q; H04R; H04W; H05B; H05F; H05G; H05H; H05K; H05R; H61B; H61K; H61M; H61N

Reference:

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https://www.ephmra.org/media/1884/atcguidelines2018final.pdf

Appendix 3: Alliance network (Chapter 5)

Figure A3-1. Alliance portfolio network (2001)

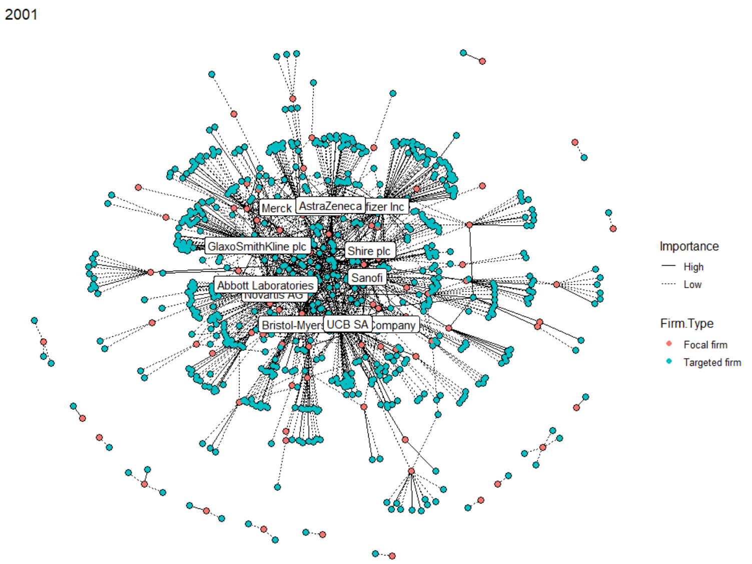


Figure A3-2. Alliance portfolio network (2006)

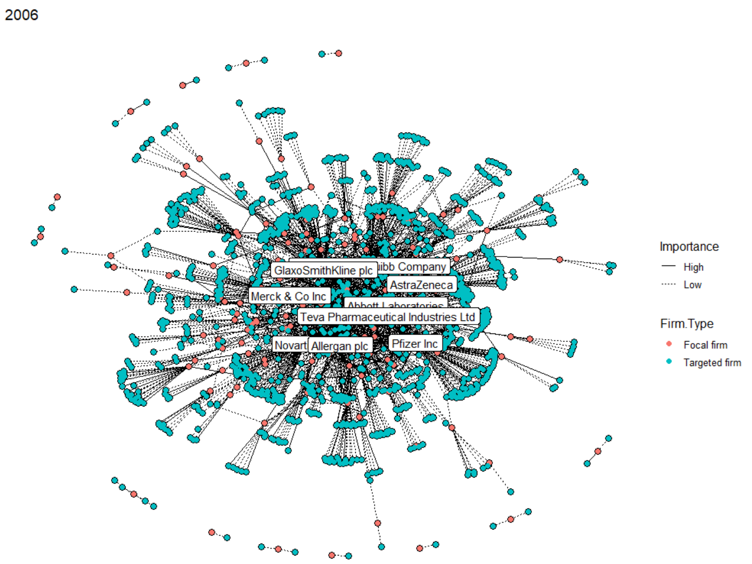


Figure A3-3. Alliance portfolio network (2011)

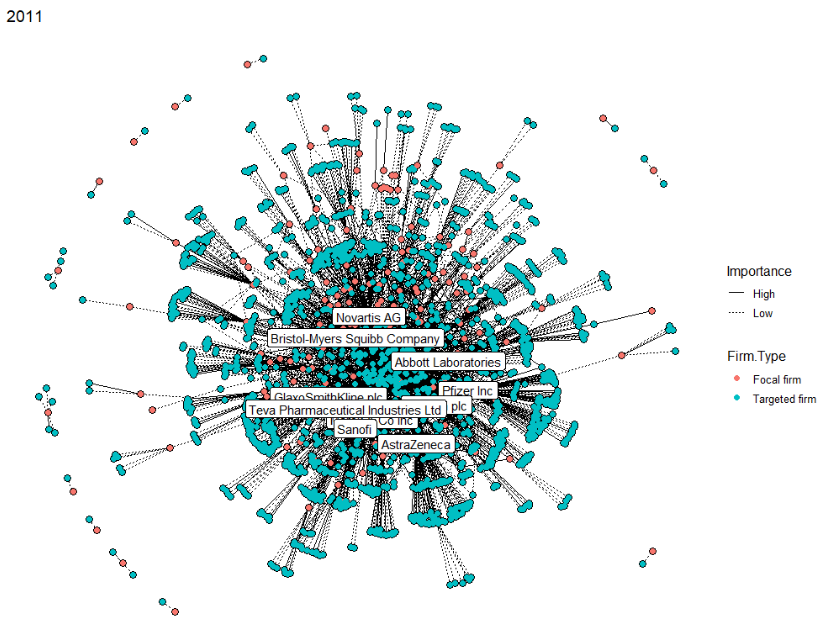
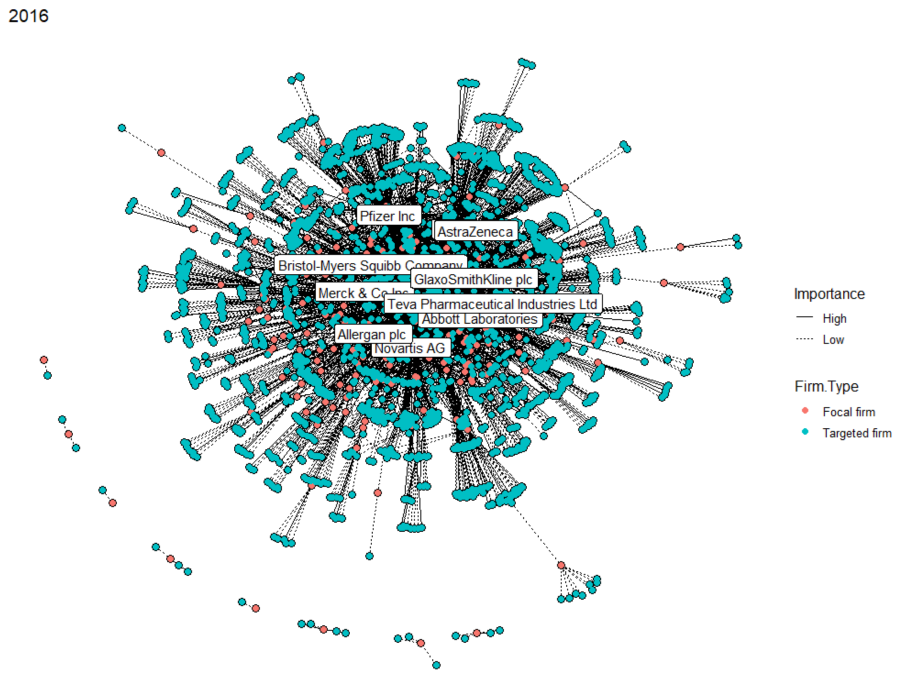


Figure A3-4. Alliance portfolio network (2016)



Appendix 4: Open innovation activities

Table A4-1. Open innovation activity category

Deal Category	Sub-deal Category	Open innovation activity
Acquisition (Product/Technology)		Outside-in
	Acquisition	Outside-in
Acquisition of Rights	Outside-in	
	Co-development	Coupled
	Collaboration	Coupled
	Co-Marketing	Coupled
	Commercialization	Coupled
	Co-promotion	Coupled
	Cross-Distribution	Coupled
	Cross-license	Coupled
	Development	Outside-in
	Distribution	Coupled
	Manufacturing	Coupled
	Joint Venture	Coupled
	Licensing Agreement	(Depending on lower category)
	Manufacturing	Coupled
	Affinity Marketing	Coupled
Co-development		Coupled
Collaboration		Coupled
Co-Marketing		Coupled
Commercialization		Coupled
Co-promotion		Coupled
Cross-Distribution		Coupled
Cross-license		Coupled
Funding/Grant		None
Infringement		None

Joint Venture	None
Letter of Intent	Inside-out
Licensing	Outside-in
Option	None
Manufacturing, Supply & Distribution	Coupled
Research & Development	Coupled
Settlement	None

Abstract (Korean)

시장 내외에서 발생하는 여러 불확실한 상황들 속에서 지속적으로 수익을 창출하고 경쟁 우위를 확보하는 것은 기업 활동에 요구되는 중요한 역량 중 하나이다. 이를 위해서 기업은 단순한 생존뿐만 아니라 지속적인 성장을 추구할 수 있는 경쟁력을 강화해야 한다. 이러한 측면에서, 다각화는 전략 경영 분야에서 가장 중요한 연구 주제이자 기업 활동으로 여겨지고 있다. 하지만 이를 달성하기 위해 요구되는 새로운 투자 및 기술과 시설 때문에 또 다른 한편으로 다각화는 복잡하고 불확실한 활동으로 알려져 있다. 이러한 의미에서, 전략적 제휴는 위험과 불확실성을 관리하면서 다각화를 달성하는 효과적인 수단으로 사용된다. 이에 기업들은 다각화 달성을 위해 제휴 포트폴리오를 구축하여 더 많은 파트너와 다양한 형태의 전략적 제휴 활동을 이어나가고 있다.

기업 다각화 관련 연구가 오랜 기간 지속되어 왔음에도 불구하고, 본 연구에서는 기존의 연구에서는 발견된 세 가지 한계점들을 다루고자 한다. 첫째, 다각화 지수의 선정 문제가 충분히 논의되지 않았다. 다각화의 개념은 그 특성에 따라 다르게 정의될 수 있으며, 기존의 다각화 지수들은 서로 다른 다각화 특성을 내포하고 있으므로 지수 선정에 관한 불충분한 논의는 단순한 결과의 차이뿐만 아니라 해석의 차이를 일으킬 수 있다. 둘째, 시장과 제품 다각화가 명확하게 구별되지 않았다. 이전의 연구에서 시장과 제품 다각화는 동일한 방식으로 측정되었기 때문에, 어떤 시장에 진입하고 어떤 제품을 개발할

것인지를 결정하는 실제 기업의 전략적 선택에 함의를 제공하는 데 한계를 나타냈다. 마지막으로, 기업의 제휴 포트폴리오 효과가 다각화에 미치는 효과를 보는 데 있어 제휴 포트폴리오 관리 능력의 역할이 고려되지 않았다. 더 많은 기업이 다른 파트너와 다양한 제휴 관계를 맺고 있음에도 불구하고 기존의 연구에서는 기업의 제휴 포트폴리오 관리 역량에 따른 그 효과의 차이를 보이지 못하였다. 이에 제휴 포트폴리오와 다각화의 관계를 이해하는 데 있어 제휴 포트폴리오 관리 역량에 대한 추가적인 접근 방식이 필요하다.

이에 본 연구는 다음의 세 가지 연구로 구성되었다. 먼저 첫 번째 연구에서는 다각화 특성의 관점에서 다각화 지수의 선택 문제를 다루었다. 다각화 지수의 내용 타당성을 확보하기 위해 특허 데이터를 이용한 기술 다각화를 세 가지 사례로 나누어 살펴보았다. 여기서 기존의 다각화 지수들은 Stirling이 제시한 다각화 프레임워크에 명시된 다각화 특성을 중심으로 분류하였고, 실증 분석으로는 각 지수 간의 패턴과 유사성을 분석하기 위해 주성분 분석을 사용하였다. 그 결과, 기존의 다각화 지수들은 두 가지 주요 구성 요소로 분류된다는 것을 확인할 수 있었다. 여기서 첫 번째 요소는 다각화의 균형을, 두 번째 요소는 다각화의 이질성을 나타내며, 각각의 대표 지수에는 Gini-Simpson과 Rao-Stirling이 제시되었다. 이러한 의미에서 본 연구는 균형 중심 및 이질성 중심 다각화 관점의 필요성과 대표 지수 선정의 근거를 제시하였다.

두 번째 논문에서는 기업 성과에 대한 기업 차원의 다각화의 효과에 대해 살펴보았다. 본 연구에서는 기업의 다각화는 시장, 제품 및 기술에 대한 기업

의 다각화 활동으로 구성되었다. 시장과 제품 다각화는 제품이 판매되는 시장의 유형과 제품의 기능적 유형으로 구분되었으며, 기술 다각화는 특허의 기술 분류코드로 측정하였다. 이와 함께 각 다각화 활동은 모두 균형 중심 및 이질성 중심 다각화 관점에서 측정되었다. 실증 분석에는 제약 산업의 사례를 중심으로 살펴보았으며, 이를 위해 기업의 시장, 제품 및 특허 데이터를 통합한 패널 데이터를 구축하였다. 그 결과, 기업 성과 향상을 위해 이질적인 시장 다각화, 균형 있고 덜 이질적인 제품 다각화, 그리고 집중되고 이질적인 기술 다각화라는 전략적 함의가 도출되었다.

셋째 논문에서는 개방형 혁신 활동과 기업의 다각화 간의 관계를 제휴 포트폴리오 관리 역량의 영향을 고려하여 분석하였다. 이를 위해 네트워크 분석을 이용한 기업의 제휴 포트폴리오 관리 능력 측정 방식이 제시되었으며, 회사의 개방형 혁신 활동들은 전체 누적이 아닌 연도별 거래 기록으로 평가되었다. 그 결과, 제휴 포트폴리오 관리 기능의 조절 효과가 확인되었는데, 이는 기업의 Outside-in 제휴 활동은 시장과 제품의 집중화된 다각화를 추진하고 Coupled 제휴 활동은 균형 잡힌 기술 다각화를 촉진하는 것을 확인하였다.

본 연구에서는 두 가지 다각화 관점으로 시장, 제품 및 기술로 구성된 기업 다각화 프레임워크를 제안하였다. 본 연구에서 제시한 다각화 프레임워크는 기업의 다각화 전략 유형을 일반주의자, 전문가, 개척자 및 보수주의자의 네 가지 유형으로 분류하는 데 사용할 수 있다. 또한, 본 연구는 기업의 다각화 활동을 이해하기 위한 개방형 혁신 활동과 제휴 포트폴리오 관리 역량을 함께 고려하여 분석하였다. 본 연구에서 제시한 기업 다각화 프레임워크는 이

러한 접근 방식 외에도 기업의 다각화 활동을 분석하고 이해하는 다양한 형태로 사용되어 추가적인 전략적 시사점을 제공하는데 사용될 수 있다.

주요어 : 기업 다각화, 다각화 특성, 특허 분석, 제휴 포트폴리오, 제휴 포트폴리오 관리 역량
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