Alliance Portfolio Diversity on Innovation Performance
- the Role of Internal Capabilities of Value Creation

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논문 요약

In this study, we suggest a new perspective on the linkage between alliance portfolio diversity and innovation performance based on a contingency approach. Using a longitudinal data set on alliance portfolios and patents of 182 firms in the U.S. manufacturing industries, we examined that alliance portfolio diversity has a U-shaped relationship with firm-level innovation. Internal value creation capabilities in terms of routine and ability are found to moderate the relationship between alliance portfolio diversity and innovation performance: Organizational search routine strengthens the relationship of alliance portfolio diversity and innovation performance while technological capabilities weaken and flip the relationship.

Keywords : Alliance Portfolio Diversity; Innovation Performance; Internal Capabilities.

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Ⅰ. Introduction

Collaborations between firms are regarded as one of the key elements for driving their innovation. Solely on their own resources, most firms are not sufficiently able to address the changes in their environment. Collaborations allow access to new ideas and resources, encourage new ways of combining of existing resources, and increase the participants' innovation capabilities (Gupta, Tesluk, & Taylor, 2007).

Collaboration with diverse parties allows firms to create value in different ways: Collaborations with suppliers contribute to increasing input quality and realizing process innovation and cost reduction (Sobrero & Roberts, 2002). Collaborations with buyers contribute to obtaining feedback on products and services, improving existing processes, and developing new products (Lee & Wong, 2009; Von Hippel, 2007). Collaborations with competitors allow access to specific knowledge in the industry and allow to share the burden of investment in facilities and research (Kim & Higgins, 2007; Miotti & Sachwald, 2003). The type of collaborations varies from joint ventures, alliances to M&As. Firms choose a type of collaboration according to their goals and situations to increase their competitive advantage (Man & Duysters, 2005). In this paper, among the various type of inter-firm collaborations, we focus on alliances. Alliances allow firms to flexibly cooperate with external parties and gain access to their resources without incurring the high costs and complexities associated with other collaboration modes such as M&As or joint ventures.

To fully take advantage of the benefits offered by external partners, firms often simultaneously participate in multiple alliances with different partners (Gulati & Singh, 1993) build up what is commonly referred to as an alliance portfolio. With the interest of its diverse nature and relating consequences, a number of recent studies examine the relationship between alliance portfolio diversity and innovation performance. Alliance portfolio diversity represents the distribution of differences in partners' characteristics within a firm's alliance portfolio. While a number of prior studies have emphasized the important performance implications of alliance portfolio diversity, no clear consensus was reached on the optimal degree of diversity, which maximizes innovation performance.

As reported in previous studies, alliance portfolio diversity should be seen as a double-edged sword, possessing both advantages and disadvantages (Oerlemans, Knoben, & Pretorius, 2013; Vasudeva & Anand, 2011). A stream of literature stresses the advantage of diverse partners such as access to diverse resources, low redundancy in resources, and the possibility of an increased number of innovative combinations using the acquired resources (Cui & O'connor, 2012; Duysters & Lokshin, 2011; Faems, Janssens, & Neyens, 2012). On the other hand, another stream of literature points out the drawbacks of high degrees of alliance portfolio diversity such as the complexity derived from extramural resources or the increasing costs of managing diverse relationships (Bae & Gargiulo, 2004; Faems *et al.*, 2008; Gualti & Singh, 1998). The two-dimensional arguments for these effects of alliance portfolio diversity are often equally compelling (Jiang, Tao, & Santoro, 2010).

We believe that it is difficult to fully understand the mechanism of the alliance portfolio's effects on firm innovation unless it is considered from a contingency perspective. Prior literature has found the effects of Alliance portfolio diversity to depend on the context within the organization (Srivastava & Gnyawali, 2011; Wuyts & Dutta, 2014; Zaheer & Bell, 2005). Even if firms assemble a strong portfolio with great partners, the impact on its performance will vary depending on how the alliance portfolio is utilized within the organization.

From this perspective, we argue that the firm's internal capability of value creation plays a critical role in leveraging alliance portfolio diversity. Alliance portfolio diversity can be seen as a pool of external resources which the focal firm can access. The extent of benefit that the focal firm derives from the portfolio will depend upon its internal capabilities to create value from the external resource pool.

Based on the dynamic capabilities framework that emphasizes that competitive advantage is generated from the capabilities to combine and recombine internal and external resources (Teece, 1996; Teece, Pisano, &, Shuen, 1997), this study empirically investigates how the fit between the firm's alliance portfolio strategy and its internal capabilities affects innovation performance. We examine how the internal capabilities of value creation allow firms to leverage the relationship between innovation performance and alliance portfolio diversity defined in terms of the industrial diversity of the partners. In this study, the internal capabilities of value creation are examined using two aspects: routine (organizational search routine) and ability (technological capabilities).

This study makes several contributions to literature on alliances and innovation. Emphasizing the contingency perspective on the mechanisms of alliance strategy, this paper increases the understanding of the relationship between alliance portfolio diversity and innovation performance. By developing the concept of fit through a comprehensive empirical test, this study specifies the role of organizational search routine and technological capabilities as internal capabilities of value creation which influence the effects of alliance portfolio diversity on innovation performance. This is noteworthy on both the theoretical and practical level.

This study also provides guidelines for selecting new alliance partners. In case of forming new alliances, firms usually consider the individual attributes of potential partners such as their technological capabilities, previous performance, and their top management's capabilities. In the meantime, firms do not sufficiently consider the composition of their alliance portfolios and the fit between their alliance portfolio, organizational search routine, and technological capabilities. However, for the sake of increased innovation performance, the findings of this study highlight that it is critical to consider the strategic fit between the firm's alliance portfolio and its internal capabilities as well as the composition of the alliance portfolio when selecting suitable alliance partners.

The remainder of this paper is organized as follows: First, we present the theoretical background which is used to develop hypotheses which link alliance portfolio diversity, organizational search routine, technological capabilities, and innovation performance. Second, employing negative binomial regression in a fixed-effect model, we tested these hypotheses using a dataset of alliance deal and firm-level data of 182 manufacturing firms in the time period between 2000 and 2011. Finally, we present the empirical results and conclude with a discussion of the implications of this paper.

II. THEORY DEVELOPMENT

1. Alliance Portfolio Diversity and Firm Innovation

In the technology intensive sector, the pace of technological development is accelerating, product life cycles are shortening, and the expense of updating capital equipment is increasing (Sampson, 2007). In response to these pressures, many firms pursue inter-firm technological alliances as an alternative to in-house R&D. Through technological alliances such as R&D collaboration, licensing and joint venturing, firms can gain access to capabilities or knowledge in promising fields (Powell, Koput, & Smith-Doerr, 1996), pool complementary capabilities (Eisenhardt & Schoonhoven, 1996), reap economies of scale in R&D, and shorten development time (Mariti & Smiley, 1983; Powell, 1990), while spreading the risk and cost of such new developments (e.g. Sampson, 2007). Thus, alliances are an attractive tool which helps to overcome the limitations of internal resources and enables firms to gain additional benefits (Ahuja, 2000; Gulati, 2007).

A firm usually engages in multiple alliances at the same time (Lavie, 2007). The challenge of coordinating multiple simultaneous alliances has prompted firms to establish dedicated alliance functions and formalize their alliance programs (Kale, Dyer, & Singh, 2002). An alliance portfolio, the set of the focal firm's active formal alliances (Baum et al, 2000; Ozcan & Eisenhardt, 2009), is regarded to be a significant factor in the firm's alliance strategy. Since an alliance portfolio allows the focal firm to gain access to the diverse resources of its partners (Wassmer & Dussauge, 2011, 2012), it also represents the scope of external resources available to the focal firm (Cui & O'Connor, 2012). The knowledge within these external resources blends with the focal firm's existing knowledge and contributes to creating innovation (Swaminathan & Moorman, 2009; Wuyts, Dutta, & Stremersch, 2004).

Choosing partners is a critical issue in forming an alliance portfolio (Doz & Hamel, 1998; Hagedoorn, 1993; Park, Kim, & Kang, 2015). The composition of an alliance portfolio defines the character of the portfolio and affects the performance of the focal firm. Hagedoorn and Schakenraad (1994) also suggest that the partner characteristics in an alliance portfolio affect firm performance more than the number of partners does. Thus, it is important to examine the characteristics of alliance portfolios in terms of alliance strategy. Among the basic characteristics of alliance portfolios, alliance portfolio diversity has received much scholarly attention (Oerlemans, Knoben, & Pretorius, 2013; Ozcan & Eisenhardt, 2009; Wuyts & Dutta, 2014). Alliance portfolio diversity is commonly defined as the distribution of differences in the characteristics of alliance partners such as industry, geographical location, their size, or age (Harrison & Klein, 2007; Isobe, Makino, & Montgomery, 2000).

As alliance portfolio diversity increases, firms face trade-offs. Although diverse portfolios have the advantage of providing broadened search options and an extended resource pools, there are also disadvantages such as an increase in complexity and cost, and increased potential for conflicts among the alliance partners. In order to punctuate arguments for such two-dimensional attributes, we attempt to examine the relationship between alliance portfolio diversity and innovation performance by a curvilinear perspective

Basically, diverse partners within an alliance portfolio provide several benefits to the focal firm in terms of technological innovation (Deeds & Rothaermel, 2003; Poot, Faems, & Vanhaverbeke, 2009). Higher portfolio diversity is likely to provide complementary assets and allows the inflow of new resources and knowledge (Burt, 1992). The inflow of various resources and knowledge leads to their unexpected combinations and results in innovative ideas and solutions for developing new technology (Swaminathan & Moorman, 2009; Wuyts, Dutta, & Stremersch, 2004). Superior innovation performance can be attained by combining diverse market and technological knowledge sources in the alliance portfolio and exploiting possible complementarities and synergies (Leeuw, Lokshinb, & Duysters, 2013; Nieto & Santamaria, 2007).

Partner diversity also helps firms to cope with the scarcity of excellent resources and uncertainty. When developing new technologies, firms are required to make choices of more valuable and rare resources to create outputs different from the past in uncertain environments (Bowman & Hurry, 1993). In this situation, alliance portfolio diversity provides more alternatives to solve problems and create new knowledge, which increases the expected value of choice (Gavetti & Levinthal, 2000).

However, in order to take benefit from these advantages of diverse partners, firms must overcome several hurdles (Jiang, Tao, & Santoro, 2010). When obtaining distant knowledge, the firm engages in search to fill in gaps and to correct transmission errors in the knowledge (Sorenson, Rivkin, & Fleming, 2006). This is difficult and incurs costs which increase with the complexity of the knowledge. In addition, conflicts due to cultural differences with heterogeneous partners and coordination costs to establish cohesive ties arise as the diversity increases (Koka & Prescott, 2008). The fundamental differences between the specific processes of resource transfer between firms can additionally restrict the realization of synergies with the partners (Goerzen & Beamish, 2005).

These limitations arise from the moment a firm increases the diversity of its partners. As learning effects accumulate and the firm becomes more proficient in managing the alliance portfolio, however, the influence of the limitations will eventually decrease (Jiang, Tao, & Santoro, 2010). As the diversity increases, routines for managing external partners are gradually established. Negative effects such as the conflicts caused by the diverse partners will be reduced as external routines are established (Pelled, Eisenhard, & Xin, 1999). If the firm has diverse partners, it can more easily find alternative solutions that will make up for the arising conflicts or deficits. In addition, the benefits from various resources are increasing (Jiang, Tao, & Santoro, 2010). As a result, as the alliance portfolio diversity increases, advantages of diversity will surpass the disadvantages encountered at moderate levels of diversity, and the innovation performance increases.

In summary, in line with previous research exploring the nonlinearity of network partners' industry diversity (Jiang, Tao, & Santoro, 2010; Goerzen & Beamish, 2005), we expect alliance portfolio diversity to have a U-shaped relationship with the innovation performance of the firm.

Hypothesis 1: Alliance portfolio diversity has U-shaped curvilinear relationship with the innovation performance of the firm.

2. Internal capabilities of value creation

We further suggest that the U-shaped relationship is not a complete account of the association between alliance portfolio diversity and innovation performance. Several recent studies tend to approach the impact of alliance portfolio diversity from a contingency perspective. Wuyts and Dutta (2014) argued that the impact of portfolio diversity varies according to the firm's internal knowledge strategy. Zaheer and Bell (2005) argued that obtaining utility from network positions depends on internal contexts. Following prior studies, this study examines how internal contingency affects the impact of alliance portfolio diversity on innovation performance.

Alliance portfolio diversity represents a pool of external resources that focal firms can access. The extent of benefit the focal firms gain from their alliance portfolios depends on their internal capacities to create value from external resources. Firms equipped with proper internal capabilities gain more benefits from external resources (Cohen & Levinthal, 1990). In this study, we highlight firms' internal routine and ability and, thus, investigate how organizational search routines and technological capabilities affect the relationship between alliance portfolio diversity and innovation performance.

3. Organizational search routine

From the perspective of dynamic capability, organizational capabilities are a collection of routines (Winter, 2003). Routines represent behaviors that are learned, highly patterned, repetitious, or founded in tacit knowledge (Winter, 2003). Especially, organizational search is the routine that extracts value from various resources at the initial stage of the innovation process. Thus, organizational search impacts the organizational process of creating and recombining novel ideas (Nelson and Winter, 1982), as well as the innovation outcome (Katila and Ahuja, 2002).

Firms usually retain their own search routines (Chung, Cho, & Kang, 2015; Greve & Taylor, 2000). For example, the scope of search varies from a narrow one to a broad one depending on each firm's routine. A narrow search represents firms' search routines depending on their existing knowledge base or on knowledge fields similar to their existing ones (Helfat, 1994; Martin & Mitchell, 1998; Stuart & Podolny, 1996). Firms with narrow search tend to pursue profit opportunities by leveraging their existing knowledge bases rather than explore opportunities in remote fields (Smith & Tushman, 2005). Narrow search pursues cohesiveness rather than openness (March, 1996) and reduces variance, uncertainty and unexpected conflicts (Rivkin & Siggelkow, 2003; Flynn & Chatman 2001).

On the contrary, broad search organizations strive to expand their search boundaries and reach new technological trajectories. They combine their existing knowledge base with new ones and pursue novelty (March, 1991; Miller, 2006). A broad search represents having access to remote knowledge that contributes to solving problems (March, 1991; Minor, Bassoff, & Moorman, 2001). A broad search tends to pursue new opportunities which address the change of the external environment (Smith & Tushman, 2005). Moreover, a broad search increases variance and emphasizes learning by doing via trial and error (Rivkin & Siggelkow, 2003; Flynn & Chatman 2001).

Organizations with broad search routines are more exposed to the risk of complexity. They already deal with diverse variables within their search routines (Rivkin & Siggelkow, 2003). Meanwhile, diverse knowledge from external partners adds more variables to their existing broad search routines and increases the complexity they have to handle (Srivastava & Gnyawali, 2011). As a result, it becomes a major challenge for broad search firms to manage their knowledge base and to choose relevant knowledge among the overflow of knowledge (Cohen & Levinthal, 1990, Koput, 1997, Sampson, 2007). Thus, we expect that the combination of broad search routine and alliance portfolio diversity would promptly reinforce the complexity within the firms' knowledge base and prevent them from outperforming up to a certain level of immature combination.

However, the benefit of alliance portfolio diversity will be secured for broad search firms as alliance portfolio diversity sufficiently increases. A huge pool of diverse knowledge increases the selection effect of variation and leads to more choices for problem solving and creating novel innovations (March, 1991). Broad search firms are familiar with new experimentation and integrating a heterogeneous pool of knowledge (March & Simon, 1958). They are also proficient in combining internal and external resources (March, 1991; Miller, 2006), and generating more positive synergies with diversified knowledge.

Moreover, broad search firms are capable of correctly responding to new information when the knowledge variances increase within the organization and reduces the issue of reliability (Katila & Ahuja, 2002). While narrow search firms find it difficult to handle knowledge variance, broad search firms have a variety of technological interfaces within their organizational boundaries and are able to identify and evaluate heterogeneous knowledge (Wuyts & Dutta, 2012). Thus, without being bound by reliability problems, broad search firms can create valuable technologies and knowledge when handling diversified knowledge.

In sum, broad search firms find it difficult to handle the amplified complexity of diversified alliances up to a certain level of the alliance portfolio diversity. However, leveraging their broad search routines, they will be able to interact with diversified knowledge more effectively and turn it into a superior innovation performance as the knowledge pool from the diversified alliance portfolio becomes abundant. Broad search routines would contribute to absorbing the valuable knowledge from a diversified alliance portfolio and ultimately outweigh the cost of handling the diverse knowledge.

We therefore expect that the synergy generated by broad search routines and alliance portfolio diversity would have a greater impact on innovation performance than narrow search routines and alliance portfolio diversity.

Hypothesis 2: Organizational search routine moderates the U-shaped relationship between alliance portfolio diversity and innovation performance, such that the relationship will be strengthened when the firm pursues broad search but weakened when the firm pursues narrow search.

4. Technological Capabilities

Technological capabilities, as the other internal context of value creation, are the ability of a firm to actually create impactful innovation (Sears & Hoetker, 2014, Teece, 1987). It is difficult to imitate a firm's technological capabilities which include technological knowledge, know-how generated by R&D, and other technology-specific intellectual assets (Dollinger, 1995). Although focal firms with an alliance portfolio obtain appropriate knowledge from their alliances, they cannot turn it into performance without sufficient capabilities for creating value. Firms' technological capabilities contribute to realizing the potential value of the obtained knowledge and should be taken into account in studying the link between knowledge and innovation (Stuaty & Podolny, 1996).

Technological capabilities largely offset the drawbacks of portfolio diversity. Firms with strong technological capabilities are less vulnerable in situations with high complexity (Rush, Bessant, & Hobday, 2007). Technological capabilities enable firms to maintain their absorptive capacity, and to achieve the expected outputs of knowledge creation without constraints in a large variance environment. Since the threat of complexity from a diverse portfolio is reduced by technological capabilities, firms are not constrained in enhancing their innovation performance.

More specifically, technological capabilities contribute to leveraging resources obtained from the alliance partners and to generating more breakthrough innovations (Ahuja & Lampert, 2001; Srivastava & Gnyawali, 2011). Technological capabilities allow the focal firms' own innovation process to better assimilate the diversity of its alliance portfolio (Cohem & Levinthal, 1990; Rosenkopf & Almeida, 2003) and combine external resources with internal ones to create novel technologies (Afuah, 2002). Thus, we predict that a moderate level of alliance portfolio diversity is ideal for a firm with strong technological capabilities. Beyond moderate levels, however, we expect a different effect.

Technological capabilities induce high resource consumption in its nature (Kumar, Kumar, & Persaud, 1999; McCutchen & Swamidass, 1996). Technological capabilities drive the firm to absorb and assimilate new external knowledge through long-term resource allocation and various collaborations to create novel knowledge (Zahra & George, 2002). Firms with higher technological capabilities aggressively consume resources and capabilities to find and develop novel knowledge (Wales, Parida, & Patel, 2013).

For firms with high technological capabilities, increasing knowledge diversity provides a positive synergy until a moderate level is reached. If the diversity reaches extremely high levels, however, resources which are needed for leveraging the diverse knowledge would be overcharged. As resource commitments to absorb and assimilate the vast knowledge are overloaded, the efficiency of resource allocation decreases sharply (Wales, Parida, & Patel, 2013). With a significant increase in knowledge diversity, technologically strong firms eventually reach a point at which they are unable to further pursue novelty (Nooteboom et. al, 2007).

Firms with high technological capabilities also tend to establish strong mechanisms to protect their proprietary resources (Srivastava & Gnyawali, 2011). When the flow of external knowledge increases, technologically strong firms increase their controls to protect knowledge expropriation and in order not to be overwhelmed by too many opportunities by constructing governance structures (Heiman & Nickerson, 2004). These protective reactions and risk mitigating actions hinder integrating the partners' knowledge and creating breakthrough innovation that requires an open mindset.

For firms with high technological capabilities, therefore, the increase in alliance portfolio diversity generates positive synergies on innovation performance up to a moderate level of diversity, but extremely high level of portfolio diversity will rather dampen their innovation performance. This represents a shift from the earlier curvilinear predictions, which are outlined in Hypotheses 1 and 2. The first hypothesis suggests that alliance portfolio diversity and innovation performance have a U-shaped relationship, and the second hypothesis suggests that the broad search routine strengthens this U-shaped relationship. In the third hypothesis, however, technological capabilities flip over the hypothesized relationships, suggesting now that alliance portfolio diversity and innovation performance have an inverse U-shaped relationship.

Hypothesis*3: Technological capabilities moderate the relationship between alliance portfolio diversity and innovation performance, such that low and high, but not moderate levels of alliance portfolio diversity will negatively relate to innovation performance, resulting in an inverted U-shaped relationship.*

Ⅲ. METHODS

1. Data and Sample

This study investigated data on patent activities, alliance deals, and asset data of U.S.-based manufacturing firms (corresponding to SIC codes 2011-3999). Patent data was obtained from the patent citation record provided by the US Patent and Trademark Office (USPTO). Alliance contract records were obtained from the SDC Platinum alliance database provided by Thomson Reuter. In this database, we include the technological alliance type such as R&D collaborations, licensing, collaborative exploration, and co-manufacturing. Firm asset data was obtained from the Compustat database.

The empirical analysis of this study is based on a panel data model. For the analysis, our panel spans four focal years from 2004 to 2007. For each focal year t, the innovation performance, our dependent variable, was measured in the period from t+1 to t+4. The independent and moderating variables such as search scope, alliance portfolio diversity, and technological capabilities were measured in the period of t-1 to t-4. The control variables were measured in the focal year.

To construct the variables with the above mentioned time lag, we collectedfirm-level financial, patenting, and alliance data during the 2000-2011 period, eight years around each of the focal years of 2004-2007We then randomly selected 3,000 US manufacturing firms. Then, we constructed and filtered the sample according to the following steps: First, we matched Compustat financial data to USPTO patent data using the number of Committee on Uniform Securities Identification Procedures (CUSIP). Thus, firms for which we were able to confirm both financial and patent data remained. Second, we limited the sample to firms which entered into alliances deals and which were listed in the SDC platinum database. This process left us with 332 sample firms. Third, we limited the sample to firms which existed over the entire analysis time period from 2000 to 2011. After this step, 182 firms remained in our sample. The fixed-effect model we adopted for the main analysis considered 509 observations from 152 firms. Our final sample consist of 57 firms in the chemical and allied products industry, 42 firms in the computer and office equipment industry, 24 firms in the laboratory apparatus and analytical, optical, measuring, and control equipment industry, 38 firms in the surgical, medical and dental instruments and supplies industry, and 21 firms in other manufacturing industries. The organization size in terms of employees in our sample ranges from 21 to 475,000 employees with an average size of 18,342 employees. Our analysis is based on 1,703 technological alliance deals and on 21,973 focal patents. Therefore, the total number of longitudinal observations was 539 from 182 firms from 2004-2007.

2. Measurement

Innovation performance. The dependent variable, innovation performance, represents the output generated by the firm’s R&D. We measured forward citations as a proxy for the innovation performance of the focal firm by counting the total number of times its patents were cited by other patents during the four-year period after the focal year (Miller *et al.*, 2007). This way of measurement focuses on the qualitative performance of firms' R&D. As the number of forward citations of patents is closely associated with their technological importance (Trajtenberg, 1990), many researchers have adopted this qualitative measurement to represent a key performance aspect of innovation (Kim, Arthurs, Sahaym, & Cullen, 2013; Trajtenberg, 1990).

Alliance Portfolio Diversity. Focal firms' alliance portfolio diversity was measured based on the industries in which their partner firms were involved. This measurement is based on the fact that firms in the same industry tend to have not only similar assets and operations but also similar intangible resources such as market knowledge, manufacturing processes, and management expertise (Wang & Zajac, 2007). Thus, we identified the three digit SIC codes of the partner firms and used the entropy measure developed by Palept (1985) to measure alliance portfolio diversity. Jaquemin & Berry(1979) suggests that the entropy measure performs best to measure concentration (or diversity) (Jaquemin & Berry, 1979).

Within an alliance portfolio which consists of N different three digit SIC industries, Pi indicates the portion of industry i among the entire industries constituting the portfolio. For example, assuming that the focal firm has alliances with five partners, two in the semiconductor industry, two in the health care equipment industry, and one in the computer equipment industry, the proportion of each industry in this focal firm's portfolio is 0.4, 0.4, and 0.2, respectively. Based on the above equation, the alliance portfolio diversity of this firm would be 1.05. The higher the value of the entropy, the higher the level of alliance portfolio diversity.

Organizational search routine. Organizational search routine in terms of the scope of search activity represents the degree to which the patents of the focal firms are citing other patents from diverse technology domains. A number of previous studies employed patent classification to measure the scope of innovation activity (Katila & Ahuja, 2002; Kim *et al.*, 2013). Patent classification allows to identify the heterogeneity and distance between patents (Ying, Wim, & Wilfred, 2008). We calculated the search scope of each focal firm based on the backward citations of their patents applied in each focal year.

Pj is the portion of the three-digit technological classification j among the entire three digit technological classifications from which a focal firm's focal patents are citing. The higher level of search scope represents the expanded technological root of the focal firms' search activities (Trajtenberg, Henderson, & Jaffe, 1997). As the search scope approaches zero, it indicates a focal firm's search is being focused, and vice versa.

Technological Capabilities. Technological capabilities are the firm's ability to identify, assimilate, and integrate external knowledge (Cohen & Levinthal, 1990). Higher technological capabilities lead to better leveraging external knowledge and creating impactful innovation. As done in prior studies, we used the total amount of R&D expenditure as a proxyfor each focal firm's technological capabilities (Kumar, Kumar, & Persaud, 1999; McCutchen & Swamidass, 1996; Morbey & Reithner, 1987).

Control Variables. We also included several control variables, which account for factors that might affect firms' innovation output, in our empirical models. They are firm size, alliance portfolio size, firm age, experience of alliance portfolio diversity, and industry volatility. All control variables were measured in the focal year. Firm size was measured by the log value of the total number of employees of each firm in the focal year. Firm size is a typical control variable in innovation studies because larger firms have a greater ability to innovate and possess more strategic freedom than smaller firms do (Duysters and Hagedoorn, 2002). For measuring alliance portfolio size, we counted the number of alliance partners. Alliance portfolio size was regarded to positively affect firm performance in a number of prior studies (Ahuja, 2000a; Baum *et al.*, 2000; Stuart *et al.*, 1999). Firm age was also controlled because previous literature suggests that older firms tend to intensify their organizational rigidity and inertia which can negatively affect their innovation performance (Kelly and Amburgey, 1991; Van de Venet *et al.*, 1999). Experience of alliance portfolio diversity is an additional control variable. If firms have experience in handling alliance portfolio diversity, it influences the effectiveness and performance gained from alliance portfolio diversity (Leeuw, Lokshin, & Duysters, 2014). A dummy variable with the value of one was created if the focal firm had an experience of alliance portfolio diversity before our observation period. We calculated industry volatility following the approach used by Synder and Glueck (1982) and Tosi, Aldag, and Storey (1973), which is the average of the coefficients of variation of sales divided by average sales revenue for individual firms in the industry. We distinguish high volatility industries from others using a dummy variable. We assigned the value 1 for firms operating in an industry which falls within the top 20% industries in terms of volatility. We also assume that external factors such as the general economic environment or market conditions are changing over time and may significantly influence patenting activities. Therefore, such year effects were controlled for by including year dummies for each focal year.

3. Analysis

The dependent variable of this study was measured by counting the forward citations of the focal firms' patents and thus takes non-negative integer values. In this case, the variable does not follow the assumption of homoscedasticity in linear regression but follows Poisson distribution (Hausman,Hall, and Griliches, 1984). However, the strict assumption of Poisson regression, i.e., the equality of the mean and variance of the event count, cannot be easily met. In the case of a dependent variable with over-dispersed count data, negative binomial regression is an appropriate method to analyze the model (Hausman, Hall, and Griliches, 1984). With respect to individual specific effects, the conducted Hausman test suggested that a fixed effects model is appropriate for analyzing our data. It helps to partial out unobserved differences among firms. Thus, we analyzed our data using a Negative Binomial Model with fixed effects (Benner and Tushman, 2003).

IV. RESULTS

1. Main analyses

Table 1 provides the descriptive statistics and correlations between the variables used in our analysis. The sample data is comprised of observations across 182 firms from the year 2004 to 2007. For the multicollinearity check, we conducted a variance inflation factor (VIF) test for all the variables. The average value of the VIF is 1.30 and the highest value is 1.663. These figures are well below the recommended cutoff value of 10 (Chatterjee, Hadi, & Price, 2000; Neter, Kutner, Wasserman, & Nachtsheim, 1996). Thus, we conclude that no multicollinearity issue are present in our results.

InsertTable1Here

Table 2 shows the results of the negative binomial model with fixed effects. Model 1 includes all of the control variables. Model 2 adds the independent variables including alliance portfolio diversity and its squared term to show the main effect of our model. Model 3 adds the interaction of alliance portfolio diversity and search routine while Model 4 adds another interaction of alliance portfolio diversity and technological capabilities. Model 5 is the full model and includes all main effects and interactions.

Hypothesis 1 predicts that alliance portfolio diversity and innovation performance have a U-shaped relationship. Model 2 shows the root term for alliance portfolio diversity is significant and negative (β=-0.28, $p<0.1$), while the squared term is significant and positive (β=0.17, $p<0.05$). In Model 3 and Model 5, which include interaction terms, however, the significant effect for alliance portfolio diversity disappeared. Thus, the results did not support the presence of a U-shaped relationship between alliance portfolio diversity and innovation performance in the tested sample.

InsertTable2Here

Hypothesis 2 predicts that organizational search routine has a positive moderation effect on the relationship between alliance portfolio diversity and innovation performance. Model 3 of Table 2 exhibits the result of testing this hypothesis. The coefficient for the interaction between alliance portfolio diversity and search routine is statistically significant and negative (β=-1.05, $p<0.1$) and the coefficient of the interaction with the squared term is significant and positive (β=0.60, $p<0.1$). Thus, these results support Hypothesis 2.

Figure 1 shows the moderation effect of organizational search routine on the relationship between alliance portfolio diversity and innovation performance. As the value for search routine increases (signifying a broader search routine), the U-shape relationship between alliance portfolio diversity and innovation performance becomes clearer and the innovation performance exhibits a higher value.

InsertFigure1Here

Hypothesis 3 predicts that technological capabilities moderate the relationship between alliance portfolio diversity and innovation performance. Model 4 shows the result of testing this hypothesis. The coefficient for the interaction between alliance portfolio diversity and technological capabilities is statistically significant and positive (β=0.10, $p<0.1$) while the coefficient of the interaction with the squared term in Model 4 is insignificant. However, in Model 5, the model including all main effects and interactions, the coefficient for the interaction between alliance portfolio diversity and technological capabilities is statistically significant and positive (β=0.12, $p<0.05$). Also the interaction between technological capabilities and the squared term of alliance portfolio diversity is significant and negative (β=-0.04, $p<0.05$), providing support for Hypothesis 3.

Figure 2 shows the moderation effect of technological capabilities on the relationship between alliance portfolio diversity and innovation performance. As the value of technological capabilities become greater (signifying higher technological capabilities), the U-shape relationship between alliance portfolio diversity and innovation performance turns into an inverted U-shape relation.

InsertFigure2Here

These results show that the alliance portfolio diversity alone cannot explain the relationship with innovation performance, and that this relationship is determined by internal contexts such as organizational search routine or technological capabilities. Thus, the results clearly demonstrate the premise of this study that 'the benefit from alliance portfolio diversity depends on the internal capabilities of value creation'.

Apart from the hypotheses tests, we conducted additional analysis by adding interaction terms with industry volatility as dummy variable, to examine how the interplay between alliance portfolio diversity and internal capabilities is applied in certain environments such as highly volatile industries. In Model 6 of Table 2, the interaction of alliance portfolio diversity and organizational search routines becomes more significant in industries with a high level of volatility, while the interactions of alliance portfolio diversity, technological capabilities, and high volatility have no significance. This result will be discussed again in the discussion section.

2. Sensitivity analyses

To improve the robustness of our test results, we conducted additional sensitivity analyses with two different test settings. First, we conducted the analysis using random-effects techniques in our model (Model 7 in Table 3).

Random-effects allow for retaining firms with only one observation and time invariant variables. Although the Hausman test suggested that a fixed effects model is more appropriate for analyzing our data, our model will be more robust if the random effects model also supports the results of the original analysis.

Moreover, we tested our model by changing the measurement of the dependent variable. Using the number of citation-weighted patents is another approach to measure innovation performance. Trajtenberg (1990) demonstrates that citation-weighted patent counts are more closely correlated with their innovation output. For this reason, many studies have adopted citation-weighted patent counts as measures for innovation output (Ahuja, 2000; Henderson and Cockburn, 1994). To analyze the sensitivity using this approach, we measure our dependent variable by the number of patents applied in each focal year weighted by the number of citations subsequently received (Model 8 in Table 3).

InsertTable3Here

The results of the two robustness tests are almost similar to those presented in the original analysis. While the curvilinear relationship between alliance portfolio diversity and innovation performance is not significant, the interactions with organizational search routines and technological capabilities turned out to be significant. For both analyses, the results provide additional support for the conclusions drawn from the original analysis.

V. DISCUSSION AND CONCLUSION

This study offers a new perspective on the linkage between alliance portfolio diversityand organizational innovation by examining factors reflecting internal context such as organizational search routine and technological capabilities. We argue that the effects of alliance portfolio diversityon firm-level innovation performance depend upon the firm’ s internal capabilities of value creation.

We examined the relationship between alliance portfolio diversity and innovation performance with a curvilinear perspective. Recently, many studies tend to suggest an inverse U-shaped relationship between firm-level performance and alliance portfolio diversity in terms of alliance type or partner nationality (Leeuw, Lokshinb, & Duysters, 2013; Wassmer, 2010). In terms of industry diversity of partners, however, scholars suggest a U-shaped relationship with firm performance (Jiang, Tao, & Santoro, 2010; Goerzen & Beamish, 2005). Following prior literatures, we anticipated the direct relationship between alliance portfolio diversity in terms of industry and innovation performance of the firm forming a U-shape.Although our empirical results did not fully support the hypothesized curvilinear relationship between alliance portfolio diversity and innovation performance of the firm, we did confirm that such effects are evident in specific strategic contexts. More specifically, in firms with broad search routine, both low and high portfolio diversity were associated with higher innovation performance than was moderate diversity. The combination of broad search routine and alliance portfolio diversity amplifies complexity and constrains the innovation until a moderate level. However, the benefits of portfolio diversity such as selection effects of variation are eventually reinforced for broad search firms. After the benefits surpass the constraints, broad searchers' innovation performance is improved. Thus, this finding suggests that broad search firms are more advantageous, in enhancing innovation performance, as they acquire abundant heterogeneous resource pools through a high-diversity alliance portfolio or avoid complexity risk through a low-diversity portfolio. In case of narrow search firms, they can enhance their innovation performance by complementary synergy through moderate levels of diversity of their alliance portfolio.

On the other hand, technological capabilities, as value creation ability, flip the hypothesized relationship between alliance portfolio diversity and innovation performance. Firms with strong technological capabilities are less vulnerable in situations with high complexity. The firm achieves the full benefits of diversity since its technological capabilities offset the constraints of complexity, allow it to leverage the resources obtained from partners, and increase the effectiveness of its innovation process.

However, technological capabilities are costly. This makes the firm bear a heavy burden when the diversity becomes extremely high. In situations of high diversity, resource commitments to assimilate various knowledge are overloaded and the efficiency of resource allocation sharply decreases. In addition, the typical weaknesses of high technological capabilities such as a risk mitigating mindset on too much opportunities decrease innovation performance. Thus, firms with strong technological capabilities can maximize innovation performance through a moderately diverse portfolio rather than an extremely heterogeneous or homogeneous portfolio.

Alliance portfolio diversity has both advantages and disadvantages.

However, our results show that the mechanisms allow firms to gain benefits from their portfolio of partners are completely different contingent upon the firm's internal capabilities of value creation.

Apart from the hypothesis testing, we conducted additional analysis to see how these results applied in certain environments such as highly volatile industries including the electronic computing equipment, electronic components, and medical chemical products industries. Industry volatility is defined as the level of instability or unpredictability faced within a certain industry (Dugal and Gopalakrishnan 2000, Dess and Beard 1984). In these industries, the interaction effect of alliance portfolio diversity and organizational search routines is strengthened. Because volatile industries have their own risk of complexity, broad search firms will face a greater risk of losing sight in a flurry of opportunities as the portfolio diversity and resulting complexity increase. Moreover, especially the broad searcher's capabilities to quickly develop new technologies, and overcome uncertainty by strategic collaboration are more critical in an environment characterized by high volatility (Tushman & Anderson, 1986; Brown & Eisenhardt, 1997; Teece et al., 1997).

One of our key contributions is advancing the understanding of the influence of alliance portfolio diversity through a contingency perspective, which extends prior work focused solely on partner attributes. Although it is critical to manage innovation activities by considering diverse contexts, the contingency view has not received sufficient attention in alliance literature. This study develops the concept of fit through a comprehensive empirical test. This is noteworthy on both the theoretical and practical levels.

For practicing managers, our findings suggest the strategic importance of developing a comprehensive firm-level innovation strategy, adopting a portfolio perspective, establishing an appropriate internal-external routine, and actively managing such an integrated complementary system to further develop capabilities for improving firm performance.

Especially, this study provides a guideline for choosing new alliance partners. When allying with new partners, firms generally pay attention to individual level attributes of partners such as their organizational capabilities, past performance, executives' capabilities, etc. Recent studies have expanded this point of view to the alliance portfolio perspective and incorporated the view of composing the whole alliance portfolio. On top of this, this study differentiates internal capabilities of value creation from alliance formation and highlights the importance of a strategic fit between the alliance strategy and the internal capabilities such as organizational routine and ability. Beyond considering the composition of alliance portfolios and their diversity, this study adopts a more holistic view on alliances and their performance by considering organizational learning from a wider perspective.

This study has several limitations, which we hope can be overcome by future research in this field. First, adopting the idea of path dependency might have contributed to the concepts studied in this research. Due to the embedded path dependency (Syow, Schreyogg, & Koch, 2009) in organizational routine, we may doubt some constraints on pursuing the relationship across firm boundaries. For instance, the exploitative tendency of narrow search firms might extend to how they form alliances. They might prefer partners from similar fields or absorb knowledge in similar domains even in case of alliances with diverse partners. In the same vein, the explorative tendency of broad search firms may affect their alliance formation. In the meantime, a number of prior studies suggest not only an organizational tendency of maintaining knowledge acquisition propensity but also inverse incentives on pursuing something contrary. For instance, firms who pursue exploitative search tend to seek for complementary resources through diverse alliances (Eisenhardt & Schoonhoven, 1996) and recombine their core competency with the diverse knowledge. On the contrary, broad search firms seeking exploratory innovation build focused alliance formations to intensively exploit a specific technology (Srivastava & Gnyawali, 2011). In line with these literatures, we assume that path dependency is not a critical factor which prevents the strategic fit across firm boundaries. However, we expect future research to operationalize the influence of path dependency on alliance formations and innovation performance and suggest a more detailed mechanism.

Second, we tried to conduct an additional analysis using log-transformed sales as the dependent variable to examine how our model can be applied to profit-related performance. However, all factors which were significant in predicting innovation performance were found to be not significant in this analysis. The result shows the factors we identified do not affect profit-related performance. However, in order for our research model to be more useful in academia and practical areas, it should be able to provide implications on a broader range of performance measures. We hope for future studies to extensively analyze the impact of the strategic fit discussed in this paper on other measures of firm performance.

Third, the empirical analysis in this study was conducted on a sample of US manufacturing firms. Samples of US-based firms are used by many studies due to the availability and comparability of data such as US patent data. However, we cannot assure that our findings can be applied equally to firms from other environments or regions because market conditions or the technology development environment may be different for firms located, e.g., in Asia or Europe. In order for this study to present a greater academic contribution, it should be generalized to other regions. Therefore, it is necessary to further apply our logic and model to samples composed of firms from other regions and environments to improve its applicability.

Finally, we believe that investigating the overlap of domains will contribute to examining the consistency fit between organizational search scope and alliance portfolio diversity in more detail. This study investigates the breadth of organizational search scope and the diversity of alliance portfolios and simply matches them to discern their fit. However, such a scope fit may be different from the fit of the knowledge domain. Depending on the coherence between the knowledge base of the external partners and the knowledge base of the focal firm, the interaction effects of alliance portfolio diversity and internal capabilities may change. For example, the complexity problem of broad search firms may be alleviated if the overlapped scope of external and internal knowledge is large even though the firms assemble a diverse alliance portfolio. Thus, we expect future research to incorporate the overlap or the fit of contents and corroborate the suggestion of this study in a different perspective.

In conclusion, we have developed a model of the strategic fit between alliance portfolio diversity and internal capabilities of value creation for innovation activity. We suggest researchers and practitioners to regard such fit as an important strategic tool by which firms build their collaboration strategy and effectively harness it in pursuit of value-creating innovation.

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Table 1. Descriptive statistics and correlations

Variables	VIF	Mean	s.d.	1	2	3	4	5	6	7	8
Innovation performance	-	159.83	443.18								
APD	1.484	0.63	0.68	0.31*							
Search routine	1.076	0.67	0.25	0.21*	0.18*						
Technological capabilities	1.379	11.19	2.40	0.20*	0.26*	0.14*					
Firm size(employee)	1.567	7.83	2.11	0.29*	0.30*	0.20*	0.50*				
Firm age	1.173	42.02	41.44	0.14*	0.21*	0.05	0.16*	0.29*			
Portfolio size	1.587	5.66	10.01	0.47*	0.54*	0.17*	0.27*	0.36*	0.26*		
APD experience	1.027	0.80	0.40	-0.04	0.07*	0.11*	0.08*	0.03	0.06	0.07	
Industry volatility	1.101	0.29	0.45	0.11*	-0.09*	0.03	-0.04	-0.16*	-0.19*	0.05	0.07

* $p < .05$

Table 2. Result of the Negative Binomial Model with Fixed-Effects Predicting Innovation Performance

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Firm size (employees)	.06 (.02)**	.05 (.03)*	.04 (.03)	.05 (.03)**	.04 (.03)	.04 (.03)
Firm age	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)	.00 (.00)
Portfolio size	.01 (.01)**	.01 (.01)	.01 (.01)	.01 (.01)	.01 (.01)	.00 (.01)
APD experience	-.16 (.19)	-.11 (.19)	-.11 (.19)	-.11 (.19)	-.09 (.20)	-.05 (.19)
Industry volatility	.45 (.17)***	.30 (.16)*	.26 (.16)	.32 (.17)*	.30 (.17)*	.53 (.20)***
APD		-.28 (.17)*	.57 (.50)	-1.45 (.64)**	-.68 (.75)	-.69 (.77)
APD squared		.17 (.08)**	-.32 (.27)	.54 (.26)**	.10 (.34)	.08 (.35)
Search routine		1.10 (.19)***	1.20 (.26)***	1.07 (.20)***	1.19 (.26)***	1.18 (.26)***
Technological capabilities		.01 (.02)	.02 (.02)	-.03 (.03)	-.03 (.03)	-.02 (.03)
APD × search routine			-1.05 (.61)*		-1.21 (.62)*	-.90 (.68)
APD squared × search routine			.60 (.31)*		.69 (.32)**	.63 (.34)*
APD × technological capabilities				.10 (.05)*	.12 (.05)**	.11 (.06)*
APD squared × technological capabilities				-.03 (.02)	-.04 (.02)**	-.03 (.02)*
APD × search routine × volatility						-.83 (.45)*
APD × tech capabilities × volatility						.03 (.03)
Year effects	Y	Y	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y	Y	Y
Log likelihood	-1549.8714	-1530.5936	-1528.3622	-1528.6983	-1525.9327	-1522.5019
Wald chi2	129.13	186.83	195.62	190.15	202.82	217.23

N = 182

* $P < .10$; ** $p < .05$; *** $P < .01$

Table 3. Result of the Negative Binomial Model with Fixed-Effects Predicting Innovation Performance (Sensitivity analyses)

(Dependent variable, Model)	Model 5 (Citation counts, FE)	Model 7 (Citation counts, RE)	Model 8 (Citation weighted counts, FE)
Firm size (employees)	.04 (.03)	-.01 (.03)	.07 (.02)***
Firm age	.00 (.00)	-.00 (.00)	.00 (.00)
Portfolio size	.01 (.01)	-.01 (.01)	.01 (.01)
APD experience	-.09 (.20)	-.02 (.18)	.00 (.14)
Industry volatility	.30 (.17)*	.02 (.16)	.20 (.12)*
APD	-.68 (.75)	-.77 (.71)	-.48 (.70)
APD squared	.10 (.34)	.06 (.32)	0.10 (.33)
Search routine	1.19 (.26)***	.84 (.24)***	1.24 (.23)***
Technological capabilities	-.03 (.03)	-.01 (.03)	-.01 (.03)
APD × search routine	-1.21 (.62)*	-.67 (.60)	-1.08 (.59)*
APD squared × search routine	.69 (.32)**	.73 (.31)**	.71 (.32)**
APD × technological capabilities	.12 (.05)**	.09 (.05)*	.10 (.05)**
APD squared × technological capabilities	-.04 (.02)**	-.03 (.02)*	-.04 (.02)**
Year effects	Y	Y	Y
Firm fixed effects	Y	Y	Y
Log likelihood	-1525.9327	-2136.2572	-2639.7338
Wald chi2	202.82	129.17	293.81

N = 182
* P < .10; ** p < .05; *** P < .01

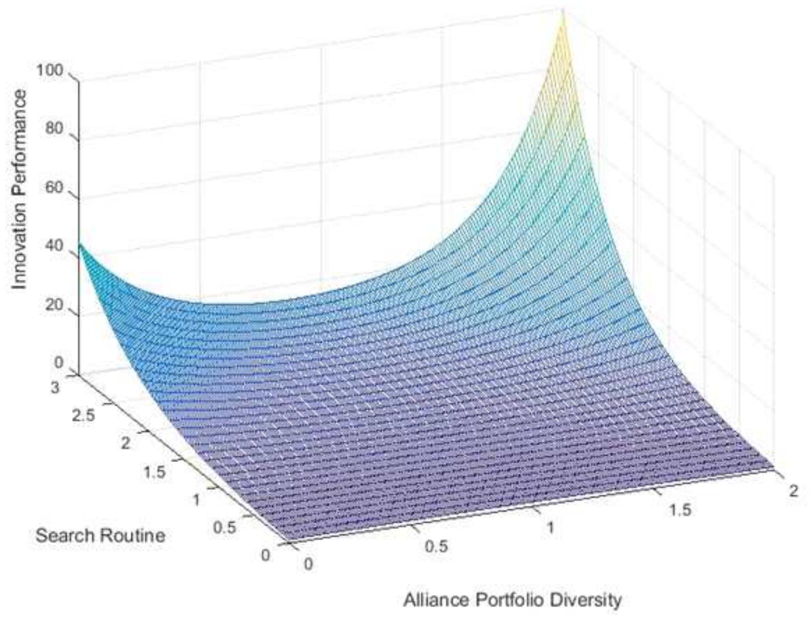

Figure 1. The Moderation Effect of Search Routine

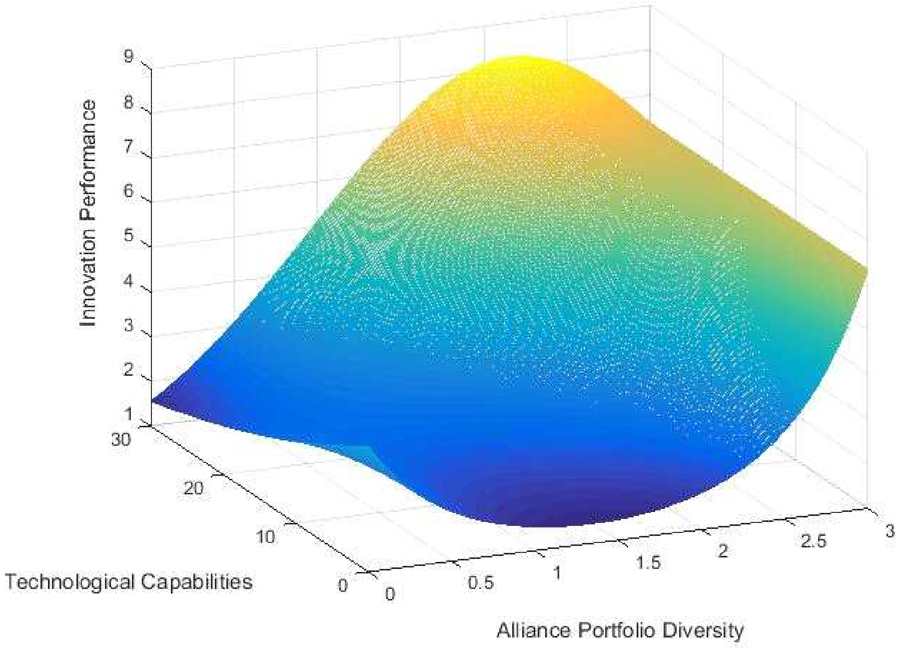

Figure 2. The Moderation Effect of Technological Capabilities