

MARKET DISSIMILARITY, TECHNOLOGY COMPLEMENTARITY AND COLLABORATIVE INNOVATION PERFORMANCE: THE MODERATING EFFECTS OF IT ADOPTION

ABSTRACT

As collaborative innovation is becoming an important management issue, the lack of a holistic framework for collaborative partners' resource heterogeneity and its different effects on firms' innovation is becoming a critical research gap. So, one intension of our study is to differentiate two types of resource heterogeneity between collaborative partners, i.e. market dissimilarity and technology complementarity, and construct the model on the influence of that resource heterogeneity on firms' collaborative innovation performance. Specifically, we differentiate two dimensions of innovation performance, which is innovation novelty and innovation efficiency. And another intension is to explore the boundary condition of the relationships mentioned above. Using the survey data on the collaboration between innovative firms, we tested our hypotheses using partial least squares. The results show that both market dissimilarity and technology complementarity between collaborative partners relate positively to a focal firm's innovation performance in terms of both novelty and efficiency, while technology complementarity is more effective. Our results also indicate that IT adoption negatively moderates the relationship between market dissimilarity and collaborative innovation novelty/efficiency and that in the relationship between technology complementarity and innovation efficiency, in terms of the relationship between technology complementarity and innovation novelty, the moderating effect becomes significantly positive. This study provides a holistic framework for analysing different effects of partners' resource heterogeneity. Second, this study constructs a contingency model by confirming empirically that IT adoption greatly moderate firms' collaborative innovation process. Third, this study appears to challenge traditional IT theories by indicating that the moderating effects of IT adoption are actually nonlinear.

Key words: Market dissimilarity; Technology complementarity; IT adoption; Collaborative innovation

INTRODUCTION

In many industries, resources are widely distributed, and firms are compelled to collaborate with each other to access additional resources needed to achieve innovation (Ahuja, 2000; Davis, 2016; Sytch & Tatarynowicz, 2014). However,

despite some well-publicized examples, few collaborations actually produce innovations (Davis, 2016; Davis & Eisenhardt, 2011). Hence, how to make use of both partners' advantages to promote collaborative innovation is becoming an important managerial issue, especially in developing countries such as China (Fang, 2011).

The existing literature tends to explain how certain characteristics of partners influence collaboration, for example, the effects of knowledge overlap, resource heterogeneity or complementarity (Adner & Levinthal, 2001; Chen, 1996; Cui, 2013). However, these studies do not provide an integrated framework for contrastive analysis of the impacts of different characteristics, which leaves a critical research gap. Hence, we place two types of resource heterogeneity, i.e. market dissimilarity and technology complementarity, into a holistic framework to better understand how those resource heterogeneities affect a focal firm's innovation performance and to explore the differences between these effects.

In addition, the literature on collaborative innovation focuses mainly on a single dimension of innovation performance, such as the production (Kim & Finkelstein, 2009) or innovativeness (Fang, 2011) of the new products. However, innovation collaboration may have different influences on different dimensions of innovation performance. Hence, it is important to place different dimensions of innovation performance into a holistic framework and explore the different mechanisms through which innovation collaboration affects them. Based on these premises, we study innovation performance from two dimensions: novelty and efficiency.

Furthermore, previous studies that examined the direct effects of partners' different resources also failed to answer the question, "Under what conditions do these resources of partners generate collaborative innovation performance?" In fact, even collaborate with same partners, firms may still achieve different performances (Fang, 2011). The value of partner resources depends on other resources available to the firm, such as those available from other sources (Cui, 2013). Thus, factors that provide access to external resources may influence the effect of partners' heterogeneous resources. However, extant literatures have paid little attention on these factors. This paper tries to address to this question by highlighting how IT adoption, an effective way to get and use external knowledge resources (Dong & Yang, 2015), moderates the effect of both market dissimilarity and technology complementarity on focal firm's innovation. While several empirical studies have highlighted the direct positive effects of IT adoption (Devece, 2013; Dong & Yang, 2016), few have explored its possible interactions with resource heterogeneity among partners. Specifically, we

suggest that IT adoption during collaborative projects can significantly moderate the effects of market dissimilarity and technology complementarity, thus building contingency mechanisms.

Based on the arguments above, this study focuses on the effect of market dissimilarity/technology complementarity between partners on different dimensions of a focal firm's innovation performance, i.e., novelty and efficiency, as well as the moderating effects of IT adoption. We find that both market dissimilarity and technology complementarity significantly promote the focal firm's innovation performance (in terms of novelty and efficiency), with technology complementarity being the more effective of the two. We also find evidence that in collaborative innovation projects, the widespread use of IT tools between collaborative partners sometimes negatively moderates the market dissimilarity/ technology complementarity- performance relationships.

This article contributes to existing research in the following ways. First, our study provides an integrated framework for analyzing different effects of partners' different characteristics, which is an extension of existing research. Second, this study constructs a contingency model and advances extant literature by confirming empirically that external intervention factors (e.g., IT adoption) greatly moderate firms' collaborative innovation process. It also suggests that future research should delve more deeply into other dimensions of dissimilarity and complementarity and their effects on firms' collaboration performance and should more carefully examine the effects of external intervention factors in a collaboration, such as IT adoption.

This article is structured as follows: we first derive and formalize our theoretical prediction. Section three describes the data and methods, and section four reports the empirical findings. In the final section, we discuss the main findings and draw several conclusions and implications for both academics and innovation practitioners.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

As mentioned earlier, dissimilarity is of great importance to firms' innovation collaboration. However, based on existing theories, there is actually a lack of consensus on the impact of dissimilarity on collaborative performance (Lee et al., 2014). Some studies support the positive effects of dissimilarity, stating that different partners provide firms with diversified resources, including important information and knowledge (Hong et al., 2004), which eventually benefit firms' innovation. However, others note that dissimilarity causes mistrust and erects

communication barriers between collaborative partners (Parkhe, 1991); dissimilarity is also associated with weak legal and regulatory environments, especially in developing societies (Fang, 2011). Thus, dissimilarity challenges collaborative partners' efficiency. However, some researchers note that the reason there is no agreement on this question is that existing studies do not delimit the dimensions of dissimilarity (Parkhe, 1991). As a result, the research scope of this study is framed in market dissimilarity, which refers to the different market segments of a focal firm and its partner (Chen, 1996).

Traditional studies on complementarity also focus on different aspects, such as resource complementarity (Pullen et al., 2012), strategic complementarity and market complementarity (Kim & Finkelstein, 2009). As the essential goal of alliance is always learning and creation of technical knowledge, researchers currently always focus centrally on the complementarity of technology or knowledge between firms and their collaborative partners (Hitt et al., 2000; Luo, 2000). Consequently, in this article we frame complementarity in technology complementarity.

Technology complementarity is defined as the non-overlapping technology bases of two firms that fall within an acceptable range of difference (Sivadas & Dwyer, 2000) and might be combined and integrated to create value (Fang, 2011). Hence, complementarity does not simply entail the "differences" between two firms (different technologies or knowledge in their respective domains with little to no combination and integration); it also requires firms to successfully manage such differences (Kim & Finkelstein, 2009). This means that the focal firm's technology must generate a "good match" with its partner's technology (Sivadas & Dwyer, 2000).

Specifically, in this article, we also divide innovation performance into novelty and efficiency of innovation. Novelty is the extent to which a firm's new product differs from competing alternatives in a way that is meaningful to customers (Dewar & Dutton, 1986; Fang, 2011). Every innovation contains a certain degree of novelty, and that degree of novelty has usually been considered a major factor affecting the commercial success or failure of innovation (Duhamel & Santi, 2012). To some extent, innovation novelty reveals the extent of innovation radicalness (Henderson & Clark, 1990; Koc & Bozdog, 2017). Finally, innovation efficiency is the quality of being able to complete innovation activities successfully with fewer costs and in less time.

Market Dissimilarity and Firms' Collaborative Innovation Performance

There is general academic agreement that market dissimilarity promotes collaborative partners' innovation. On the one hand, firms with similar market areas tend to take competitive action, and with competitive threats from partners, firms face the risk of being replaced (Wassmer & Dussauge, 2012). Hence, firms tend to restrict knowledge-sharing with partners and to a certain extent this restriction limits the firms' innovation. In contrast, dissimilar market segments reduce competition and enhance innovation collaboration between partners.

On the other hand, researchers also note that diverse market knowledge shapes the radical product definition and the scope of a firm's innovation activities (Berchicci & Tucci, 2010; Kyriakopoulos et al., 2016) and helps firms adapt to the changing technology and market. However, firms always tend to be restricted to their existing market knowledge and have routines and processes that provide an advantage in understanding their existing market demand (Fabrizio & Thomas, 2012). Therefore, firms always focus on the satisfaction of existing customer needs and forego explorations of new ideas for emerging markets (Zhou & Li, 2012). In fact, this prevents firms from absorbing more market knowledge to introduce better innovations. Instead, when firms collaborate with partners of different markets, they can obtain access to diversified market knowledge more easily, and the infusion of new knowledge likely generates new ideas for innovations (Zhou & Li, 2012).

Knowledge source diversity increases the likelihood of producing innovative ideas (Amabile, 1988; Cui et al., 2015). Partners with market dissimilarity provide firms with diverse market knowledge domains and varied market solutions (Ahuja & Lampert, 2001), which expand the scope of information search beyond existing customers or markets (Zhou & Li, 2012). Thus, those partners can help firms experiment with new and different ideas about product concepts and functions, as well as with the development process itself, and enhance their products' novelty (Amabile, 1983).

Moreover, by integrating different market knowledge from its partner's markets into a deep understanding of its own current segments, a focal firm may detect new future market trends, discover new market opportunities and invest accordingly to explore them in its own market (Chesbrough, 2003). Consequently, a focal firm will be forced to take another look at its own market segments and develop new products to meet market demand (Zhou & Li, 2012).

Thus, we posit the following:

Hypothesis 1a: Market dissimilarity between a focal firm and its collaborative partners is positively associated with firms' innovation novelty.

Market dissimilarity between collaborative partners can also stimulate firms' innovation efficiency. First, market dissimilarity reduces the competitive concern between collaborative partners (Chen, 1996), as they do not directly compete with each other. Hence, to some extent, firms do not become too deeply entrenched with their own resources (Zhou & Li, 2012) and will relax the restrictions on knowledge and technology sharing. Accordingly, firms are able to absorb more resources from partners and collaborate with each other more closely, which promotes technical synergies and innovation performance (Phelps, 2010). In addition, market dissimilarity helps reduce objectives conflicts between collaborative partners and highlights their common objectives. As long as they exist in similar market segments, they will take competitive actions (Yang et al., 2015) and emphasize individual objectives in order to obtain competitive advantages; this leads to conflicts in objectives (Gimeno, 2004). Instead, firms with market dissimilarity will be more willing to focus on their common objectives and to understand their partners' different market knowledge, which facilitates long-term collaboration and innovation efficiency.

Moreover, market dissimilarity provides firms with additional external market knowledge. These increased knowledge stocks then provide firms with "knowledge buffering" (Jourdan & Kivleniece, 2016) and give them more experience and knowledge to develop new products. Such a process enhances firms' flexibility and the ability to adapt to the changes in technology and market (Volberda, 1996) as well as reduces their own risks of innovation (Porter & Fuller Mark, 1986), thereby contributing to increased innovation efficiency.

Thus, we posit the following:

Hypothesis 1b: Market dissimilarity between a focal firm and its collaborative partners is positively associated with firms' innovation efficiency.

Technology Complementarity and Firms' Collaborative Innovation Performance

Research has consistently shown that technology complementarity has positive effects on firms' collaborative innovation (Fang, 2011; Makri et al., 2009). On the one hand, similarity in technology bases always creates a significant path dependency (Makri et al., 2009), which is deemed a limit for the new recombination of technology that can be used for creation and innovation

activities. On the other hand, technology complementarity provides firms with diversified technical resources. Previous research has recognized that technology source diversity increases the likelihood of radical innovation (Amabile, 1988; Cui et al., 2015). In addition, technology complementarity facilitates technical resource matching, which helps firms obtain access to partners' technology and ensures synergies with partners' technology bases (Makri et al., 2009). Therefore, technology complementarity promotes efficient technical resource transfer and integration, since it enables the coordination of mutual learning and collaboration activities (Bechky, 2003; Lakemond et al., 2016). It can thus promote firms' innovation outcomes and innovation performance.

Technology complementarity has a positive effect on the novelty of firms' innovation, since the product-innovation stage involves technology recombination quite intensely (Fleming & Sorenson, 2004). Integrating complementary technology provides a much greater portfolio of new and unique technology combinations for the collaborative partners, which in turn enhances their new products' leading position of technology and market applicability (Vanhaverbeke et al., 2006), and helps firms develop their products' new functions and improve their process planning (Hung & Tang, 2008). Thus, technology complementarity enhances product novelty.

Furthermore, collaborative partners share, transfer and absorb diversified but complementary technology, during which process they challenge their old perspectives of product development by breaking away from previously specified rules and processes, generating new ideas about product concepts and exploring more novel technical resources and knowledge. Accordingly, technology complementarity provides potential opportunities for firms' technical resource "exploration" activities (Fang, 2011; March, 1991). According to Krishnan and Ulrich (2001), technical resource exploration can extend firms' resource bases and resource stocks, which results in better innovation ability and the discovery of novel linkages (Hogarth, 1980) among product elements (Krishnan & Ulrich, 2001). Such discovery substantially connects different design parameters that had not been previously linked (Amabile, 1983). Moreover, this enhances the novelty of new products.

These observations lead to the following hypothesis:

Hypothesis 2a: Technology complementarity between a focal firm and its collaborative partners is positively associated with firms' innovation novelty.

In addition to its effects on innovation novelty, technology complementarity also affects innovation efficiency (Rosenkopf & Nerkar, 2001). According to Rothaermel, Hitt, and Jobe (2006), firms tend to integrate complementary resources from internal and external sources through collaboration (Rothaermel et al., 2006). When collaborative partners enjoy technology complementarity, they have matchable technical resource bases that help facilitate communication and coordination. Thus, the increased communication helps each party understand the value of a partner's unique but complementary sets of technical resources and facilitates the integration of their complementary technical resource stocks (Makri et al., 2009). Accordingly, complementary technical resources help firms form a synergy to carry out innovation activities (Jourdan & Kivleniece, 2016), enhancing their ability to absorb and use new information in effective ways and be more flexible and responsive in the face of competition, thereby contributing to increased innovation productivity and efficiency (Cyert & March, 1963). This additional complementary technology also enhances the focal firm's flexibility to adapt to changes in technology. Technology complementarity thus contributes positively to more and richer innovation activities as well as to better innovation efficiency.

Moreover, the key to open innovation lies not only in the acquisition of external resources from their partners but also in the accumulation of their own R&D capabilities (Lichtenthaler, 2011). Partners with technology complementarity provide firms with the opportunity to obtain external technical knowledge from a variety of disciplines and domains, thus helping them consolidate and develop their own technology bases and improve their own absorptive capacities and R&D capabilities (Zobel, 2016). The increased capabilities can also promote firms' flexibility in the face of the dynamic environment (Yli-Renko et al., 2001). Therefore, technology complementarity helps them achieve better innovation efficiency.

These observations lead to the following hypothesis:

Hypothesis 2b: Technology complementarity between a focal firm and its collaborative partners is positively associated with firms' innovation efficiency.

The Moderating Effect of IT Adoption

Given that information is one of the strategic factors that can help improve business productivity and performance (Jabbouri et al., 2016), firms always value Information Technology (IT) as a strategic resource (Grover & Saeed, 2007). Thus, the effects of IT on the attainment of business objectives and the facilitation of

organizational performance are important management issues (Rivard et al., 2006; Sabherwal & Tsoumpas, 1993). In the context of open innovation, with advances in IT applications, firms are able to easily and actively use these applications to engage in innovation virtually with distant firms (Nambisan, 2002). To some extent, this provides firms with the opportunity to use IT applications to collaborate with their partners. Thus, the growing literature on IT is beginning to examine the use of IT in innovation activities from inter-organizational and network-based perspectives (Frank & Duarte Ribeiro, 2014).

IT adoption refers to firms' use of IT applications when collaborating with partners. As an information management system, IT itself is an effective way to share, use and manage information and other knowledge resources (Dong & Yang, 2015). It enables firms to widely adapt IT applications to support evolving resource-sharing requirements, including information-sharing and knowledge-sharing requirements (Cui et al., 2015; Langdon, 2006). Research on inter-organizational resource sharing has shown that the use of IT enhances the timely exchange of information and knowledge with collaborative partners (Cui et al., 2015; Grover & Saeed, 2007) and facilitates the extensive absorbing of knowledge from partners. Additionally, studies focusing on open innovation show that firms must develop their absorptive capacity to learn from external sources of knowledge (Hoang & Rothaermel, 2005), and one of the most important enablers of absorptive capacity is information technology. In short, the use of IT applications in collaboration effectively provides firms with extra resources from partners to achieve better innovation performance.

While researchers claim a direct relationship between IT and innovation performance (Dong & Yang, 2015; Jabbouri et al., 2016; Oh & Pinsonneault, 2007), we argue instead for the moderating effect of IT adoption. We assume that it is precisely the considerable effects of IT adoption that have weakened the positive relationship between market dissimilarity and firms' innovation performance. As mentioned above, the use of IT facilitates the sharing of information and knowledge (Dong & Yang, 2015). Just as it accelerates information inflows, IT also accelerates information outflows (Jabbouri et al., 2016), which challenges IT security and strengthens the competition between firms and their partners. However, since market knowledge and information are of vital importance to firms' competition, distrust is inevitable during the sharing of market information. Moreover, market dissimilarity always results from dissimilarities in resource bases or other characteristics. As a result of different or even disparate knowledge and technology bases and coordination costs,

conflicts and suspicions are inevitable in the collaboration (Sarkar et al., 2001). Just as IT adoption breaks down information barriers between collaborative partners, it also reduces the trust between them and decreases their willingness for collaboration, thus weakening the positive relationship between market dissimilarity and firms' innovation performance.

Furthermore, IT adoption increases a focal firm's absorptive capacity (Roberts et al., 2012), which helps the firm absorb, assimilate and utilize greater external resources at a lower cost (Cohen & Levinthal, 1990; Winter, 2003). Accordingly, a focal firm can improve its access to diversified market knowledge from more sources simultaneously (Dong & Yang, 2016). The possibility of obtaining similar market knowledge by IT renders the partner's dissimilar resource less valuable. As a result, IT adoption reduces a firm's dependence on partners with market dissimilarity to get heterogeneous market knowledge (Pfeffer & Salancik, 1978). That is, firms do not need to collaborate with those partners with whom they have significant differences, thus avoiding unnecessary coordination costs and conflicts (Sarkar et al., 2001). In other words, IT adoption replaces market dissimilarity to provide diversified market knowledge and information for the focal firm, thus weakening the positive relationship between market dissimilarity and firms' innovation performance.

Thus, we hypothesize the following:

Hypothesis 3a: IT adoption weakens the positive relationship between market dissimilarity and firms' innovation performance (novelty and efficiency).

Similarly, IT adoption also weakens the positive relationship between technology complementarity and firms' innovation performance. IT adoption enables a firm to access a wide range of external resources, including complementary technological knowledge (Dong & Yang, 2015). As the value of a partner's resources depends on other similar resources (Cui, 2013), the external complementary technological knowledge provided by IT could weaken the value of technological complementarity between focal firm and its partners. Thus, IT adoption may serve as a substitute, and weaken the effect of technological complementarity.

Furthermore, IT adoption enables a firm to collaborate with multiple partners with similar resources (Winter, 2003), which, in turn, help reduce the focal firm's dependence on an individual partner with complementary technological knowledge (Hoffmann, 2007). The reduced dependence lowers the role of technology complementarity. As a result, there is less need for technological

complementary partners. Consequently, IT adoption weakens the effects of technology complementarity on a focal firm’s innovation activities, and weakens the positive relationship between technology complementarity and firms’ innovation performance.

Thus, we hypothesize the following:

Hypothesis 3b: IT adoption weakens the positive relationship between technology complementarity and firms’ innovation performance (novelty and efficiency).

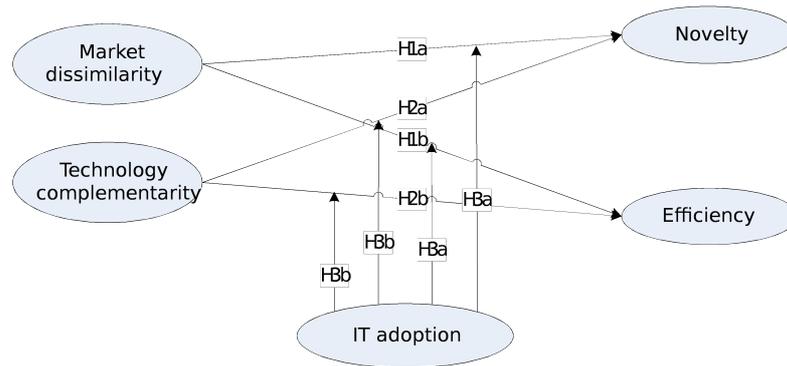


Figure 1: Conceptual Framework and Research Model

METHOD

Data Collection

Participants in our study were all innovative enterprises enrolled in a large firm collaborative innovation survey carried out by their provincial government. In this study, we followed the key informant approach to collect data from one R&D manager at each firm (Phillips & Bagozzi, 1986). Those R&D managers could download the electronic questionnaire from the website and answer it. The questionnaire was based on their organizational conditions in the year 2012 (data collection was conducted in January 2013). To ensure the quality of the data, we collaborated with a Chinese government agency (Municipal Science and Technology Commission) to send out survey invitations. Of the 733 participants in this project, 402 surveys were returned (rate of return = 54.8%). Among returned surveys, 53 R&D managers did not complete most of the questions; hence, they were eliminated from the sample. Finally, 349 completed surveys were received. This represents a response rate of 47.6%.

Measures

At the beginning of each questionnaire, we asked the R&D managers of the firms surveyed to remind one firm that their firm had collaborated with it on at least one project and to answer the following questions. All questionnaire items used a 7-point Likert scale, where 1 = “completely disagree” and 7 = “completely agree.”

Dependent Variables

We measured *innovation novelty* by three items reported by the R&D managers (we dropped one item due to its low factor loading). Consistent with previous studies, the scale items asked respondents about the extent to which the developed product is novel and offers new ideas to the industry (Fang, 2011). Sample items included, “Your new product developed in the collaboration project was novel to the world.” To measure innovation efficiency, we asked R&D managers to judge the efficiency and costs of the collaborative project. The sample item was, “Compared with your competitors, your new product was more efficiently created by the collaboration project.”

Independent Variables

To measure *market dissimilarity*, we adapted two items from Tanriverdi and Venkatraman (2005). We divided market dissimilarity into two dimensions, namely, “customer” and “market competition” (Tanriverdi & Venkatraman, 2005). Sample items included, “We serve different customers from our partner.” Next, consistent with previous studies (Luo, 2005), we measured technology complementarity with a three-item (one dropped), 7-point Likert scale. Respondents indicated the extent to which carrying out the collaboration projects depended on technical resources input by their partners. Sample items included, “We need our partner’s technical resources to achieve the objectives of the project.”

Moderating Variables

The measure of *IT adoption* came from Tallon & Pinsonneault (2011). We used two items to evaluate the extent to which participants used IT applications (IT system) to collaborate with their partners in the projects (Tallon & Pinsonneault, 2011). The sample item was, “In the collaborative innovation project, we used IT tools widely to share data and information with our partners.”

Control Variables

We also included several variables to control for differences at the firm and project levels, which might serve as potential confounding factors or alternative explanations for our results. First, at the firm level, we control for the effects of the firm's age (*age*), size (*size*) and nature (whether it is a state-owned enterprise) (*SOE*). The age variable is defined as the difference between the year 2012 and the firm's founding year. Moreover, firm size is an important attribute that shapes firms' behaviors and decisions (Schumpeter, 1934). Hence, we control for the effect of firm size by including the total number of employees in our model. Then, we measure firm nature as a dummy variable (1 if the focal firm is state-owned, 0 if it is not).

Second, at the project level, we control for the effects of the project cost (*projectcost*) and project size (*projectperson*). We define project cost as the total cost of the collaboration project reported by the focal firm. In addition, we control for project size, measured as the number of full-time employees in the collaboration project (Fang, 2011).

Descriptive statistics and correlations for the variables are provided in Table 1. The table shows that none of the reported correlations between IT adoption and the two independent variables are significantly high, which will not lead to a confused moderating effect. In addition, the correlation between market dissimilarity and technology complementarity is also not significantly high, and thus multi-collinearity is not an issue in this study.

RESULTS

The hypotheses were tested using partial least squares (PLS), a structural equation modeling technique employing a principal component-based estimation approach (Chin et al., 2003). PLS explicitly estimates the latent variables (LVs) and their relationships, accommodates smaller sample sizes, requires no assumptions of data distributions, overcomes identification problems in formative relationships and is more suitable for modeling complex relationships (Henseler et al., 2009; Zobel, 2016). As a result, compared with linear structural relationships (LISREL), PLS is more appropriate for this study. The sample size is sufficient, as it is 10 times greater than the number of indicators of the scale with the largest number of formative indicators and is also 10 times greater than the largest number of structural paths directed at a particular construct in the inner path model (Henseler et al., 2009; Zobel, 2016).

We first conducted an exploratory factor analysis. Six factors were extracted with all items loading on their respective constructs. Second, we conducted a

confirmatory factor analysis. As shown in Table 1, composite reliabilities and Cronbach's alphas for all reflective constructs are above 0.7, which exceeds the suggested benchmark (Nunally, 1978) and shows internal consistency. Moreover, all items load more highly on their own constructs than on others, and none of the cross-loadings exceed 0.7, which shows discriminant validity at the item level. Construct level discriminant validity can also be confirmed, as the square roots of the average variances extracted (AVEs) are greater than the correlations between constructs, meaning that all constructs share more variance with their own measures than with others (Fornell & Larcker, 1981). In addition, AVEs exceed the cut-off value of 0.5 (Fornell & Larcker, 1981), thereby showing convergent validity.

Table 1: Correlations Matrix and Reliability

	Mean	Std. Dev.	Cron. Alpha	Comp. Rel.	1	2	3	4	5	6	7	8	9	10
1. age	10.14	7.82	n/a	n/a										
2. size	544.45	2004.88	n/a	n/a	0.27									
3. SOE	0.09	0.28	n/a	n/a	0.19	0.02								
4. projectcost	883.73	2599.08	n/a	n/a	-0.05	-0.00	-0.03							
5. projectperson	29.81	89.88	n/a	n/a	-0.05	0.08	-0.04	0.11						
6. market dissimilarity	4.90	1.27	0.81	0.91	-0.00	0.04	0.13	0.04	0.09	(0.84)				
7. technology complementarity	5.17	1.16	0.79	0.91	0.12	0.02	0.07	0.02	0.02	0.30	(0.82)			
8. novelty	5.73	0.97	0.94	0.97	0.09	-0.02	-0.03*	0.01	0.01	0.20***	0.46***	(0.94)		
9. efficiency	5.27	1.06	0.92	0.96	0.08	0.06	0.04	0.08	0.06	0.22**	0.35***	0.67	(0.93)	
10.IT adoption	4.61	1.27	0.73	0.88	0.07	0.02	0.01	0.06	-0.01	0.08	0.29	0.22**	0.18*	(0.78)

Note. $N = 349$. Average variances extracted (AVEs) are shown in parentheses along the diagonal.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

We tested our hypotheses with SmartPLS 2.0. The significance of path coefficients was assessed with 1,000 bootstrap subsamples. Figure 2 shows the complete model and our estimating results.

Hypothesis 1 predicts a positive effect of *market dissimilarity* on collaborative partners' innovation performance (novelty and efficiency). First, as shown in Figure 2, we found support for Hypothesis 1a because the correlation coefficient between *market dissimilarity* and *innovation novelty* is positive and significant ($\beta=0.08$, $p < 0.1$). In addition, *market dissimilarity* also has a significant positive association with *innovation efficiency* ($\beta=0.13$, $p < 0.01$), thereby supporting H1b. In addition, as predicted (Hypothesis 2a and 2b), *technology complementarity* between a focal firm and its collaborative partners is positively associated with firms' innovation performance. From Figure 2, we can see that the correlation coefficient between *technology complementarity* and *innovation novelty* is positive and significant ($\beta=0.44$, $p < 0.01$), the same as that between *technology complementarity* and *innovation efficiency* ($\beta=0.31$, $p < 0.01$), which strongly supports Hypothesis 2. We also found that the effects of *technology complementarity* are stronger than those of *market dissimilarity*. The results show that technical resources from collaborative partners may be more important for firms than market knowledge and that complementarity character may also have greater effects than total dissimilarity on firms' collaboration.

Figure 2 also presents the moderating effects of *IT adoption*. As predicted (Hypothesis 3), *IT adoption* negatively moderates the positive effects of both *market dissimilarity* and *technology complementarity* on a focal firm's innovation performance. We first estimated the interaction effects between *market dissimilarity* and *IT adoption*. Figure 2 shows that there are negative significant interactions between *market dissimilarity* and *IT adoption* on *innovation novelty* ($\beta=-0.11$, $p < 0.1$) and *innovation efficiency* ($\beta=-0.09$, $p < 0.1$), thereby wholly supporting Hypothesis 3a. To evaluate Hypothesis 3b, we again tested the interaction effects of *technology complementarity* and *IT adoption* on *innovation novelty and efficiency*. We found that the moderating effects can be partially supported. On *innovation efficiency*, the interaction effect is negatively significant ($\beta=-0.12$, $p < 0.05$), which partially supports H3b. However, on *innovation novelty*, the interaction effect is positive ($\beta=0.11$, $p < 0.05$). Although this finding is rather unexpected, it can be explained as follows: first, the competitive concern caused by sharing technical resources is not as direct or strong as that caused by transferring market knowledge. In addition, compared with irreconcilable dissimilarity, complementarity provides a more solid

collaborative foundation for collaborative partners. As a result, the negative effects of *IT adoption*, namely, distrust and intensified competition, can be weaker on the relationship between technology complementarity and collaborative innovation performance. On the other hand, cooperating with technologically complementary partners is easier and less costly than cooperating with market-dissimilar partners. Hence, the substitution effect of IT adoption on technology complementarity will be weaker. In contrast, the use of IT enhances the timely exchange of information and knowledge with collaborative partners (Cui et al., 2015; Grover & Saeed, 2007), which promotes efficiency of resource integration, reduces collaborative costs, and thus strengthens the positive effects of technology complementarity.

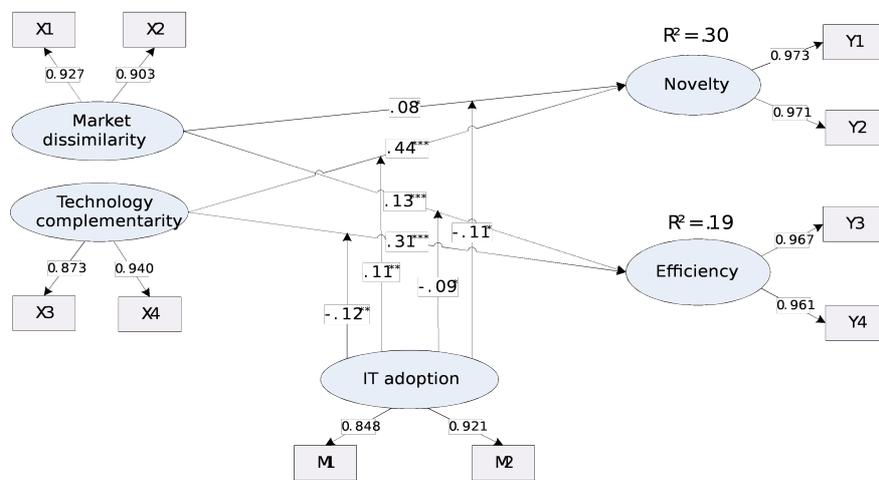


Figure 2 PLS Analysis of Results

CONCLUSION AND DISCUSSION

As strategic alliance between firms is becoming increasingly popular, and collaborative innovation is becoming an important management issue, the lack of a holistic framework for different collaborative partners' characteristics and their different effects on firms' innovation has become a critical research gap. Using collaboration data between innovation-type firms, we hope to understand how market dissimilarity and technology complementarity affect collaborative partners' innovation novelty and efficiency. Another dimension of our study is to explore the moderating factors that affect market dissimilarity/technology complementarity and innovation performance relationships. We argue that to understand how market dissimilarity and technology complementarity affect collaborative innovation performance, researchers and practitioners must explore external intervention factors of collaboration, such as IT adoption. The results are mostly consistent with the predictions of the theoretical framework.

Theoretical contributions

First, our study provides an integrated framework for analyzing different effects of partners' resource heterogeneity, which is an extension of existing research. The existing literature tends to explain the direct effects of similarity, heterogeneity or complementarity (Adner & Levinthal, 2001; Cui, 2013). However, those studies do not provide an integrated framework for contrastive analysis of the impacts of different characteristics, leaving a critical research gap. As we show in Figure 2, both market dissimilarity and technology complementarity relate positively to innovation novelty and efficiency. The results highlight the importance of collaborative partners' heterogeneous resource bases to firm innovation. Resource heterogeneity (both market resource dissimilarity and technical resource complementarity) exposes the development team to diverse information inputs and enables it to engage in resource exploration activities that enhance innovation (Fang, 2011). Although the existing literature has failed to reach an agreement on the effects of partner heterogeneity, empirical research may still reveal enough evidence to prove its positive effects. When dissimilarity is delimited by the market dimension, it will provide firms with innovative ideas and reduce competition between partners, which facilitates innovation performance. In addition, technology complementarity, the non-overlapping technology bases of two firms that fall within an acceptable range of difference and might be combined and integrated to create value, is more effective on collaborative partners' innovation performance because of its "matchable" feature and ease of integration (Sivadas & Dwyer, 2000).

Second, in addition to examining the direct effects of market dissimilarity and technology complementarity, the article also contributes to answering the question, "Under what conditions do market dissimilarity and technology complementarity generate collaborative innovation performance?" We find that the role of resource heterogeneity in influencing focal firm's innovation depends on conditions that enable access to similar resources. Specifically, this study constructs a contingency model and advances extant literature by confirming empirically that external intervention factors (such as IT adoption) greatly moderate firms' collaborative innovation process. We hypothesize that the external intervention factor (IT adoption) has moderating effects on market dissimilarity/technology complementarity and innovation performance relationships. Our results indicate that IT adoption negatively moderates the major effects. The findings reveal important interactions between partners'

heterogeneous resources and the conditions that enables access to broader portfolio of external resource. The contingent effects of resource heterogeneity between partners on firm innovation suggest that research on collaborative innovation should not merely focus on resource diversity(Fang, 2011), but need to balance the effect of resource heterogeneity and the need for access to wide range of external resources.

Interestingly, despite its direct positive effect, which is widely accepted (Devece, 2013; Dong & Yang, 2016), IT adoption also accelerates information outflows, which greatly challenges IT security. Additionally, IT applications almost replace the advantages of both market dissimilarity and technology complementarity, as IT itself helps firms match and integrate their resources with partners' effectively and economically (Dong & Yang, 2016). However, our results also show that the moderating effect of IT on the relationship between technology complementarity and innovation novelty is significantly positive, while its effect on the relationship between technology complementarity and innovation efficiency becomes negative. It may be concluded that the moderating effects are actually nonlinear. In order to achieve innovation efficiency, it may be true that firms do not need complementary partners when there are positive effects of IT adoption, while in terms of innovation novelty, complementary resources are difficult to replace. These findings will require further research, as they appear to challenge traditional IT theories. The results indicate that IT adoption does not have positive effects in all situations, which extends previous research on Information Technology and Information Systems.

Managerial Implications

In terms of managerial implications, the results suggest that investments in establishing collaborative relationships with heterogeneous partners (such as partners with market dissimilarity and technology complementarity) are strategically justified in many firm environments. As noted, a partner's dissimilar market knowledge and complementary technical resource reconfigure a firm's resource base, provide it with novel ideas and enable it to engage in resource exploration activities that enhance innovation (Fang, 2011; Zhou & Li, 2012). Hence, managers need to pay attention to finding such collaborative partners and establishing collaborative relationships with them to generate a competitive advantage and better collaborative innovation performance.

Moreover, although we find that heterogeneous partners are beneficial for firms, and conventional wisdom also states that it is desirable to form an alliance with a

“complementary” partner, our results suggest that the equation actually is much more complex. Establishing a collaborative relationship with a partner with dissimilar or complementary resources may, in some circumstances, such as when using too many IT applications, hurt collaborative innovation performance. Managers, therefore, should pay attention to external intervention factors, such as IT adoption. Although using IT applicants enables firms to reduce collaboration costs, enhances the timely exchange of information and knowledge (Cui et al., 2015; Grover & Saeed, 2007) and facilitates the extensive absorbing of knowledge from partners, it also contributes to distrust. Consequently, collaborative partners must always strike a balance between the advantages and disadvantages of IT applicants in order to maintain long-term friendships and collaboration.

Limitations and Further Research

This study has several limitations, some of which suggest important avenues for future research. First, although this dataset includes a broad range of innovation-type firms representing a variety of industries, it is limited to only one province in China and to only one year, and therefore, care should be exercised in generalizing the results. Future studies may scrutinize this study’s findings in another setting, possibly incorporating a greater number of industries, localities, and/or time periods in order to ensure even higher levels of variance of environmental dynamism in the dataset.

Second, our study focuses on only one dimension of dissimilarity and complementarity, namely, market dissimilarity and technology complementarity. Future studies should examine other aspects, such as dissimilarity of corporate cultures, which may cause irreconcilable differences and conflicts between partners and harm collaboration. In addition, consistent with Fang (2011), we focus on technology complementarity—that is, non-overlapping technology bases between collaborative partners within an acceptable range of difference—whereas the broader definition of technology complementarity also includes “related but not the same” technology. Such notions of technology complementarity may have different impacts on innovation, and future studies should address this issue in more detail.

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