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Market Dissimilarity, Technology Complementarity and Collaborative Innovation Performance: The Moderating Effects of IT Adoption

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Abstract

As the strategic alliance between firms is becoming increasingly popular, and collaborative innovation is becoming an important management issue, the lack of a holistic framework of different collaborative partners' characteristics and their different effects on firms' innovation is becoming a critical research gap. Another intension of our study is to explore the moderating factors that affect the market dissimilarity/technology complementarity—innovation performance relationships. Using the data of collaboration between innovative firms, we tested our hypotheses using partial least squares (PLS). The results show that both market dissimilarity and technology complementarity between collaborative partners relate positively to focal firms' 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 the relationship between technology complementarity and innovation efficiency, while in terms of the relationship between technology complementarity and innovation novelty, the moderating effect becomes significantly positive. This study extends previous research on collaborative innovation.

Key words

market dissimilarity; technology complementarity; IT adoption; collaborative innovation

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1. 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 (Sytch and Tatarynowicz, 2014; Ahuja, 2000; Davis, 2016). However, despite some well-publicized examples, few of the collaborations actually produce innovations (Davis, 2016; Davis and Eisenhardt, 2011). Hence, how to make use of both partners' advantages to promote collaborative innovation is becoming an important managerial issue, especially in those developing countries, such as China (Fang, 2011).

Existing literature tends to explain how a certain characteristic of the partner influences the collaboration, such as the effects of knowledge overlap, resource heterogeneity or complementarity (Adner and Levinthal, 2001; Chen, 1996; 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. Hence, we put market dissimilarity and technology complementarity into a holistic framework and hope to understand how market dissimilarity and technology complementarity between collaborative partners affect focal firms' innovation performance, and explore the differences between these effects.

Besides, literature on collaborative innovation mainly focuses on a single dimension of innovation performance, such as the production (Kim and Finkelstein, 2009) or the innovativeness (Fang, 2011) of the new products. However, innovation collaboration may have different influence on different dimensions of innovation performance. Hence, it is important to put different dimensions of innovation performance in a holistic framework and explore the different mechanism through which innovation collaboration affects them. Based on these arguments, we study innovation performance from two dimensions— novelty and efficiency.

Previous researches that examined the direct effects of partners' different characteristics also fail to answer "under what conditions do those characteristics of partners generate collaborative innovation performance?". In fact, even same partners collaborate together, they may still achieve different performance (Fang, 2011). During the collaboration projects, firms always tend to use some external interventions (*e.g.* innovative instruments, such as IT applications; or control mechanism, such as project management) to collaborate with their partners, in order to attain better collaboration efficiency (Cui *et al.*, 2015; Grover and Saeed, 2007). While several empirical studies have already highlighted the direct positive effects of IT adoption (*e.g.* Devece, 2013; Dong and Yang, 2016), few have explored its possible interactions with partners' different characteristics. Specifically, we suggest that IT adoption during the collaboration projects can significantly moderate the effects of market dissimilarity and technology complementarity between partners, thus to build the contingency mechanisms.

Based on the arguments above, this paper focuses on the effect of market dissimilarity/technology complementarity between partners on different dimensions of focal firms' innovation performance, *i.e.* innovativeness and efficiency, as well as the moderating effects of IT adoption. We find that both market dissimilarity and technology complementarity of collaborative partners significantly promote the focal firm's innovation performance (in terms of novelty and efficiency), while technology complementarity is more effective. We also find evidence that in the collaborative innovation projects, the widely use of IT tools between collaborative partners sometimes negatively moderates the market dissimilarity/ technology complementarity — performance relationships.

This article contributes to existing researches from the following aspects. 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 more dimensions of dissimilarity and complementarity and their effects on firms' collaboration performance, and should more carefully examine the effects of the external intervention factors of the collaboration such as IT adoption.

The paper 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, and then we test it empirically using the data of collaboration between innovation-type firms.

2. Conceptual Framework and Hypotheses

As we 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. Yet others point out that dissimilarity causes mistrusts and communication barriers between collaborative partners (Parkhe, 1991), and is also associated with weak legal and regulatory environments especially in developing societies (Fang, 2011). Thus, dissimilarity challenges collaborative partners' efficiency. However, some researchers point out that the reason why there is not an agreement on this question is that existing studies do not delimit the dimensions of dissimilarity (Parkhe, 1991). As a result, the studying scope of this paper is framed in market dissimilarity, which refers to the different market segments of the focal firm and its partner (Chen, 1996).

Traditional researches on complementarity also focus on different aspects, such as resource complementarity (Pullen *et al*., 2012), strategic complementarity and market complementarity (Kim and Finkelstein, 2009). As the essential goal of an alliance is always learning and creation of technical knowledge, researchers nowadays always centrally focus 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 nonoverlapping technology bases of two firms that fall within an acceptable range of difference (Sivadas and Dwyer, 2000) and might be combined and integrated to create value, which did not exist in either firm before collaboration (Fang, 2011). Hence, complementarity does not simply entail the "differences" between two firms (different technology or knowledge in their respective domains with no or little combination and integration), it also requires firms to successfully manage such differences (Kim and Finkelstein, 2009). That means technology of the focal firm must generate a "good match" with the partners' technology (Sivadas and Dwyer, 2000).

Specifically, in this article, we also divide innovation performance into novelty and efficiency of innovation. Novelty refers to the extent to which a new product of a firm differs from competing alternatives in a way that is meaningful to customers (Dewar and Dutton, 1986; Fang, 2011). Every innovation contains a certain degree of novelty, and the degree of novelty usually has been considered

as a major factor weighing the commercial success or failure of innovation (Duhamel and Santi, 2012). To some extent, novelty of innovation shows the extent of innovation radicalness (Henderson and Clark, 1990; Koc and Bozdag, 2017), and innovation efficiency refers to the quality of being able to complete innovation activities successfully with less costs and time.

2.1. Market dissimilarity and firms' collaborative innovation performance

There is a 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 the competitive threats from partners make firms face the risk of being replaced (Wassmer and Dussauge, 2012). Hence, firms tend to restrict knowledge sharing with partners, and this restriction limits the innovation of firms to a certain extent. In contrast, dissimilar market segments reduce the competition and enhance the innovation collaboration between partners.

On the other hand, researchers also point out that diverse market knowledge shapes the radical product definition and the scope of firm's innovation activities (Berchicci and Tucci, 2010; Kyriakopoulos *et al*., 2016), and also 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 and Thomas, 2012). Therefore, firms always focus on the satisfaction of existing customer needs and forgo explorations of knowledge and new ideas for emerging markets (Zhou and Li, 2012). In fact, that prevents firms from absorbing more market knowledge to carry out better innovations. Instead, when firms collaborate with partners of different markets, they can get access to diversified market knowledge more easily, and the infusion of new knowledge likely generates new ideas for innovations (Zhou and Li, 2012).

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

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

Thus, we posit,

Hypothesis 1a: Market dissimilarity between the focal firm and its collaborative partners is positively associated with the firm's 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 are not direct competitors of each other. Hence, to some extent, firms will not become so deeply entrenched with its own resources (Zhou and Li, 2012), and will relax the restrictions on knowledge and technology sharing. Accordingly, firms are able to absorb more resources (knowledge and technology in particular) from partners and collaborate with each other in a tighter way, which promotes technical synergies and innovation performance (Phelps, 2010). Besides, market dissimilarity helps reduce

objectives conflicts between collaborative partners and highlight 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. That leads to objectives conflicts (Gimeno, 2004). Instead, firms with market dissimilarity will have more willingness to keep attention on their common objectives and to understand partners' different market knowledge, which facilitates long-term collaboration and their innovation efficiency.

Moreover, market dissimilarity provides firms with additional external market knowledge. The increased knowledge stocks then provide firms with "knowledge buffering" (Jourdan and Kivleniece, 2017) and give firms more experience and knowledge to develop new products. Such a process enhances the firms' flexibility and ability to adapt to the changes in technology and market (Volberda, 1996) as well as reduces their own risks of innovation (Porter and Fuller Mark, 1986), thereby contributing to increased innovation efficiency.

Thus, we posit,

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

2.2. 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 significant path dependency (Makri *et al*., 2009), which is deemed a limit to 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, it promotes efficient technical resource transfer and integration since it enables the coordination of mutual learning and collaboration activities (Bechky, 2003; Lakemond *et al*., 2016). Thus, technology complementarity can promote firms' innovation outcomes and innovation performance.

Technology complementarity between collaborative partners has a positive effect on novelty of the firms' innovation, since the product-innovation stage involves technology recombination very intensely (Fleming and Sorenson, 2004). Integrating complementary technology provides a much greater portfolio of new and unique technology combinations for the collaborative partners, which 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 and Tang, 2008). Thus, it enhances their products' novelty.

Furthermore, collaborative partners share, transfer and absorb diversified but complementary technology, in this process they challenge their old and traditional perspectives of product development by breaking away from previously specified rules and processes, generating new and different ideas about product concepts, and tend to explore 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 and Ulrich, 2001). Such discovery substantially connects different design parameters that had not been linked previously (Amabile, 1983). Further, that enhances the novelty of new products.

These arguments lead to the following hypothesis:

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

In addition to the effects on novelty of innovation, technology complementarity also affects firms' innovation efficiency (Rosenkopf and 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 the collaborative partners have technology complementarity, they have matchable technical resource bases that help facilitate communication and coordination between them. Thus, the increased communication helps each party understand the value of partner's unique but complementary sets of technical resource, and facilitates the integration of their complementary technical resource stocks (Makri *et al*., 2009). Accordingly, complementary technical resources help firms form synergy to carry out innovation activities (Jourdan and Kivleniece, 2017), 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 and March, 1963). Also, the additional complementary technology enhances the focal firm's flexibility to adapt to the changes in technology. Hence, technology complementarity contributes positively to more and richer innovation activities as well as 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 chances to get to external technical knowledge from a variety of disciplines and domains, thus help them consolidate and develop their own technology bases, and improve their own absorptive capacities and R&D capabilities (Zobel, 2017). The increased capabilities can also promote the firms' flexibility in the face of the dynamic environment (Yli-Renko *et al*., 2001). Therefore, technology complementarity helps them achieve better innovation efficiency.

These arguments lead to the following hypothesis:

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

2.3. 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 strategic resource (Grover and Saeed, 2007). Thus, the effects of IT on the achievement of business objectives and the facilitation of organizational performance are important management issues (Rivard *et al*., 2006; Sabherwal and Tsoumpas, 1993). In the context of open innovation, with advancements in IT applications, firms are able to easily and actively use these applications to engage in innovation virtually with other distant firms (Nambisan, 2002). To some extent, that provides firms with the opportunity to use IT applications to collaborate with their partners. Hence, the growing literature on IT begin to examine the use of IT in innovation activities from inter-organizational and network-based perspectives (Frank and Duarte Ribeiro, 2014).

IT adoption refers to firms' use of IT applications (or Information System, IS) when collaborate with

their partners. As an information management system, IT itself implies an effective way to share, use and manage information and other knowledge resources (Dong and 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 and Saeed, 2007) and facilitates the extensive absorbing of knowledge from partners. Additionally, studies focused on open innovation show that firms have to develop their absorptive capacity to learn from external sources of knowledge (Hoang and Rothaermel, 2005), and one of the most critical enablers of absorptive capacity is information technology (IT). To sum up, the use of IT applications in the collaboration effectively provides firms with more extra resources from partners to achieve better innovation performance.

While researchers claim a direct relationship between IT and innovation performance (Dong and Yang, 2015; Jabbouri *et al*., 2016; Oh and Pinsonneault, 2007), we argue instead for a moderating effect of IT adoption. It is precisely the great 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 and Yang, 2015). The same time IT accelerates the inflows of information, it also speeds up the information outflows (Jabbouri *et al*., 2016). Hence, it challenges the information technology security and strengthens the competition between firms and their partners. However, since market knowledge and information are of vital significance to firms' competition, distrusts are inevitable during the sharing of market information. Besides, market dissimilarity is always resulted from resource bases dissimilarity or other characteristic dissimilarity. As a result of the different or even disparate knowledge bases and technology bases, coordination costs, conflicts and suspicions are also inevitable in the collaboration (Sarkar *et al*., 2001). As long as IT adoption breaks down information barriers between collaborative partners, it also reduces the trust between them and decreases their willingness of collaboration, thus weakens the positive relationship between market dissimilarity and firms' innovation performance.

Furthermore, IT adoption increases the focal firm's absorptive capacity (Roberts *et al*., 2012), which helps the firm absorb, assimilate and utilize more external resources (information and knowledge) at a lower cost (Cohen and Levinthal, 1990; Winter, 2003). Accordingly, the focal firm is capable to improve its access to diversified market knowledge from more sources simultaneously (Dong and Yang, 2016), and no longer confined to the certain previous partners. As a result, firms do not need to collaborate with those partners that have vast differences with themselves, in order to avoid unnecessary coordination costs and conflicts (Sarkar *et al*., 2001). In another word, IT adoption replaces market dissimilarity to provide diversified market knowledge and information for focal firms, thus weakens 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).

IT adoption also weakens the positive relationship between technology complementarity and firms' innovation performance. Although technology complementarity facilitates the communication between collaborative partners as well as enhances the integration and coordination between external resources and internal resources, researchers also claim that even when technical resources are similar, firms need time to learn how to integrate and combine their resource bases for sharing and collaboration activities

(Mayer and Argyres, 2004). Therefore, it is understandable that compared with technology similarity, technology complementarity can provoke cognitive and relational barriers to technology combination (Fang, 2011), and create challenges for resources integration (Harrison *et al*., 2001). At the same time, one of the important functions of IT is that it helps collaborative partners match, integrate and coordinate their resources (Dong and Yang, 2015). IT promotes communication between firms, offers firms an effective way to share, use and manage their technology and reduces the integration costs (Dong and Yang, 2016). As a result, there is no need for technical complementary partners. Consequently, IT adoption weakens the effects of technology complementarity on focal firms' innovation activities, and further, 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 depicts our theoretical model.

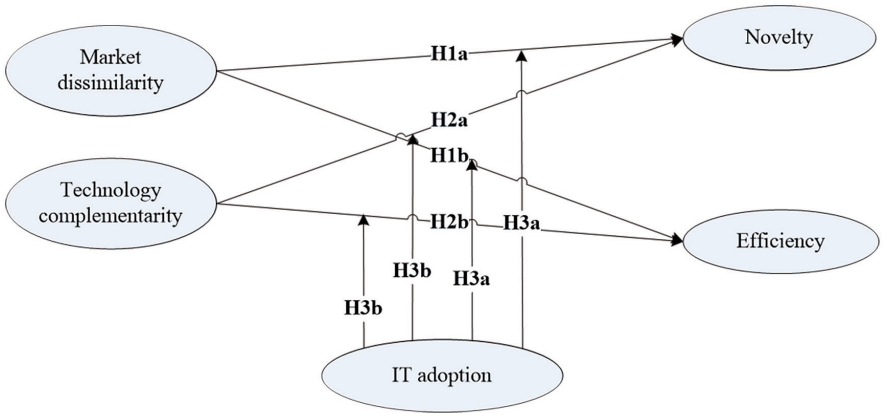

Fig. 1. Conceptual Framework and Research Model.

3. Method

3.1. Data collection

Participants in our study were all the innovative enterprises of a province in China that were 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 and 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 (Provincial Science and Technology Commission) to send out survey invitations. Of the 733 participants in this survey, 402 returned their results (rate of return =54.8%). Among the returned questionnaires, 53 R&D managers did not complete most of the questions; hence, they were eliminated from the sample. Finally, 349 completed questionnaires were received. This represents a response rate of 47.6%.

Table 1 presents the profiles of the responding companies, including the age, size (number of employees) and ownership of the firms represented in the sample.

Table 1
Demographic profile of the sample (N = 349).

	N	Percentage(%)
Age		
<10	196	56.16
10-20	136	38.97
>20	17	4.87
SOE		
State-owned	31	8.88
Non-state-owned	318	91.12
Firm size (number of employees)		
<50	34	9.74
50-99	61	17.48
100-299	143	40.97
300-499	53	15.19
>500	58	16.62

3.2. Measures

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

3.2.1. Dependent variables

We measured innovation novelty by three items reported by the R&D managers (we drop 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 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".

3.2.2. 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 and 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 the technical resources input by their partners. Sample items included "We need our partner's technical resources to achieve the objectives of the project".

3.2.3. Moderating variables

The measure of IT adoption came from Tallon and 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 and Pinsonneault, 2011). The sample item was "In the collaborative innovation project, we widely used IT tools to share data and information with our partners."

3.2.4. Control variables

We also include several variables to control for differences at firm and project levels, which might serve as potential confounds or alternative explanations for our results. First, at the firm level, we control for the effects of the firm age (age), size (size) and nature (namely whether it is a state-owned enterprise) (SOE). The firm age variable is defined as the difference between the year 2012 and the firm's founding year. Also, the 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 a state-owned enterprise, 0 if it is not).

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

Descriptive statistics and correlations for the variables are provided in Table 1. As is shown in Table 1, none of the reported correlations between IT adoption and the two independent variables are significantly high, indicating impossibility of a confused moderating effect. Besides, the correlation between market dissimilarity and technology complementarity is also not significantly high, and therefore multi-collinearity is not an issue in this study.

Table 2
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

4. 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, does not require any assumptions of data distributions, overcomes identification problems in formative relationships, and is more suitable for modeling complex relationships (Henseler *et al*., 2009; Zobel, 2017). As a result, compared with linear structural relationships (LISREL), PLS is more appropriate for this study. The sample size is sufficient as it is larger than 10 times the number of indicators of the scale with the largest number of formative indicators, and is also larger than 10 times the largest number of structural paths directed at a particular construct in the inner path model (Henseler *et al*., 2009; Zobel, 2017).

We first conducted exploratory factor analysis. Six factors were extracted with all items loading on their respective constructs. Second, we conducted 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 demonstrates 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 demonstrates 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 (FornellL and Larcker, 1981). In addition, AVEs exceed the cut-off value of 0.5 (Fornell and Larcker 1981), thereby demonstrating convergent validity.

We tested our hypotheses with SmartPLS 2.0. The significance of path coefficients was assessed with 1000 bootstrap subsamples. Figure 2 displays 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 we indicate in Figure 2, we found support for Hypothesis 1a because the correlation coefficient between market dissimilarity and innovation novelty is positive and significant (β= 0.08, p< 0.1). And market dissimilarity also has a significant positive association with innovation efficiency (β= 0.13, p< 0.01), thereby supporting H1b. Besides, as predicted (Hypothesis 2a and 2b), technology complementarity between the focal firm and its collaborative partners is positively associated with the firm's innovation performance. From Figure 2, we can find that the correlation coefficient between technology complementarity and innovation novelty is positive and significant (β= 0.44, p< 0.01), the same as the correlation coefficient between technology complementarity and innovation efficiency (β= 0.31, p< 0.01), which strongly support Hypothesis 2. We also found that the effects of technology complementarity are stronger than market dissimilarity. The results show that technical resources from collaborative partners may be more important for firms than market knowledge, and the complementarity character may also have stronger effects than totally 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 the 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 (β= -0.11, p< 0.1) and innovation efficiency (β= -0.09, p< 0.1), thereby totally supporting Hypothesis 3a. To evaluate Hypothesis 3b, we again tested the interaction effects of technology complementarity and IT adoption on innovation novelty and efficiency.

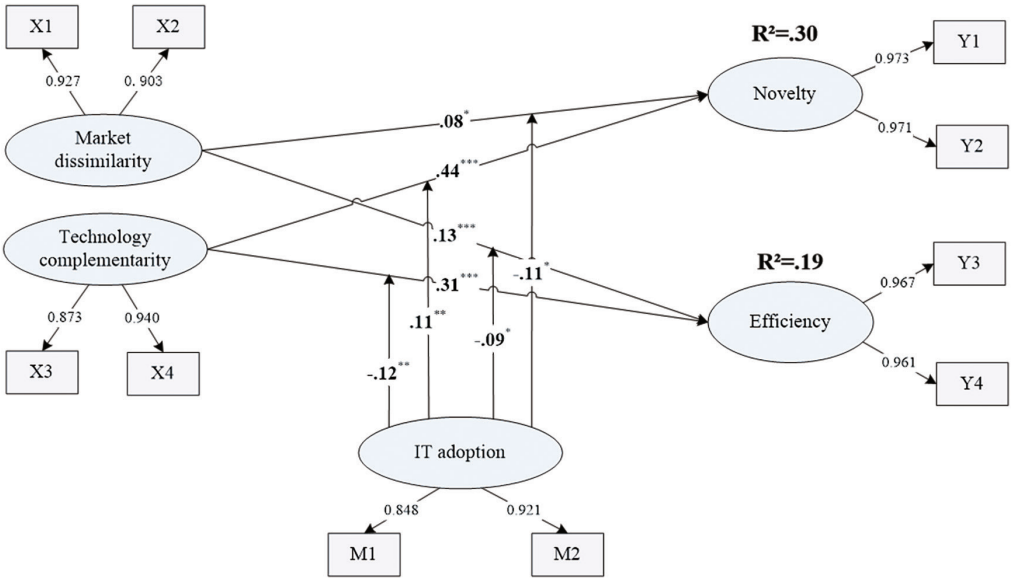

Fig. 2. PLS analysis of result.

We found the moderating effects can be partially supported. On innovation efficiency, the interaction effect is negatively significant (β= -0.12, p< 0.05), which partially support H3b. However, on innovation novelty, the interaction effect is positive (β= 0.11, p< 0.05). Although this finding is rather unexpected, it can be explained as follows: first, the competitive concern caused by sharing of technical resources is not so direct and strong as it caused by transferring of market knowledge. And compared with irreconcilable dissimilarity, complementarity provides more solid collaborative foundation for collaborative partners. As a result, the negative effects of IT adoption, namely leading to distrusts and intensifying competition, can be weaker on the relationship between technology complementarity and collaborative innovation performance. On the other hand, cooperating with technology 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 and Saeed, 2007), which promotes the efficiency of resource integration, reduces their collaborative costs, and thus strengthens the positive effects of technology complementarity.

To gain more insight into the interaction effects of Hypothesis 3, we follow Aiken and West's (1991) procedure to decompose the interaction terms (Aiken and West, 1991). Specifically, we conduct simple slope tests and plot the relationships in Figure 3a,3b and 4a,4b. In the tests, we split the IT adoption variable into two groups — low (one standard deviation below the mean) and high (one standard deviation above the mean) — and estimate the effects of market dissimilarity/technology complementarity on innovation novelty/efficiency for both levels.

5. Conclusion and Discussion

As the strategic alliance between firms is becoming increasingly popular, and collaborative innovation is becoming an important management issue, the lack of a holistic framework of different collaborative

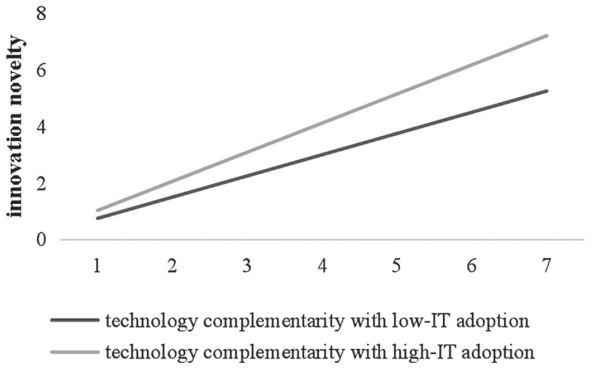

Fig. 3a. The moderating effect between market dissimilarity and innovation novelty.

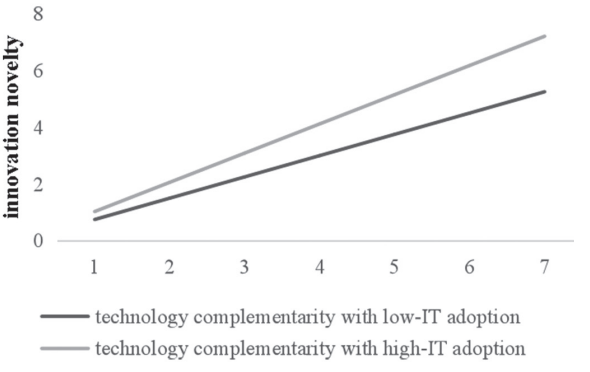

Fig. 3b. The moderating effect between technology complementarity and innovation novelty.

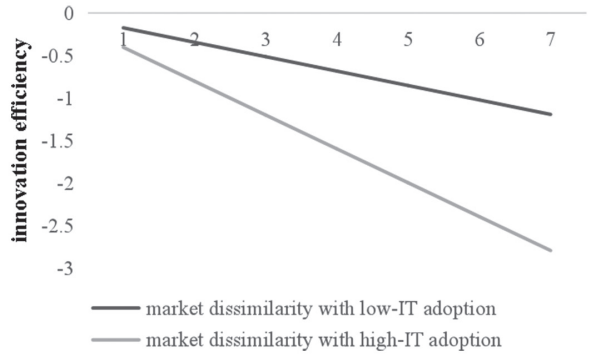

Fig. 4a. The moderating effect between market dissimilarity and innovation efficiency.

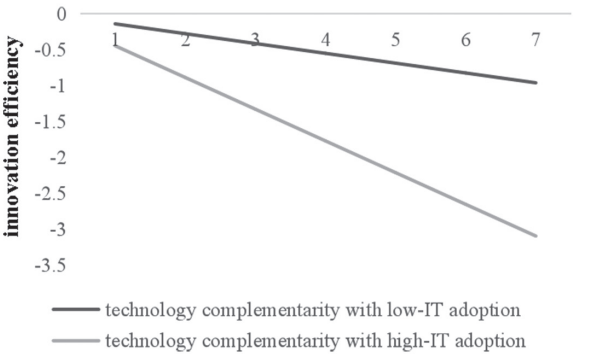

Fig. 4b. The moderating effect between technology complementarity and innovation efficiency.

partners' characteristics and their different effects on the firms' innovation is becoming a critical research gap. Using the data of collaboration between innovation-type firms, we hope to understand how market dissimilarity and technology complementarity affect collaborative partners' innovation novelty and efficiency. Another intension of our study is to explore the moderating factors that affect the market dissimilarity/technology complementarity — innovation performance relationships. We argue that to understand how market dissimilarity and technology complementarity affect collaborative innovation performance, researchers and practitioners must explore the external intervention factor of the collaboration such as IT adoption. The results are mostly consistent with the predictions of the theoretical framework.

5.1. Theoretical contributions

First, our study provides an integrated framework for analyzing different effects of partners' different characteristics, which is an extension of existing research. Existing literature tends to explain how a certain characteristic of the partner influences the collaboration, such as the direct effects of similarity, heterogeneity or complementarity (Adner and Levinthal, 2001; Chen, 1996; 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 firms' 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). Though existing literature has failed to reach an agreement on the effects of partners' heterogeneity, through empirical research, we can still find enough evidence to prove the positive effects of it. When dissimilarity is delimited to the market dimension, it will provide firms with innovative ideas and reduce the competition between partners, which facilitates innovation performance. In addition, technology complementarity, the nonoverlapping 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, due to its "matchable" feature and its easiness of integration (Sivadas and 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?" This study constructs a contingency model and advances extant literature by confirming empirically that external intervention factor (such as IT adoption) greatly moderate firms' collaborative innovation process. We hypothesize that the external intervention factor (IT adoption) has moderating effects on the market dissimilarity/technology complementarity—innovation performance relationships. Our results indicate that IT adoption negatively moderates the main effects.

Interestingly, despite its direct positive effect which is widely accepted (Devece, 2013; Dong and Yang, 2016), IT adoption also speeds up the information outflows, which greatly challenges the information technology security and strengthens the competition between partners. Meanwhile, IT applications almost replace the advantages of both market dissimilarity and technology complementarity, as IT itself helps firms match, integrate their resources with their partners' effectively with less costs, and get access to diverse market knowledge from more channels simultaneously (Dong and 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 on the relationship between technology complementarity and innovation efficiency, the effect becomes negative. It may be concluded that the moderating effects are actually nonlinear. In order to achieve an innovation efficiency, it may be true that firms do not need the complementary partners when there are positive effects of IT adoption, while in terms of innovation novelty, complementary resources are difficult to be replaced. That still needs further research. This finding appears to challenge the traditional theories of IT. The result points out that IT adoption does not have positive effects in all kinds of situations, which extends previous research on Information Technology and Information System.

5.2. 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, partners' dissimilar market knowledge and complementary technical resource reconfigure a focal firm's resource base, provide it with novel ideas, and enable it to engage in resource exploration activities that enhance innovation (Fang, 2011; Zhou and Li, 2012). Hence, managers need to pay attention to finding such

collaborative partners and establishing collaborative relationships with them to generate competitive advantage and better collaborative innovation performance.

Moreover, although we find that heterogeneous partners are beneficial for firms' innovation, and conventional wisdom also states that it is desirable to form an alliance with a partner with a complementary resource set, our results suggest that the equation actually is much more complex. Forming a strategic alliance or establishing a collaborative relationship with a partner with dissimilar or complementary resource 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 and Saeed, 2007) and facilitates the extensive absorbing of knowledge from partners, it also contributes to distrusts between them. Consequently, collaborative partners must always strike a balance between the advantages and disadvantages of IT applicants, in order to maintain long-term friendship and collaboration.

5.3. 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 in only one year, and care should be exercised in generalizing the results. Future studies may scrutinize the study's findings in other settings, possibly incorporating a greater number of different 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 the dissimilarity of corporate cultures, which may cause irreconcilable differences and conflicts between partners and hurt the collaboration. In addition, consistent with Fang (2011), we focus on technology complementarity—that is, nonoverlapping 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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