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The Impact of Virtual Integration on Innovation Speed:

On the View of Organizational Information Processing Theory

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ABSTRACT

In the current environment, rapid innovation has become an essential source of time-based competitive advantage. Cooperation is an effective way to achieve rapid innovation. Inter-firm virtual integration is an emerging cooperation mode through information and communication technology (ICT) support. Its impact on rapid innovation needs to be further confirmed. Based on the organizational information processing theory, this work explores the effects of virtual integration on product innovation speed and how guanxi moderates the relationship of virtual integration on innovation speed. Samples of Chinese manufacturing enterprises provide evidence in this study. The results show that inter-firm electronic coordination and collaboration, as two dimensions of virtual integration, play active roles in quickening the product innovation speed. However, these effects become weaker for firms with close guanxi ties. This study provides new evidence for the relationship of inter-firm cooperation on product innovation speed. The results once again confirmed the critical role of guanxi in China's business activities.

KEYWORDS

Information and Communication Technology (ICT), Information Sharing, Innovation Speed, Knowledge Collaboration, New Products Development, Process Integration, Virtual Integration

1. INTRODUCTION

In the current environment of competition increasing, product life cycle shortening, product obsolescence accelerating, and globalization deepening, time-based competition has gradually become a competitive paradigm to gain advantages (Al Serhan et al., 2015; Hum & Sim, 1996; Stalk, 1988).As one critical strategy to realize the time-based competition (Stalk, 1988) rapid innovation is an important source of competitive advantage for a firm. Cooperation is an effective way to make product innovation rapidly. The so-called cooperation refers to a long-term relationship established by two or more autonomous enterprises to obtain more benefits than acting alone (Xue et al., 2018; Cao et al., 2010; Simatupang et al., 2005). Cooperative enterprises with a common goal strive to

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work together; share information, resources, and risks; and joint decision-making and execution to achieve mutually beneficial results (Cao et al., 2010; Bowersox et al., 2003).

Virtual integration is an external integration type implemented by cooperative enterprises based on information and communication technology (ICT) support. In essence, it is a form of external cooperation. With the development of ICT and the popularity of the Internet, virtual integration activities have become more and more common in practice. Especially due to the Coronavirus Disease 2019 (COVID-19) sweeping the world and many economic activities driven to carry out virtually (Fedushko et al., 2021) in recent years, virtual integration has burst out of unprecedented vitality. Compared with traditional external integration, inter-firm virtual integration supported by ICT enhances the supply chain visibility (Asamoah et al., 2021; Wang et al., 2007). That enables all co-op enterprises to access relevant information and knowledge real-timely (Mandić et al., 2019) and make joint-decision timely (Aydiner et al., 2019), as well as enhances the collaboration (Zhang et al., 2018) and responsiveness of the supply chain (Asamoah et al., 2021).In practice, some enterprises that cooperate with their partners through ICT support successfully shorten the development cycle time of new products. Many previous studies have also confirmed that cooperation with external entities (e.g. suppliers, customers, scientific research institutes) can quicken product innovation. (e. g. Morgan et al., 2019; Taghizadeh et al., 2018; Mcnally et al., 2011; Carbonell et al., 2009; Droge et al.,2004). Cooperation with the outers, such as integration information with customers (Fang, 2008), customers engaging in the conceptualization and launching of new products (Chang et al., 2016), integration knowledge with customers (Taghizadeh et al., 2018), advanced integration with customers (Morgan et al., 2019), process integration with suppliers (Perols et al., 2013), would speed up the new products into the market. However, some studies have found that the effect of cooperation on the speed of product innovation is not always positive (e. g. Chang et al., 2016; Danese et al.,2010; Sun et al., 2010; Fang, 2008). Such as customers participating in executing development (Chang et al., 2016), product integration with suppliers (Perols et al., 2013) slow down the entry of new products into the market. Therefore, it is necessary to provide further evidence on how external cooperation affects the speed of product innovation. Virtual integration is an emerging cooperation mode that has many advantages. Focusing on that co-op mode this study answers how external co-operation plays on innovation speed below.

Based on the theory of organizational information processing, this work provides evidence from China for that issue. With the Chinese government's strategic support, the fast development of the Internet and ICT provide a breeding ground for virtual inter-firm integration. Well-known companies such as Haier, Shangpin Home Collection, Red Collar Apparel, Xiaomi Technology have become the benchmarks for virtual integration in China. However, as an emerging economy, China has a unique economic environment characterized by a defective institutional foundation, regional differentiation in legal enforceability, sustained economic reform, unique traditions. Guanxi is a unique factor that prevails in Chinese business activities (Xue et al., 2018; Standifird et al., 2000), which acts as an alternative governance mechanism in the Chinese economy (Shen et al.,2019; Gu et al., 2008). When a guanxi tie is close, whether the effect of virtual integration on innovation speed would change will answer another question later.

2. THEORETICAL BACKGROUND

2.1 Virtual Integration

Defined as a vertical quasi-integration (e.g. Kim et al., 2018; Wang et al., 2006), virtual integration is a form of non-property external integration between enterprises and external partners based on ICT. Through ICT support, virtually integrated enterprises in the supply chain can coordinate vertically across organizational boundaries (Mola et al., 2017). From the perspective of transaction cost theory, virtual integration is regarded as a coordination mechanism and is believed to the one that can reduce transaction costs and risks (e.g. Kim et al., 2018; Zhou et al., 2018; Wang et al., 2006) and strengthen flexibility (Kim et al., 2018; Wang et al., 2006). Some studies indicate that virtual integration helps quicken feedback and error correction. Virtually integrated companies can access information on the production process, product quality, inventory, and supply capacities through ICT support (Wang et al., 2006). Due to the advantage of seamless information channels and visibility, virtually integrated enterprises can plan and adjust more quickly. Those enable virtually integrated firms to deal with accidents better.

Depending on the extent to which partners coordinate and control through ICT support, virtual integration was divided into different dimensions that are inherently consistent (e.g. Kim et al., 2018; Wang et al.,2006). Based on previous studies, we viewed virtual integration as a two-dimensionalities construct. One is the inter-firm electronic coordination capturing coordination and control of virtual integration. The other is the inter-firm electronic collaboration, the degree to which the collaborative channel activities are carried out through ICT support. Just like Kim et al. (2018) did.

2.2 Innovation Speed

Innovation speed refers to how long it takes to develop a new product from the stage of idea creation to product commercialization (e. g. Chen et al., 2010; Heirman et al., 2007). Related terms such as innovation speed, product development speed, time-to-market, and cycle time are used in previous studies. Innovation speed includes two concepts in literature: absolute velocity and relative velocity. However, most studies suggest that the specific time required to develop a new product is not enough to mean the time-based advantage. Only enterprises innovating quicker than their competitors can gain that edge (Carbonell et al., 2010). Therefore, the relative speed is often used in studies.

Many works focusing on the driving factors of innovation speed have found that cooperation is an effective way to quicken product development (e. g. McNally et al., 2011; Droge et al., 2004). This opinion has been widely confirmed. Studies indicate that cooperation such as integrating information (Fang, 2008) and knowledge (Taghizadeh et al., 2018) with customers, customers engaging in conceptualization and the launch (Chang et al., 2016), and integration with customers deeply (Morgan et al. 2019) are conducive to the speed performance of product innovation.

2.3 Guanxi

As a ubiquitous factor in Chinese business activities (Standifird et al., 2000), guanxi is an interpersonal relationship that binds a series of mutual obligations, expectations, and favours (Xue et al., 2018; Amblera et al., 1999). It originates from the Confucianism Doctrine with "Five Ethics" as the core, regulating Chinese society's interpersonal relationships and social roles (Fei, 1992). Unlike pure personal relationships or friendship, guanxi means favour, obligation, and reciprocity (Chen et al., 2011). It is a derivative of reciprocity norms. Following the norm, guanxi implies that when one does a favour for others, the others are obliged to provide help to repay the favour when he needs it (Hwang, 1987; Lee et al., 2005; Shen et al. 2019). If the other refuses to return with specific help, their guanxi will be damaged (Hwang, 1987). In an environment with a defective institutional foundation, guanxi often transfers from individuals to organizations and becomes an alternative to the institution (Gu et al., 2008).

The importance of guanxi beneficial for business activities has been recognized by scholars (Lee et al., 2017; Barnes et al., 2011). Entrepreneurs and managers build networks through guanxi ties to promote the exchanges between companies. It was found that an inter-firm network connected by guanxi provides many functions beyond socialization, such as resource sharing, inter-organizational learning, knowledge transfer, and other cooperative activities (Yang et al., 2011). Other studies admitted that guanxi strengthens the information and resources to exchange and transfer among firms (Wong, 2010; Shou et al., 2014). Enterprises taking advantage of their guanxi can obtain non-public information (Gu et al., 2008) and core resources (Sheng et al., 2011) that others cannot access.

2.3 Organizational Information Processing Theory

The organizational information processing theory regards organizations as open social systems dealing with work-related uncertainty (Thompson, 2017; Tushman et al., 1978). The uncertainty here refers to the information gap between the need and the available (Srinivasan et al., 2018; Egelhof, 1991). It limits the ability of an organization to plan and make decisions in advance. If a task is understood better before being performed, enterprises can map out schemes for most activities in advance. Otherwise, more knowledge and information need to be obtained during the task carried out, which will lead to changes in resource allocation, planning, and priorities, all of which require information processing (Galbraith, 1974).

This theory believes whether an enterprise can achieve good performance depends on how the information-processing needs match information-processing abilities (Egelhof, 1991). When uncertainty is higher, the more information the decision-makers have to process, the higher the Information-processing abilities are needed (Tushman et al., 1978; Galbraith, 1974). Organizations can achieve the match by reducing the information-processing need or improving information-processing abilities (Srinivasan et al., 2018; Galbraith, 1974).

Information-processing needs can be lower for an enterprise organized mechanically (Galbraith, 1974). Mechanical enterprises coordinate in the way of division of labour and centralization. When accidents are more frequent in a highly uncertain environment, managers in such enterprises will be overwhelmed soon (Srinivasan et al.,2018). Enterprises can build horizontal relationships to improve information-processing abilities (Srinivasan et al.,2015/2018; Galbraith, 1974). Through horizontal relationships (e.g. cross-organizational cooperation), companies can access valuable information from partners. Thus is beneficial to make decisions efficiently.

3 CONCEPTUAL FRAMEWORK AND HYPOTHESES

3.1 The Main Effect of Virtual Integration on Innovation Speed

New product development is a task characterized by high uncertainty. From the perspective of organizational information processing theory, it is a process of dealing with uncertainty. Developing a new product is to create some new thing. So, there are not routines for a copy (Emmanuelides, 1993). The procedures and the links among developing activities are vague at the early stage (Duimering et al., 2006). They become apparent only as the development process moves forward. From the perspective of organizational information processing theory, there is a significant information gap between the needed and the availability to complete the development task. The process of developing a new product is meeting the information gap between the available and the required, that is, a process of reducing uncertainty.

However, a company is unlikely to have all the necessary information or knowledge (Grant et al., 2004) because of it decentralization (Hayek, [1937] 1948, 50-1). Therefore, an effective way to bridge the gap is integrating the internal information and knowledge with the external ones (Walsh et al., 2016). Virtual integration is a cross-organizational relationship that can effectively reduce uncertainty. Running cross-organizational activities would stimulate the information and knowledge to transfer and drive the processes to integrate. Therefore, in a sense, electronic coordination is also an input process of information and knowledge for a virtually integrated enterprise. Co-op enterprises coordinated well can access the necessary information and knowledge (von Briel et al., 2019; Petersen et al., 2005), such as valuable information about materials, pricing and process capability of new products, market information, as well as creative ideas, opinions, suggestions, development solutions. Therefore, the amount of available information increases (Luzzini, 2015), which will reduce the uncertainty, rework and delay of new product development, and finally, shorten the development time of new products.

Previous studies suggested that the flowing of information (Zhang et al., 2017) and knowledge (Zhu et al., 2019) among co-op enterprises can shorten the new product development cycle. Co-op enterprises can capture learning opportunities from sharing knowledge and information on new product development. In addition, enterprises that share information and knowledge with their partners can better understand what products are needed and each partners' capabilities and limitations (Carbonell et al., 2010) to increase goal consistency and take action faster (Lynn et al., 2003). All kinds of information, proposals, and solutions from partners can make up for the firms' gap of knowledge and technical experience in new product development. Those can effectively reduce rework and delay to quicken the developing pace (Zirger et al.,1994). Therefore, we propose the hypothesis as following:

H1a: The closer electronic coordination between virtually integrated enterprises is, the faster the innovation speed is.

While an electronic collaboration task moves forward, there often following cross-organizational process integration. A complex process chain is built up by a flow of activities connected closely (Tallon, 2011). Inefficiency in any section will affect the whole chain. When virtually integrated enterprises simplify and redesign business processes to run efficiently, the redundant work will be removed (Hammer, 2003). As a result, that will reduce the time delays and make the businesses be performed more efficiently. Previous studies also show that process integration among co-op companies helps speed up new products to the market (Perols et al., 2013).

From the perspective of organizational information processing, cross-organizational collaboration is also an information processing process. Because process reengineering and integration eliminate redundant activities, the need of information-processing is decreased correspondingly. That not only saves information-processing time; but also improves the efficiency of information-processing. In other words, it enhances the efficiency of enterprises dealing with uncertainty. Therefore, it is helpful to speed up product development. So, it can be assumed that:

H1b: the deeper electronic collaboration between virtually integrated enterprises is, the faster the innovation speed is**.**

3.2 The Moderating Effect of Guanxi

A large number of studies have shown that guanxi plays a positive role in inter-firm cooperation. Co-op enterprises with close guanxi ties are confident of long-term co-op interests(Shen et al., 2019; Lee et al., 2005). They interpret and manage setbacks and conflicts in a more open and mutually beneficial way (Xue et al., 2018; Qian et al., 2016; Zhuang et al., 2010). These could reduce the opportunism of partners and make them more willing to cooperate. In addition, guanxi is suitable for cultivating goodwill, cooperation norms, and stability among partners (Lee et al., 2017; Qian et al., 2016), as well as positive emotions, thus strengthen partners' tendency to cooperate (Shen et al., 2019; Xue et al., 2018; Barnes et al., 2011).

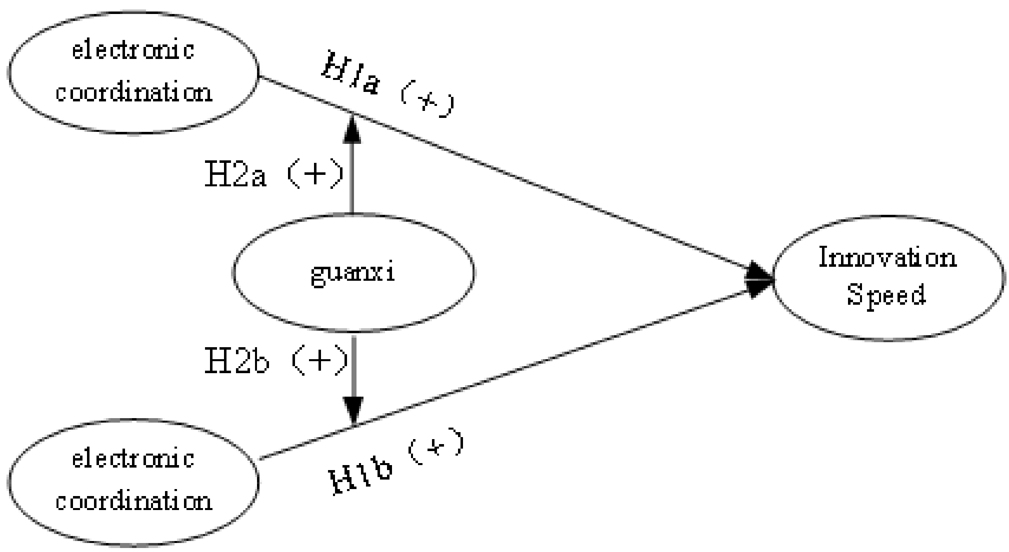
Therefore, when a guanxi tie is intimate, partners are more willing to cooperate deeply due to the bright prospects and the tendency to continue cooperation. Thus, co-op enterprises can coordinate more sincerely and openly, which promotes more core information and knowledge among enterprises to transfer. From the perspective of organizational information processing theory, a close guanxi tie allows virtually integrated companies more cooperative. Therefore, companies can obtain more core information and knowledge from their partners to bridge the information and knowledge gap between the needed and the available. That means reducing the uncertainty they face, the rework and delays in development, and finally, speeding up the new product development. So, we can propose the following hypothesis:

H2a: The closer the guanxi ties are, the stronger the relationship between electronic coordination and innovation speed is.

When co-op enterprises with close guanxi ties cooperate more deeply, the cross-organizational processes will be integrated deeper. When the cross-organizational processes are simplified and integrated as much as possible to improve collaboration efficiency, the amount of information that needs to be processed will be reduced, and the efficiency of information processing will be enhanced. As a result, a virtually integrated enterprise can improve the efficiency of dealing with uncertainties, and finally, quicken new product development. Therefore, we hypothesize:

H2b: The closer the guanxi ties are, the stronger the relationship between electronic collaboration and innovation speed is.

Figure 1. Proposed conceptualization of virtual integration on innovation speed



4. RESEARCH METHOD

4.1 Setting and Data Collection

The analyzed units of this work are the partnerships between manufacturing enterprises and their suppliers through ICT supported. Samples coming from the three major economic regions of China were collected by a questionnaire survey method through two steps. First, we interviewed several managers to clear the research background, frame the research constructs, and develop the survey instrument. Later, a large-scale investigation was performed. Our target respondents were senior managers of interviewed firms. Potential participants were invited by e-mail and personal connection at first to improve the response rate. Subsequently, the questionnaires were distributed electronically to the respondents who accepted the invitation. Finally, 369 valid questionnaires were achieved. The effective response rate is 23.56% (369/1566). Table 1 reports the characteristics of the respondent firms.

Table 1. Characteristics of Respondent Firms (n=369)

	Percentage		Percentage
Firm age		**Employee numbers**	
Less than 3 years	9.2	Less than 100	17.1
3~5 years	20.9	100-500	37.7
6~10 years	41.5	501~1000	32.0
11~15 years	16.3	1001 and above	13.3
16 years and above	12.2		
Education		**Firm ownership**	
High school and below	19.2	Wholly and partially state-owned	22.5
Junior college and undergraduate	77.5	Domestic privately owned	39.6
Postgraduates or above	3.3	Wholly and partially foreign-owned	37.9
Industry			
Electronic information industry	34.4		
Non-electronic information industry	65.6		

If there is a significant difference between the responses and non-response, the estimation may be biased (Armstrong & Overton, 1977). We classified the responses into two independent groups (n =40) to estimate non-response bias. One group consisted of early respondents, and the other consisted of the last respondents (Armstrong et al., 1977). Independent T-tests were run on demographic variables of firm age, firm size, firm ownership, industry, and general educational level of employees. The test results show there was no significant difference between the two groups. We also run the extra T-tests on key variables in this work. Again, the results show that the non-response bias is not a problem (Armstrong et al., 1977).

4.2 Measurement

7-point Likert scales were used in this work. We viewed virtual integration as a two-dimension construct based on previous works: Inter-firm electronic coordination and collaboration. Inter-firm electronic coordination was measured by a four-item scale capturing the coordination and control of inter-firm virtual integration. A three-item scale was used to measure the inter-firm electronic collaboration, mainly focusing on the degree to which collaborative channel activities were carried out through ICT support. Both scales were adapted from Wang et al. (2006) and Kim et al. (2018). A four-item scale was adapted from Taghizadeh et al. (2018) and Wang et al. (2012) to measure the innovation speed. It captures the time-based competition advantage virtually integrated enterprises achieved for launching new products faster than their competitors. As a business tie, guanxi essentially is the personal relationship that band a series of favour, obligations, reciprocity. It involves a series of interactions of doing a favour and repaying the favour. It embeds in the boundary spanners' interpersonal relationships. A four-item scale, which was adapted from Liu et al. (2008), Cheng (2011), and Luo et al. (2015), was used to measure this construct.

In this study, we controlled for the firm age, size, type of ownership, and industry. Valuable resources are an essential source to gain a competitive advantage for enterprises (Barney, 1991). It is acknowledged that smaller and younger businesses are more likely to encounter severe challenges because their resource is not well-off comparatively (Stam & Elfring, 2008). Enterprises running longer are rich in experience and practice. Therefore, we controlled for firm age measured with the number of years since a firm was founded. Then we controlled for the firm size and measured it with each firm's total number of full-time employees (Stam et al.,2008). Findings reveal that the ownership of a company affects its available resources. State-owned enterprises have more resources than others. In addition, the ICT Level is different from one industry to another. Generally, it is better for the electronic information industry than other industries. Therefore, we controlled for the type of ownership and industry. Ownership and industry are categorical variables. So, several dummy variables were introduced as following.

5 ANALYSIS AND RESULTS

5.1 Common Method Bias

Using the same questionnaire to collect data may lead to common method bias (Podsakoff & Organ, 1986). A two-step approach was applied to deal with that issue in this work. First, the Harman one-factor test was used (Podsakoff et al.,1986). A principal component analysis was performed on all items. The results show that no dominant factor appeared because the explained variance of the first factor is less than 50% of the total variance. Subsequently, following the method of Cote & Buckley (1987), we estimated the influence of common method bias on data analysis. We tested four models: null model (M1), trait-only model (M2), method-only model (M3), trait and method model (M4). The comparison results of model fit show that trait factors and a method factor are present (Cote et al., 1987). Table 2 reports the results. Furtherly we calculated the percentage of the average variance explained by the trait factors and the common method factor (after Fisher's z-transformation). The results show that the percentage of variance explained by the trait factors is above 55%, while explained by the common method is less than 20%. Compared with the trait factor, the method factor seemed to play a minor role in the measures in this study (Lee, 2005; Kim et al.,2018).

5.2 Measurement Model and Construct Validity

MPLUS 7 was used to run a confirmatory factor analysis (CFA). To improve the convergent validity and the discriminant validity, we removed items with loading values less than 0.6 or linking to more than one construct. As a result, an item measuring electronic coordination was eliminated. Compared with all the 1-factor, 2-factor and 3-factor models, the hypothetical model has an excellent fit with $\chi 2=$

Table 2. Assessment of common method bias

Model	χ 2	df	χ 2/df	GFI	CFI	TLI	RMSEA
M1:null	3887.567	91	42.721	0.285	n/a	n/a	n/a
M2: Trait only	86.771	71	1.222	0.967	0.996	0.995	0.025
M3: Method only	2081.328	77	27.03	0.478	0.472	0.376	0.266
M4: trait and method	62.847	57	1.103	0.976	0.998	0.998	0.017
Model Comparison			$\Delta\chi$ 2	Δdf	p	Conclusion	
Testing for the presence of trait factors							
M1–M2			3800.796	20	0.000	M1>M2[a]	
M3–M4			2018.481	20	0.000	M3>M4[a]	
Testing for the presence of a method factor							
M1–M3			1806.239	14	0.000	M1>M3[b]	
M2–M4			23.92	14	0.000	M2>M4[b]	

Notes: a. Evidence supporting the existence of trait factors. b. Evidence supporting the existence of a method factor.

87.007 on 71 df, CFI= 0.996, TLI= 0.995, RMSEA= 0.025, and SRMR= 0.021 (Bentler & Chou, 1987), just as Table 3 shows. That shows that the construct has a good discriminant validity (Table 3).

Table 3. Model fits of the measurement model

Model	Factor	χ/df	CFI	TLI	RMSEA	SRMR
Hypothetical model	1,2,3,4	1.225	.996	.995	.025	.021
Alternative 3-factor model 1	1+2,3,4	7.598	.872	.842	.134	.082
Alternative 3-factor model 2	1+3,2,4	9.498	.835	.797	.152	.133
Alternative 3-factor model 3	1+4,2,3	8.625	.852	.818	.144	.103
Alternative 3-factor model 4	1,2+3,4	9.707	.831	.792	.154	.144
Alternative 3-factor model 5	1,2+4,3	7.871	.866	.836	.136	.094
Alternative 3-factor model 6	1,2,3+4	14.057	.746	.688	.188	.165
Alternative 2-factor model	1+2,3+4	19.752	.626	.552	.225	.183
Alternative 2-factor model	1+3,2+4	15.543	.710	.652	.199	.161
Alternative 2-factor model	1+4,2+3	16.495	.691	.630	.205	.177
Alternative 1-factor model	1+2+3+4	27.104	.472	.376	.266	.154

Notes: 1electronic coordination; 2 electronic collaboration; 3 Innovation Speed; 4 guanxi.

Confirmatory factor analysis (CFA) was performed on each construct to estimate reliability and validity. Reliability is applied to measure the internal consistency of measurement indicators. Loadings and composite reliability (CR) are usually used to evaluate it. The results show that all item loadings are above 0.7, and all CR values are above 0.7, which indicate that the internal consistency is satisfactory (Hair et al.,2021). Average of Variance Extracted (AVE) is used to estimate the convergence validity, which indicates whether constructs are reflected by the measurement indicators collectively (Fornell & Larcker, 1981). As shown in Table 4, all AVE values are above 0.5, which shows the convergence validity is good (Fornell et al., 1981).

If the AVE value of a construct is higher than its shared variance, it shows that the discriminative validity is satisfactory(Fornell et al., 1981). As shown in Table4 and Table 5, the AVEs ranged from 0.723 to 0.784, obviously are higher than the shared variances ranged from 0.095 to 0.202, indicating that the discriminant validity is good (Fornell et al., 1981). The fits of the hypothesis model are better than other alternative models, which also shows that the construct has a good discriminant validity (Table 3).

5.3 Structural Model

Firstly, we built a main-effect structural equation model containing three latent variables of inter-firm electronic coordination and collaboration and innovation speed. MPLUS 7 was used to test it. The results show that the estimation terminated normally. The model has an excellent model fits with $\chi 2$=77.085 on 77 df, CFI=0.988, TLI=0.988, RMSEA=0.034, and SRMR=0.012. All residual variances are positive and significant at the 0.001 level. Those present that the model estimation does not violate rules.

Hypothesis H1a and H1b claimed that inter-firm electronic coordination and collaboration would speed up product innovation. Both hypotheses are supported by the results (b = 0.321, p = 0.000; b=0.173, p=0.000 respectively).

Table 4 CFA of Measurement Model

Measure and source	Description	Std loadings
electronic coordination (COOD) (Wang et al., 2006; Kim et al., 2018) AVE=.735 CR=.893	COOR_01 Our suppliers and us coordinate inventory levels with each other electronically.	0.831
	COOR_02 We exchange product prices and market information with our suppliers electronically.	0.833
	COOR_03 Our suppliers and us coordinate production plans with each other electronically.	0.906
electronic collaboration(COLB) (Wang et al., 2006; Kim et al., 2018) AVE=.723 CR=.887	COLB_01 we collaborate on forecasting and planning with our suppliers electronically.	0.839
	COLB_02 It is always possible for suppliers and us to collaborate in demand forecasting and to plan electronically.	0.853
	COLB_03 We collaborate with our suppliers on new product design and development electronically.	0.858
Innovation Speed (IS) (Taghizadeh et al., 2018; Wang et al., 2012) AVE=.784 CR=.936	IS_01 Compared to the key competitors, our company is quick in coming up with novel ideas.	0.895
	IS_02 Compared to the key competitors, our company quickly uses new processes/new technology/new methods.	0.889
	IS_03 Compared to the key competitors, our company is quick in launching new products.	0.873
	IS_04 Compared to the key competitors, our company is quick in buying or mastering original technology.	0.885
Guanxi (GX) (Liu et al., 2008; Cheng, 2011; Luo et al.,2015) AVE=.724 CR=.931	GX_01 Our leaders are familiar with the ones of our partners.	0.867
	GX_02 Our leaders and the ones of our partners may call on each other sometimes.	0.832
	GX_03 Our leaders and the ones of our partners always invite each other to participate in annual dinners or other social activities.	0.802
	GX_04 Our salesmen and the staff of our partners do personal favours for each other.	0.899

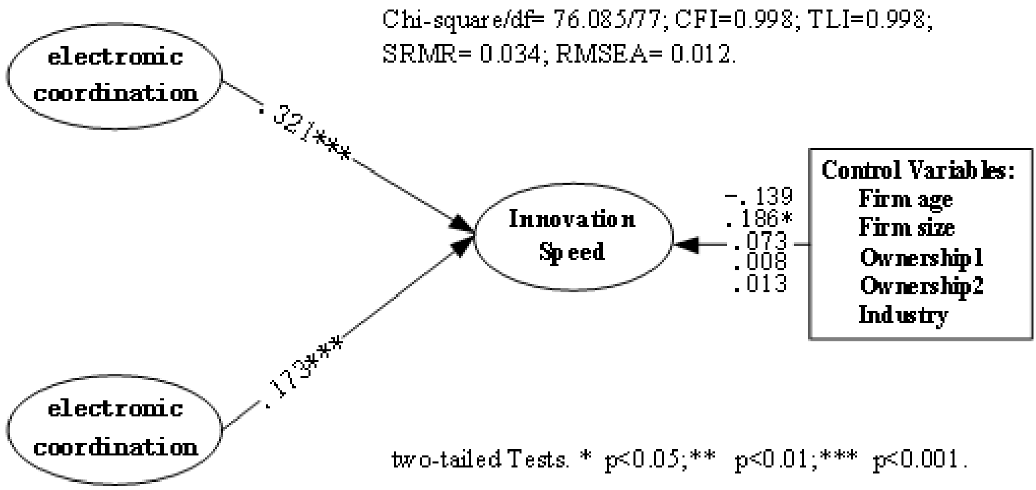
Notes: All scales are seven-point level (1 = “strongly disagree”, and 7 = “strongly agree”). CR = composite reliability. AVE = average variances extracted. N = 369.

Table 5. Estimated correlation matrix for the latent variables

	MEAN	SD	λ Range	electronic coordination	electronic collaboration	Innovation speed	guanxi
electronic coordination	5.089	1.413	0.831-0.906	**.857**	.202	.147	.190
electronic collaboration	5.184	1.515	0.839-0.858	.450	**.850**	.095	.200
Innovation speed	4.864	1.477	0.873-0.895	.383	.309	**.885**	.119
guanxi	5.009	1.314	0.802-0.899	.436	.448	.345	**.851**

Notes: N=369.The lower triangle of the matrix shows the correlations. The upper triangle of the matrix shows the shared variances. The diagonal of the matrix shows the square root of AVEs (in bold).

Figure 2 Effects of virtual integration on the innovation speed



Similar to the findings of previous studies, the test results show that inter-firm virtual integration, as a new co-op mode, is beneficial to the speed of product innovation. From the perspective of organizational information processing theory, inter-firm electronic coordination and cooperation can effectively reduce uncertainties and speed up new product development.

Later, the latent moderated structure equation (LMS) approach was used to examine the moderating effects of guanxi in this study. We built two latent moderated structure models in this phase. Model 1 was used to test the effect of guanxi moderating the relationship of electronic coordination on innovation speed. Model 2 was used to test how guanxi moderates the relationship of electronic collaboration on innovation speed. Two models estimation terminated normally. Table 6 and Table 7 report the results. Fits of a latent moderated structural model are not available in Mplus 7. Following the method of Maslowsky et al. (2015), we reported the approximate goodness of fits.

Table 6 reports the effects of guanxi moderating the relationship of electronic coordination on innovation speed, and table 7 of guanxi moderating the relationship of electronic collaboration on innovation speed. Hypothesis H2a and H2b claimed that the relationship of inter-firm electronic coordination and collaboration on innovation speed would be strengthened for firms with close guanxi ties, which are supported inversely by the results (respectively is β=-.363, p= 0.000; β= -.380, p= 0.000).

To advance further interpretations, we plotted these moderating effects for two levels of guanxi by following the procedures Aiken & West (1991) and Dawson & Richter (2006) recommend. The low level is minus one standard deviation from the mean, and the high level is plus one standard deviation from the mean.

Under the conditions of distant guanxi ties, the slopes of inter-firm electronic coordination and collaboration on innovation speed cross, respectively, further confirming guanxi's moderating effect. Conversely, the slopes of electronic coordination and collaboration on innovation speed become negative for firms with close guanxi ties. At this time, the positive effects of electronic coordination and collaboration on innovation speed are significantly weakened, as shown in Figure 3 and Figure 4.

Table 6. Moderating effect tests for model 1

	β	p-Value
innovation speed on age	-.686	.248
innovation speed on size	1.026	.112
innovation speed on ownership1	.210	.236
innovation speed on ownership2	.020	.910
innovation speed on industry	.074	.605
innovation speed on electronic coordination	.024	.648
innovation speed on guanxi	.092	.074
innovation speed on guanxi *electronic coordination	-.363	.000
Model fit indices:	n/a	
Chi-square/df	106.081/91[a]	
CFI	0.995[a]	
TLI	0.994[a]	
RMSEA	0.021[a]	

Note: [a] Those fit indices are not yet available in Mplus 7 for latent moderated structural equations. The given values are from the comparison model (Maslowsky et al.,2015).

Table 7. Moderating effect tests for model 2

	β	p-Value
innovation speed on age	-.652	.259
innovation speed on size	1.009	.109
innovation speed on ownership1	.294	.099
innovation speed on ownership2	.096	.595
innovation speed on industry	.183	.198
innovation speed on electronic collaboration	-.041	.415
innovation speed on guanxi	.069	.232
innovation speed on guanxi *electronic collaboration	-.380	.000
Model fit indices:	n/a	
Chi-square/df	96.614/91[a]	
CFI	0.998[a]	
TLI	0.998[a]	
RMSEA	0.013[a]	
Note: [a] These fit indices are not yet available in Mplus 7 for latent moderated structural equations. The given values are from the comparison model (Maslowsky et al.,2015).		

Figure 3 guanxi moderating the relationship of electronic coordination on innovation speed (the moderating effect tested with standardized latent variables.)

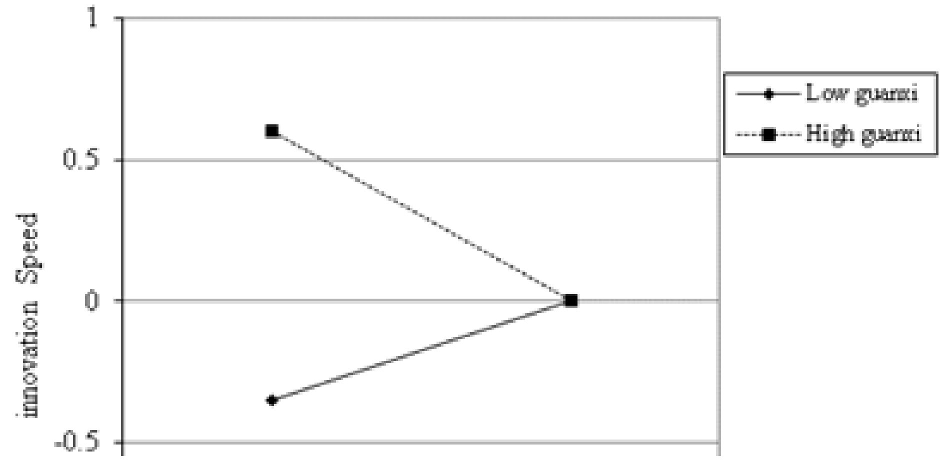
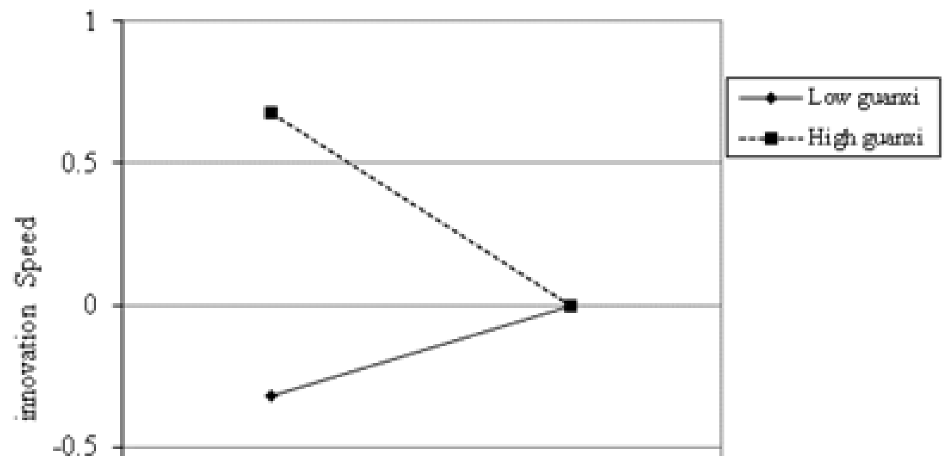


Figure 4 guanxi moderating the relationship of electronic collaboration on innovation speed (the moderating effect tested with standardized latent variables.)



6 DISCUSSION AND MANAGERIAL IMPLICATIONS

Inter-firm virtual integration supported by ICT has been increasingly adopted as a coordination mechanism among supply chain members (Kim et al.,2018). Although inter-firm virtual integration has significant managerial relevance, the evidence about how it speeds up product innovation is limited. We discussed the relationship between inter-firm virtual integration and innovation speed moderated by guanxi, drawing from organizational information processing theory. The results demonstrate that cooperation is an effective way to achieve rapid innovation again, and Guanxi still plays a vital role in Chinese business activities. Virtual integration as an effective alternative governance mechanism is still applicable to collaborative innovation. Enterprises that integrate with their suppliers deeper through ICT support can efficiently reduce uncertainties, ultimately improving product innovation speed. However, the innovation speed has significantly slowed down for firms with close guanxi ties. The findings offers some implications for the theoretical development and managerial practice of cooperation innovation.

(1) The important role of information and knowledge sharing on innovation speed: From the perspective of organizational information processing theory, we believe inter-firm coordination stirs up sharing information and knowledge among virtually integrated enterprises. That makes up for the information and knowledge gap between the needed and the available. That means the uncertainties will be reduced. So, the rework and delays in development can be decreased and finally speed product development. This opinion is supported by the test results(hypothesis H1a, b = 0.321,p = 0.000). Information is a basic element for an enterprise to maintain the daily run. Reliably accurate information provides support for decision-making (Mitchell et al., 2016). Cross-organizational information and knowledge sharing can allow co-op enterprises to access more market information, broaden corporates' knowledge pools, and help them identify customers needs. Information sharing enables firms to quickly understand the market, competitors, and their partners, thereby reducing the ambiguity in new product development and speeding up the pace of a new product into the market. This study provides another explanation for the relationship between inter-firm cooperation and product innovation speed. It also explains the effectiveness of collaborative innovation from another perspective.

(2) Pay attention to the role of process integration: Previous studies have found that process integration can speed up a new product to the market (Perols et al., 2013). To obtain greater cooperation benefits, virtually integrated companies may strive to streamline and integrate the cross-organizational processes. Such reengineering enables a cooperative business to run more smoothly, efficiently, and effectively. We regard the inter-organizational collaboration process as a process of information processing from the perspective of organizational information processing theory. The elimination of redundant activities means that less information is needed to be processed, which improves the efficiency of information processing. In other words, the efficiency of dealing with uncertainty issues is improved. Therefore, the rework and delay can be reduced, and finally quicken the new product development. Based on the support of the test results for this proposal (hypothesis H1b, b=0.173,p=0.000), this study further confirmed the previous findings with a different theory.

(3) Facing up to the role of guanxi: Guanxi is a unique concept to understand the behaviour of Chinese companies. Different from the western interpersonal relationship, it bands a serious of favour, obligation, and reciprocity. Guanxi is still a critical governance mechanism that affects corporate behaviour in China's economy.

The view that guanxi is beneficial to China's business activities has been recognized generally. Studies have indicated that close guanxi ties can enhance trust, reduce opportunistic tendency, make cooperation deeper, communication more open, and help trigger deeper commitments among co-op enterprises (Fryxell et al., 2002; He et al., 2014). Corporate networks connected by guanxi ties can provide many functions beyond socialization, such as resource sharing, inter-organizational learning, knowledge transfer (Yang et al., 2011). So, we assume that the relationship of virtual integration on innovation speed is stronger for virtually integrated enterprises with intimate guanxi ties. But the test results do not support it(hypothesis **H2a,** β=-.363,p= 0.000; **H2b,** β= -.380,p= 0.000).

These findings remind us to pay attention to the issues caused by close guanxi ties. Close guanxi ties induce co-op enterprises to share more core information and knowledge. Nevertheless, when an enterprise obtains too much information, the efficiency of information processing such as understanding, interpretation, and dissemination would become low down (Jaworski et al., 2002). Because too much information may cause noise and make companies get lost (Zirger et al., 1994). In addition, the over-close guanxi ties may lead to over embeddedness with partners, which would result in a lock-in effect, and block other information and knowledge entry (Gu et al., 2008; Gargiulo et al., 1999). Those limits the openness that companies access different ways of doing things (Nahapiet et al., 1998). Moreover, over-embeddedness also affects the flexibility of virtual integration enterprises, which is not conducive to dealing with uncertain problems.

Undoubtedly, there are still some issues needed to be discussed in the future. This study focused on the supply-side partnership to explore the effects of inter-firm virtual integration on performance. However, it is valuable to investigate whether the findings are equally applicable to the demand-side block. Further, while our results support the main effects of virtual integration on innovation speed, it is worth discussing how the mechanism works. Moreover, although optimizing processes can improve business execution efficiency, over-tightly cross-organizational processes can lead to virtually integrated enterprises locked in, making them unable to deal with uncertainties better. Therefore, the relationship between virtual integration and innovation speed may be inverted U-shaped. Besides, we should pay attention to the role of factors causing by environmental fluctuations such as environmental competitiveness, technological volatility, and demand change (Jaworski et al., 1993) in the future. Developing economies' context is complex and diverse, so it is worthwhile to expand the source of samples to achieve more general evidence. In addition, web management is a strategic issue that needs attention (Fedushko et al., 2021), for which virtual integration relies heavily on upon.

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