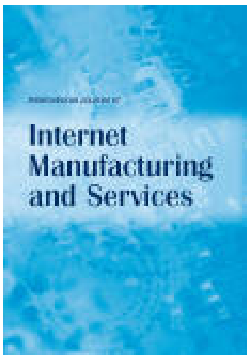

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Information technology governance in supply chain: integration mechanisms under uncertain environment

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Abstract: Virtual integration and information sharing are two important information technology (IT) governance mechanisms to foster efficient and effective collaboration among supply chain partners. However, insufficient empirical studies have been conducted to understand how the two mechanisms interplay in supply chains under an uncertain business environment. Based on data collected from 272 manufacturers in China, we empirically investigated the relationships between virtual integration, supply chain information sharing, and operational performance. Our findings showed that two dimensions of information sharing fully mediated the relationship between virtual integration and operational performance. We also found that supply uncertainty moderated the relationships between virtual integration and information sharing, and between virtual integration and operational performance. Most interestingly, the directions of moderating effects were different depending on the dimensions of information sharing and operational performance. These findings have theoretical and managerial implications for IT governance in supply chain management (SCM).

Keywords: information technology governance; virtual integration; information sharing; uncertainty; supply chain.

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1 Introduction

Under supply chain versus supply chain competition, it is essential that companies build governance structures and mechanisms to manage their relationships with supply chain partners (Formentini and Taticchi, 2016; Wang et al., 2018). Therefore, an appropriate governance structure needs to be carefully designed and configured for supply chain management (SCM) to ensure that economic profits can be gained sustainably. Information technology (IT) plays an important role in constructing such governance mechanisms in the supply chain, because of the IT-enabled transparency in monitoring supply chain activities and the IT-enabled coordination in managing supply chain processes (Dao et al., 2011; Fu et al., 2017; Paolucci et al., 2021).

IT governance is one of the most important factors that enable value creation from IT applications (Weill and Ross, 2004; Van Grembergen and De Haes, 2010). The IT governance literature suggested a group of structures, processes, and mechanisms that determine IT investment decision-making (Xue et al., 2008; Sirisomboonsuk et al., 2018). IT governance has long been explored at the intra-organisational level (Magnusson et al., 2020), however, buyer-supplier relationships in supply chains create a field for studying inter-organisational IT governance, which establishes an efficient and effective decision-making framework in inter-organisational IT systems (Riemer et al., 2020). Virtual integration is an inter-organisational IT governance mechanism that enables value generation through IT usage in SCM (Wang and Wei, 2007). Virtual integration reflects the extent to which companies utilise the internet or information systems to connect with their major supply chain partners in business transactions (Jean et al., 2020). The boom of Internet-enabled e-business technology has facilitated inter-organisational collaboration and inter-organisational decision-making across the boundary of companies. Internet-enabled e-business technologies have had a significant influence on supply chain integration due to their open standard, interoperability, and efficiency characteristics (Motiwalla et al., 2005). For example, e-procurement can be leveraged to accurately aggregate purchasing demand corporate-wide, which leads to significant buyer power (Gunasekaran and Ngai, 2008; Chang and Wong, 2010). It has also been found that the most significant benefit of e-procurement adoption is integrated information sharing (Toktas-Palut et al., 2014). Another area of using the Internet in the supply chain is collaborative planning, forecasting, and replenishment (CPFR). The internet-enabled CPFR greatly facilitates sharing information, such as point of sales data, forecasts, order, shipping, and production plans, among supply chain partners, to support joint planning, forecasting and replenishing activities (Lee and Whang, 2004). These virtual integration applications can be very helpful in resolving supply chain issues such as high transaction costs, poor information availability, and slow adaptability to new changes in the supply chain (Johnson and Whang, 2002; Srinivasan and Swink, 2017; Wong et al., 2015).

IT governance literature also suggests that IT governance should include information components as the complementarity of physical IT decisions (Tallon et al., 2013), so that information can be easily and quickly shared across a supply chain. Information sharing refers to the use of demand and supply-related information in supply chain planning and control by the supply chain partners and it relies on the IT-enabled virtual integration and plays a key role in achieving benefits from IT governance (Wang and Wei, 2007; Rasouli et al., 2016). With the increased information sharing, supply chain partners are motivated for collaboration (Dao et al., 2011; Liu et al., 2015a). Furthermore, firms in supply chains face a wide variety of uncertainties that lead to information asymmetry and opportunistic behaviour (Wang et al., 2015; Yang et al., 2021). The breakout of the COVID-19 pandemic brings more challenges to the operations of companies, especially in the upstream supply chain. The opportunistic behaviour of supply chain partners is detrimental to effective SCM (Carter and Rogers, 2008). Governance mechanisms should be constructed to deal with the uncertainties in supply chain collaboration (Wang et al., 2015). Thus, effective IT governance in a supply chain is a critical factor for establishing supply chain collaboration under an uncertain business environment.

In this study, we focused on the virtual integration between manufacturers and their major suppliers in supply chains. In supplier–manufacturer interactions, we explored the impact of virtual integration on two dimensions of information sharing (extent and quality) and operational performance, and whether the role of virtual integration was influenced by supply uncertainty. We attempted to contribute to the literature in the following ways. First, our study contributed to IT governance literature by understanding two specific IT governance mechanisms. The roles of IT-enabled virtual integration and information sharing mechanisms were investigated in a supply chain context. The relationships between virtual integration in the supply chain and operational excellence were empirically tested. Second, we empirically tested the intervening effects of two dimensions of information sharing between virtual integration and operational performance. The understanding of the relationships was also enriched by introducing the moderating effects of supply uncertainty. This study is meaningful for understanding how virtual integration enables companies to share information and achieve effective SCM under uncertain business environments. Last, our findings amplified the application of TCE and information processing theory (IPT) in virtual integration research. We suggest that TCE and IPT should be combined to understand the role of virtual integration under uncertain business environments.

The remainder of this paper is organised as follows. First, the relevant literature is reviewed and a research model is described in Section 2. Hypotheses are developed in Section 3, followed by the research design, measurements, and data analyses in Section 4. Discussion and managerial implications are shown in Section 5. Conclusions are presented in Section 6.

2 Theoretical background

2.1 Virtual integration in supply chains

IT is suggested as one of the critical elements in facilitating organisational capabilities (Melville, 2010). When the resources of IT and the supply chain are integrated, organisational capabilities can be improved (Dao et al., 2011). In addition, according to the tenet of TCE, IT reduces transaction costs by facilitating supply chain cooperation, increasing supply chain visibility, and minimising information asymmetry (Shi and Yu, 2013). Therefore, it is impossible to manage supply chains effectively without IT infrastructure (Gunasekaran and Ngai, 2004). A firm should not only equip itself with an enterprise resource planning (ERP) system to integrate internal processes but also deploy inter-organisational information systems to establish external linkages with business partners to expedite bi-directional information flows (Williamson et al., 2004; Blankley, 2008) because information can facilitate and drive resources allocation within and among firms. Virtual integration is an inter-firm governance structure that enables a firm to electronically integrate with its suppliers through partnership rather than ownership, with a view to cooperating closely (Wang et al., 2006), thus resources can be obtained from suppliers flexibly, efficiently and steadily (Magretta, 1998; Jean et al., 2010), thus reducing transaction cost and uncertainty. To have efficient and effective information sharing among supply chain partners, IT-enabled virtual integration is a more suitable governance structure to manage supply chain relationships because it provides supply chain partners with flexibility in coordination (Byun and Lee, 2015). Moreover, the use of Internet technologies in virtual integration makes it commonly acceptable among supply chain partners because of the avoidance of asset specificity (Grover and Malhotra, 2003). Some studies have shown that firms transacting with customers and suppliers using internet technologies realise superior performance (Barua et al., 2004; Liu et al. 2015b). Studies have also shown that Internet-enabled inter-firm virtual integration positively affects brand equity (Seggie et al., 2006), supply chain flexibility (Swafford et al., 2008), firm performance (Rai et al., 2006), and enhances a firm's capabilities in technology, product, and market development (Liu et al., 2010). However, researchers have suggested the possibility of the indirect role of virtual integration in a supply chain (Power and Singh, 2007). Therefore, the role of IT-enabled virtual integration in the supply chain may be contingent on certain factors. As indicated by Vijayasarathy (2010), process innovation, partnership quality, and competitive uncertainty moderated the relationship between technology use and supply chain performance. It is possible that the influence of IT-enabled virtual integration may be moderated by other factors. For example, Jean et al. (2021) claimed that IT-enabled virtual integration provides firms with more adaptability when the business environment is more dynamic. Through a review of the related literature, it was found that the roles of virtual integration in a supply chain need further investigation.

2.2 Supply chain information sharing

Information sharing has been a well-established research area in SCM since Lee et al. (2000) analytically quantified the benefits of demand information sharing. Subsequently, a vast number of analytical and simulation studies have endeavoured to investigate the impacts of other forms of information sharing under more complex supply chain structures (Huang and Gangopadhyay, 2004; Lau et al., 2004; Byrne and Heavey, 2006) and design mechanisms to allocate the benefits of information sharing among supply chain members (Wu and Cheng, 2008; Ding et al., 2011). Another strand of research on information sharing is empirical studies started by Li and Lin (2006) and Zhou and Benton (2007). Among these empirical studies, some have examined what factors lead to information sharing (Arnold et al., 2010; Du et al., 2012; Li et al., 2014). Others have explored how information sharing influences firm behaviour (Eckerd and Hill, 2012; Wang et al., 2014; Liu et al., 2015a; Huo et al., 2021). Still others have investigated the impact of information sharing on financial performance (Schloetzer, 2012), operational performance (Fawcett et al., 2007; Ye and Wang, 2013; Li et al., 2014; Yang et al., 2021), and supply chain performance (Sezen, 2008; Hsu et al., 2009; Huo et al., 2014).

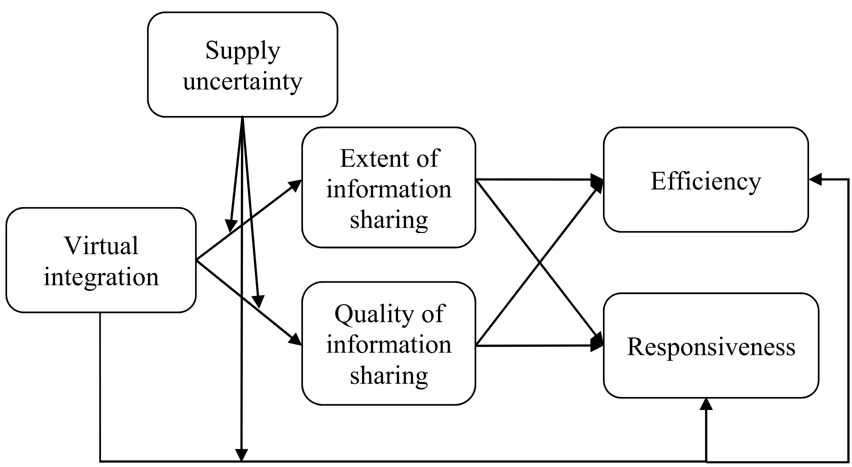
Supply chain information sharing makes operational, tactical, and strategic information available to business partners in supply chains (Mentzer et al., 2001). Fast and wide information sharing enables companies to respond to changes and facilitate collaborated decision-making in achieving operational and strategic goals (Rai et al., 2006). The shared information also reduces the opportunistic behaviours of supply chain partners such as using harmful materials and providing low-quality products (Zhu and Sarkis, 2004). Information sharing facilitates trust and collaboration among supply chain partners (Liu et al., 2015b; Fu et al., 2017; Wang et al., 2016, 2018). In addition, information sharing is one of key enablers of supply chain resilience which is the ability to cope with supply chain disruption (Jain et al., 2017; Scholten et al., 2020). In this study, supply chain information sharing was divided into two dimensions: the extent of information sharing and the quality of information sharing. The extent of information sharing denotes the category of information shared among supply chain partners (Marquez et al. 2004), whereas the quality of information sharing identifies the characteristics of information shared that satisfy the information needs of other parties (Hsu et al., 2009). It has been suggested that more granular dimensions of information sharing provide a value-added understanding of the significance of information sharing (Wang et al., 2014). In the existing information sharing literature, there is a dearth of studies investigating the impact of virtual integration on information sharing that has been divided into the dimensions of extent and quality.

2.3 Supply uncertainty

Uncertainty is a central concept of organisation and strategy theories (Sutcliffe and Zaheer, 1998), such as TCE (Grover and Malhotra, 2003), contingency theory, and information process theory (IPT) (Chen, 2013). A supply chain faces more uncertainties than an individual firm does because different supply chain members have different business objectives and more stakeholders are involved in transactions (Premkumar et al., 2005). Uncertainty, caused by different kinds of supply chain disruptions, such as late delivery, machine breakdown, order variation, natural disaster, and pandemic, brings potential harm to the operations of firms when it disseminates up and down a manufacturing supply chain (Prater et al., 2001). To some extent, uncertainty is a barrier to supply chains to be sustainable (Wu et al., 2016) and increases risk and vulnerability in supply chains (Wang and Jie, 2020). Thus, uncertainty is a critical contingent factor in effective SCM (Prater, 2005; Peidro et al., 2009). Uncertainty originates from both the demand side and the supply side of a firm (Lee, 2002). Demand uncertainty can be dealt with safety stock and lead times effectively. Most manufacturers, however, are more concerned about supply uncertainty (Ray and Jenamani, 2016). For example, the supply uncertainty imposed by COVID-19 pandemic is the most notable challenge currently faced by global supply chains (Baloch et al., 2022).

Supply uncertainty, one type of uncertainties in a supply chain, comes from the fact that suppliers are unable to satisfy an organisation's requirements, thereby adversely influencing the value-added processes (Geary et al., 2006). It is defined as the variability and unpredictability of suppliers' product quality and delivery performance (Li and Lin, 2006; Peidro et al., 2009). The price, timing, quality, or availability of products are the sources of supply uncertainty (Simangunsong et al., 2012; Snyder et al., 2016). Supply uncertainty is a key detrimental factor that negatively influences effective supply chain operations (Shukla et al., 2011; Lin et al., 2021).

Figure 1 Conceptual model



In the supply chain context, TCE provides the rationale for the moderating effect of supply uncertainty. Based on TCE, it is claimed that increased uncertainty causes higher transaction costs (Grover and Malhotra, 2003). In an uncertain business environment, companies have to spend more time and take more efforts to monitor the actions of their supply chain partners (Peidro et al., 2009). They also need to collect additional information from supply chain partners to achieve effective supply chain operations (Cheng et al., 2008). The difficulties in information collection and interpretation would greatly decrease the benefits of virtual integration. According to TCE, the roles of virtual integration in information sharing and performance improvement are greatly influenced by supply uncertainty. Our research model is depicted in Figure 1.

3 Hypotheses development

3.1 Virtual integration, information sharing, and operational performance

The relationship between IT and performance has been examined in previous studies (Bharadwaj et al., 1999; Santhanam and Hartono, 2003; Swafford et al., 2008; Mishra et al., 2013). For example, Bharadwaj (2000) indicated that firms with high IT capability tend to outperform a control sample of firms on a variety of profit and cost-based performance measures. Berthon et al. (2003) suggested that IT enables firms to reduce the cost of searching for/accessing information. On the one hand, IT facilitates more accurate demand forecasting, which in turn reduces the inventory level and increases production efficiency. On the other hand, IT shortens the order processing time and delivery time, thus enhancing responsiveness. Therefore, IT enables companies to efficiently and effectively coordinate internal and external resources to achieve goals, deliver values across supply chain, and obtain competitive advantage in facing an uncertain business environment (Chen et al., 2008; Linton et al., 2007).

IT-enabled virtual integration can make companies efficiently manage their business processes and help reduce transaction costs in supply chain collaboration (Wang et al., 2006; Hyvönen et al., 2008). One underlying reason is that seamless information sharing concerning products and services facilitates the role of IT-enabled virtual integration (Ye and Wang, 2013). Relying on inter-organisational IT, more categories of information can be easily shared and used across supply chain partners on a real-time basis (Bharadwaj, 2000; Tippins and Sohi, 2003; Ghouri et al., 2021), thus enabling manufacturers to adjust their production and service schedule, purchasing plan or inventory level quickly. Therefore, information sharing reduces production and inventory costs and enhances a company's flexibility and ability to respond to the turbulence in the market, thereby mitigating the bullwhip effect due to high information visibility (Ojha et al., 2019). In addition, when the supply chain information shared is of high quality, information processing costs can be minimised and the effectiveness of information sharing can be enhanced (Rasouli et al., 2016). Accordingly, the greater the extent and the higher the quality of information were shared, the larger benefits from lower inventory level and higher service level may be realised. Therefore, it is expected that:

H1a/1b The extent of information sharing between a manufacturer and its major supplier mediates the relationship between virtual integration and the manufacturer's efficiency/responsiveness.

H2a/2b The quality of information sharing between a manufacturer and its major supplier mediates the relationship between virtual integration and the manufacturer's efficiency/responsiveness.

3.2 Moderating effects of supply uncertainty

The relationship between virtual integration, information sharing, and operational performance is within the scope of IT governance value research (Melville et al., 2004). A wide variety of such research has claimed that IT can create governance value through a series of organisational capabilities under certain business contexts (Aral and Weill, 2007; Kohli and Grover, 2008; Wu et al., 2015). One of the contextual factors is a competitive environment where different uncertainties including supply uncertainty come from. Generally speaking, uncertainty has long been considered as 'a moderator of the relationship between organisational structures and behaviours and their performance at different levels' [Chen, (2013), p.247]. For example, demand and supply uncertainty has been identified to positively moderate the effect of business systems leveraging on supply chain performance (Chang et al., 2019). Environmental uncertainty negatively moderates the relationship between organisational flexibility and innovation capability (Saeed et al., 2022). Therefore, the relationship between virtual integration as an organisational governance structure, information sharing as an organisational behaviour, and operational performance would be definitely moderated by uncertainty. In addition, TCE views the existence of uncertainty as a reason for bounded rationality (Foss and Weber, 2016). Based on TCE, the increased supply uncertainty as one type of uncertainty leads to the perceived opportunistic behaviour of supply chain partners (Wang et al., 2015; Huo et al., 2018). Due to the high risk in opportunistic behaviour, the impact of virtual integration on information sharing may be reduced. Meanwhile, the increased transaction and coordination costs from high supply uncertainty may also reduce the benefits of virtual integration. Thus, supply uncertainty may negatively interact with virtual integration, affecting information sharing and the operational performance achieved. Therefore, these arguments lead to the following hypotheses:

H3a/3b Supply uncertainty negatively moderates the relationship between the manufacturer's use of virtual integration and the extent/quality of information sharing between a manufacturer and its major supplier.

H4a/4b Supply uncertainty negatively moderates the relationship between the manufacturer's use of virtual integration and the manufacturer's efficiency/responsiveness.

4 Methodology

4.1 Development of the measurements

The survey instrument of six constructs in this study was developed from the existing literature (see Appendix A). The wording of some items were adapted according to the Chinese context to avoid misunderstanding. A back translation method was also used to reduce the subjective understanding of the measures in the literature (Brislin, 1980). The questionnaire was pre-tested by a group of managers from Chinese manufacturers to increase the face validity. Supply uncertainty was measured by four items adapted from Chen and Paulraj (2004) and Li and Lin (2006). These items were mainly concerned with the material quality, delivery performance, and order fulfilment of the suppliers. Respondents were asked to indicate their agreement with these descriptions of the business environment. Virtual integration was measured by four items, which were adapted from Lai et al. (2008) and Wang and Wei (2007). Respondents were required to show their agreement with the statements concerning manufacturers' connections with major suppliers through internet-enabled IT. The measurement for the extent of information sharing was based on Li and Lin (2006), asking the respondents to indicate the extent of production planning information, production capacity information, inventory information, and demand forecast information shared between the manufacturer and the suppliers. The measures of quality of information sharing were adapted from Zhou and Benton (2007). Five items about timeliness, accuracy, completeness, adequacy, and reliability were used to capture the respondents' agreement on the statement concerning the usefulness and relevance of the information to manufacturers' decision-making. Both the efficiency performance and responsiveness performance were measured by items adapted from Fisher (1997) and Flynn et al. (2010). These two performance measures are core operational performance which is a precursor of overall organisational performance (Combs et al., 2005). The performance measure was evaluated through a comparison with their major competitors. All items were measured on a 1 to 7 Likert scale.

4.2 Data collection

Data collection was conducted in the Pearl River Delta (PRD), which is the primary part of the Greater Bay Area and one of the most developed regions of China. China is a viable context because China is one of the power engine of global manufacturing industries. The China Telecom Yellow Pages of PRD were used as the sampling frame. Within this frame, manufacturing companies were randomly selected. Then, the companies were contacted to solicit their participation in the survey and identify the most appropriate managers as the survey respondents. If they agreed to join the survey, the managers were contacted and the questionnaire was sent by email. In total, 963 companies participated in the survey. If the survey questionnaire was not returned on time, a follow-up email was sent out to remind the respondents. In this way, 367 finished questionnaires were sent back. Among these questionnaires, some were deleted due to the large number of missing values. Finally, 272 complete questionnaires were used in this study. Descriptive statistics for the respondents are given in Table 1. ANOVA tests showed that the industry, age, and size had no significant differences in measures. Tests for non-response bias were conducted by comparing the early respondents and late respondents regarding the number of employees and sales (Armstrong and Overton, 1977). No statistically significant differences were identified at $p < 0.05$.

As single respondents were used in this survey, the common method variance (CMV) might result in a systematic error (Podsakoff and Organ, 1986). The Harmon's single-factor test was used to check the potential bias of the data. If a single factor accounts for the majority of covariance in the variables, the CMV will be a concern (Cai et al., 2010). Exploratory factor analysis was conducted and the unrotated factor analysis results showed that none of the single factors accounted for most of the variance. Thus, the potential bias from CMV was not a problem in this survey.

4.3 Results

The partial least squares (PLS) approach to structural equation modelling (SEM) was used for measurement validation and hypotheses testing as PLS-SEM places minimal restrictions on measurement scales, sample size, and residual distribution. This study used SmartPLS software (version 3.3.9) to assess the measurement and structural models (Ringle et al., 2022).

Table 1 Profile of respondents

Characteristics		*Samples*	*Percentage*
Founded time	<= 5 years	37	13.60%
	6–10 years	65	23.90%
	11–20 years	84	30.88%
	>20 years	32	11.76%
	Others	54	19.85%
Ownership	State-owned	59	21.69%
	Collective-owned	4	1.47%
	Private-owned	61	22.43%
	Joint-ventured	54	19.85%
	Foreign-owned	80	29.41%
	Others	14	5.15%
Industry	Transportation equipment	16	5.88%
	Rubber and plastics	10	3.68%
	Textiles and apparels	6	2.21%
	Toys and printing	8	2.94%
	Furniture, wood, and concrete products	14	5.15%
	Chemicals	27	9.93%
	Electronics and appliances	81	29.78%
	Food, Beverage, and Tobacco	13	4.78%
	Fabricated metal product and machinery	42	15.44%
	Others	55	20.22%
Fixed asset	Less than RMB10 million	34	12.5%
	RMB 10 million to less than RMB 50 million	54	19.9%
	RMB 50 million to less than RMB 100 million	34	12.50%
	RMB 100 million or more	130	47.8%
	Missing	20	7.4%
Sales	Less than RMB10 million	14	5.1%
	RMB 10 million to less than RMB 50 million	39	14.3%
	RMB 50 million to less than RMB 100 million	25	9.2%
	RMB 100 million or more	175	64.3%
	Missing	19	7%
Employee	< 500	110	40.4%
	500–999	36	13.2%
	1000–4999	68	25%
	>= 5000	50	18.4%
	Missing	8	2.9%

Table 2 Measurement model

	Standardised loading	*AVE*	*Composite reliability*	*Cronbach alpha*
Efficiency		0.575	0.844	0.754
	0.842			
	0.845			
	0.741			
Extent of information sharing		0.741	0.935	0.913
	0.862			
	0.884			
	0.875			
	0.880			
	0.819			
Quality of information sharing		0.807	0.954	0.940
	0.920			
	0.927			
	0.913			
	0.857			
	0.872			
Virtual integration		0.790	0.938	0.911
	0.836			
	0.920			
	0.903			
	0.894			
Responsiveness		0.590	0.877	0.823
	0.610			
	0.839			
	0.873			
	0.776			
	0.714			
Supply uncertainty		0.50	0.80	0.66
	0.757			
	0.810			
	0.626			
	0.607			

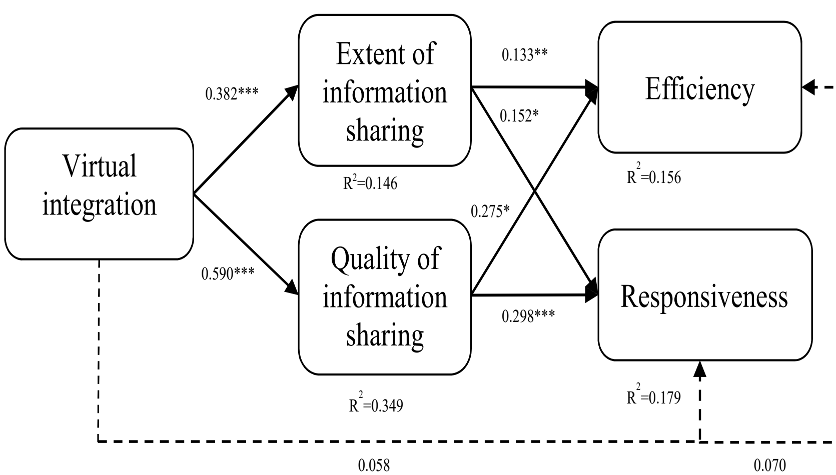
First, to assess content validity, the existing literature, in-depth managerial interviews, and a pilot test were used to secure the validity of the measures used in this study. Then, the consistency of the measures was checked by the values of composite reliability and Cronbach's alpha. Most constructs had values larger than 0.7 with the exception of supply uncertainty, indicating a high internal consistency (Table 2). Supply uncertainty had a Cronbach's alpha value close to 0.7 and a high composite reliability value (0.80). Thus, the measures of supply uncertainty were used for further analysis. Finally, convergent validity and discriminant validity were assessed. The average variance extracted (AVE) method was used to assess convergent validity. All the AVE values were larger than the recommended cut-off value of 0.5 (Table 2), suggesting an acceptable convergent validity for all constructs (Henseler et al., 2009). The discriminant validity was assessed by comparing the square roots of AVE for each construct with the correlations of any other constructs (Henseler et al., 2009). Table 3 shows that the square roots of the AVE value of any construct were larger than the correlation coefficients between the construct and any other constructs, indicating acceptable discriminant validity.

Table 3 Mean, standard deviation, and correlation

	Mean	*SD*	*1*	*2*	*3*	*4*	*5*	*6*
Efficiency (1)	4.71	1.090	0.758					
Extent of information sharing (2)	4.22	1.325	0.29**	0.861				
Quality of information sharing (3)	4.51	1.210	0.30**	0.43**	0.898			
Virtual integration (4)	4.61	1.286	0.25**	0.38**	0.59**	0.889		
Responsiveness (5)	5.39	0.838	0.46**	0.30**	0.39**	0.29**	0.768	
Supply uncertainty (6)	3.52	0.975	–0.25**	–0.29**	–0.34**	–0.14*	–0.37**	0.71

Note: ** $p < 0.01$, * $p < 0.05$.

Figure 2 SEM results



As a variance-based SEM technique, PLS-SEM does not provide goodness-of-fit indices. The strength of PLS-SEM is to make predictions of the relationships among constructs. Thus, the assessment of the path loadings and R2 values was conducted (Figure 2). Path loadings showed the relationships between independent and dependent variables, whereas R2 values showed the predictive power of the independent variables. To check the prediction capability of the model, we used Stone–Geisser's Q2, as suggested by Henseler et al. (2009). The Stone–Geisser's Q2 for endogenous constructs was 0.143 for information sharing extent, 0.333 for information sharing quality, 0.088 for efficiency, and 0.133 for responsiveness, respectively, indicating acceptable predictive relevance.

4.3.1 Mediation test

To test the mediation effects, we examined the indirect effects of virtual integration on operational performance via information sharing and determined the significant levels by using the bootstrapping method with a 95% confidence level and employing 1,000 samples (Preacher and Hayes, 2008). The method for the mediation test is more rigorous than the traditionally employed Baron and Kenny (1986) approach of the Sobel test (Rungtusanatham et al., 2014). The results showed that the bias-corrected 95% confidence intervals for the indirect effects of virtual integration on operational performance via information sharing were all positive (Table 4). Thus, the full mediating effects were confirmed, which supports H1 and H2.

Table 4 Standardised direct and indirect effects

	Extent of information sharing	*Quality of information sharing*	*Efficiency*	*Responsiveness*
Virtual integration	0.382***	0.591***	0.207***	0.256***
Extent of information sharing			0.217**	0.161**
Quality of information sharing			0.210**	0.382**

Notes: Direct effects are in bold, indirect effects are in italics; significant levels of indirect effects were obtained from bootstrapping using the bias corrected method; ***p < 0.001; **p < 0.01; *p < 0.05.

4.3.2 Moderation test

To test the moderation effect of supply uncertainty, the orthogonalising approach is used to estimate latent variables interactions (Little et al., 2006; Henseler and Chin, 2010). This approach uses residuals that are calculated by regressing all the possible pairwise product terms of indicators of virtual integration and supply uncertainty on all indicators of virtual integration and supply uncertainty. These residuals were used as indicators of the interaction term in the SEM model and were orthogonal to all indicators of virtual integration and supply uncertainty. The significance of the path from the interaction term to the dependent variable is seen as the existence of moderation effects. The coefficient of the path from the interaction term to extent of information sharing was negative and significant ($b = –0.188$, $p < 0.01$). The coefficient of the path from the interaction term to the quality of information sharing was positive and significant ($b = 0.151$, $p < 0.05$). The coefficient of the path from the interaction term to efficiency was negative and significant ($b = –0.194$, $p < 0.01$). The coefficient of the path from the interaction term to responsiveness was positive and significant (b = 0.175, $p < 0.05$). These results provide support for H3a, H3b, H4a, and H4b.

5 Discussion and implications

This study had two important findings. First, the relationship between virtual integration and operational performance was mediated by two dimensions of information sharing. Second, the effects of virtual integration on information sharing and operational performance were moderated by supply uncertainty.

The first research finding indicates that virtual integration did not directly improve operational performance. Similarly, Wang et al. (2006) also found that virtual integration can only indirectly enhance manufacturers' cost performance, an efficiency metric. The extent and quality of information sharing fully mediated the impact of virtual integration on operational performance. When more categories of information with higher quality are shared among supply chain partners, decision-making processes and outcomes would be improved because better information is the basis for better decisions. Timely, accurate, complete, adequate and reliable information shared would definitely reduce the waste of time, manpower and resources so that efficiency and responsiveness are improved. As indicated by Cai and Dang (2015), the quality of shared information positively affects a firm's operational performance. The results indicate that information sharing plays a critical role in realising the benefit of IT-enabled virtual integration in the supply chain. The information sharing secures the performance evaluation metric across the supply chain, which leads to high-quality and low-cost products (Cheng et al., 2008), thus increasing repeat patronage by demanding customers. This finding documents further evidence to support the indirect link between IT governance mechanisms and firm performance suggested by the IT productivity paradox (Wu et al., 2015). IT just provides a better platform and infrastructure to facilitate information exchange. This is a warning to business managers who are extremely enthusiastic about IT investment decisions. Establishing a strong IT infrastructure is not a sufficient condition for improving performance because physical resources alone are imitable. A similar caveat was also found in Chakravarty et al. (2013). Therefore, by combining information sharing and virtual integration, companies could make supply chain operations more efficient and effective.

Unlike the mediation effects, the second research finding demonstrated inconsistent moderation effects. Supply uncertainty played a negative moderating role in the influence of virtual integration on the extent of information sharing and efficiency. This finding was consistent with the TCE arguments. Supply uncertainty overturned the positive relationship between virtual integration and the extent of information sharing. Information being shared becomes outdated quickly when suppliers experience high uncertainty, thus making it difficult for suppliers to increase the extent of information sharing (Fu et al., 2017). Therefore, supply uncertainty increases the information asymmetry between manufacturers and suppliers. In addition, transaction risks are greatly increased due to opportunism (Kocabasoglu et al., 2007; Huo et al., 2018). Sharing more information indicates exposure to more risks due to opportunism. Similarly, supply uncertainty reverses the positive relationship between virtual integration and efficiency. When suppliers experience high uncertainty, they need to update the information shared with the manufacturer more frequently to achieve on-time delivery. Frequent information updating, on the one hand, increases the burden on the manufacturer's information system; on the other hand, it may disturb the manufacturer's decision-making processes, thus leading to inefficient operations. Therefore, high information processing and coordination costs arise when supply uncertainty is high.

However, supply uncertainty played a positive moderating role in the influence of virtual integration on the quality of information sharing and responsiveness. This finding was not consistent with the TCE arguments. IPT suggests another possible role of uncertainty. According to IPT, uncertainty limits the ability of an organisation to make decisions (Galbraith, 1984; Elbanna et al., 2017; Sniazhko, 2019). Thus, coping with uncertainty is the principal task for organisations in highly uncertain competitive environments (Gattiker and Goodhue, 2004; Gattiker, 2007). One mechanism to tackle uncertainty is to increase the information processing capabilities by implementing integrated information systems to build virtual integration across supply chain partners to achieve better information flows (Premkumar et al., 2005; Gattiker, 2007), because IT in a single firm may not be sufficient to deal with supply uncertainty as business competition is increasingly between different supply chains (Shi and Yu, 2013). Integrated information systems can provide stronger information processing capabilities, better control and more timely feedback for manufacturers to facilitate interfirm joint decision-making and collaboration with suppliers on a real-time basis, thereby giving manufacturers and their suppliers greater and more flexible capability to achieve stable relationships between them (Gosain et al., 2005; Wang et al., 2013). The increased information flows through IT and stable relationships achieved would reduce uncertainty and enable better decisions that lead to better performance (Bendoly and Swink, 2007). It is obvious that increasing information processing capabilities such as applying IT in the supply chain is an effective way to cope with supply uncertainty (Premkumar et al., 2005; Gattiker, 2007; Simangunsong et al., 2012). Therefore, it is imperative to apply IT across a supply chain to facilitate information sharing, that is, to jointly increase the information processing capabilities in a supply chain. Although information sharing can be achieved without relying on IT (Huo et al., 2021), it is unquestionable that IT creates a better platform for information sharing, especially when a firm faces high supply uncertainty in supply chain competition. It is natural that supply chain partners tend to strengthen their IT infrastructure expecting enhanced information sharing and performance when facing higher supply uncertainty because they are in the same boat.

If higher supply uncertainty makes more extent of information sharing less effective, then the effect of information sharing needs to be compensated by a higher quality of shared information because of the reduced information sharing extent. The reason is that a supplier failing to increase the information sharing extent may attempt to enhance the quality of a smaller range of key information shared as a countermeasure. In this sense, supply uncertainty further reinforced the positive relationship between virtual integration and information sharing quality (Jean et al., 2020). In addition, it is extremely necessary to have a higher level of virtual integration to enhance the quality of information sharing, that is, to ensure that the information shared can be timely, accurate, complete, adequate and reliable. In a similar way, supply uncertainty turns the weak positive relationship between virtual integration and responsiveness into an even more positive one. If virtual integration is low, a manufacturer can be responsive only when it faces low supply uncertainty. Once supply uncertainty becomes high, the low virtual integration is not enough for a manufacturer to respond to a customer's changes in demand on a timely basis. High virtual integration is needed for enhanced responsiveness. Therefore, more investment in virtual integration with supply chain partners makes information sharing more useful for manufacturers to be more responsive by improving its quality, especially when supply uncertainty is high. The benefit is apparent. For example, the manufacturer can receive timely supply information from suppliers to quickly reschedule its production to cope with the sudden order changes of customers. In short, supply uncertainty motivates higher quality of information sharing and more responsive manufacturing processes.

Three major theoretical implications of the research are detailed as follows. First, our study documented the importance of two dimensions of information sharing in detecting the impact of virtual integration. This is consistent with the stream of research in resolving the IT productivity paradox (Stratopoulos and Dehning, 2000). With a more granular concept, this study enriched the extant literature regarding the IT-performance link and further confirmed the role of information sharing in influencing supply chain operational performance (Kang et al., 2018). Second, our study contributed to virtual integration research by investigating the relationships between supply uncertainty, virtual integration, supply chain information sharing, and operational performance. Our findings complemented the existing literature by testing the moderating roles of supply uncertainty. The findings suggest that the role of virtual integration in the supply chain is contingent on supply uncertainty, which is the contingency factor of the IT-business value relationship identified in this study. Last, our study demonstrated the application of TCE and IPT in virtual integration research. Our finding indicated that TCE and IPT should be combined to understand the moderating role of supply uncertainty.

Our study also has several managerial implications. First, our results suggest that the extent and quality of information sharing are both important in functioning virtual integration in the supply chain. Understanding the compensation effect of quality of information sharing on the extent of information sharing allows practitioners to fine-tune IT investment in virtual integration. Second, our model shows that virtual integration is more conducive to improving quality rather than the extent of information shared and the quality of information sharing has a larger impact on efficiency and responsiveness than extent of information sharing has. Therefore, practitioners should attach more importance to quality rather than quantity in terms of information sharing. Third, the virtual integration should be carefully implemented under different levels of supply uncertainty. When the occurrence of supply chain disruptions has been exponentially increasing (Kulchania and Thomas, 2017), supply uncertainty becomes a new normal in a post-pandemic era. Well-designed virtual integration, therefore, can be considered an effective strategy to alleviate and adapt to supply uncertainty (Wang et al., 2006; Byun and Lee, 2015).

6 Conclusions, limitations and future research

The realisation of operational targets is the prerequisite for effective SCM (Porter and Kramer, 2002; Carter and Rogers, 2008). By following the 'IT-business value' framework proposed by Melville et al. (2004), this study empirically examined the relationships among supply uncertainty, virtual integration, supply chain information sharing, and operational performance. While the literature on IT governance mechanisms in supply chains revealed the impact of virtual integration on performance, the contingency aspects have been little explored. We identified two aspects of information sharing that mediated the relationship between virtual integration and operational performance. We also found that the role of virtual integration was moderated by supply uncertainty. Furthermore, the results indicated that the directions of the moderating effects were different when considering different outcomes. Our study has added knowledge of IT governance in the supply chain by considering TCE and IPT simultaneously.

However, this study had several limitations, which call for future research. First, this study used a cross-sectional design to investigate the relationship between virtual integration, information sharing, and operational performance. Nevertheless, these relationships are established in a process of multiple transactions, or in stages. A longitudinal study would thus be useful to further substantiate the research model in this study. Second, a further study can be conducted to explore the ways in which IT-enabled virtual integration and information sharing contribute to enhancing social and environmental performance, as discussed by Melville (2010), Srivastava (2007), and Thöni and Tjoa (2017). Third, other forms of uncertainties besides supply uncertainty can be considered moderators in future studies. When firms establish virtual integration with both their suppliers and customers, it is worth exploring the moderating effects of demand uncertainty and supply uncertainty simultaneously. Finally, only Chinese manufacturers in PRD were studied. The generalisation of conclusions to other countries as well as to service industries could be the subject of future research.

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Appendix

Survey instrument

Extent of information sharing
The major suppliers share the production planning information with us
The major suppliers share the production capacity information with us
The major suppliers share the inventory information with us
We share the production planning information with the major suppliers
We share the order forecasting information with major suppliers
Quality of information sharing
The information exchange between the major suppliers and us is timely
The information exchange between the major suppliers and us is accurate
The information exchange between the major suppliers and us is complete
The information exchange between the major suppliers and us is adequate
The information exchange between the major suppliers and us is reliable
Virtual integration
We and our major suppliers exchange product and market information through inter-organisational information systems
We process orders from our major suppliers through the internet applications
We coordinate with the major suppliers through inter-organisational information systems
We and our major suppliers conduct business transactions through inter-organisational information systems
Efficiency
Our inventory level is low
Our inventory cost is low
Our production cost is low

Note: *Reverse coded.

Survey instrument (continued)

Responsiveness
We can quickly respond to the change of market demand
We have a good on-time delivery record to our customers
We have a good accurate delivery record to our customers
Our stock out rate is low
We can provide high service level for our customers
Supply uncertainty
Our major suppliers can consistently satisfy our needs*
Our major suppliers provide us materials with consistency*
The material supply of our major suppliers is unpredictable
The delivery of our major supplier is always not on-time

Note: *Reverse coded.