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The impact of knowledge complementarities on supply chain performance through knowledge exchange

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ABSTRACT

The extent of knowledge complementarities (KC) is an important theoretical and practical issue in inter-firm relationships. However, extant research on KC is not clear about what constitutes KC and how the benefits of KC are realized. Further, few empirical studies have examined the impact of KC on inter-firm performance. The purpose of this study is to identify the dimensions of KC and to empirically examine the relationships among KC, inter-firm knowledge exchange, and supply chain performance. We have used data collected from 70 matched pairs of buyer and supplier in a procurement dyad to test a proposed model. In both sample sets, the results show that the relationship between knowledge exchange and supply chain performance was positive and significant. We also found positive relationships between knowledge exchange and inter-organizational relationship characteristics such as inter-organizational trust and inter-organizational information systems integration. While the path from KC to knowledge exchange was positive and significant in the buyer sample, it was not significant in the supplier sample.

1. Introduction

Few firms can internally control all the resources required to function effectively. Among other resources, knowledge is considered as the most strategically significant resource possessed by a firm. If a firm is deficient in a particular knowledge domain, and possession of that knowledge is deemed essential to gain competitive advantages, then the firm will take purposive actions such as forming strategic alliances to access that needed knowledge (Reid, Bussiere, & Greenaway, 2001).

Alliances are more likely to form for firms with mutual needs to exchange knowledge. In reality, however, many alliances are not successful (Hitt, Dacin, Levitas, Arregle, & Borza, 2000). Harrison, Hitt, Hoskisson, and Ireland (2001, p. 685) assert that strategic alliances may fail because of '*poor partner selection*' or '*poor management of the alliance*'. An important criterion for *partner selection* is the presence of complementary knowledge that cannot be developed internally in either a timely or a cost-effective manner (Park & Ungson, 2001). The concept of knowledge complementarities (KC) is rooted in the economic theory of complementarities (Milgrom & Roberts, 1990; Milgrom & Roberts, 1995). Complementary knowledge held by a partner leads the participants to cooperate for economic purposes. However, extant research on KC is not clear about what constitutes partner knowledge complementarities. Thus, the first objective of this study is to scrutinize the understudied construct of KC by identifying its dimensions in the context of supply chain management.

KC refers to the relevant knowledge each partner brings to the relationship and works as a "raw material" that is used to create synergistic value. In this definition, synergistic value derived from a partner's complementary knowledge is an essential component of complementarities. In order to achieve the synergistic value, complementary knowledge needs to be exchanged and combined between supply chain partners. The general idea of inter-organizational relationships is to arrange cooperative relationships so as to obtain mutual benefits by '*exchange, sharing or co-development of products, technologies or services*' (Gulati, 1998, p. 293). In accordance with these ideas, several researchers emphasize effective knowledge actions for the implementation of synergistic value (Cohen & Olsen, 2015). However, empirical investigations on the relationship between KC and knowledge exchange have rarely been conducted (Harrison et al., 2001). Thus, the second objective of this study is to investigate the relationship between KC and knowledge exchange.

Furthermore, few studies have been devoted to a theoretical work in the development of causal relationships between KC and inter-organizational relationship management (Stieglitz & Heine, 2007, p. 2). Potential benefits that can arise from the ideal

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combination of complementary knowledge may not be realized due to *poor management of the alliance* as well. Knowledge management (KM) literature suggests that knowledge exchange may be affected by the characteristics of inter-organizational relationships. Hence, we attempt to advance our understanding on knowledge exchange by simultaneously examining the inter-organizational relationship characteristics. Specifically, we incorporate inter-organizational information systems (IOS) integration as a way for knowledge exchange, relationship continuity, and trust as antecedents for knowledge exchange.

In this paper, we formulate a research model in the context of buyer–supplier relationships in a supply chain and test hypotheses, using data collected from 70 matched-pairs of buyer and supplier in two major automobile manufacturers and a major telecommunication service firm. Buyers and suppliers have specialized knowledge in their own domains and their knowledge should be complementary to achieve competitive advantages. The required coordination between buyers and suppliers provides a good context for the study of KC and knowledge exchange in procurement and supply relationships.

2. Theoretical background

Several authors (e.g., Madhok, 1997; Ramanathan, Seth, & Thomas, 1997) have made attempts to systematically apply the resource-based view (RBV) to strategic alliances. RBV is considered an appropriate lens for examining strategic alliances in that firms usually form alliances to gain access to other firms' valuable resources when these resources cannot be efficiently obtained through other ways (Das & Teng, 2000). The knowledge-based theory of the firm considers organizational knowledge as the most critical resource of a firm because it is usually difficult to imitate and socially complex, resulting in sustainable competitive advantage (Alavi & Leidner, 2001; Kogut & Zander, 1992). Strategic alliances are a useful vehicle for enhancing the focal firm's critical knowledge when the necessary knowledge is lacking (Madhok, 1997). Competitive advantage of alliances also arises from the effective integration of the partners' complementary knowledge.

2.1. Dimensions of knowledge complementarities

Das and Teng (2000) propose a typology of inter-partner resource alignment based on the two dimensions of resource similarity and resource utilization, generating the four types of partner resource alignment: complementary, wasteful, supplementary, and surplus. Among these, the complementary alignment has been studied extensively in the strategic alliance literature (Lei, 1993). Das and Teng further assert that complementary alignment exists under two conditions: the resources have to be *dissimilar* and also be *utilizable*. Extant literature explains the requisite attributes of dissimilarity in various ways such as non-redundant unique resources (e.g., Hill & Hellriegel, 1994), different resources (e.g., Helfat, 1997), and compatible resources (Parkhe, 1991). Based on the extant literature, we propose that dimensions of KC encompass both uniqueness and utilizability of a partner's knowledge. First, uniqueness of knowledge refers to the extent to which knowledge contributed by a partner for achieving the alliance goals is valuable and different from that of the focal firm (Dyer & Singh, 1998). Recent studies on complementarities (Harrison, Hitt, Hoskisson, & Ireland, 1991; Harrison et al., 2001; Hill & Hellriegel, 1994; Krishnan, Miller, & Judge, 1997) emphasize the uniqueness of knowledge resources. An exchange of different knowledge has a higher possibility to create valuable synergy than that of similar knowledge (Harrison et al., 1991). Thus, uniqueness of knowledge among the firms in a supply chain is considered an important dimension of KC.

Second, extant research on strategic alliances argues that utilization of the partner's specialized knowledge provides important motivation for forming an alliance. Das and Teng (2000, p. 49) define *utilizability* as "*the degree to which the resources contributed by the partners are utilized for achieving the goals of the alliance*". In order for the partner's knowledge to be of any value, it should be utilizable and have the capacity to enhance the alliance performance. Efficient utilization of knowledge is achieved where the knowledge domain of the firm matches exactly the knowledge requirements of the product domain of the firm.

2.2. Two different types of knowledge in a supply chain

SCM literature (Bowersox, Closs, & Cooper, 2007; Lockamy & McCormack 2004) treats planning and operational knowledge as two distinct categories of a firm's knowledge required for effective functioning in a supply chain. First, planning is related to the forecasting of future events which deals with aggregate data, simulation models, and longer-term periods. In order to balance future supply and demand, firms need to plan future activities in key functional areas such as raw material procurement, production, and shipping and delivery (Huang, Stewart, & Chen, 2010). In this planning process, the focal firm's knowledge needs to be complemented by the partner's knowledge (Wang & Shao, 2012). For example, effective production planning for a supplier requires knowledge about ultimate markets from its buyers. Second, operation is related to the execution of supply chain plans which requires great attention to details of a transaction such as available storage capacity and delivery time. Operational knowledge encompasses all the major functional areas such as procurement, production, and sales and marketing. This classification of knowledge categories is consistent with the SCOR (Supply Chain Operations Reference) model, developed by the nonprofit Supply Chain Council (The Supply Chain Council (SCC), 2005) and widely used by SCM practitioners.

Building on the above discussion, this study specifies KC as a second-order construct that comprises four first-order constructs: (1) uniqueness of planning knowledge, (2) utilizability of planning knowledge, (3) uniqueness of operational knowledge, and (4) utilizability of operational knowledge. Fig. 1 depicts the second-order KC construct.

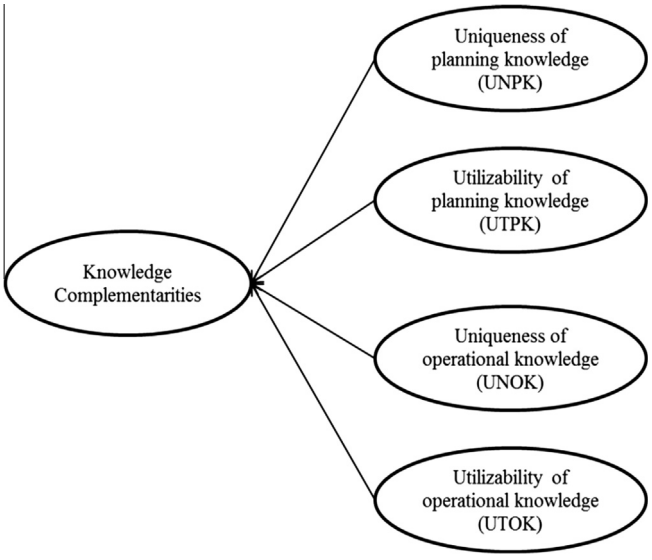


Fig. 1. Second-order KC construct.

2.3. Knowledge exchange and its antecedents

In order for the partners' complementary knowledge to create synergy, knowledge exchange is a prerequisite for effective combination (Nahapiet & Ghoshal, 1998). Inter-organizational knowledge exchange refers to the communication process through which the focal firm is affected by the knowledge of an alliance partner (Argote & Ingram, 2000). For example, supply chain partners exchange knowledge for effective cooperation in various areas such as engineering and new product development. To understand inter-organizational knowledge exchange better, scholars (e.g., Gupta & Govindarajan, 2000; Szulanski, 1996) categorize the antecedents of knowledge exchange into five groups: type of knowledge, characteristics of exchange partners (sender and receiver), the exchange channel, and characteristics of the partner relationship. Considering that KC represents the type of knowledge exchanged, this research includes inter-organizational trust for characteristics of exchange partners, IOS for the exchange channel, and relationship continuity for characteristics of the partner relationship. Regarding the partner characteristics, existing literature provides considerable evidence that trusting relationships lead to greater knowledge exchange (Mayer, Davis, & Schoorman, 1995). Inter-organizational trust refers to the collective trust that every member of a firm puts into another firm (Zaheer, McEvily, & Perrone, 1998). Trust is particularly important in knowledge exchange because knowledge is subject to loss of control in that the focal firm cannot control the subsequent use of transferred knowledge by the receiving firm (Clemons & Hitt, 2004). As for the exchange channel, we confine our research context to IOS for two reasons: (1) IOS has been touted in the literature as a dominant means for knowledge exchange (Paulraj & Chen, 2007), and (2) it is not practically feasible for current SC partners to achieve up-to-the-minute knowledge exchange without IOS. Also, continuity of the relationship, which refers to the duration of business relationship between two firms, has been used as a collective indicator of the quality of inter-organizational relationship (Kim, Park, Ryoo, & Park, 2010). It reflects the power balance, communication effectiveness, level of cooperation, distribution fairness, and the level of commitment between the partners (Anderson & Weitz, 1989). Hence, we include these three variables as the antecedents of knowledge exchange.

3. Research model

3.1. Knowledge complementarities and knowledge exchange

Hamel, Doz, and Prahalad (1989) suggest that mutual gains are possible if partners can complement each other through their individual strengths since each partner in an alliance ought to be able to access the complementary capabilities of its partner. In fact, an important reason for forming an alliance is to gain access to the partner's knowledge that firms otherwise lack (Reid et al., 2001). When the partner's knowledge is complementary to the focal firm's knowledge, there can be more knowledge exchange in expectation that combination of both firms' knowledge will create synergistic knowledge (Yao, Yang, Fisher, Ma, & Fang, 2013). Firms participating in a supply chain collectively develop situation specific knowledge by new combinations of their existing complementary knowledge. Several studies (e.g., Borgatti & Cross, 2003; Gupta & Govindarajan, 2000) also assert that perceived value of partner's knowledge is an important antecedent to inter-firm knowledge exchange. Thus, we propose:

H1. Knowledge complementarities positively influence inter-firm knowledge exchange.

3.2. Inter-organizational trust and knowledge exchange

Regarding inter-organizational trust, Zaheer et al. (1998) assert that informal safeguards such as trust supplement formal controls and are "the most effective and least costly means of safeguarding specialized investments and facilitating complex exchange" (p. 669). Interorganizational trust reduces concerns about releasing internal information to trustworthy partners and encourages SC partners to implement knowledge exchange that would otherwise be considered risky (Putnam, 1993). In high-trust relationships, organizations tend to be more open to the potential for value creation through the exchange and combination of knowledge resources. Empirical research provides further support that trust is an essential antecedent for knowledge exchange (Collins & Smith, 2006; Nahapiet & Ghoshal, 1998). Thus, we posit the following hypothesis.

H2. Inter-organizational trust positively influences inter-firm knowledge exchange.

3.3. IOS integration and knowledge exchange

Knowledge exchange between partners is affected by structural characteristics of an exchange channel (Tsai, 2002). As a channel for knowledge exchange, IOS refers to technical structure which links people, information, and knowledge between organizations. IOS has the potential to lead to better communication between supply chain partners (Nakayama, 2003). Compatible IOS helps reduce the costs of knowledge exchange and leverage the appropriate resources during the knowledge exchange process (Colombo & Mosconi, 1995). As empirical evidence, Malhotra, Gosain, and El Sawy (2007) also suggest that inter-firm electronic interconnections influence collaborative information exchange. Thus, we posit the following hypothesis.

H3. IOS integration positively influences inter-firm knowledge exchange.

3.4. Partner relationship and knowledge exchange

An inter-firm relationship adjusts over time. Accordingly, as the relationship period between partners increases, firms must adapt to one another, which increases the chances of cooperative relationships (Kim et al., 2010). As the relationship period becomes longer, expectations that the relationship will continue in the future become more certain (Anderson & Narus, 1990). This motivates a partner to promote a cooperative partner relationship (Lusch & Brown, 1996), leading to higher confidence and more receptive attitudes toward knowledge exchange. This point implies that a longer relationship period may enhance the level and range of knowledge exchange so as to improve the inter-organizational performance. Thus, the following hypothesis.

H4. Continuity of the relationship positively influences inter-firm knowledge exchange.

3.5. Knowledge exchange and supply chain performance

Supply chain performance is defined as the benefits derived from supply chain cooperation, including efficiency improvement, cost reduction, and enhancement in cycle time. However, mere existence of complementary knowledge is a necessary but *insufficient* condition to improve supply chain performance (Harrison et al., 2001). Partners' complementary knowledge should be

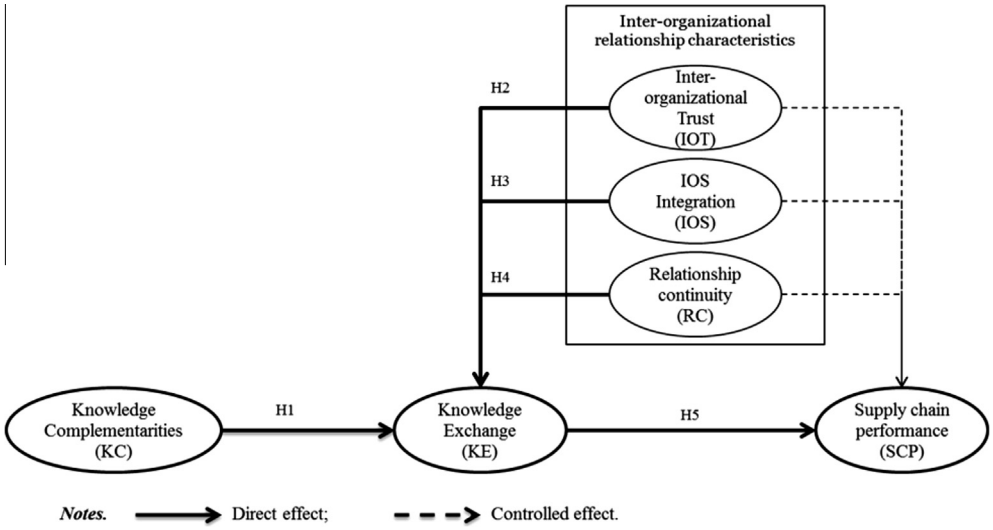


Fig. 2. Research model.

exchanged through the collaborative relationship (Larsson, Bengtsson, Henriksson, & Sparks, 1998). Tanriverdi (2005) assert that KM capabilities may influence the firm performance in two ways: (1) knowledge relatedness contributes to the achievement of sub-additive cost synergies and (2) knowledge complementarities create super-additive value synergies. Especially, synergies arising from KC are not easy to observe (Harrison et al., 2001) and, therefore, competitors may lack the strategic foresight to recognize KC (Tanriverdi, 2005). Firms can adjust inter-firm processes to collectively improve operational performance (Jeffers, 2010; Malhotra et al., 2007; Wang & Wang, 2012). This discussion leads to the following hypothesis.

H5. Inter-firm knowledge exchange positively influences supply chain performance.

The research model is presented in Fig. 2.

4. Methods

4.1. Sample and data collection

The unit of analysis in this study is the inter-organizational relationship — more specifically, matched pairs of buyers and suppliers. Kim et al. (2010) assert that investigating inter-organizational relationship from the perspectives of both partners is important, especially when channel relationships are asymmetric in dependence and power. Thus, the data were collected from two different sources: (1) purchasing managers in two automobile manufacturers and a telecommunication service firm[1] and (2) suppliers who provide their products to these buyers. Supply chain partners were matched by a 'snowballing technique' (Richey, Daugherty, & Roath, 2007, p. 204).

Purchasing departments of buyer firms perform boundary spanning roles between supply chain partners and are responsible for component procurements from their suppliers. Thus, purchasing managers are in a good position to evaluate the relationship characteristics between the two firms from the buyer firm's perspectives. Purchasing managers were asked to respond to the instrument in the context of an ongoing relationship through which a component was being sourced. They were encouraged to get some help, if necessary, from other sources such as engineering and logistics departments. Regarding the selection of supplier firms, purchasing managers were asked to select an important component and a major supplier of that component. Then, the contact information of the supplier was solicited in order to collect data about the supplier's view of the relationship. In this way, we were able to get the responses from the matched-pair of buyer–supplier dyad.

Two follow-up emails were sent five and ten days, respectively, after the initial contact. Completed questionnaires were mailed back to the researchers. A total of 109 responses from buyer firms and 74 responses from their suppliers were received. Of those responses, seventy pairs of responses were complete and usable, leaving a final sample of 70 matched pairs of manufacturer and supplier firms. Table 1 shows the composition of the respondents from each industry. The buyer sample and the supplier sample were treated separately, to determine whether each partner's perspectives on the relationship differ, and, if so, to explain why.

One-way ANOVAs were performed to check whether there are any systematic differences in research variables among industry, number of employees, and sales volume of the sample firms. The results show that there were no statistically significant differences. Nonresponse bias was assessed by comparing mean differences for principal constructs between the early responses (first 25%, 18 firms) and the late responses (last 25%, 18 firms). The results of t-tests showed no significant differences at a 0.05 level.

4.2. Measures

We adapted most of the survey items, except for KC, from existing scales in the literature. Twelve items were developed by the authors to measure KC. Specifically, these KC items measure the buyer's and the supplier's planning/operational knowledge in terms of uniqueness and utilizability. Meanwhile, IOS integration was measured using the three items developed by McKnight, Choudhury, and Kacmar (2002). They include database compatibility, software compatibility, and file exchangeability. Relationship continuity was measured by the duration of business relationship between supply chain partners (Kim et al., 2010). Knowledge

[1] The telecommunication industry includes the telecommunication equipment manufacturers (suppliers) as well as the telecommunication service firm (buyers). The manufactures produce components that can be integrated into a whole system based on a certain agreed-upon protocol. Meanwhile, telecommunication service providers deliver services through an integrated system with these components. Effective service delivery requires mutual adjustments and cooperation between buyers and suppliers, because modular technologies must be integrated.

Table 1
Composition of the sample.

Industry		Respondents		
		Buyers	Suppliers	Percentage (%)
Automobile	Firm A	33	33	47.1
	Firm B	26	26	37.1
Telecommunication	Firm C	11	11	15.7
Total		70	70	100.0

exchange was measured based on Schulz (2001), encompassing the dimensions of strategy, technology, and sales and marketing. Based on Hult, Ketchen, and Arrfelt (2007), supply chain performance was measured by six items, covering efficiency improvement, cost reduction, and enhancement in cycle time.

All the research variables, except for relationship continuity, were measured with multi-item instruments on a seven-point Likert scale anchored from "strongly disagree" to "strongly agree". The instruments of this study were pre-tested with two buyers and two suppliers to determine the content validity. As a result of the pretest, some questions were modified to enhance clarity. The complete questionnaire and their sources appear in Appendix A.

5. Data analysis and results

This study uses partial least square (PLS) for data analyses. A structural equation modeling technique can be used to test multiple relationships simultaneously and, specifically, PLS is widely accepted as a method for relatively small sample and for testing theory in early stages (Howell & Higgins, 1990; Ordanini & Rubera, 2008). Further, PLS can handle formative constructs (Chin, Marcolin, & Newsted, 2003).

5.1. Measurement model

This study utilizes a second order factor model (Chin, 1998). Of the four types of second order models (Jarvis, Mackenzie, Podsakoff, Mick, & Bearden, 2003), this study applies Type II which combines reflective first order and formative second order measures as shown in Fig. 1 and Appendix B. Specifically, the KC construct, a higher order factor, uses formative scales, whereas the measures of its four sub-dimensions use reflective scales. Other constructs (i.e., inter-organizational trust, IOS integration, relationship continuity, knowledge exchange, and supply chain performance) use reflective scales.

Following Yi and Davis (2003), we tested first order confirmatory factor analysis (CFA) for the items measuring KC. The frequently cited standard of 0.60 was applied as the cut off value for the factor loadings (Barclay, Higgins, & Thompson, 1995). Two items in each sample were dropped from further analyses due to their low loadings; utilizability of the operational knowledge in logistics (SCP1) and utilizability of the planning knowledge in logistics (SCP2). These two items were dropped from both samples to maintain consistency in measurement items and discarded from further considerations.

The CFA without two items was re-conducted. The results of CFA in Appendix B show that all factor loadings are greater than 0.6 except for two items; utilizability of the operational knowledge in logistics and utilizability of the planning knowledge in logistics. These two items were dropped from both samples to maintain consistency in measurement items and discarded from further consideration. In both samples, composite reliabilities of sub-dimensions are all greater than 0.8 and AVEs are all greater than 0.6 (Gefen, Straub, & Boudreau, 2000). Thus, the first order sub-dimensions of KC can be aggregated to form a higher order construct of KC.

Considering that KC is modeled as a formative construct, this study examines the weights of KC items (Petter, Straub, & Rai, 2007), which appears in Table 2. This study also estimates the multicollinearity problem between the first order factors using the PLS scores. The variance inflation factors (VIF) are lower than the common threshold value of 10, which indicates no multicollinearity problems (Stevens, 1992).

Table 2
Factor structure matrix of loadings and cross-loadings.

	KC	IOT	IOS	RC	KE	SCP
(a) Buyer sample						
UNPK	0.83 (0.36)	0.49	0.44	0.06	0.46	0.41
UTPK	0.77 (0.25)	0.37	0.28	−0.12	0.32	0.12
UNOK	0.84 (0.34)	0.36	0.39	0.10	0.43	0.32
UTOK	0.79 (0.29)	0.37	0.30	−0.02	0.37	0.14
IOT1	0.38	0.76	0.45	0.13	0.55	0.45
IOT2	0.34	0.74	0.35	0.18	0.45	0.35
IOT3	0.50	0.79	0.47	−0.04	0.55	0.44
IOT4	0.46	0.82	0.47	−0.01	0.54	0.50
IOT5	0.44	0.81	0.58	0.19	0.52	0.45
IOT6	0.40	0.83	0.53	0.13	0.51	0.37
IOT7	0.42	0.87	0.54	0.04	0.53	0.46
IOT8	0.33	0.79	0.44	−0.04	0.50	0.42
IOT9	0.21	0.71	0.45	0.15	0.52	0.39
IOT10	0.35	0.79	0.40	−0.06	0.57	0.40
IOT11	0.51	0.87	0.39	−0.02	0.52	0.43
IOS1	0.38	0.63	0.90	0.11	0.65	0.46
IOS2	0.27	0.28	0.76	0.25	0.32	0.33
IOS3	0.45	0.45	0.82	0.05	0.56	0.20
RC	0.02	0.07	0.16	1.00	0.03	0.24
KE1	0.44	0.64	0.56	−0.02	0.83	0.23
KE2	0.39	0.49	0.53	0.10	0.86	0.24
KE3	0.40	0.49	0.48	−0.01	0.79	0.19
SCP2	0.19	0.51	0.34	0.18	0.14	0.80
SCP3	0.32	0.47	0.32	0.23	0.25	0.84
SCP4	0.21	0.39	0.32	0.10	0.26	0.79
SCP5	0.33	0.39	0.40	0.27	0.24	0.88
(b) Supplier sample						
UNPK	0.84 (0.22)	0.49	0.31	−0.24	0.31	0.48
UTPK	0.89 (0.31)	0.52	0.32	−0.24	0.45	0.36
UNOK	0.86 (0.26)	0.44	0.34	−0.18	0.37	0.43
UTOK	0.92 (0.35)	0.53	0.33	−0.16	0.49	0.34
IOT1	0.45	0.77	0.38	−0.09	0.55	0.47
IOT2	0.48	0.84	0.43	−0.01	0.68	0.51
IOT3	0.47	0.78	0.44	−0.17	0.52	0.50
IOT4	0.49	0.85	0.49	−0.03	0.57	0.54
IOT5	0.57	0.85	0.40	−0.19	0.57	0.62
IOT6	0.38	0.85	0.47	−0.04	0.65	0.49
IOT7	0.43	0.86	0.50	−0.09	0.65	0.60
IOT8	0.49	0.85	0.43	−0.15	0.60	0.48
IOT9	0.52	0.88	0.55	−0.17	0.67	0.59
IOT10	0.47	0.87	0.45	−0.05	0.58	0.47
IOT11	0.39	0.71	0.33	0.01	0.47	0.44
IOS1	0.38	0.48	0.89	−0.01	0.73	0.23
IOS2	0.23	0.47	0.85	−0.13	0.60	0.27
IOS3	0.34	0.44	0.85	−0.14	0.61	0.22
RC	−0.23	−0.11	−0.10	1.00	−0.04	−0.09
KE1	0.39	0.64	0.77	−0.06	0.91	0.29
KE2	0.23	0.61	0.57	0.06	0.79	0.13
KE3	0.57	0.64	0.64	−0.08	0.92	0.39
SCP2	0.42	0.57	0.25	−0.14	0.28	0.92
SCP3	0.43	0.60	0.26	−0.05	0.36	0.92
SCP4	0.38	0.53	0.17	−0.14	0.21	0.86
SCP5	0.38	0.56	0.32	−0.03	0.32	0.91

Note: Figures in parenthesis for KC are values of weights.

The measurement model was also tested by examining reliability, convergent validity, and discriminant validity (Gray & Meister, 2004). Table 2 shows the loadings and cross-loadings for all the research variables, including the second order dimensions of KC. As a result of the CFA, a few items in each sample were dropped from further analyses due to their low loadings. Reliability is assessed using internal consistency computed by the composite reliability scores. Results reported in Table 3 show acceptable values, exceeding the recommended threshold value of 0.7 (Hair, Anderson, Tatham, & Black, 1998).

Convergent validity is evaluated by examining individual item reliability and average variance extracted (AVE). The results in Table 2 show that all items loaded on their own constructs and loadings are higher than 0.6 criterion (Hulland, 1999). The results in Table 3 demonstrate that all constructs meet the 0.5 AVE standard (Fornell & Larcker, 1981).

Finally, this study checks the discriminant validity in two ways: (1) whether the items measuring each construct load more highly on their intended construct than on other constructs, and (2) whether the square root of each construct's AVE is larger than its correlations between that construct and other construct (Chin, 1998). The results in Table 2 and 4 suggest adequate discriminant validity in both samples.

5.2. Structural model

Table 5 and Fig. 3 summarize the results of the PLS analyses. In the buyer sample, the results show that both the path from KC to knowledge exchange (H1) ($t = 1.92$; $p < 0.05$) and the path from knowledge exchange to supply chain performance (H5) ($t = 2.31$; $p < 0.05$) were positive and significant. We also found a positive effect of inter-organizational trust on knowledge exchange (H2) ($t = 4.56$; $p < 0.001$), and a positive influence of IOS integration on knowledge exchange (H3) ($t = 3.77$; $p < 0.001$). However, contrary to our expectations, relationship continuity was not significantly associated with knowledge exchange (H4) ($t = 0.90$; *not significant*).

In the supplier sample, the results are quite similar to those of the buyer sample, except for KC. The path from KC to knowledge exchange (H1) was not significant ($t = 1.03$; $p = 0.154$), while the path from knowledge exchange to supply chain performance (H5) was significantly positive ($t = 2.36$; $p < 0.05$). Also, both inter-organizational trust (H2) ($t = 5.82$; $p < 0.001$) and IOS integration (H3) ($t = 8.94$; $p < 0.001$) turned out to be significant influencers of knowledge exchange. However, contrary to our expectations, relationship continuity was not significantly associated with knowledge exchange (H4) ($t = 1.28$; $p = 0.103$).

As a supplementary analysis, we conducted the mediation analysis using the three-step process, suggested by Baron and Kenny (1986).

- Step 1: Regress the dependent variable on the independent variables.
- Step 2: Regress the mediator on the independent variables. If the mediator is not significantly associated with the independent variables, then there is no mediation.
- Step 3: Regress the dependent variable on both the mediator and independent variables.

In the buyer sample, step 1 was not significant. In the supplier sample, step 2 was not significant. Thus, it was concluded that, in both samples, the effects of KC on SCP were not mediated by KE.

Since all data were collected from a single respondent, this may raise a concern of common method bias. To address this problem, we conducted Harman's one-factor test to analyze the extent to which common method bias might influence our findings (Podsakoff & Organ, 1986). In the buyer sample, the results revealed six factors explaining 74.57% of the variance in all constructs and the first factor explaining 42.42% of the total variance. In the supplier sample, the results revealed six factors explaining 79.03% of the variance in all constructs and the first factor explaining 48.00% of the total variance. These results imply that common method bias is not a significant issue in our study. In addition, we checked the inter-construct correlation matrix (Table 4). According to Pavlou and El Sawy (2006), the presence of common method bias results in very high correlations ($r > 0.90$); however, Table 4 does not show any exceptionally high correlations in either sample (highest correlation in the buyer sample is 0.66 and highest correlation in the supplier sample is 0.75). These results indicate no significant common method bias problem.

5.3. Multi-group analysis

Since the principal constructs and the sample sizes of this study are the same in the two groups, we performed a multi-group analysis to establish whether relationship patterns differ between buyers and suppliers (Nyaga, Whipple, & Lynch, 2010). Based on the equation suggested by Chin et al. (2003), we assessed whether the path coefficients in these two groups differ significantly. The results of multi-group analysis are shown in Table 6. Our findings show that there are some significant differences in path coefficients between the buyer and supplier samples. First, the effect of inter-organizational trust on knowledge exchange is significantly stronger for the suppliers than for the buyers. Second, IOS integration influences knowledge exchange significantly stronger for the suppliers than for the buyers. Finally, knowledge exchange has a greater impact on supply chain performance for the suppliers than for the buyers.

In sum, the suppliers weigh more on the effect of inter-organizational relationship characteristics such as inter-organizational trust and IOS integration on knowledge exchange and its resulting impact on supply chain performance than the buyers.

Table 3
Results of convergent validity tests.

Respondents	Constructs	Items	Mean (s.d.)	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
Buyers	KC	4	5.49 (0.62)	–	–	–
	IOT	11	5.26 (0.82)	0.94	0.95	0.64
	IOS	3	4.85 (1.05)	0.77	0.87	0.68
	RC	1	12.56 (7.65)	1.00	1.00	1.00
	KE	3	5.34 (0.86)	0.77	0.86	0.68
	SCP	4	4.47 (0.91)	0.85	0.90	0.68
Suppliers	KC	4	5.42 (0.75)	–	–	–
	IOT	11	4.90 (0.89)	0.95	0.96	0.69
	IOS	3	4.65 (1.03)	0.83	0.90	0.74
	RC	1	12.56 (7.65)	1.00	1.00	1.00
	KE	3	4.92 (1.15)	0.85	0.91	0.76
	SCP	4	4.70 (0.94)	0.92	0.95	0.81

Note: KC is a formative measure, so its values are not reported.

Table 4
Inter-construct correlations and average variance extracted (AVE).

Respondents	Latent variables	KC	IOT	IOS	RC	KE	SCP
Buyers	KC	0.81					
	IOT	0.50	0.80				
	IOS	0.44	0.58	0.83			
	RC	0.02	0.07	0.16	1.00		
	KE	0.50	0.66	0.64	0.03	0.83	
	SCP	0.32	0.53	0.42	0.24	0.27	0.83
Suppliers	KC	0.88					
	IOT	0.56	0.83				
	IOS	0.37	0.54	0.86			
	RC	−0.23	−0.11	−0.10	1.00		
	KE	0.47	0.72	0.75	−0.04	0.87	
	SCP	0.45	0.63	0.28	−0.09	0.33	0.90

Note: Figures in the shaded diagonal are the square roots of the AVE.

Table 5
Results of hypothesis testing.

Sample			Path coefficient	*t*-value	*p*-value	Support
Buyers	H1	KC → KE	0.15	1.92*	0.030	Yes
	H2	IOT → KE	0.38	4.56***	0.000	Yes
	H3	IOS → KE	0.36	3.77***	0.000	Yes
	H4	RC → KE	−0.06	0.90	0.185	No
	H5	KE → SCP	0.25	2.31*	0.012	Yes
Suppliers	H1	KC → KE	0.07	1.03	0.154	No
	H2	IOT → KE	0.41	5.82***	0.000	Yes
	H3	IOS → KE	0.52	8.94***	0.000	Yes
	H4	RC → KE	0.07	1.28	0.103	No
	H5	KE → SCP	0.33	2.36*	0.011	Yes

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ in one-tailed tests ($df = 69$).

6. Discussion and conclusions

6.1. Discussion

Despite the growing interests in KC between buyers and suppliers in a supply chain, the operational definition of KC is not clear and few empirical research has been conducted to probe and refine the bilateral perspectives on KC (Stieglitz & Heine, 2007). This study makes substantial contributions to broader literature related to supply chain management. First, it contributes to the theory of complementarities by identifying the dimensions of KC and developing an instrument to measure KC in the context of a procurement dyad. Our measure encompasses two distinct dimensions of KC (i.e., uniqueness and utilizability), in two knowledge domains (i.e., operational and planning knowledge) in a supply chain.

Second, little empirical research has been conducted on the causal relationships between KC and synergistic value derived from it. This study contributes to the KM and SCM literature by providing empirical evidence about the relationship between KC and supply chain performance, mediated by knowledge exchange. Specifically, in the buyer sample, the results confirmed our hypotheses except for the relationship continuity. An implication of these findings is that mere presence of KC may not necessarily lead to the implementation of its value. While KC works as a precondition for knowledge exchange, the amount of knowledge exchange between supply chain partners influences the realization of the potential value of complementary knowledge. In the supplier sample, however, KC does not have significant impact on the knowledge exchange behavior. That is, from the supplier's point of view, it has no choice but to exchange knowledge with its buyer, regardless of the level of KC. This unexpected result can be explained by asymmetric power relationships (Crook & Combs, 2007). In our research context, typically the buyer (e.g., an automobile manufacturer) has more power over its suppliers because it has the decision making authority about whether to continue business with a specific supplier. According to the bilateral deterrence theory, the party with great power is more likely to use its relative power under conditions of higher asymmetric interdependence (Lawler & Bacharach, 1987). This implies that the dependent supplier has to exchange its knowledge with the powerful buyer, whenever asked, regardless of the level of KC. However, the powerful buyer can make a decision about knowledge exchange, based on a rational approach, i.e., whether there is KC or not.

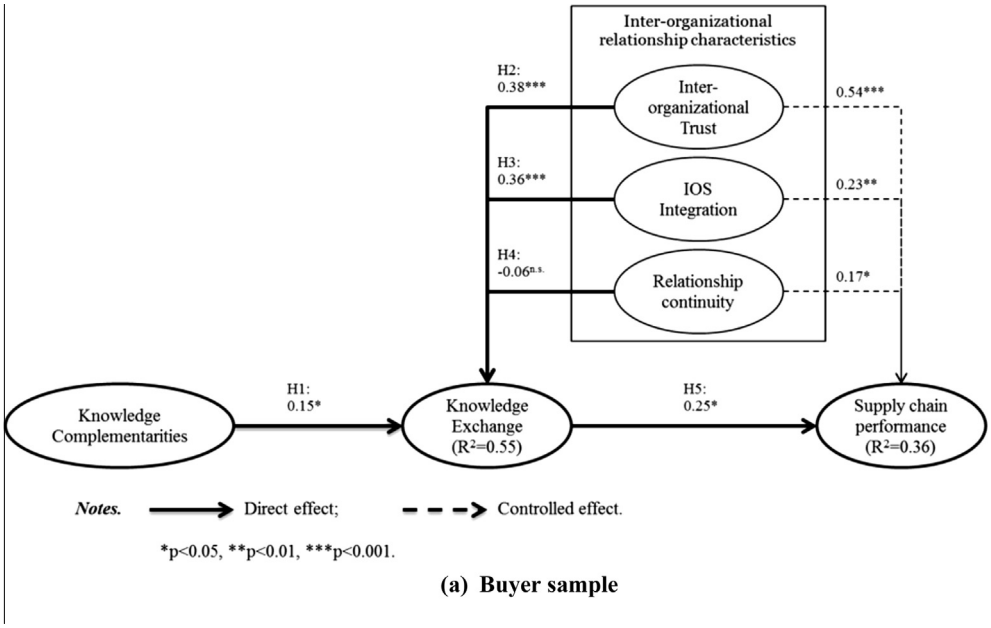
Meanwhile, inter-organizational relationship characteristics such as inter-organizational trust and IOS integration turn out to be significant determinants of knowledge exchange. In addition, inter-organizational trust and IOS integration are expected to play a vital role in promoting knowledge exchange (Levin & Cross, 2004; Premkumar, Ramamurthy, & Crum, 1997). Our results confirm these expectations and imply that a firm needs to develop inter-organizational trust and integrate IOS in order to realize the benefits from KC.

Contrary to our expectations, relationship continuity is not a significant determinant of knowledge exchange. We expected that interaction over time may lead to mutual commitments, resulting in more knowledge exchange. However, there can be other factors inhibiting knowledge exchange between firms with long-term relationships. For example, dependence asymmetry or an imbalance between the partners' dependence may work as a dysfunctional force that can destabilize cooperative relationships by creating conflicts (Kumar, Scheer, & Steenkamp, 1995). That is, if one party is more dependent on another party for complementary knowledge, the dependent party may be more cautious about voluntary knowledge exchange, despite the long-term relationships (Zhu, 2004). Clearly, this explanation is speculative and can be confirmed or refuted by future empirical testing.

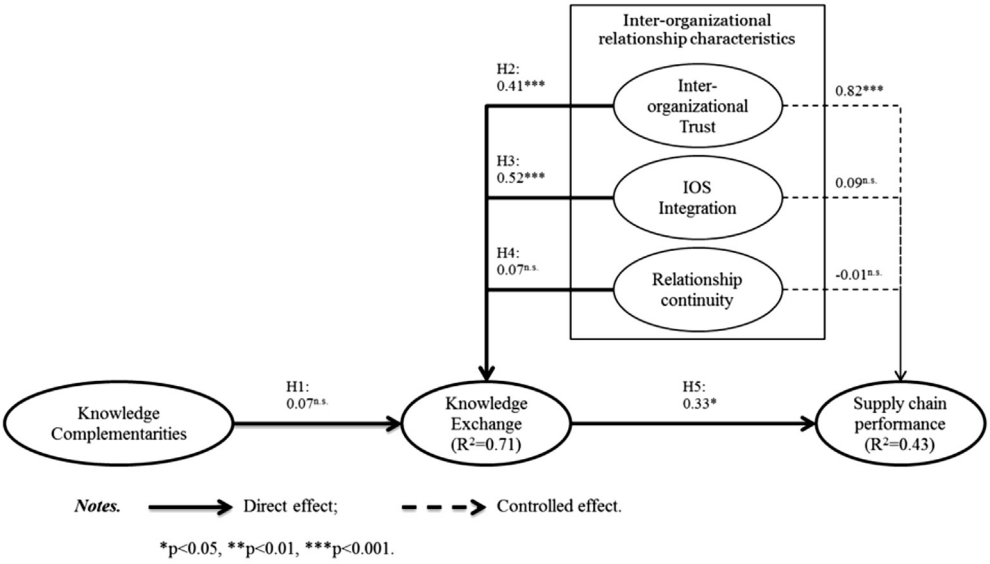
6.2. Limitations and future research

Although this study is a first attempt to empirically verify the theoretical model related to KC, our findings should be interpreted in light of potential limitations. First, since the data were collected from firms in a single country, further research is needed that incorporates a sample from multiple countries. Second, as the research design of this study is cross-sectional, it limits the ability to examine the changes of the hypothesized relationships over time.

This study has some implications for future research that may deepen our understanding of KC. First, Cohen and Levinthal (1990) highlight the distinction between similar knowledge and



(a) Buyer sample



(b) Supplier sample

Fig. 3. PLS test results of the proposed model.

Table 6
Comparison of structural paths between the buyer and supplier samples.

Hypothesis	Categories	Buyer	Supplier	Significant Differences
H2 (IOT → KE)	Path-coefficient	0.38***	0.41***	Yes
	Standard error	0.08	0.07	
	Number of sample	70	70	
	t-value	−2.64**		
H3 (IOS → KE)	Path-coefficient	0.36***	0.52***	Yes
	Standard error	0.10	0.06	
	Number of sample	70	70	
	t-value	−11.43***		
H5 (KE → SCP)	Path-coefficient	0.25*	0.33*	Yes
	Standard error	0.11	0.14	
	Number of sample	70	70	
	t-value	−3.98***		

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

different knowledge among partners. They emphasize the role of shared knowledge for effective communications and interactions between partners. Future research can extend this study by incorporating commonality of knowledge between partners that influence knowledge exchange.

Second, firms should be aware of the capabilities that are required to realize the value of partner's complementary knowledge (Harrison et al., 2001). Among others, Zahra and George (2002) assert that KC affects firm's absorptive capacity. They state that internal and external triggers which could moderate the relationship between KC and absorptive capacity should be considered. Future research may include absorptive capacity as another variable related to KC.

Third, our findings about the effects of KC on knowledge exchange can provide a guideline for supply chain partner selection. However, a critical component of KC is synergistic effects which is a result of combining partners' complementary knowledge. Then, it takes time to produce the desired synergistic effects from the potential complementary knowledge. Future research may investigate the process of creating synergistic effects from complementary knowledge which requires a longitudinal study. This line of research may have to incorporate different knowledge typology from our research.

Finally, among the many types of synergistic value of KC, this study includes only supply chain performance. However, there can be other benefits from KC in a supply chain. Knowledge creation, for example, results from a dual process of combination and exchange (Nahapiet & Ghoshal, 1998). While knowledge exchange is a requisite for combination, knowledge creation requires the combination of knowledge acquired from external sources. Thus, to explain knowledge creation, future studies should consider the process related to the combination and/or internalization of knowledge (Collins & Smith, 2006).

6.3. Implications for practice

This paper has some implications for practitioners as well who are interested in supply chain management and knowledge management. Specifically, the results of this study provide guidance for how to leverage knowledge complementarities of supply chain partners. First, buyers might as well search for suppliers who have complementary knowledge. Partner's complementary knowledge can be integrated to create value synergies through knowledge exchange. Furthermore, firms should develop mechanisms including partner selection criteria and procedures to identify complementary knowledge of partners.

Second, firms should continue their endeavor to develop their own unique knowledge so that their knowledge can benefit the entire supply chain. If a firm pays less attention to develop and maintain its unique knowledge, a firm may face the risk of losing their potential value in the supply chain in the long term.

Finally, inter-organizational trust and IOS integration among supply chain partners turn out to be important factors for knowledge exchange. Therefore, effective management for engendering trustworthy buyer–supplier relationships and cautious decision making for integrating IOS should receive appropriate attention from managers.

Appendix A. Survey items

Knowledge Complementarities (developed by the authors based on SCOR Model)

(Uniqueness related to Planning: UNPK)

1. The partner firm has very different and unique knowledge in procurement planning for raw materials or parts.
2. The partner firm has very different and unique knowledge in production planning.
3. The partner firm has very different and unique knowledge in shipping/delivery planning for finished products.

(Utilizability related to Planning: UTPK)

1. The partner's knowledge in procurement planning for raw materials or parts can be utilized for our business.
2. The partner's knowledge in production planning can be utilized for our business.
3. The partner's knowledge in shipping/delivery planning for finished products can be utilized for our business.

(Uniqueness related to Operation: UNOK)

1. The partner firm has very different and unique knowledge in purchasing of raw materials or parts.
2. The partner firm has very different and unique knowledge in production.
3. The partner firm has very different and unique knowledge in shipping/delivery for finished products.

(Utilizability related to Operation: UTOK)

1. The partner's knowledge in procurement of raw materials or parts can be utilized for our business.
2. The partner's knowledge in production can be utilized for our business.
3. The partner's knowledge in shipping/delivery of finished products can be utilized for our business.

Inter-organizational Trust (adapted from McKnight et al. 2002)

1. I believe that this partner firm would act in our best interest.
2. If I required help, the partner firm would do its best to help us.
3. The partner firm is interested in our well-being, not just its own.
4. The partner firm is truthful in its dealings with us.
5. I would characterize the partner firm as honest.
6. The partner firm would keep its commitments.
7. The partner firm is sincere and genuine.
8. The partner firm is competent and effective in providing knowledge related to business.
9. The partner firm performs its role of providing knowledge very well.
10. Overall, the partner firm is a capable and proficient knowledge provider.
11. In general, the partner firm is very knowledgeable about their business.

IOS (Inter-organizational systems) Integration (adapted from Grover & Saeed 2007)

1. Our firm shares databases with the supplier (or buyer).
2. Our firm shares applications with the supplier (or buyer).
3. Our firm exchanges files with the supplier (or buyer).

Relationship Continuity (Kim et al. 2010)
Continuity of the relationships between partners.
Knowledge Exchange (adapted from Schulz 2001)

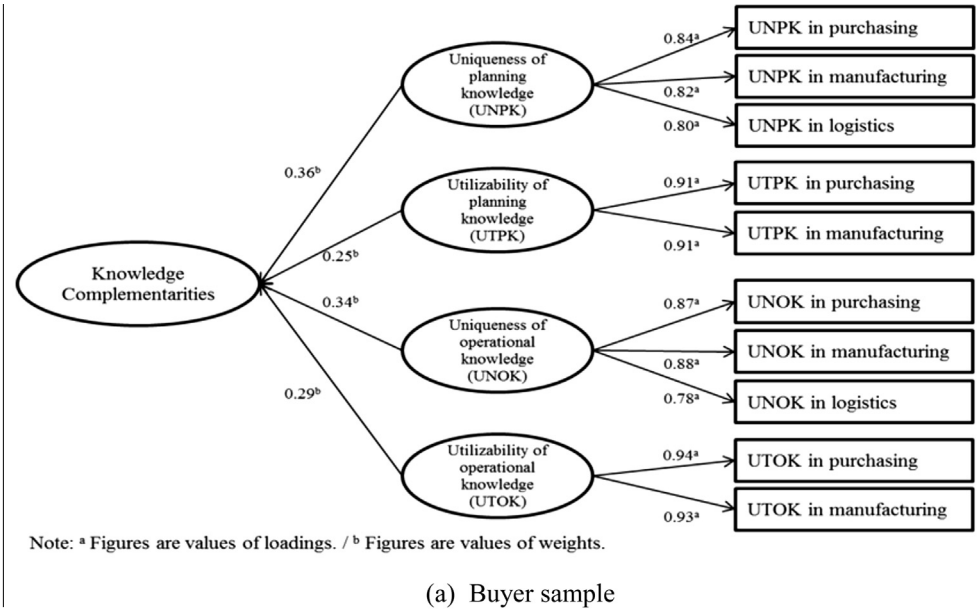
1. We exchange a great deal of knowledge about sales and marketing with our partner (e.g., knowledge about advertisement, public relations, service delivery, etc.).

2. We exchange a great deal of knowledge about technology with our partner (e.g., knowledge about R&D, information systems, engineering, etc.).
3. We exchange a great deal of knowledge about strategies with our partner (e.g., knowledge of competitors, suppliers, and government regulations).

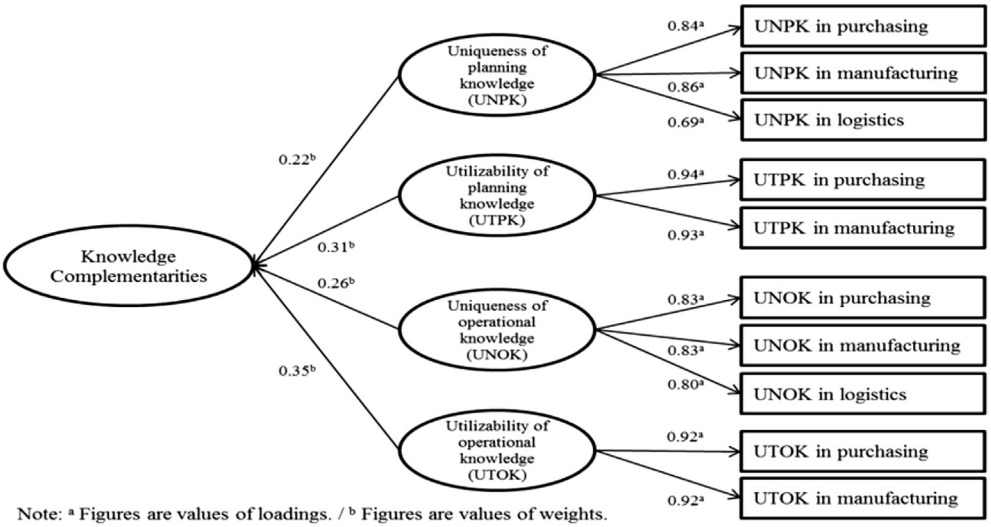
Supply Chain Performance (adapted from Hult et al. 2007)

1. The length of the supply chain management process is getting shorter every time.
2. We have seen an improvement in the cycle time of the supply chain management process recently.
3. We are satisfied with the speediness of the supply chain management process.
4. Involving the participants in decision making shortens the supply chain management process.
5. Based on our knowledge of the supply chain management process, we think it is short and efficient.
6. The length of the supply chain management process could not be much shorter than today.

Appendix B. Results of Second order CFA



(a) Buyer sample



(b) Supplier sample

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