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■ *Research Article*

Impact of Knowledge Management in Supply Chain Management: A Study in Malaysian Manufacturing Companies

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This research deals with two important aspects of Knowledge Management (KM) within the context of Supply chain Management (SCM): Knowledge Acquisition and Knowledge Application. Supply Chain Learning (SCL) and Applied Supply Chain Process Knowledge (Applied SCPK) are used as proxies for Knowledge Acquisition and Application. This study aims to test the relationship between Applied SCPK, SCL, and Organization Performance. This study also looks at the effect of Environment Knowledge as a moderating variable. About 1608 questionnaires were distributed to all the manufacturing firms in Malaysia. Path Analysis and ANOVA were used to study the various relationships. Results indicate existence of strong relationships between the variables. The combined effect of SCL and Applied SCPK on Organization Performance is more significant than looking at the effects separately. Furthermore, Environment Knowledge is found to have moderating effect on the relationship between Applied SCPK and Organization Performance. This paper demonstrates the application of KM in SCM and shows the effect on Organization Performance. This may guide supply chain managers to create an environment conducive to acquisition and application of knowledge.

INTRODUCTION

The concept of supply chain management (SCM) has received increasing attention since businesses have been able to achieve significant benefits as the result of implementing collaborative relationships both within and beyond their own organizations (Lummus and Vokurka, 1999). Christopher (1998) has further stated that effective SCM is a powerful tool with which to achieve cost advantage and a more profitable outcome for all parties in the supply chain. Of late, researchers have started to recognize the contribution of knowledge management (KM) within the domain of supply chain (Claycomb *et al*., 2001; Spekman *et al*., 2002). According to Maqsood *et al*. (2007), managing knowledge in supply chains facilitates innovation and creativity required to survive in the unpredictable business environment of today. In this context, a ''good'' definition of knowledge has been a subject of debate for many years and even now we do not really have a definition that is comprehensive (Nonaka and Takeuchi, 1995; Shin *et al*., 2001). The working definition of knowledge that is used in this research is that it represents an ''understanding of some phenomenon'' and the use of this understanding to organization's advantage (Claycomb *et al*.,

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2001:269). According to Spekman *et al*. (2002), effective SCM requires effective knowledge management (KM). They have argued that the KM can constitute the basis of competitive advantage if it is extended beyond individual organizations to embrace the whole supply chain. Both businesses and academic communities believe that a competitive edge can be gained and sustained through an efficient KM (Bhatt, 2001; Neef, 1997, 1999). Maqsood *et al*. (2007) argue that through KM a supply chain's intangible assets can be better exploited to create value. Managing knowledge is becoming crucial for the long-term survival in the long-term of firms.

The research described in this paper deals with two important aspects of KM: (1) knowledge acquisition and (2) knowledge application. The inclusion of the second aspect arises from the straightforward insight that knowledge acquisition without appropriate knowledge application does not add significant value to a firm (Pauleen *et al*., 2007). Earlier research has looked at the impact of these two components of KM on organization performance separately (Claycomb *et al*., 2001; Spekman *et al*., 2002). This research takes an integrated view. According to Shin *et al*. (2001), knowledge acquisition or creation relates to the addition of knowledge or correction of existing knowledge. A key component of knowledge acquisition is learning (Strategic Direction, 2006) and we use the construct *Supply Chain Learning* (SCL) and its antecedents to capture supply chain knowledge acquisition. Knowledge application is addressed through the construct *Applied Supply Chain Process Knowledge* (applied SCPK). These two constructs (SCL and applied SCPK) are internal to a supply chain. Besides these constructs, this research deals with a construct that is external to the supply chain, *Environment Knowledge*. We explain the constructs and the accompanying theoretical framework in the next section.

The aims of this study are to investigate: (1) the impact of SCL on applied SCPK and organization performance, (2) the impact of applied SCPK on organization performance, and (3) the moderating effect of environment knowledge on the relationship between applied SCPK and organization performance. The contributions of this study are as follows. First, earlier studies have looked at the impact of supply chain knowledge acquisition on organization performance (Spekman *et al*., 2002) and the impact of supply chain knowledge application on organization performance (Claycomb *et al*., 2001), separately. The model presented in this paper integrates these three constructs. We believe that the combined effect of proper knowledge acquisition (SCL) and efficient knowledge application (applied SCPK) is a key to maximizing the performance of the organizations. Second, the sample elements were drawn from the manufacturing industries in Malaysia, a fast developing economy. Prior studies on SCM, in this part of the world, are very scarce. Knowledge sharing, at its core, is a social activity and therefore it is reasonable to conclude that culture would play a very important role (Lucas and DT Ogilvie, 2006). According to Shin, Holden, and Schmidt (2001. p. 15), ''culture has been identified as the most fundamental issue over all the KM researches''. It is further important to observe that there are significant differences between Western and Asian cultures (Hofstede, 1984). Thus, it is essential to study the integration of KM in SCM in all cultures to understand the extent of impact completely. Thirdly and finally the analysis on moderating effecting of environment knowledge on the relationship between applied SCPK and organization performance can indicate the environmental factors that are relevant in an Asian setting.

In the following paper we first discuss the theoretical framework and the methodology. Then we describe the characteristics of the sample. This is followed by a section which discusses the results of statistical tests. In the final section of the paper managerial and research implications and further research directions are discussed.

THEORETICAL FRAMEWORK AND METHODOLOGY

Theoretical framework and hypothesis development

It has been noted in the extant research literature that sustaining competitive advantage requires more than just the accumulation of knowledge. Competitive advantage derives from the ability of a firm to convert accumulated knowledge into specific capabilities which differentiate the firm from other firms in relevant and appropriate ways (Kaplan *et al*., 2001). In this context knowledge may be defined as ''information whose certainty is given by a specific context, which creates space for a justified true belief and gives a firm the capacity to act'' (Kaplan *et al*., 2001, p. 17). Knowledge management (KM) is thus concerned with the creation (acquisition), storage, dissemination, and application of organizational tacit and implicit knowledge (Maqsood *et al*., 2007; Shaw *et al*., 2003; Shin *et al*., 2001). In this research, two aspects of KM are considered, namely knowledge acquisition and knowledge application. Through the

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systematic development and use of KM, firms in a supply chain can minimize wasteful activities and improve productivity and efficiency (Maqsood *et al*., 2007). Thus, in order to harness the expertise, enthusiasm, and dynamism of the firms, and to facilitate the delivery of excellent products and services to end-users, firms should recognize the importance of understanding and using knowledge within a more competitive environment (Hines *et al*., 1998). Embedding KM in SCM ensures that the best available knowledge is utilized to create and deliver the products and services. In this manner valuable experience and knowledge of best practices can then be efficiently stored and utilized throughout the supply chain (Maqsood *et al*., 2007). In this research, five constructs that are developed and used in subsequent analysis namely, applied SCPK, SCL, and antecedents of SCL, environment knowledge, and organization performance. SCL and applied SCPK are distinct and different constructs and analysis is performed to investigate their utility in explaining different aspects of KM. In the following section the development and nature of these concepts are discussed.

Applied SCPK

Based on the strategic management literature, ''[the] knowledge base of a firm leads to a set of capabilities that enhances the chances for competitive growth and survival'' (Claycomb *et al*., 2001:265). Firms differ in the nature and content of their knowledge bases and the set of capabilities derived from these knowledge bases. These differences have long-term effect on the relative performance of the firms (Grant, 1991). It is further noted that knowledge creation practiced by organizations should be purposeful and the knowledge must be applied in some way to make it valuable (Armistead, 1999; Claycomb *et al*., 2001). According to Pfeffer and Sutton (1999), knowledge that is acquired or generated should be employed in order to create/improve a product, a process, or services. Firms that have the capability to apply knowledge can significantly cut costs and achieve higher performance outcomes (Claycomb *et al*., 2001; Pauleen *et al*., 2007). Simchi-Levi *et al*. (2000) argue that information is a tool to facilitate organizations in integrating various stages in their supply chain. They further maintain that the costs of overall system, despite conflicting goals of different managers in the supply chain, can be reduced if the available information is transformed into knowledge and utilized carefully. To achieve success at SCM, an organization must possess and share knowledge about many different aspects of the supply chain processes in which it is engaged. Lack of knowledge sharing between members of the supply chain can affect the overall performance of the chain (Shaw *et al*., 2003). Further, Li, Lin, Wang, and Yan (2007) have shown that timely sharing of information enhances the agility of firms in a supply chain while improving the stability and performance of the entire supply chain.

In the context of the research discussed in the following paper applied SCPK is defined as the knowledge that facilitates the exchange and application within supply chain. Clearly, collaborative arrangements between the firms within a supply chain are necessary to facilitate the sharing of knowledge. These arrangements allow firms within a supply chain gain access to the knowledge assets of other firms within the supply chain (Mowery *et al*., 1996). This also allows for the integration of knowledge from internal and external sources allows for the acquisition and development new capabilities rapidly resulting in the creation or improvement of products, processes, and/or systems. It should be noted that some aspects of applied process knowledge are tacit and hence are difficult to identify and understand, and imperfectly transferable (Grant, 1991). Such tacit knowledge is often the key to achieving sustainable competitive advantage and thus it is important to investigate specifically how it can be shared (Claycomb *et al*., 2001).

Two components of applied SCPK are addressed in this research namely: (1) applied supplier-process-knowledge and (2) applied customer-process-knowledge. Applied supplier-process-knowledge deals with the use of knowledge that is shared between the firm and suppliers concerning supplier processes. This knowledge includes shared production plans, knowledge relating to the flexibility to respond to unexpected demand, knowledge concerning suppliers' order entry and invoicing systems, communication systems, and suppliers' knowledge relating to such practices as JIT and other quality assurance practices. Applied customer-process-knowledge includes knowledge relating to shared production plans, the actual use of supplied product, the nature of after-sales service that is required, the knowledge relating to the nature and development of flexibility to meet end customer's needs, knowledge relating to the measurement of customer satisfaction and the measures themselves, and knowledge concerning the existence and nature of communication systems. Based on the above discussions, we posit the following hypothesis:

H_A1: *Firms that have a higher level of applied supply-chain-process-knowledge have a better performance*

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Supply chain learning (SCL)

According to Hamel (1991), the accumulated intellectual capital of a firm is the aggregate of its technologies, experiences, skills, and management processes and these are combined together to create the firm's core competencies. Interestingly, these competencies are not equally distributed throughout industries since some firms are better in developing and internalizing them. A plausible explanation of this phenomenon is that some firms learn better than others (De Geus, 1997). Clearly supply chains provide an environment within which all firms can benefit from learning processes based on the transfer of skills and knowledge. Spekman *et al*. (2002) have recognized that a learning environment is vital for the members in a supply chain to achieve efficiency and improve performance. They have explained that a firm's ability to learn is largely dependent on its capability to harness the information, transform, and transfer it as internal knowledge. In fact, the knowledge that is actually implemented is much more likely to have been acquired through the process of learning by doing than as a result of reading, listening, or even thinking (Nonaka and Takeuchi, 1995; Pfeffer and Sutton, 1999). It is here that one can sense an overlap between knowledge acquisition and knowledge application. The application of knowledge leads to the generation of additional knowledge that is often likely to be tacit. Further, repeated performance of actions given the existence of dynamic internal and external organizational environments is likely to lead to continuous learning as a result of continuous creation of new knowledge.

Armistead (1999) has demonstrated that within the field of KM, the processes, people, and technology jointly improve the organizational efficiency and effectiveness through learning, the creation, sharing, and incorporation of knowledge. Spekman *et al*. (2002) have further emphasized that, in the context of supply chains, if members of a supply chain are to succeed jointly they must acknowledge that a learning environment improves the overall effectiveness of the supply chain as well as the abilities of individual members. They claim that the performance of firms depend upon the quality of the available knowledge-based assets and the successful application of these assets in operations. Maqsood, Walker, and Finegan (2007) have gone a step further and have claimed that the ''learning chains'' can be created through managing knowledge in supply chains. These learning chains can facilitate innovation and creativity that can help supply chains to thrive and perform better.

Two measures are used to characterize SCL: learning encouragement and learning structure/system/process. *Learning encouragement* explains the encouragement given by the supply chain members to learn continuously and hence develop and share new insights and new ideas. Attitudes and behaviors of supply chain members are essential to encourage learning (Spekman *et al*., 2002). *Learning structure/system/process* refers to the systems, processes, and structure in place to encourage the exchange of new insights and new ideas. According to Love *et al*. (2000), specific processes and structure have to be in place for learning to occur. According to Pauleen *et al*. (2007) the knowledge that is acquired through learning processes can be meaningful only if it can be applied to value adding organizational processes resulting in improved organizational performance. The application of knowledge thus only becomes fruitful only after the knowledge has been ''learnt'' and internalized. Superior learning ability helps firms to develop or acquire superior knowledge (Spekman *et al*., 2002) and this superior knowledge helps the firms to enhance customer relationships, achieve operational efficiencies, and devise better operational systems through proper application (Claycomb *et al*., 2001). Based on the above discussion, we posit the following hypotheses:

H_A2: *Firms that have a higher level of Supply-Chain-Learning have a better performance*

H_A3: *Supply-Chain-Learning has a positive relationship with the level of applied Supply-Chain-Process-Knowledge*

Antecedents of SCL

The existing research literature on supply chain integration has identified variables that contribute to supply chain learning and transfer of knowledge among the members of the supply chain (Spekman *et al*., 2002). Examples of these variables which may be considered to be antecedents of SCL are: (1) the existence of integrative mechanisms, (2) the existence and extent of shared culture, (3) the degree of commitment, (4) the existence and nature of trust, (5) the degree of communication, (6) the existence and extent of joint decision-making, and (7) the extent to which a win-win approach is adopted.

The term '*integrative mechanisms*' refers to the processes and structures that link the supply chain partners. When the linkages between the supply chain members are strong it is posited that this leads to greater effectiveness in the transfer of implicit and explicit knowledge between firms. Integrative mechanisms may be supported by technologies

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such as EDI, IT links, and integrative software such as ERP that is used to integrate the exchange of information between the supply chain members.

Shared culture is likely to have a direct impact in the ability of supply chain partners to learn and absorb knowledge. According to Deshpande and Webster (1989: p. 4), culture is defined as ''a pattern of shared values and beliefs that help individuals understand organizational functioning and thus provide them norms for behavior in organizations''. This, a shared culture that encourages openness, experimentation with new ideas and trusting behavior is likely to benefit through the learning and sharing process.

Trust is the keystone of any collaborative supply chain. Trust takes time to nurture and develops after repeated transactions between the supply chain members. Many studies (Kwon and Suh, 2005; Mohr and Spekman, 1994; Perry *et al*., 2004) have shown that trust indeed is one of the most important features for building a successful supply chain alliances.

Commitment denotes a ''partner's willingness to devote time, energy, and/or resources to the supply chain alliance'' (Spekman *et al*., 2002: p. 44). When the supply chain partners make such an investment, alliances between the supply chain partners succeed. Commitment, in the supply chain context refers to the commitment of supply chain members to learning, to the maintenance of relationships and trust, and to the sharing of relevant and appropriate information and knowledge. The linkage between the concepts of commitment and trust is evidenced by the following quotation that commitment is ''the physical and mental manifestation of the concept of trust'' (Maqsood *et al*., 2007: p. 127).

Communication is a vital factor that facilitates knowledge transfer (Mohr and Spekman, 1994). The frequency, depth, and content of communications between supply chain members impacts on learning and the associated knowledge transfer between the supply chain members.

The existence of *Joint decision-making* by the supply chain partners strengthens the learning process through highly interactive exchanges and knowledge transfers. Flexible, adaptive, and open organizations learn much faster than the organizations that are inflexible and not open to new ideas.

If supply chain partners have adopted a *Win-win approach* by the supply chain partners this discourages the partners to act opportunistically and work for the common good. The existence of a win-win approach decreases the tension between the partners and encourages the learning process.

Since the emphasis of this study is on the integrated role of SCL and applied SCPK on organizational performance, we do not posit a separate hypothesis to test the antecedents. However, we have included the antecedents in the empirical testing of the framework.

Environment knowledge

In the context of KM the adoption of a contingency theory approach is based on the assumption that ''to remain viable organizations in uncertain environments will adapt their knowledge generation and application capabilities to the changing contingencies in the environment'' (Terreberry, 1968; Claycomb *et al*., 2001: p. 268). It may also be observed that in an economy faced with increasing turbulence, application of environment knowledge is the most strategically significant resource of the firm for creating and sustaining a competitive advantage (Grant, 1996). When environmental uncertainty/turbulence is high, highly successful companies continuously create and apply knowledge to products and processes (Grant, 1991; Grant, 1996). Acquiring and applying knowledge requires time and effort from the companies in the supply chain. Therefore, firms in a supply chain, through collaborative partnerships, can avoid making risky knowledge investments.

Knowledge pertaining to identification and management of risk and uncertainties from external environments is necessary in order to allow firms to remain competitive in the marketplace and this knowledge is termed as the environment knowledge. The greater the effect of environmental risk and uncertainties/turbulences then the more pronounced is likely to be the impact of applied SCPK on the organizational performance. Environment knowledge consists of the following: knowledge of demand predictability, knowledge of process change, and knowledge of product churning (Claycomb *et al*., 2001). *Knowledge of demand predictability* concerns knowledge needed to predict sales and the stability of demand, accurately. *Knowledge of process change* concerns knowledge associated with the need to change core production and logistics processes. *Knowledge of product churning* measures knowledge associated with the need to introduce new products frequently and the need to act rapidly when products become obsolete. In all the three types of knowledge greater turbulence typically leads to the need to have richer knowledge. Further, we propose that when the level of uncertainty/turbulence is high, the impact of applied SCPK on organizational performance is more pronounced than when the level of uncertainty/turbulence is low. As a result of the above discussions, we posit the following hypothesis:

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H_A4: *Environment knowledge moderates the relationship between applied Supply-Chain-Process-Knowledge and organization performance*

Organization performance

The dependent construct, organization performance, is proposed to be captured by: (1) market share, (2) overall product quality, (3) overall competitive position, (4) sales in the last 3 years, and (5) profit in the last 3 years. Claycomb *et al.*, 2001 have used market share and sales growth as measures of performance. We have developed that construct for organizational performance so as to take account of two distinct perspectives: (1) data which concerns the organizations themselves (2) data that is comparative and establishes the relative position of the company with respect to the closest competitors or leader along a number of different dimensions. Unfortunately, many of the respondents refused to give specific values for these items and provided information (relative position of the company) on the first three items only. However, we have made the best use of the available data in our analysis.

The conceptual framework which forms the basis of the research model is given in Figure 1.

Measurement of constructs

As we have noted above, the various constructs used in this research are: applied SCPK, SCL and antecedents of SCL, environment knowledge, and organization performance. Applied SCPK consists of 20 items and the respondents have been asked to rate the extent of use of the items (knowledge) in improving the supply chain activities using a 5-point scale with end-points indicating ''very high'' and ''very low''. The items capture applied knowledge with suppliers, and with customers. The items have been generated from literature reviews in marketing, decision-making, and operations (Claycomb *et al.*, 2001). Table 1 gives the items under applied SCPK and environment knowledge. *SCL* consists of 10 items and the respondents have been asked to rate their firm's support to supply chain learning using a 5-point scale with end-points indicating ''strongly agree'' and ''strongly disagree'' (Spekman *et al.*, 2002). Antecedents of SCL consist of 28 items and the respondents have been asked to indicate the level of agreement of the items in the firm's supply chain learning process using a 5-point scale with end-points indicating ''very high'' and ''very low''. Table 2 gives items under SCL and antecedents of SCL. *Environment knowledge* consists of six items and the respondents have been asked to rate the need for the use of the items in the firm's supply chain activities using a 5-point scale with end-points indicating ''very high'' and ''very low'' (Claycomb *et al.*, 2001). *Organization performance* has been captured by asking the organizations to rate their firm's performance with respect to the closest competitor. This has been achieved using a 5-point scale with the end-points indicating ''low level'' and ''high level''.

Formative versus reflective constructs

In this research, we use SEM (structural equation modeling) to analyze the conceptual framework, SEM requires clear distinction between formative, and reflective constructs as the models that specify them are different. A misspecification of the constructs can lead to wrong results (Hair *et al.*, 2006). Constructs such as personality, feeling, attitude, or knowledge are viewed as underlying factors that cause the measured variables and these constructs are called reflective constructs. Constructs that combine observed behaviors or combine

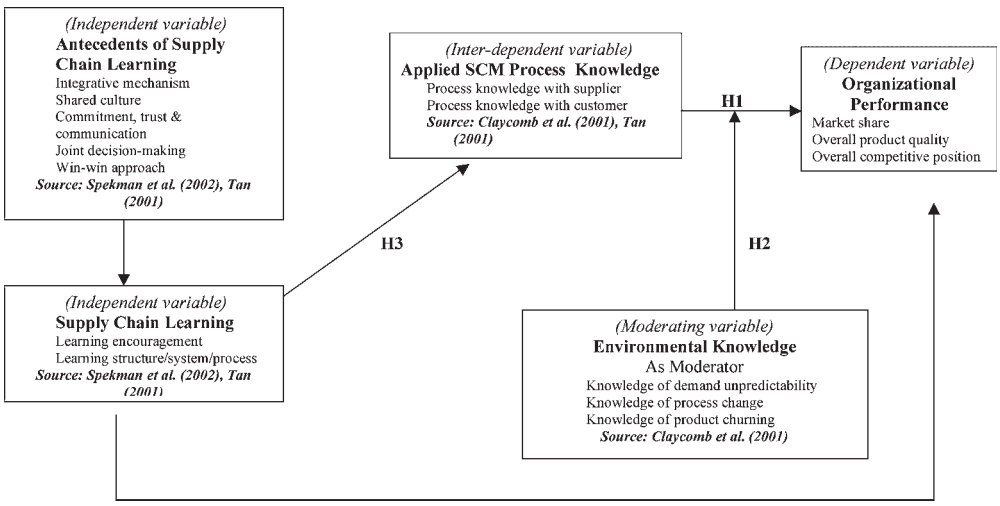

Figure 1 Conceptual framework of the model

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Table 1 Items used in measuring applied scpk and environmental knowledge

Construct	Items
Applied SCPK—Suppliers	• Sharing of sensitive information • Sharing of production plans/information to improve inbound delivery/inventory management • Flexibility to respond to unexpected demand to improve response time • Quick response in case of emergency or problem • Honest and frequent communications • Supplier's order entry and invoicing system • Communication systems • Willingness to integrate in the supply chain and share benefits • Supplier's efforts in promoting JIT principles • Quality assurance practices in supplier's organization
Applied SCPK—Customers	• Sharing future production plans/information to improve outbound delivery/inventory management • Sharing information on the actual use of the supplied product to improve the design of the product • Sharing information on the type of after-sales service required to improve customer service • Honest and frequent communications • Flexibility to meet end customer's changing needs • System to measure customer satisfaction • System to follow-up customer complaints • Interaction with customers to set reliability, responsiveness, and other standards • Successful resolution of customer complaints • Use of technology in communications to improve the response time
Environmental knowledge	Need to • predict sales/demand • accurately forecast sales/demand • introduce new product frequently • act rapidly when products become obsolete • change core production processes quickly • change logistic processes quickly

disjoint observed risk or protective factors are viewed as factors that are caused by the measured variables and these constructs are called formative constructs (Jarvis *et al*., 2003). In this research, all the constructs (applied SCPK, SCL and antecedents of SCL, environment knowledge, and organization performance) are treated as reflective constructs. For example, applied SCPK consists of 21 items that are correlated, sharing a common theme, and dropping any of these items does not alter the conceptual definition of applied SCPK. Similar arguments may be made with respect to the other constructs.

Sampling frame and sample size

In this study, the sampling frame was the listing of all manufacturers in the Federation of Malaysian Manufacturers (FMM) Directory, with more than 50 employees. The sampling unit was the companies from the 24 categories of industries listed in the FMM Directory as given in Table 3. One thousand six hundred and eight companies satisfied the criterion. Questionnaires were sent to all the companies.

Non-response bias

In spite of follow-ups through e-mails and phone calls, the response rate was only 10.2% (or 164/1608). Mail surveys with a return of about 30% are considered satisfactory as a basis for the generalization of results (Cooper and Schindler, 2001) and, as a result, low response rates affect the generalizability (Armstrong and Overton, 1977). Therefore, we tested for non-response bias. According to Armstrong and Overton (1977), sample elements that respond after prodding are more like non-respondents. We observed that the responses were received in two ''waves''. We received 105 responses during the first wave and 59 responses during the second wave. We tested for the (non) existence of non-response bias based on the responses received during the first and second waves. We statistically studied the means of all the measures under each of the constructs. Based on the independent *t*-tests between the two samples (first and second waves), we did not find any

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Table 2 Items used in measuring scl and antecedents of scl

Learning encouragement	■ Different points view are encouraged within this supply chain ■ Developing new insights is important to our supply chain ■ Members of this supply chain develop many new insights ■ New ideas are generally accepted by members of this supply chain ■ This supply chain supports experimentation
Learning structure/system/process	■ The system and procedures of this supply chain support innovation transfer between supply chain members ■ This supply chain structure supports the development of new ideas ■ This supply chain structure facilitates the sharing of ideas between members ■ This supply chain reward new ideas ■ Within the supply chain, we are rewarded for sharing our ideas within our supply chain partners
Extent of use of integrative mechanism within supply chain	■ Electronic data interchange (EDI) links ■ Integrated business system ■ Partner as operational part of supply/demand planning ■ IT integration with all suppliers/customers
Shared culture	■ Our company and our supplier have a shared continuous improvement philosophy ■ We share a similar sense of fair play with our suppliers ■ We have high level of shared understanding about key supply chain issues ■ Within this supply chain, we have shared vision or mission statement
Commitment	■ Our partner is committed to us ■ Maintaining the relationship with our partner is vital ■ Sustaining the relationship with our partner is important ■ Our partner is willing to devote energy to sustain the relationship
Trust	■ Our partner is trustworthy ■ We have complete confidence in our partner's motives ■ We have faith in our partner ■ We have a high level of trust within this supply chain
Communication	■ Frequent communication occurs between the firms ■ There is continuous contact between our firm and partner ■ Communication between our organization and the partner is frequent ■ There is a high level of contact between our firm and partner
Joint decision-making	■ Our firm works with the partner on long-range planning ■ We establish a joint team to manage our relationship ■ Within this supply chain, we value consensus in decision-making ■ Individuals throughout this supply chain participate in decisions that are critical to its overall success
Win-win approach	■ We sense that the partner has a willingness to help when problems arise ■ We proactively try to enhance each other's business ■ We take the needs of other parts of this supply chain into account when making changes in our organization ■ We understand the critical issues that affect our partners' business

Table 3 List of manufacturing companies given in FMM

- Agricultural products & machinery
- Building materials & related products
- Chemicals & adhesive products
- Food and beverage product
- Furniture & wood related products
- Giftware & jewellery
- Iron, steel product
- Packaging, labeling & printing
- Plastics products & resins
- Rubber products
- Stationery
- Textiles & wearing apparel
- Tin
- Automotive & component parts
- Ceramics & tiles
- Cement, concrete products
- Electrical &, electronic product
- Footwear
- Gas & household appliance
- industrial & engineering products
- Laboratory equipment
- Pharmaceutical, medical equipment, cosmetics, toiletries & household
- Playground equipment
- Shipping products & services

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significant differences between the means of the samples for all the measures. We also checked for significant differences in demographic characteristics between the two waves of responses. We did not observe any significant difference indicating the lack of non-response bias.

Description of the sample

The majority of the respondents were final product manufacturers (58%), followed by component manufacturers (21%). Approximately 7% were wholesalers and 7% were miner/raw material manufacturers. However, there was no respondent from the retailing industry. Malaysian-owned companies represented the highest number of respondents (50%), followed by foreign-owned companies (26%t). About 15% of the respondents could be categorized as ''others'' and they mainly consisted of joint-venture companies.

RESULTS

Reliability and validity of constructs

Reliability refers to the consistency and stability of a score from a measurement scale and the measurement scale is valid if it does what it is supposed to do. That is measure what it is supposed to measure (Davis, 1999). In this study, confirmatory factor analysis (CFA) has been used to verify measurement adequacy and Cronbach alpha has been used to verify the reliability. The reliability and validity of constructs are given in Table 4. The results of CFA on various constructs indicate that the constructs measure what they are supposed to measure and hence we did not remove any item. We have used threshold values of 0.08 for RMSEA and RMR and 0.9 for GFI and CFI and a score of 0.70 for Cronbach alpha (Hair *et al.*, 2006).

Relationship between SCL, applied SCPK and organization performance

Path Analysis using SEM (for a detailed discussion on SEM, refer to Hair *et al.*, 2006) was applied to test the relationship between SCL, applied SCPK and organization performance. The SEM model was run with SCL, antecedents of SCL, applied SCPK, and organization performance as latent constructs. The manifest variables under each of these constructs were learning encouragement and learning structure/process under SCL; integrative mechanism, shared culture, trust, commitment, communication, joint decision making, and win-win approach under antecedents of SCL; process knowledge with supplier and process knowledge with customer under applied SCPK; market share, overall product quality, and overall competitive position under organization performance.

The fit statistics were $\chi^2/\mathrm{df} = 1.63$; p-value $= 0.15$; RMSEA $= 0.052$; GFI $= 0.93$; CFI $= 0.99$; RMR $= 0.025$. The R-squared value for the structural equation linking organization performance, SCL, and applied SCPK was 0.71. From Figure 2, it can be seen that there are significant relationships between the level of applied SCPK and organization performance ($r = 0.39$, $t = 3.53$) and between SCL and organization performance ($r = 0.44$, $t = 3.73$). In prior research Claycomb *et al.* (2001) have already found a significant relationship between applied SCPK and organization performance and Spekman *et al.* (2002) have found a significant relationship between SCL and organization performance. Our analysis confirmed these relationships with a different data set.

Table 4 Reliability and vaidity of various constructs

Construct	Reliability	RMSEA	GFI	Chi-square/df
SCMPK—Supplier	0.8911	0.07	0.92	3.05
SCMPK—Customer	0.9305	0.075	0.91	3.10
Learning encouragement (SCL)	0.9177	0.064	0.99	1.78
Learning structure (SCL)	0.9430	0.078	0.98	2.34
Integrative mechanism	0.8768	0.01	0.99	1.65
Shared culture	0.8888	0.02	0.99	1.85
Commitment	0.9288	0.04	0.98	2.05
Trust	0.9591	0.08	0.98	2.97
Communication	0.9500	0.073	0.99	3.01
Joint decision-making	0.9508	0.057	0.99	1.56
Win-win approach	0.9238	0.04	0.98	2.85
Environmental knowledge	0.7356	0.02	0.97	2.54
Organization performance	0.8587	0.01	0.98	2.95

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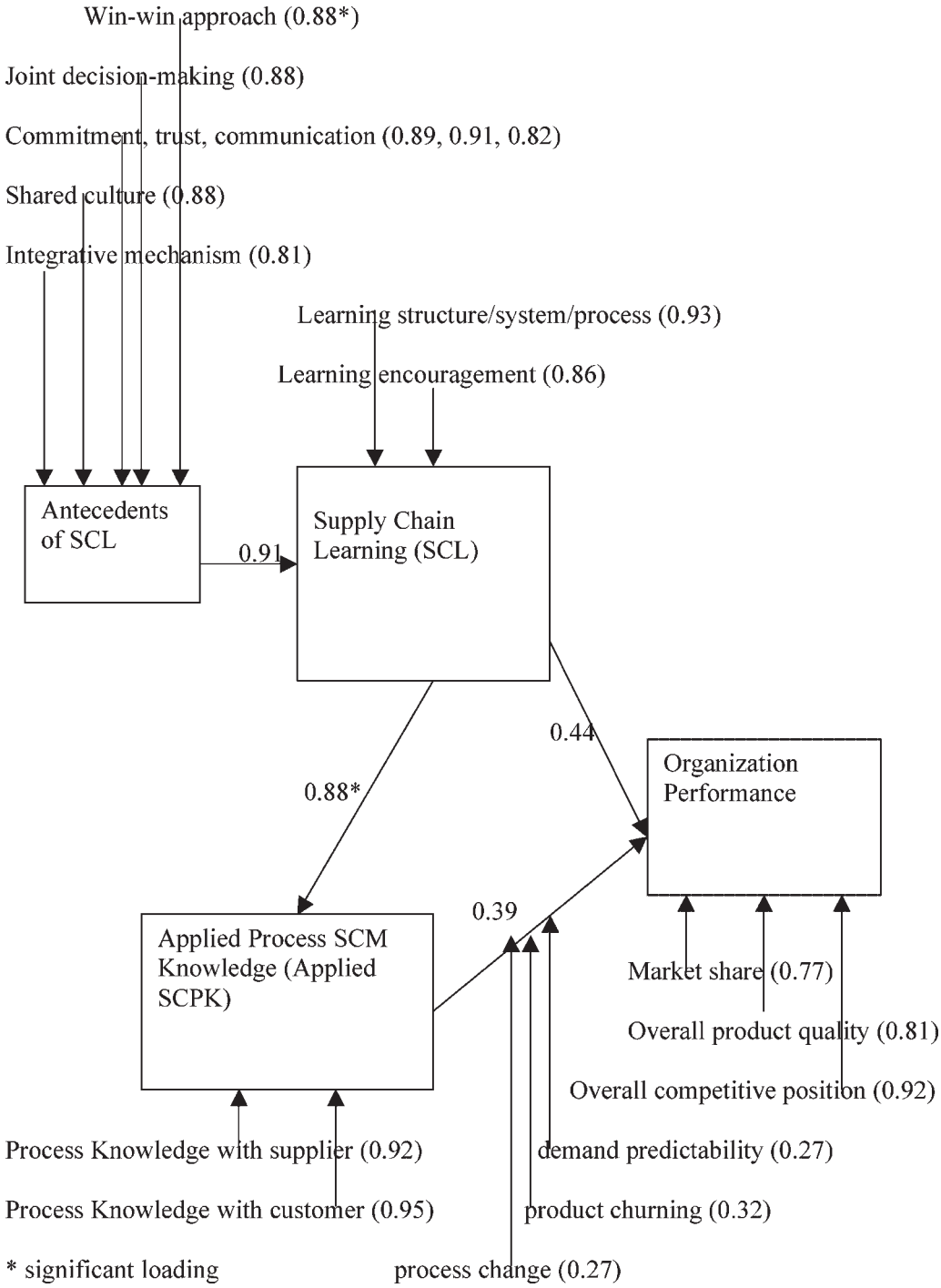

Figure 2 Path analysis results (with significant loading)

As noted above, in this research, we have gone a step further and have looked at the direct and indirect effects, through applied SCPK, of SCL on organization performance. The combined effect of SCL and applied SCPK on organization performance has a coefficient (correlation) value of 0.78 (0.44 + (0.87*0.39)). This shows that the combined effects of SCL and applied SCPK on organization performance are significantly higher than looking at the effects independently. This vindicates the need for integrating supply chain learning and application of supply-chain-process knowledge.

Environment knowledge as a moderating construct in the relationship between applied scpk and organization performance

As stated earlier, in our analysis environmental knowledge is comprised of: (1) knowledge of

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demand predictability, (2) knowledge of product churning, and (3) knowledge of process change. Each of the knowledge items has been treated as a separate moderating variable in this research. We have followed the approach of Claycomb *et al*. (2001) and have divided the knowledge level of each variable into high and low in order to study the moderating effect.

Knowledge of demand predictability as a moderating variable

In this case the fit statistics from Path Analysis output are: $\chi^2/\mathrm{df} = 4.63$; p-value $= 0.03134$; RMSEA $= 0.050$; GFI $= 0.99$; CFI $= 0.99$; RMR 0.031; t-values for SCL, Applied SCM process knowledge and knowledge of demand predictability are 4.00, 7.61, and 5.10, respectively. The R-squared value for the structural equation linking organization performance, SCL applied SCPK, and the moderating variable is 0.75. Based on these results, it can be inferred that demand predictability moderates the relationship between applied SCPK and organization performance.

Knowledge of product churning as a moderating variable

In this case the fit statistics from Path Analysis output are: $\chi^2/\mathrm{df} = 0.44$; p-value $= 0.50603$; RMSEA $= 0.001$; GFI $= 0.99$; CFI $= 0.99$; RMR $=$ 0.0098; t-values for SCL, applied SCPK and knowledge of product churning are 4.71, 7.22, and 6.27, respectively. The R-squared value for the structural equation linking organization performance, SCL, applied SCPK, and the moderating variable is 0.77. From the results, it can be inferred that the knowledge of product churning moderates the relationship between applied SCPK and organization performance.

Knowledge of process change as a moderating variable

In this case the fit statistics from the Path Analysis output are $\chi^2/\mathrm{df} = 4.10$; p-value $= 0.04277$; RMSEA $=$ 0.039; GFI $= 0.99$; CFI $= 0.99$; RMR $= 0.034$; t-values for supply SCL, applied SCPK, and knowledge of process change are 4.06, 7.45, and 4.98, respectively. The R-squared value for the structural equation linking organization performance, SCL, applied SCPK, and the moderating variable is 0.75. From the results, it can be concluded that knowledge of process change moderates the relationship between applied SCPK and organization performance.

All three moderating variables have been found to have moderating effects on the relationship between applied SCPK and organization performance. In support of our analysis Claycomb *et al*. (2001), however, found that knowledge of demand uncertainty and knowledge product churning have moderating effects on the relationship between applied SCPK and organization performance.

Relationship between SCL and applied SCPK

From Figure 2, it can be seen that there is a significant relationship between SCL and applied SCPK ($r = 0.87$, *p-value* $= 0.000$). Further analysis reveals that both the dimensions of SCL, learning encouragement, and learning structure/process/system, are significant. The results also indicate that integrative mechanisms, shared culture, trust, commitment, and communication between the supply chain members, joint decision-making mechanisms, and the existence of a win-win approach by the supply chain members are antecedents of SCL.

DISCUSSIONS AND CONCLUSIONS

The findings in this study support a variety of conclusions. First, the relationship between SCL and applied SCPK with respect to the data set has been established. This study highlights the fact that a higher level of learning among the supply chain members result in effective application of knowledge. Spekman *et al*. (2002) have acknowledged that learning contributes to the process of knowledge creation and transfer. The knowledge that is created and transferred can help the supply chain members to create a product or service, to improve the operational efficiencies, and to create or improve processes. Therefore, we contend that learning is a pre-requisite to effective application of knowledge. A very high correlation coefficient ($r = 0.87$) between SCL and applied SCPK vindicates this conclusion.

Second, the relationships between applied SCPK and organization performance and between SCL and organization performance has been established. Claycomb *et al*. (2001) have shown a positive relationship between applied SCPK and organization performance. Spekman *et al*. (2002) have shown a positive relationship between SCL and organization performance. Our study confirms these relationships. The results from this study indicate that organizations will improve their performance if they can acquire and apply knowledge in an integrated manner. Knowledge acquisition (learning and transfer) and application go hand-in-hand. Learning, *per se*, is a necessary but not sufficient precondition for the improvement of firm performance. Improved performance results

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from the translation of learning into meaningful applications. Top management should encourage and create an environment by providing the necessary hardware, software, systems, and processes to facilitate creation and exchange of knowledge within the supply chain. The exchange of knowledge cannot be complete without trust, commitment, and frequent communication between the supply chain members. The application of knowledge drives superior firm performance by cutting costs, by improving operational efficiencies, and by improving relationships with customer and supplier. Earlier studies have analyzed the effects of applied SCPK and SCL on organization performance, separately. Our integrated view has produced encouraging results.

Third, the study emphasizes the importance of environment knowledge in moderating the relationship between applied SCPK and organization performance. All three components of environment knowledge (knowledge of demand predictability, knowledge of process change, and knowledge of product churning) have been found to moderate the relationship between applied SCPK and organization performance. We have examined the moderating effects separately. When the demand uncertainty is high or when the products become obsolete and the new products are introduced frequently or when the core processes are changed rapidly, the impact of applied SCPK on organization performance is greater than when the uncertainty/turbulence levels are low. Supply chain managers should use process knowledge to the organization's advantage when the environmental uncertainty/turbulence is high. This knowledge helps to mitigate the risks and uncertainties and therefore, improves the performance of the supply chain members.

This study establishes the fact that the ability of supply chain members to create, to integrate, and to apply knowledge assets provide primary significant source of competitive advantage. Supply chain managers face several challenges to ensure that maximum value can be achieved and this study highlights these challenges. First, managers have to ensure that learning takes place throughout the supply chain, as it is a pre-requisite for application the application of relevant knowledge. Managers are responsible for providing the right conditions for learning to take place. Second, the managers have to ensure that the supply chain members understand the integrated effects of learning and application. The knowledge (implicit and/or explicit) acquired through learning has to be applied in some way to create/improve products, processes or systems. Third, the managers need to understand the different effects of environmental uncertainty/turbulence and make use of process knowledge to mitigate the risks. The effects of the environmental turbulence can be reduced through the frequent sharing of relevant knowledge/information with suppliers and customers. Fourth, the managers have to ensure that there is a high level of trust among members by frequent communication, by a show of commitment and by not behaving in an opportunistic manner. Fifth, the managers have to ensure that necessary hardware and software are in place to facilitate learning and application. The hardware and the software can facilitate proper storage and dissemination of knowledge. Sixth, the managers have to ensure that the members do not breech trust by having appropriate rules of engagement.

In light of the constraints of the current study, further research must be considered. This study has examined only one type of applied knowledge. The quantity (and quality) of knowledge generated and applied may depend not only on the specific sources to which the firm has access, but also on the proportionate representation of each type of knowledge in the firm's total knowledge base (Claycomb *et al*., 2001). A longitudinal study needs to be conducted in order to understand the real effects of supply chain learning and application. Our research has considered the applied SCPK with suppliers and customers. A future study can also include applied SCPK with internal processes. In order to reduce the common-source bias, responses may be obtained from multiple respondents (sources) in each company. The study has covered only the manufacturing sector and it will be interesting to study the service sector.

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