Governance of Learning Mechanisms: Evidence from Construction Firms

Patrick S. W. Fong¹ and Le Chen²

Abstract: The focus of knowledge management (KM) in the construction industry is moving towards capability building for value creation. The study reported by this paper is motivated by recent assertions about the genesis and evolution of knowledge management capability (KMC) in the strategic management field. It attempts to shed light on the governance of learning mechanisms that develop KMC within the context of construction firms. A questionnaire survey was administered to a sample of construction contractors operating in the very dynamic Hong Kong market to elicit opinions on the learning mechanisms and business outcomes of targeted firms. On the basis of a total of 149 usable responses, structural equation modeling (SEM) analysis identified relationships among knowledge-governance mechanisms, knowledge processes, and business performance, thereby supporting the existence of strategic learning loops. The study findings provide evidence from the construction context for capability assertions that knowledge-governance mechanisms and processes form learning mechanisms that carry out strategic learning to create value, effect performance outcomes, and ultimately drive the evolution of KMC. The findings imply that it is feasible for managing construction firms to govern learning mechanisms through managing the capability-based holistic KM system, thereby reconfiguring KMC to match needs in the dynamic market environment over time. DOI: 10.1061/(ASCE)CO.1943-7862.0000521. © 2012 American Society of Civil Engineers.

CE Database subject headings: Construction companies; Contractors; Construction management; Knowledge-based systems; Performance characteristics; Evaluation.

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Introduction
The construction industry is characterized as rapidly changing, highly complex, and extremely competitive (Green et al. 2008; Price and Newson 2003). Within such a volatile environment, on the one hand, construction firms have to manage industry-specific challenges such as the globalization of the industry, greater private sector participation in infrastructure projects, and increasing vertical integration in the packaging of projects (Toor and Ofori 2008). On the other hand, they need to deal with economic challenges including funding difficulties, uncertain economic conditions, and rapidly fluctuating exchange rates (Toor and Ofori 2008). Construction is also a knowledge- and information-intensive industry in which stakeholders communicate a large amount of information across various stages of the project lifecycle (Dave and Koskela 2009), whereas the temporary nature of projects and heavy fragmentation of the supply chain make construction a complex process and knowledge management (KM) a very difficult task (Egbu and Robinson 2005). In the last decade, the strategic importance of knowledge has been increasingly recognized by the industry (Ribeiro 2009), and KM has been viewed as a strategy to promote innovation and gain a competitive edge (Anumba 2009). The focus of KM application within the industry has shifted from information and communication technology (ICT)-driven knowledge and information sharing (first generation) to organizational culture-centric knowledge nurturing (second generation), and is now moving toward capability building for value creation (third generation) (Rezgui et al. 2010). Indeed, facing a rapidly changing scenario and dynamics in the market environment, top construction firms appear to be bracing themselves for major strategic transformations to enhance and sustain their market share and competitiveness (Bhattacharya et al. 2009). Dynamic capabilities, the capacities of a firm to purposely create, extend, or modify its resource base (Helfat et al. 2007), are deeply embedded in these firms’ learning processes and are best conceived as something that they do, rather than something that they have (Green et al. 2008). Moreover, the strategic choices available to these firms are heavily shaped by the path along which they have traveled (Green et al. 2008).

Empirical investigations into the competitiveness of construction firms have been limited (Flanagan et al. 2007). Although the validity of applying resource-based and core competence approaches to the construction context has been demonstrated (Haan et al. 2002), the dynamic capabilities view (Eisenhart and Martin 2000; Helfat et al. 2007; Teece 2007; Teece et al. 1997; Zollo and Winter 2002) has neither received enough attention in construction-related strategy literature nor been widely applied in the industry (Green et al. 2008). Moreover, empirical studies experienced difficulties in revealing insights about how the learning and transformation processes were enacted in the evolutionary path of construction firms (Green et al. 2008). Strategic management literature has proposed the structure of and asserted the capability

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implications of learning mechanisms. From an evolutionary economics perspective (Nelson and Winter 1982), the genesis and evolution of dynamic capabilities is driven by strategic learning carried out by knowledge processes such as experience accumulation, as well as knowledge articulation and codification (Eisenhart and Martin 2000; Zollo and Winter 2002). Recent capability assertions further suggest that learning mechanisms have complex structures, within which knowledge-governance mechanisms create conducive cognitive contexts to facilitate knowledge processes, which carry out learning for the purpose of creating value and improving performance (Foss 2007; Lichtenthaler and Lichtenthaler 2009; Nooteboom 2009). In this respect, investigation into the learning mechanisms of construction firms would help to explain the evolution of their dynamic capabilities. Few empirical studies, however, have discussed learning mechanisms within the context of construction firms from a capability-based perspective (Bosch-Sijtsema and Postma 2009; Green et al. 2008). As KM application in the industry evolves into the third generation, there is an apparent need for a better understanding of the link between learning mechanisms and capability building for value creation (Rezgui et al. 2010). In view of the research need, this study was undertaken within a context of construction firms aiming to (1) identify key components of learning mechanisms, (2) reveal relationships among the components, and (3) assess whether learning mechanisms influence variances in business performance, i.e., effect performance heterogeneity. To shed light on potential means by which construction firms could govern their learning mechanisms, the study draws on the theoretical perspectives of the knowledge-based view (KBV) (Grant 1996b; Spender 1996, 1998), the dynamic capabilities view (Eisenhart and Martin 2000; Helfat et al. 2007; Teece 2007; Zollo and Winter 2002), the knowledge-governance approach (KGA) (Foss 2007), and strategic learning (Kaplan and Norton 1996a; Pietersen 2010; Stacey 2003). The empirical evidence derived from this study suggests that through manipulating a capability-based holistic KM system formed by the interactions of governance mechanisms, knowledge processes, and performance measurement, management would have the potential to govern the learning mechanisms of a firm to a greater degree, thereby being able to develop value-adding knowledge management capability (KMC) so as to shape the evolutionary path of the firm more proactively. In more specific terms, value created by knowledge processes is likely to be maximized through developing conducive knowledge-governance mechanisms.

Theory and Hypotheses

Governance of Learning Mechanisms of Firms

Given that the origin of all tangible resources lies outside firms, in which markets are assumed to be reasonably efficient, the KBV of the firm argues that under dynamic competition, superior profitability is likely to be associated with resource- and capability-based advantages derived from superior access to and integration of specialized knowledge (Grant 1996a). Accordingly, the KBV asserts that the integration of specialist knowledge to perform a discrete productive task is the essence of a firm’s capability (Grant 1996a). In line with these assertions, the KBV perceives the firm as a dynamic, evolving, quasi-autonomous system of knowledge production and application (Spender 1998), and its primary role is to integrate knowledge and provide the context for creating knowledge-based competitive advantage (Grant 1996a). Hence the KBV shifts analytic focus from the firm’s intangible knowledge assets to the processes that generate, distribute, and apply them, because knowledge, as a strategic resource, needs to be translated into activities and business processes to have a positive effect on a firm’s performance (Spender 1996, 1998).

Recently Lichtenthaler and Lichtenthaler (2009) specifically defined KMC as a “firm’s ability to dynamically manage its knowledge base over time by reconfiguring and realigning the processes of knowledge exploration, retention, and exploitation inside and outside the organization” (p. 1,322). In other words, they perceive KMC as a special type of dynamic capability, that is deeply embedded in the knowledge processes (i.e., the creation, retention, and sharing of knowledge) and related governance mechanisms of a firm (Lichtenthaler and Lichtenthaler 2009). These arguments are also in line with the early KBV assertion made by Grant (1996a), that “the competitive advantage conferred by an organizational capability depends, in part, upon the efficiency of knowledge integration which is a function of: (a) the level of common knowledge among organizational members; (b) frequency and variability of the activities; (c) a structure which economizes on communication” (p. 385). The emerging KGA specifically stresses that governance mechanisms can and should be purposely deployed to influence firm members’ behaviors, particularly in relation to their engagement in knowledge processes (Foss 2007). Recent capability assertions within the strategic management field imply that first, learning mechanisms that guide the genesis and evolution of KMC are composed of both knowledge-governance mechanisms and knowledge processes. Secondly, the need to manage KMC for the purpose of achieving competitive advantage would most likely be fulfilled through creating conducive knowledge-governance mechanisms that facilitate knowledge processes, which will ultimately create value and contribute to performance outcomes (Abell et al. 2008; Foss 2007; Lichtenthaler and Lichtenthaler 2009; Teece 2007). In other words, knowledge processes mediate the effect of knowledge-governance mechanisms on business performance (Abell et al. 2008; Foss 2007).

Furthermore, from the perspective of strategic learning (Kaplan and Norton 1996a; Pietersen 2010; Stacey 2003), the three categories of constructs, i.e., knowledge-governance mechanisms, knowledge processes, and business performance, are associated with each other in a cyclic system and connected by feedback loops. In a fast-changing environment, in which new threats and opportunities arise constantly, firms must become capable of double-loop learning, which occurs when managers challenge the expectations, values, and assumptions that led them to adopt the knowledge or engage in the action in the first place (Pietersen 2010). Therefore, as an organic component of overall corporate strategies, the KM strategy evolves through strategic learning (Heisig and Orth 2007; Kaplan and Norton 1996a), which is in essence a double-loop learning process (Stacey 2003) that gathers feedback, tests the hypotheses on which the strategy was based, and makes all the necessary adjustments (Kaplan and Norton 2007; Pietersen 2010). In view of the assertions of the KBV and strategic learning that a firm is a coherent entity that has an capability to learn and respond to the changes in its environment through both negative and positive feedback (Pietersen 2010; Spender 1998; Stacey 2003), the essence of KM is to build up learning mechanisms (Eisenhart and Martin 2000; Zollo and Winter 2002) by which the firm can put its KMC into use, and through which the firm can further develop the KMC (Lichtenthaler and Lichtenthaler 2009).

As summarized in Fig. 1, the strategic management literature posits a framework of a capability-based holistic KM system that is composed of knowledge-governance mechanisms, knowledge processes, and performance measurement, and can be manipulated by management to govern learning mechanisms for the purpose of
developing value-adding KMC. To illustrate this, performance measurement outcomes would reveal a firm’s competitive position and trigger strategic learning, which involves intensive knowledge governance mechanisms and processes and drive the evolution of value-adding KMC (Abell et al. 2008; Eisenhart and Martin 2000; Lichtenhals and Lichtenhals 2009). These knowledge processes would help to update KM strategy that needs to be translated into more conducive knowledge-governance mechanisms and processes and drive the evolution of value-adding KMC (Abell et al. 2008; Eisenhart and Martin 2000; Lichtenhals and Lichtenhals 2009; Zollo and Winter 2002).

**Knowledge Management within the Construction Industry**

KM has grown in importance within the construction industry over the last decade (Anumba 2009). It is evident that construction firms that have adopted KM are reaping rewards, albeit still struggling to quantify these (Anumba 2009). It has been empirically established that within construction firms, knowledge creation takes place primarily through problem-solving aspects of individual professionals (Egbe 2006). Meanwhile, professionals’ abilities to solve project-related problems increase with a wider spectrum of knowledge, which in turn can be further combined to solve problems in new projects (Hartmann 2006). Hence, within the construction context, the most important knowledge processes, such as applying, distributing, creating, storing, and identifying knowledge (Heisig 2009), are carried out as various construction-related business processes (Fong 2003; Fong and Choi 2009). Recently, these knowledge processes have been empirically found to be associated with each other and form a cyclic pattern influenced by organizational contextual factors and significantly associated with business performance variations (Chen and Mohamed 2007, 2008a, b). In addition, two broad categories of governance mechanisms have been empirically identified as facilitators of the knowledge processes, i.e., “technological approaches,” which focus on the development of ICT tools (Tatari et al. 2007), and “people-centered approaches,” which center on the human and organizational aspects (Fong and Kwok 2009). It is also evident that sources of competitive advantage of construction firms could come from a wide range of innovative solutions (e.g., new construction methods) related to their business processes, in which the knowledge incorporated reaches a level that exceeds the current state of the art and can be exclusively used by a firm (Hartmann 2006).

Despite intensive construction-specific research investigating KM-related issues, understanding of the learning mechanisms of construction firms and the KM system that governs the mechanisms is still limited. Because a large proportion of construction-specific knowledge is tacit by nature and project-based organizational structures of construction firms are dynamic, it is difficult for firms to define “knowledge” (Pathirage et al. 2007) and to specify components of their KM system that are intermingled within business processes (Bishop et al. 2008; Fong and Choi 2009). Because of this challenge, a formal review process for monitoring and communicating the benefits of KM initiatives has not yet become a widely adopted practice (Robinson et al. 2006). In addition, empirical support for the existence of strategic learning loops within a
capability-based holistic KM system in the context of construction firms is not evident in the literature. With KM application in the industry evolving into a third generation that focuses on capability building for value creation (Rezgui et al. 2010), the need for further understanding of learning mechanisms that drive KMC to sustain competitive advantage becomes apparent. In view of this research need, this study attempted to reveal empirical insights by providing answers to the following research questions: (1) what are the knowledge-governance mechanisms and knowledge processes that form the learning mechanisms of construction firms? (2) what knowledge-related performance measurements are currently adopted by construction firms? (3) what relationships, if any, exist between these three key components of a capability-based holistic KM system within these firms? and (4) how are these three components associated with each other? An in-depth literature review was undertaken to provide answers to the first two research questions. Questions 3 and 4 were primarily investigated through exploring and testing a conceptual model that postulates relationships among the three categories of constructs that represent knowledge processes and business performance within the context of construction firms. Their empirical model is in line with recent theoretical propositions (Foss 2007; Heisig 2009; Zollo and Winter 2002) and with empirical findings derived from recent construction-specific studies (e.g., Bishop et al. 2008; Fong and Kwok 2009; Robinson et al. 2006; Tatari et al. 2007). In view of these facts, this empirical model was adopted as a foundation for studying learning loops within a capability-based holistic KM system in the context of construction firms. Accordingly, the study proposes a conceptual model (Fig. 2) containing a total of seven constructs that are conceptually defined in Table 1 and operationalized by the measurement scales developed by Chen and Mohamed’s study (2007, 2008a, b). Because the balanced scorecard (BSC) recognizes intangible assets as critical performance drivers (Kaplan and Norton 1996b), it has been adopted as a measurement framework by some construction firms for the purpose of strategic review and planning and in particular for the evaluation of KM performance (Robinson et al. 2006). Therefore, the business-performance (BP) construct was measured on the basis of the four perspectives of the BSC (Kaplan and Norton 1996b, 2007). Because relative measures have been used in many empirical studies (e.g., Ling et al. 2007), this study adopted fully subjective self-reporting measures to address the latent performance construct directly, following the suggestion of Richard et al. (2009). The conceptual model proposes two hypotheses, which are presented in Fig. 2.

Hypothesis I: The organizational and technological mechanisms (OM and TM), the four types of knowledge processes (KR, KA, KD, KU) and their interactions with the business performance construct (BP) within the context of construction firms is expected to form a holistic KM system.

A Capability-based Holistic KM System within the Context of Construction Firms

Fig. 2. Conceptual model
Table 1. Conceptualization of the Conceptual Model Constructs

<table>
<thead>
<tr>
<th>Knowledge-governance mechanisms: Two constructs represent the two primary mechanisms, i.e., people-centered approaches and technological approaches (Anumba 2009; Egbu 2006; Scholl et al. 2004)</th>
<th>Knowledge processes: Four constructs represent the most important knowledge processes proposed by published KM frameworks and empirical studies (Chen and Mohamed 2007; Darroch 2003; Gold et al. 2001; Heisig 2009)</th>
<th>Business performance (BP): One construct measures the performance from the four perspectives of the BSC (Kaplan and Norton 1996b, 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational mechanisms (OM) represent the mechanisms that encourage innovations, provide leadership and strategic guidance for knowledge initiatives, and support open communications (Chen and Mohamed 2008b; Egbu 2006).</td>
<td>Responsiveness to knowledge (KR) epitomizes the process that comprises knowledge activities in response to the various types of knowledge a firm has access to externally and in the internal environment (Chen and Mohamed 2007; Darroch 2003).</td>
<td>The four dimensions of the BP construct: Financial performance measures the economic consequences of actions already taken.</td>
</tr>
<tr>
<td>Technological mechanisms (TM) represent the mechanisms that help develop and apply ICT systems (Chen and Mohamed 2008b; Egbu 2006).</td>
<td>Knowledge acquisition (KA) denotes the process that involves seeking and acquiring knowledge from the external environment and creating new knowledge on the basis of existing knowledge within the firm (Chen and Mohamed 2007; Darroch 2003; Gold et al. 2001)</td>
<td>Performance from customer perspective measures the firm’s performance within the target market segments.</td>
</tr>
<tr>
<td></td>
<td>Knowledge dissemination (KD) characterizes the process of creation and maintenance of structures, systems, and interactive themes for sharing and retaining knowledge within the firm (Chen and Mohamed 2007; Darroch 2003).</td>
<td>Performance from internal business process perspective measures the internal business process derived from explicit strategies to meet shareholders’ and target clients’ expectations.</td>
</tr>
<tr>
<td></td>
<td>Knowledge utilization (KU) represents the process of the utilization of knowledge (Chen and Mohamed 2007; Gold et al. 2001).</td>
<td>Performance from learning and growth perspective measures the infrastructure (people, system, and organizational procedures) a firm builds to create long-term growth and improvement.</td>
</tr>
</tbody>
</table>

KD and KU), and the business performance (BP) are positively associated with each other, forming a cyclic system.

Hypothesis II: The knowledge processes (KR, KA, KD and KU) mediate the effect of the organizational and technological mechanisms (OM and TM) on business performance (BP).

Research Methods

Participants and Procedures

The literature review showed that extensive evidence had been derived from construction-related studies, which had followed the inductive portion of the theory-building process (Carlile and Christensen 2006) and employed approaches of observation, categorization, and association to reveal insights into KM applications within the context of construction firms. This study sought to extend the theory-building cycle into the deductive portion by testing the hypotheses that had been inductively supported (Carlile and Christensen 2006), i.e., to begin with an abstract, logical relationship between the constructs, then move toward concrete empirical evidence (Neuman 2003). A questionnaire survey was administered to elicit the opinions of managerial and professional staff members of construction firms to provide cross-sectional data about knowledge-related governance mechanisms, processes, and business performance. As presented in the Appendix, the survey instrument used five-point Likert scales to measure the operationally defined constructs of the proposed conceptual model.

Large- and medium-sized construction contracting firms operating in Hong Kong were chosen as the theoretical population on the basis of two primary considerations. First, large- and medium-sized contractors are important sources and adopters of innovations that improve construction technologies and integrate different activities and knowledge introduced by different parties in the construction process (Miozzo and Dewick 2002). Secondly, contractors in Hong Kong worked within a very dynamic and competitive market, in which a large number of firms competed for a declining volume of work at the time of the study (Chan et al. 2005; Chiang et al. 2008). Randomly drawn from two trade directories, the List of Approved Contractors for Public Works [Environment, Transport and Works Bureau (ETWB 2005)], and the Members List of the Hong Kong Construction Association (HKCA) (HKCA 2005), the sampling frame comprised 260 contractors, including 109 Group C contractors for public works with contract values exceeding HK$50 million (ETWB 2005) and 125 Group B contractors for public works with contract values of up to HK$50 million. Some Group A contractors (for public works with contract values of up to HK$20 million (ETWB 2005)) and in-house contractors of major developers, were also considered as a part of the sampling frame. Following Sekaran’s (2000) suggestion on the sampling process, no more than three managerial and professional staff members who were knowledgeable about KM implementation were chosen from each firm of the sampling frame to provide opinions about KM in a particular firm. Well-informed respondents were also selected to reduce the psychological biases faced by fully subjective measures (Richard et al. 2009).

The questionnaire was pretested with 10 contractors in Hong Kong to evaluate its clarity, bias, ambiguous questions, and relevance to the business environment and operations of Hong Kong contractors. The data-collection process began after the questionnaire had been finalized, on the basis of the pretest feedback. Over a four month period in 2005, valid responses were provided by 99 companies, representing about 38% of the sampling frame. Subsequent to data preparation, a total of 149 usable responses were kept in the data set. Given that 500 questionnaires were distributed, the response rate was 30%, which is acceptable according to Sekaran (2000). The responses were considered a good representation of the opinions of the population, because the majority of the respondents were experienced in construction operations and knowledgeable about KM implementation-related issues within...

Table 2. Demographic Information of Respondents

<table>
<thead>
<tr>
<th>Respondents feature</th>
<th>Frequency</th>
<th>Percentage (%)</th>
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<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Over 40</td>
<td>117</td>
<td>78.5</td>
</tr>
<tr>
<td><strong>Educational background</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A bachelor’s degree or higher</td>
<td>123</td>
<td>82.6</td>
</tr>
<tr>
<td><strong>Position</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top management</td>
<td>48</td>
<td>32.2</td>
</tr>
<tr>
<td>Senior professional staff members</td>
<td>70</td>
<td>47.0</td>
</tr>
<tr>
<td><strong>Professional industry experience</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mean = 21.1 years; median = 23.0 years; standard deviation = 7.4 years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 10 years</td>
<td>136</td>
<td>91.3</td>
</tr>
<tr>
<td><strong>Years working for the company</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mean = 10.4 years; median = 9.0 years; standard deviation = 7.0 years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 5 years</td>
<td>113</td>
<td>75.8</td>
</tr>
<tr>
<td><strong>Company category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local contractors</td>
<td>92</td>
<td>61.7</td>
</tr>
<tr>
<td>Branches or subsidiary companies of overseas corporations</td>
<td>32</td>
<td>21.5</td>
</tr>
<tr>
<td>Branches of state-owned enterprises of the People’s Republic of China</td>
<td>23</td>
<td>15.4</td>
</tr>
<tr>
<td><strong>Company annual turnover</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than HK$100 million</td>
<td>35</td>
<td>23.5</td>
</tr>
<tr>
<td>HK$100–500 million</td>
<td>34</td>
<td>22.8</td>
</tr>
<tr>
<td>HK$500–1,000 million</td>
<td>18</td>
<td>12.1</td>
</tr>
<tr>
<td>HK$1,001–5,000 million</td>
<td>33</td>
<td>22.2</td>
</tr>
<tr>
<td>&gt;HK$5,000 million</td>
<td>26</td>
<td>17.4</td>
</tr>
</tbody>
</table>

their firms. The demographic information of the respondents is summarized in Table 2.

**Analytical Approach**

Building on the findings derived from Chen and Mohamed’s (2007, 2008a, b) exploratory study, the technique of SEM was employed to provide a transition from exploratory to confirmatory analysis (Hair et al. 1998). During the data analysis process, confirmatory factor analysis (CFA) was first used to confirm the structures of the measurement scales developed by Chen and Mohamed (2007, 2008a, b). Then, on the basis of the scales of higher validity and reliability, a structural regression (SR) model was estimated to simultaneously examine a series of dependence relationships, including the potential feedback links between the seven constructs (OM, TM, KR, KA, KD, KU, and BP). Version 17 of AMOS (Analysis of Moment Structure), the SEM software, was used to perform the CFA and estimate the SR model. In this study, maximum likelihood estimation (MLE) was adopted as an estimation method for SEM analysis, because MLE is the preferred method for most model-fit indexes, particularly when the sample size is relatively small (Shah and Goldstein 2006). Given that the sample size was medium (between 100 and 200) (Kline 2005) and the data was slightly multivariate nonnormal, a bootstrap procedure was performed across 1,000 bootstrap samples to assess the stability of the modeling results (Mathieu et al. 2008). Data-screening techniques were applied to all variables to assess their distribution and ensure that normality and linearity were reasonably upheld (Hair et al. 1998).

**Data Analysis and Results**

**Confirmatory Factor Analysis**

The relations between the observed measurement variables and the underlying factors identified by the exploratory factor analysis (EFA) in Chen and Mohamed’s study (2007, 2008a, b) were postulated a priori and then tested by CFA (Byrne 2001). The first-order CFA model of each construct was then evaluated by statistical means to determine the adequacy of its goodness of fit to the sample data. The model-generating approach was adopted in the CFA to improve the parsimony of the scale structure (Byrne 2001), the convergent and discriminant validity (Kline 2005), and the dimensionality of the measurement scales of the seven constructs (Kline 2005). The fit indexes presented in Table 3 indicate a very good overall model fit of the final CFA models. Modification indexes reveal an absence of factor-cross loadings and error covariances. Consistent with the MLE results of the original sample, 95% bias-corrected confidence intervals suggest sound feasibility of regression weight estimates that are significant at $p < 0.05$ level (Byrne 2001). In addition, the correlation values between factors are much lower than the limit of 0.85, indicating good discriminant validity (Kline 2005). The reliability coefficients (Cronbach’s alpha) of all scales are above 0.80, reflecting very good consistency (Kline 2005). In view of the foregoing, the measurement scales represented by the final CFA models are considered of good validity and very good reliability to measure the constructs in the subsequent SR modeling. The measurement scales of the seven constructs are presented in the Appendix. The Appendix shows that the CFA removed the financial performance factor (PF) from the scale of the BP construct to achieve better fit. The reason could be that some respondents might provide ambiguous ratings for

<table>
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<tr>
<th>Table 3. Reliability and Model-Fit Indexes of the Final CFA Models</th>
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<tbody>
<tr>
<td><strong>Model-fit indexes</strong></td>
</tr>
<tr>
<td>Chi-square ($\chi^2$)</td>
</tr>
<tr>
<td>Normed Chi-square: $\chi^2/df$ (df: degree of freedom)</td>
</tr>
<tr>
<td>$p$ (probability level)</td>
</tr>
<tr>
<td>Bollen-Stine bootstrap $p$ (computed across 1,000 bootstrap samples)</td>
</tr>
<tr>
<td>RMR (root-mean square residual)</td>
</tr>
<tr>
<td>GFI (goodness-of-fit index)</td>
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<tr>
<td>AGFI (adjusted goodness-of-fit index)</td>
</tr>
<tr>
<td>NFI (normed-fit index)</td>
</tr>
<tr>
<td>CFI (comparative-fit index)</td>
</tr>
<tr>
<td>RMSEA (root-mean square error of approximation)</td>
</tr>
<tr>
<td>Reliability: Cronbach’s alpha</td>
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$a$References: Byrne 2001; Hair et al. 1998; Kline 2005.

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financial performance indicators because of a lack of clear awareness of their firms’ financial positions at the time of the survey. As a result, the actual distribution of the values of the two financial indicators could become distorted.

**Structural Regression Model Estimation**

Pearson’s product-moment correlation was performed to determine the extent to which the seven constructs are linearly related (Jaccard and Becker 1997). As shown in Table 4, the Pearson correlation \( r \) values between the seven constructs range from 0.73 to 0.27 and are significant at \( p < 0.01 \) level (2-tailed), indicating positive correlations between them. The results of this correlation analysis, the proposed relationships of the conceptual model, and the results of the regression analysis derived from Chen and Mohamed’s study (2007, 2008a, b) provided potential relationships for specification of the initial SR model that was theoretically justified and could be empirically supported (Hair et al. 1998). The potential feedback links asserted by the dynamic capabilities view (Zollo and Winter 2002), the KGA (Foss 2007), and strategic learning (Pietersen 2010; Stacey 2003) were also included in the initial model for testing. In view of the medium sample size (Kline 2005), the measurement component of the initial SR model was specified as a partial aggregation model (Bagozzi and Edwards 1998), in which all indicators for a factor are aggregated and the aggregations serve as indicators of a construct, as presented in Fig. 3. The principal advantages of the partial aggregation model lie in its capacity to reduce the number of parameters to be estimated and to decrease measurement error, particularly when the sample size is relatively small (Bagozzi and Edwards 1998). The model-generating strategy was adopted in the SR model estimation to “discover” a model with two properties: the model makes theoretical sense, and its statistical correspondence to the data is reasonable (Kline 2005).

**Table 4. Descriptive Statistics and Correlations**

<table>
<thead>
<tr>
<th>Constructs of the conceptual model</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>OM</th>
<th>TM</th>
<th>KR</th>
<th>KA</th>
<th>KD</th>
<th>KU</th>
<th>BP</th>
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<tbody>
<tr>
<td>Organizational mechanisms (OM)</td>
<td>1.67</td>
<td>5.00</td>
<td>3.58</td>
<td>0.58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Technological mechanisms (TM)</td>
<td>1.00</td>
<td>5.00</td>
<td>3.61</td>
<td>0.68</td>
<td>0.53</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responsiveness to knowledge (KR)</td>
<td>2.17</td>
<td>5.00</td>
<td>3.86</td>
<td>0.56</td>
<td>0.62</td>
<td>0.45</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge acquisition (KA)</td>
<td>2.38</td>
<td>5.00</td>
<td>3.66</td>
<td>0.52</td>
<td>0.58</td>
<td>0.49</td>
<td>0.71</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge dissemination (KD)</td>
<td>1.57</td>
<td>5.00</td>
<td>3.50</td>
<td>0.62</td>
<td>0.70</td>
<td>0.52</td>
<td>0.68</td>
<td>0.73</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge utilization (KU)</td>
<td>2.00</td>
<td>5.00</td>
<td>3.85</td>
<td>0.60</td>
<td>0.56</td>
<td>0.37</td>
<td>0.65</td>
<td>0.51</td>
<td>0.65</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Business performance (BP)</td>
<td>1.40</td>
<td>4.40</td>
<td>3.26</td>
<td>0.46</td>
<td>0.40</td>
<td>0.27</td>
<td>0.51</td>
<td>0.42</td>
<td>0.58</td>
<td>0.54</td>
<td>1.00</td>
</tr>
</tbody>
</table>

\( ^{a} \)Correlation is significant at the 0.01 level (2-tailed).

![Fig. 3. Structural regression model](source)
In the model fitting process, the insignificant links \((p > 0.05)\) were deleted. The 95% bias-corrected confidence intervals indicate that regression weight-parameter estimates in the final SR model are significant at the \(p < 0.05\) level (Byrne 2001). Fig. 3 shows the final SR model with its significant paths and deleted insignificant links. The model has significant feedback paths from the BP to the KR and KD constructs and from KR to OM. In addition, according to the procedures suggested by Kenny et al. (1998), the fitted model confirmed that the knowledge-processes constructs completely mediate the relationship between OM and BP \((r = 0.40, \text{see Table 4})\), and that between TM and BP \((r = 0.27)\). Moreover, as shown in Table 5, both absolute- and incremental-fit indexes of the final SR model are indicative of a good fit to the data. In view of this, the final SR model has a very good fit to the data and provides significant support for both Hypotheses I and II.

The final SR model provides statistical evidence that variance of OM and TM would influence the BP level through the interactions of the knowledge processes, whereas variance of BP would provide feedback to OM and TM through knowledge processes. In other words, the final SR model endorses Hypothesis I, namely that the organizational and technological mechanisms, the four types of knowledge processes, and the business performance are positively associated with each other, forming a cyclic system. This finding suggests that a conducive OM would encourage knowledge dissemination and help produce a better TM to facilitate the acquisition of knowledge. Effectively acquired and disseminated knowledge would then be used in business operations to achieve a certain level of BP. Changes in BP would in turn provide further guidance for the firm to respond to changes in both internal and external environments and to disseminate knowledge more actively. Meanwhile, a higher level of responsiveness to knowledge would influence OM positively. The model also reveals that OM appears to have a stronger effect on both the knowledge processes and TM, providing extra insight for the shift of attention from the information-technology (IT) perspective to organizational aspects of KM (Scholl et al. 2004). In addition, the SR model reveals that OM’s influence on KA is mediated by TM, suggesting the essential role of technological mechanisms in acquiring knowledge in the internet era. In the meantime, the model also indicates that TM’s effect on KD is mediated by KA, implying that a large proportion of knowledge is acquired with the support of ICT infrastructures, whereas the degree to which knowledge gets shared and disseminated depends primarily on the cognitive context produced by OM, which encourages innovation and open communication.

The final SR model also upholds that the knowledge-process constructs (KA, KD, KR, Ku) completely mediate the relationships between the governance mechanisms constructs (OM and TM) and the BP, according to the criteria set by Kenny et al. (1998), thereby supporting Hypothesis II. This empirical evidence supports the primary argument of the KGA, i.e., that governance mechanisms can be deployed in the belief that influencing the conditions of actions in a certain manner will lead employees to take those actions that, when aggregated, lead to favorable organizational outcomes (Foss 2007). Furthermore, the squared multiple-correlation value in the final SR model suggest that the model explains and predicts 35.1% of the variance in the BP construct (Kline 2005), indicating that learning mechanisms formed by the interactions between the knowledge-governance mechanisms and processes have a significant degree of effectiveness in predicting the level of BP, thus deserving strategic attention.

### Concluding Discussion

#### Theoretical Implications

The study findings are congruent with the main arguments of the KBV (Grant 1996a; Spender 1996), the KGA (Foss 2007), the dynamic capabilities view (Eisenhart and Martin 2000; Helfat et al. 2007; Teece 2007; Teece et al. 1997; Zollo and Winter 2002), and strategic learning (Kaplan and Norton 1996a; Pietersen 2010), and lead to three main conclusions. First, the learning mechanisms of the firm comprise both knowledge processes and related governance mechanisms. Second, the effect of the governance mechanisms on the business performance needs to be realized through knowledge processes that are integrated into day-to-day business operations. Third, the performance-measurement outcomes trigger strategic learning through knowledge processes that offer feedback to the government mechanisms. The conclusions imply that it is feasible for the management of construction firms to govern learning mechanisms through managing the capability-based holistic KM system, thereby driving the evolution of KMC to match with needs in a dynamic market environment.

The analysis revealed that different knowledge processes are related to each other in a cyclic pattern that can be described as the knowledge-processes cycle. This finding provides evidence from the construction context for interactions between the different kinds of knowledge processes, which has been asserted by many of the KM frameworks theoretically proposed within the past decade (Heisig and Orth 2007). The finding also implies that organizational knowledge evolves through a series of stages chained in a recursive cycle, as described by Zollo and Winter (2002). The analysis endorses the significance of the feedback links from performance measurement outcomes to knowledge processes, and in turn to knowledge-governance mechanisms, which underscores the two-way interactions between them, thereby revealing the essential role of an evaluation and control process in improving the conduciveness of the governance mechanisms asserted by the KGA (Foss 2007) and strategic learning (Kaplan and Norton 1996a; Stacey 2003). The analysis highlights the important governance function of the organizational mechanisms in this multiple-loop KM system. It appears that the organizational mechanisms not only have a greater capacity to influence the extent to which individuals of the firm engage in knowledge-related actions and interactions, but also are influenced by the variance of the knowledge-processes cycle. Moreover, the mechanisms seem to fully mediate the effect of the knowledge-processes cycle on the technological mechanisms. This finding mirrors the priority shift toward human factors.

### Table 5. Model-Fit Indexes of the Final SR Model

<table>
<thead>
<tr>
<th>Model-fit indexesa</th>
<th>Value representing a well-fitting model</th>
<th>Final SR Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-square ((\chi^2))</td>
<td>71.81</td>
<td></td>
</tr>
<tr>
<td>Normed Chi-square: (\chi^2 / df)</td>
<td>(1.0−2.0)</td>
<td>1.28</td>
</tr>
<tr>
<td>(p) (probability level)</td>
<td>(&gt;0.05)</td>
<td>0.08</td>
</tr>
<tr>
<td>Bollen-Stine bootstrap (p)</td>
<td>(&gt;0.05)</td>
<td>0.37</td>
</tr>
<tr>
<td>RMR (root-mean square residual)</td>
<td>(&lt;0.05)</td>
<td>0.02</td>
</tr>
<tr>
<td>GFI (goodness-of-fit index)</td>
<td>(&gt;0.90)</td>
<td>0.93</td>
</tr>
<tr>
<td>NFI (normed-fit index)</td>
<td>(&gt;0.90)</td>
<td>0.94</td>
</tr>
<tr>
<td>CFI (comparative-fit index)</td>
<td>(&gt;0.95)</td>
<td>0.99</td>
</tr>
<tr>
<td>RMSEA (root-mean square error of approximation)</td>
<td>(&lt;0.05)</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*aReferences: Byrne 2001; Hair et al. 1998; Kline 2005.*
in recent theoretical advancements in KM (Scholl et al. 2004). In addition, the finding is in line with the social cognitive theory that although ICT plays an increasingly important role in facilitating knowledge acquisition, the degree to which acquired knowledge gets shared and disseminated depends primarily on the cognitive context produced by organizational mechanisms that encourage innovation and open communication (Nooteboom 2009).

In general, the study findings imply that KM behaviors and organizational outcomes (e.g., business performance) could be the result of the interactions of multiple interdependent processes as asserted by Zollo and Winter (2002). This, in the language of the KGA, means that by “pulling the levers of formal organization” (Foss and Michailova 2009, p. 276), i.e., manipulating a KM system, management would be able to control the learning mechanisms of the firm to a greater degree, which would ultimately offer better KMC to improve performance. According to the dynamic capabilities view (Eisenhart and Martin 2000, Helfat et al. 2007; Teece 2007; Zollo and Winter 2002), in the long run such efforts could give management more power to control the evolutionary path of the firm. Furthermore, the study endorsed the feasibility of measuring the effectiveness of the KM system in realizing strategic objectives, given that integrating knowledge into the production processes requires resources and incurs costs (Reus et al. 2009; Zollo and Winter 2002), and that all the key components of the KM system are measurable, as demonstrated by the empirical model established by this study. Therefore, it can be asserted, with empirical support, that although knowledge is largely tacit and its validity hard to evaluate, the effectiveness of a KM system that is purposely designed to govern the learning mechanisms for achieving a firm’s long-term ambitions, can in fact be measured from a capability perspective.

Managerial Implications

The evidence derived from this study indicates that the essence of KM is to develop a capability-based holistic KM system that effectively governs learning mechanisms for the purpose of developing KMC to sustain knowledge-based competitive advantage in the increasingly dynamic and competitive market. To fulfill this purpose, firms need to consider establishing a holistic rather than a segmented KM system, i.e., the KM system should comprise not only knowledge processes but also knowledge-governance mechanisms, and include a control and evaluation process. The focus of attention thus should be on identifying and strengthening the knowledge-governance mechanisms and knowledge processes through proper assessment, evaluation, and modification against a firm’s strategic needs. The measurement scales developed by this study can help contractors to map and assess the level of development of knowledge-governance mechanisms and processes within their firms, as well as performance outcomes. Meanwhile, the multiloop KM system implies that evaluating, planning, implementing, and controlling it requires system thinking, in which “you can’t just do one thing” because “everything is connected to everything else” (Sterman 2000, p. 4). The analysis provided additional empirical support for the widely accepted view that knowledge processes mutually complement each other and require coordination (Heisig 2009). This means that failing to address any process category would affect the whole knowledge-processes cycle. Therefore, a specific combination of organizational and technological mechanisms needs to be created to facilitate a special set of knowledge processes designed for a particular strategic objective. In addition, as learning mechanisms evolve with changing market conditions, strategic planning needs to foresee the effect of changes in order to adjust resource allocation, i.e., “learning investments” (Zollo and Winter 2002, p. 345), to facilitate the necessary evolution of a KM system that is required to govern the learning mechanisms. This raises concern over the balance between the costs of the capability (i.e., KMC) and the use that is actually made of it (Zollo and Winter 2002). Thus, special analytical tools are needed to assist construction firms to assess the effectiveness of their KM system dynamically, by taking into consideration the interactions of the dynamic factors (including resource availability) and their evolution through time.

Limitations and Future Research

Given that the study only employed a cross-sectional design and tested a sample of just one type of construction firm (contractors) in one geographical region (Hong Kong) because of resource constraints, further research studies employing qualitative and/or quantitative approaches are still needed to provide more insight into how to identify and integrate a KM system within the strategic management system currently adopted by construction firms. Most of firms in the sample of this study were not publicly listed companies. Because of their need for commercial confidentiality, objective financial and market-performance data were very difficult to obtain from these firms. Future survey studies may consider incorporating objective performance data (e.g., from publicly listed firms) to validate the findings of this study. In addition, the SR model significantly explains and predicts 35.1% of the variance in the BP construct, which means that variance in BP might also depend on other factors, such as resources availability (Zollo and Winter 2002) and strategic networks (Dyer and Hatch 2006; Gulati et al. 2000; Zaheer and Bell 2005). Future studies might consider including more factors based on the recent advancement of theoretical assertions, e.g., the capability implications of strategic networks (Dyer and Hatch 2006; Zaheer and Bell 2005), into their conceptual models for testing. Moreover, studies that attempt to create measurement for the KM system would benefit from a larger sample size and greater sample diversity (e.g., sizes and types of organizations, cultural contexts) to achieve better generalizability.

In addition, empirical analysis using the general linear model has limitations in studying the interactions of multiple interdependent organizational processes, which typically produce nonlinear system behavior with feedback (Harrison et al. 2007). Within this context, more systematic methodology such as simulation modeling may prove useful for both scientific investigation and theory development (Davis et al. 2007; Sterman 2000). Therefore, future investigations would benefit from a system dynamics (SD) approach in modeling the dynamics of the complex multiple-loop system (Sterman 2000) that affects evolution of learning mechanisms in real-life industrial situations. Evidence can also be obtained from in-depth case studies (Yin 2009), through interviews, focus group discussions, and field study approaches, which reveal how learning mechanisms drive the evolution of KMC over time within a dynamic market environment.

Appendix. Measurement Scales Developed by the CFA

Governance Mechanisms Constructs

Organizational Mechanisms

Survey question: “Please indicate your opinions about the current internal organizational environment in your company. In our company . . .”
(Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree)

Factor 1: Organizational creative mechanisms (OCM)
- Formal and informal innovation activities are integrated
- Innovations are rewarded
- Innovations to deliver better cost-effectiveness are encouraged
- Divisions, departments, construction sites often work jointly on innovations
- Interdisciplinary team work is encouraged

Factor 2: Organizational supportive mechanisms (OSM)
- We have shared vision for managing organizational knowledge
- We have committed leadership to manage organizational knowledge
- Problems/ errors are discussed openly
- Team look to see how they can contribute more to the company

Technical Mechanisms
Survey question: “Please indicate your opinions about the current internal technical environment in your company. In our company . . .”
(Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree)
- Senior management support IT development
- IT applications are designed to share information across the whole organization
- Employees are trained to use IT
- IT is adopted with a view to change traditional business processes
- Interaction is established between end-users and IT professionals
- IT is designed to aid efficient decision-making

KM Processes Constructs
Survey question: “Please indicate your opinions about the intensity of KM activities in your company. Our company…”
(Scale: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree)

Responsiveness to Knowledge
Factor 1: Response to market knowledge (KRM)
- Periodically reviews the likely effect of technological changes on clients
- Effectively implements our marketing plans
- Keeps up to date with technological developments that could affect our business

Factor 2: Response to clients’ needs (KRC)
- Responds quickly to any complaint raised by clients
- Promptly acts if clients are unsatisfied with the quality of our service
- Responds positively to changes in clients’ product or service needs

Knowledge Acquisition
Factor 1: Market knowledge acquisition (KAM)
- Actively and timely collects information about our competitors
- Drives business direction according to the changes in market needs
- Undertakes structured and meaningful market research
- Occasionally meets with major clients to find out their future needs
- Frequently acquires new business ideas through working with others

Factor 2: Financial knowledge acquisition (KAF)
- Analyses regularly the financial contribution of our projects or services
- Has good financial information about our business operations
- Knows how much each of our projects costs us

Knowledge Dissemination
Factor 1: Tacit knowledge dissemination (KDT)
- Encourages open communication
- Actively encourages staff mentoring or coaching
- Regularly records internal best practices
- Frequently reviews all aspects of the business

Factor 2: Explicit knowledge dissemination (KDE)
- Periodically circulates documents (e.g., reports and newsletters) about our business achievements to external stakeholders
- Frequently updates policy and procedure manuals
- Circulates written reports to disseminate knowledge

Knowledge Utilization
- Uses accumulated knowledge to solve new problems
- Is able to apply knowledge to changing competitive conditions
- Uses shared knowledge to improve efficiency
- Applies knowledge learned from mistakes

Business Performance Construct
Survey question: “To the best of your knowledge, please circle the number which you feel estimates how your company compare to the average level of immediate competitors (contractors) in Hong Kong on each item, within the past financial year . . .”
(Scale: 1 = much less, 2 = less, 3 = same, 4 = more, 5 = much more)

Factor 1: Performance from financial perspective (PF) (removed during CFA)
- Average profit
- Average return on investment

Factor 2: Performance from customer perspective (PC)
- Ability to gain contracts
- Market share

Factor 3: Performance from internal business process perspective (PP)
- Streamline internal processes
- Increase working to schedule
- Rapidly commercialize new innovations

Factor 4: Performance from learning and growth perspective (PL)
- The level of employee satisfaction
- Employees’ motivation to act in the best interest of the company
- Employees’ freedom to take to make decisions and take actions
- The productivity of employees
• Ability of our existing information system to provide rapid, timely and accurate information about market and business operations

References


