Knowledge Management and Innovation Performance in the Context of Global High-Tech Firms

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ABSTRACT: This paper examines how knowledge management affects innovation performance in the context of biotechnology: a global high-tech industry. We conceptualize KM as a set of practices and dynamic capabilities, and hypothesize that KM dynamic capabilities act as a mediating variable between KM practices and innovation performance. We use structural equation modeling to test the hypotheses on a data set from the biotechnology industry. The results support our conceptualization and demonstrate its utility in explaining differences in innovation performance across firms. Findings provide useful recommendations for decision-makers.

Subject Areas: Knowledge Management, Dynamic capabilities, Innovation, Structural Equation Modeling.

INTRODUCTION

A principal concern articulated in strategic management research is to understand reasons for performance differences among firms (Nelson, 1991). The resource-based view of the firm offers an explanation for this phenomenon: the possession of unique organizational practices implies that some firms outperform others and, therefore, represent the main source of sustainable competitive advantage. Currently, this explanation is being complemented by taking into account the role of dynamic capabilities in achieving such sustainability: dynamic capabilities allow the firm to reconfigure its set of practices in order

to adapt them to environmental changes (Kogut & Zander, 1992; Teece, Pisano, & Schuen, 1997; Zott, 2003; Teece, 2007).

In parallel with this issue, researchers are devoting particular attention to knowledge management (KM). Knowledge, in its different manifestations (organizational practices, technology, know-how, etc.), is regarded as a crucial resource for competitive advantage (Grant, 1996a; Brockman & Morgan, 2003). In general, the performance of organizations depends on the extent to which managers can mobilize all of the knowledge resources at their disposal and turn them into value-creating activities (von Krogh, 1998). However, prior research has usually focused on specific aspects of the creation and the application of knowledge such as preconditions for effective KM (Hult & Ferrell, 1997; Gold, Malhotra, & Segars, 2001; Janz & Prasarnphanich, 2003), knowledge stocks and flows (Argote & Ingram, 2000; Tallman, Jenkins, Henry, & Pinch, 2004), teamwork (Nonaka & Takeuchi, 1995; Fedor, Ghosh, Caldwell, Maurer, & Singhal, 2003), or identification and transfer of internal best practices (O'Dell & Grayson, 1998). As a consequence, the study of KM remains difficult because there is a need for greater clarity about the domain and operationalization of this construct.

This study clarifies and measures the contribution of KM to innovation performance and thereby to competitive advantage. We propose a global conceptualisation of KM as a set of practices and dynamic capabilities. We formulate and test hypotheses on the respective effects of KM practices and dynamic capabilities on innovation performance in the context of biotechnology firms. The biotech industry is especially interesting due to its knowledge-intensive condition and its specific global nature: the marketing of biotech products and services, the competition in the sector, and the sources such as finance, technology, or human resources fuelling the biotech industry are international (Khilji et al., 2006; Gurau & Ranchhod, 2007; Pla-Barber & Alegre, 2007).

We make two contributions to the literature. First, we conceptualize KM as a firm function constituted by organizational practices and dynamic capabilities that can create sustainable competitive advantage. This distinction between practice and dynamic capabilities facilitates the analysis of KM and explains how new repertories of KM practices and dynamic capabilities are created on a continuous basis in order to adapt the firm to change. Previous research has shown a positive link between several individual KM practices, such as organization of teamwork for achieving transfers of tacit knowledge within groups, and innovation performance (Nonaka & Takeuchi, 1995; Brown & Eisenhardt, 1995). However, a wider focus that takes into account the impact of KM practices *and* dynamic capabilities is still missing from extant literature. Futhermore, dynamic capabilities have often been considered without specifying the nature of the capability (Teece et al, 1997). Recent empirically-based studies are conceptualizing and using specific dynamic capabilities dealing with acquisitions (Zollo & Singh, 2004), alliances (Kale, Dyer, & Singh, 2002), R&D (Henderson & Cockburn, 1994; Yeoh & Roth, 1999), marketing (Morgan, Zhou, Vorhies, & Katsikeas, 2003), or joint new product development (Ettlie & Pavlou, 2006). Therefore, our study extends the range of specific dynamic capabilities considered in the literature by conceptualizing and implementing KM dynamic capabilities in the context of innovation.

Second, we explain intra-industry differences in innovation performance in global high-tech firms as a function of the interaction between KM practice and KM dynamic capability. The discussion of this finding is culminated with the proposal of a decision-making protocol for KM issues.

Following Ray, Barney, and Muhanna (2004), we have deliberately chosen to focus on the process-level in order to offer a more accurate analysis of the link between practices and dynamic capabilities and results. By examining innovation performance and not overall firm performance we avoid confounding the impact of other firm actions that do not belong

to the knowledge management and innovation domain or may contribute differentially to overall performance. However, we also note that according to prior research, innovation performance is closely linked to export performance (Bonaccorsi, 1992; Roper & Love, 2002; Pla-Barber & Alegre, 2007) and overall performance (Nelson, 1991; Calantone, Cavusgil, & Zhao, 2002; West & Iansiti, 2003; Hult, Hurley, & Knight, 2004), especially in the case of high-technology industries. Therefore, it is reasonable to assume that innovation performance is positively related to competitive advantage.

THEORY, HYPOTHESES AND MODEL BUILDING

Knowledge Management and the Resource-Based View

The resource-based view of the firm (RBV) is an influential theoretical framework for understanding the creation and sustainability of competitive advantage and therefore for explaining why firms perform differently (Barney, 1991; Hitt, Bierman, Shimizu, & Kochhar, 2001). This perspective assumes that firms can be conceptualized as bundles of resources, that these resources are heterogeneously distributed across firms, and that resource differences might persist over time (Teece et al., 1997). Based on these assumptions, it has been theorized that valuable and rare resources constitute the foundation of competitive advantage. The advantage becomes sustainable when these resources are also inimitable and nonsubstitutable (Dierickx & Cool, 1989; Barney, 1991).

The knowledge-based view (KBV) of the firm has emerged in the strategic management literature building upon and extending the RBV. Given assumptions about the characteristics of knowledge and the knowledge requirements of production, the firm is conceptualized as an institution for creating and integrating knowledge (Grant, 1996a). Knowledge is embedded in multiple entities within the firm, such as individual employees, organizational culture, routines, policies, systems and documents (Nelson & Winter, 1982; Alavi & Leidner, 2001).

Fundamentally, KM consists of the creation and application of knowledge as a resource (Spender, 1996; Grant, 1996a; Morgan et al., 2003). The KBV focuses upon knowledge as the most strategically important resource at a firm's disposal. Researchers working on this perspective suggest that the processes by which knowledge is created and utilized in organizations may be the key inimitable resource that managers should recognize, for the purpose of creating sustainable rents (Grant, 1996a, 1996b). There is some empirical evidence on a positive effect of knowledge creation (Nonaka & Takeuchi, 1995) and of knowledge stocks and flows on firm performance (DeCarolis & Deeds, 1999). Effective KM may contribute to better performance in several business processes such as the implementation of best practices and continuous improvement (Rijnders & Boer, 2004), operational problem-solving (Dutta & Van Wassenhove, 2000), functional integration (Takeuchi & Nonaka, 1986; Sosa, Eppinger, Pich, McKendrick, & Stout, 2002), and new product development (Ash & Smith-Daniels, 1999; Ettlie & Pavlou, 2006; Marsh & Stock, 2006).

However, prior research has generally focused on specific aspects of the creation and application of knowledge. Extant literature also lacks a global framework that examines the most relevant KM issues from a dynamic point of view. Further understanding is needed about the role of KM on explaining intra-industry differences in the context of innovation processes.

Organizational Practices and Dynamic Capabilities

Organizational practices are based on the application and use of knowledge. They are operational systems, local abilities and know-how that are fundamental to day-to-day problem solving. Starting from the RBV, strategic management scholars have showed that intangible, firm-specific, socially complex and causally ambiguous organizational practices such as TQM practices (Powell, 1995) or human-related IT practices (Mata, Fuerst, &

Barney, 1995; Powell & Dent-Micallef, 1997) are able to provide sustainable competitive advantage.

However, today's core capabilities can become tomorrow's core rigidities if the firm is not able to adapt them to environmental changes (Leonard-Barton, 1992). Therefore, researchers have focused on the mechanisms by which the firm is able to adapt its repertory of organizational practices to change. It has been proposed that dynamic capabilities allow the firm to integrate, build and reconfigure internal and external competencies to address rapidly changing environments. Dynamic capabilities are based on knowedge creation and may constitute some of the most enduring sources of competitive advantage since they allow the generarion of unique and continually updated configurations of organizational practices (Kogut & Zander, 1992; Teece et al., 1997). It is in this context that the concept of dynamic capabilities has been used to explain why firms in the same industry perform differently (Henderson & Cockburn, 1994; Zott, 2003).

Organizational practices and dynamic capabilities are very closely linked. The adoption and use of local practices create expertise and learning through accumulation of experience (Yeoh & Roth, 1999). Dynamic capabilities arise from learning (Zollo & Winter, 2002; Easterby-Smith & Prieto, 2008). Internal learning comes from an accumulation of experience with practices, as well as articulation and codication of knowledge. External learning comes from competitive intelligence and external collaborations (Bierly & Chakrabarti, 1996; Koufteros, Vonderembse, & Jayaram, 2005; Ettlie & Pavlou, 2006). The repertory of dynamic capabilities allows the firm to make subsequent changes and adaptations in local practices so that they do not become core rigidities (Leonard-Barton, 1992). There is continuous interaction between organizational practices and dynamic capabilities that lead to organizational renewal and competitiveness. Figure 1 shows the loop between practices and dynamic capabilities and connects it to business process performance.

This loop allows the renewal of both dynamic capabilities and practices, and can explain performance differences across firms in the same industry (Zott, 2003).

Insert Figure 1 about here

Conceptualizing KM Practice and KM Dynamic Capability

The basic components of KM are knowledge creation and application (Spender, 1996; Grant, 1996a; Sanchez, 2001; Argote et al., 2003; Hult, 2003). Knowledge creation depends on internal and external learning (Bierly & Chakrabarti, 1996). Effective knowledge application depends on knowledge retention (Moorman & Miner, 1997; Brockman & Morgan, 2003; West & Iansiti, 2003) and knowledge transfer (Alavi & Leidner, 2001; Hult, 2003; Sabherwal & Sabherwal, 2005). Knowledge retention and knowledge transfer allow the organization organize and make available important knowledge, wherever and whenever it is needed (Sabherwal & Becerra-Fernandez, 2003; Brockman & Morgan, 2003)

KM involves the application of knowledge through the operationalization of organizational practices (Alavi & Leidner, 2001). However, Lei, Hitt and Bettis (1996) suggest that dynamic capabilities also should be taken into account when conceptualising KM. Current KM practice may become inappropriate in the future; thus, KM dynamic capabilities are needed to reconfigure KM practice. New knowledge plays a crucial role in organizational transformation (Henderson & Cockburn, 1994; Zahra & George, 2002).

So, taking into account prior perspectives on KM, we propose that in an organization KM consist of its organizational practices and dynamic capabilities that involve respectively knowledge application and creation. Indeed, this duality is critical for sustainable competitive advantage (Henderson & Cockburn, 1994; Yeoh & Roth, 1999). Organizations can harness their KM practices and dynamic capabilities to outperform their competitors and settle intra-industry performance differences (Zott, 2003).

KM practice is the result of knowledge application and represents KM systems, local abilities and know-how that have been implemented in a firm-specific way so as to enable distinctive activities to be performed (Alavi & Leidner, 2001). KM practice deals primarily with implementation and day-to-day operations issues and therefore is operational and tactical in nature (Tallman et al., 2004). The literature points at two main KM practices: knowledge dissemination and storage.

Knowledge dissemination practices. Knowledge dissemination deals with the distribution of knowledge across the organization. Knowledge dissemination practices include processes that spread explicit and tacit knowledge across the organization, through formal and informal channels, in order to facilitate the application of knowledge. Informal channels are useful in exchanging ideas, but formal ones have the advantage of being more systematic (Zahra & George, 2002). Explicit knowledge is not hard to codify and disseminate. However, the dissemination of tacit knowledge is difficult and requires interaction among employees (Nonaka & Takeuchi, 1995; Fahey & Prusak, 1998). The benefits of knowledge dissemination are widely accepted (Argote & Ingram, 2000; Sabherwal & Sabherwal, 2005), however performance improvements have been found to be more heterogeneous and unpredictable when disseminating tacit knowledge (Edmondson, Winslow, Bohmer, & Pisano, 2003)

Knowledge storage systems. These systems refer to a class of information systems applied to managing operational knowledge. They are information technology based systems developed to support and enhance the processes of operational knowledge retrieval and storage (Alavi & Leidner, 2001; von Zedtwitz, 2002; Sabherwal & Sabherwal, 2005).

KM dynamic capability, on the other hand, focuses on knowledge creation and is more related to strategic formulation. KM dynamic capability refers to an organization's ability to reconfigure KM practice, i.e., integrating it in new and flexible ways to develop

new KM systems when required (Henderson & Cockburn, 1994; Tallman et al., 2004; Easterby-Smith & Prieto, 2008). Based on a review of extant literature, we propose the following two dimensions to capture the key aspects of the KM dynamic capability: external knowledge integration and internal knowledge development. These KM dynamic capability dimensions are enablers for reconfiguring practice: they are based on a double-loop learning approach since they imply the modification of an organization's implicit norms, practices and objectives (Argyris & Schön, 1978). They allow the firm to realize all the knowledge that is available through the operationalisation of KM practices (Zahra & George, 2002; Orlikowski, 2002).

External knowledge integration. This competence refers to the ability of the firm to integrate external knowledge so that it can be stored, disseminated and used in a firm-specific way (Grant, 1996b; Zahra & George, 2002). It denotes a firm's capability to reconfigure practices through transformation of knowledge (Zahra & George, 2002), e.g., by combining existing knowledge and new knowledge coming from technology acquisition and interaction with the environment and other organizations (Ettlie & Pavlou, 2006). Integrated external knowledge is included in the knowledge base of the firm and is an important input for the innovation process (Ancona & Caldwell, 1992a, 1992b; Kessler, Bierly, & Gopalakrishnan, 2000; Sosa et al., 2002; Chang, 2003).

Internal knowledge development. This competence refers to the ability of the firm to develop internal firm-specific knowledge (Grant, 1996b). Internal knowledge is developed mainly through R&D activities and best practices implementation (Cohen & Levinthal, 1990; O'Dell & Grayson, 1998; Cardinal & Hatfield, 2000). It is also included in the knowledge base of the firm and plays an important role in the innovation process (Cohen & Levinthal, 1990; Kessler et al., 2000).

Hypotheses

In the literature there is theoretical and some empirical support for a positive relationship between several specific KM practices and innovation performance. The theory proposed by Nonaka and Takeuchi on organizational knowledge creation conceives of knowledge as the main ingredient for innovation and for firm competitiveness (Nonaka, 1994; Nonaka & Takeuchi, 1995). Further, a number of researchers have suggested a positive contribution of knowledge and learning systems on innovation processes and outcomes (Wheelwright & Clark, 1992; Sanchez & Mahoney, 1996; Helfat & Raubitschek, 2000). There is also empirical evidence of the positive impact of learning and knowledge creation on innovation results (Kessler et al., 2000; Cardinal & Hatfield, 2000; Sarin & McDermott, 2003). Therefore, we expect to show the link between a global of KM practice and innovation outcome at a process level. Thus, we hypothesize:

Hypothesis 1: The adoption and use of KM practices has a positive relationship to innovation performance.

KM dynamic capability deals with the ability of firms to reconfigure KM practice when it is required. Therefore KM dynamic capability allows the organization to have a specific and difficult to imitate KM practice configuration. KM dynamic capability is used to deploy or combine KM practices in new and flexible ways to support organizational renewal: it has a booster effect on the effectiveness of KM practice (Zott, 2003; Grewal & Slotegraaf, 2007). Further, while KM systems may improve efficiency, they could also render the firm inflexible in dealing with novel situations as entrenched practices could create rigidities (Leonard-Barton, 1992). KM dynamic capability allows KM systems to adapt to change. We expect the positive effect between KM practice and innovation performance be mediated by KM dynamic capability. Support for our claim stems directly from the RBV (Teece, Pisano, & Schuen, 1997; Yeoh & Roth, 1999, Tippins & Sohi, 2003).

KM practice plays an important role in innovation processes but an outstanding efficient KM practice configuration is not sufficient to achieve better innovation performance on a continuous basis: it only implies a better innovation performance for a certain amount of time. Soon, competitors will manage to imitate such KM practice configuration, thereby eroding the competitive advantage. Perhaps technology or market changes will arise and will make this KM practice configuration obsolete or inconvenient. So, it is also necessary to have the KM dynamic capability. The KM dynamic capability allows the organization to adapt and renew KM practice and therefore plays a crucial role in attaining better innovation performance in a sustainable way.

The distinction between KM dynamic capability and KM practice is important in examining their unique contributions to a firm's competitive advantage. Distinguishing between KM dynamic capability and KM practice shows that some firms might be inefficient in leveraging their KM dynamic capability, and therefore it explains why these firms cannot improve performance even if their day-to-day KM practices are efficient. This could produce differential innovation performance within an industry. It also shows the different ways these two components of KM contribute toward building the firm's competitive advantage.

Further, distinguishing between KM dynamic capability and KM practice provides a basis for observing and evaluating the paths that organizations may follow in developing their core competencies. Making the distinction between KM dynamic capability and KM practice can allow researchers to analyze why some firms fail because of changes in the external environment while others prosper under the same conditions.

In sum, we suggest that much of the effect of of KM practices on innovation performance is indirect and affects the dependent variable through the interaction with the KM dynamic capability. Thus, we hypothesize:

Hypothesis 2: KM dynamic capability acts as a mediating variable between KM practice and innovation performance.

METHODS

Sample and Data Collection Procedure

We test our hypotheses by focusing on a global high-tech industry: French biotechnology producers. Single industry empirical studies are useful to identify and measure firms' critical resources (Hitt et al., 2001). Moreover, knowledge manifests itself in different ways in different industries. Thus, analysis of a single industry may be appropriate to assess innovation performance, as knowledge and practices involved in innovation processes will be likely to be more homogeneous (Santarelli & Piergiovanni, 1996). Focusing on biotechnology has two further advantages: it is a knowledge intensive industry, and it is characterized by a high degree of innovation. By focusing our data collection on the biotechnology industry, we reduce the range of extraneous variations that might influence the constructs of interest. We recognize the shortcoming of such sampling, but we believe that the advantages of this approach outweighed the disadvantages of limited generalizability.

Broadly defined, biotechnology is the industrial application of biological organisms, systems or processes. It is a young, science-based industry. The life cycle of most biotechnology products is at its inception. When this situation occurs in a particular industry, innovation tends to be much more focused on products than on production processes (Utterback & Abernathy, 1975). At the beginning of a product life cycle, innovation efforts seek to increase product performance. Subsequently, as initial product problems are solved, the product tends to become increasingly standardized until it reaches its dominant design or normal configuration. Thereafter, innovation efforts tend to aim to increase production efficiency by means of process innovation. Consequently, our research focuses on product innovation.

French biotechnology carries substantial weight in the international arena (Pouletty, 2002; Kopp, 2003). Biotechnology firms in France are classified in the biotechnology directory of the French Research Ministry (http://biotech.education.fr). This directory is a database with information about French biotechnology firms: address, telephone and fax numbers, e-mail, business activities, and directors' full names.

This database included 298 organizations at the time the research was carried out. However, the sample for this study was defined narrowly to include a homogeneous set of firms. We were only interested in production firms with at least three years of experience. Therefore, our target population included 253 organizations. We excluded the following organizations: (a) 10 public research associations and institutes as they are not profit-making firms; (b) 31 service firms, mainly commercial and diagnostic firms, as they do not produce product innovations; and, (c) 4 recently created firms (less than three years old) as they would not be able to fully answer many of the questionnaire items. Capabilities generation and innovation are time-dependent processes (Dierickx & Cool, 1989; Teece et al., 1997) and therefore a recently created firm would not have enough experience for its self-assessment. That is why the OECD recommends taking three years' periods into account in innovation surveys, since innovation is a path dependent process (OECD-EUROSTAT, 1997). This appears to be a reasonable cut off for selecting firms into our sample, as we are examining a young industry.

The questionnaire was sent to the R&D director of each organization, and included his/her full name in the presentation letter. We chose to elicit responses from R&D directors because they are responsible for knowledge and innovation. Furthermore, they are usually closely involved in the firm's strategy as R&D is a crucial function in biotechnology activity (Forrest, 1996). In our view, the use of biotechnology R&D directors satisfies two accepted criteria for identification of appropriate key respondents: (1) possession of sufficient

knowledge of the domain being studied, and (2) adequate level of involvement with regard to the issues under investigation (Campbell, 1955; Tippins & Sohi, 2003). Furthermore, there are precedents for the use of R&D directors in previous surveys on assessments of innovation (Gatignon, Tushman, Smith, & Anderson, 2002) and organizational learning in technology-intensive industries (von Zedtwitz, 2002).

The survey was launched during the first week of July 2002. The questionnaire was sent mainly by e-mail and by fax and post to those few firms that did not have e-mail addresses in the biotechnology directory. The questionnaire was sent with a presentation letter describing the objective of our research project and emphasizing the confidentiality of the responses. Both the questionnaire and the letter were written in French. Following Malhotra (1993), we offered a feedback report on the survey results to the participating firms in order to encourage firms to answer. Questionnaires were sent out in four general rounds. The use of the e-mail allowed us to solve quickly any problem, question or confusion about the questionnaire. A total of 132 useable surveys were returned for a response rate of 52.17 percent.

In order to check the representativeness of the sample obtained, we compared the respondents with the non-respondents based on firm characteristics in terms of total number of employees, number of R&D employees, annual budget in R&D, annual turnover, and exports share. This comparison did not reveal any significant differences, indicating that non-response bias was not a problem.

Measurement of Variables

We examine KM practices, KM dynamic capability and innovation performance by means of measurement scales. Other empirical research has used objective proxy variables to measure practices or dynamic capabilities (Henderson & Cockburn, 1994; Yeoh & Roth, 1999). For example, Yeoh and Roth (1999) operationalize the emphasis on radical

innovations as a dynamic capability in the pharmaceutical industry by the ratio of new molecular compounds not previously tested in humans to all other new products of the firm. Such proxy variables have the advantage of being objective. However, they are also approximate indicators that do not capture all the nuances of the concept.

Scales are based on respondents' perceptions; this represents a constraint in our study. However, the use of rigorous statistical analyses can limit this constraint substantially (Hair, Anderson, Tatham, & Black, 1998). Gatignon, Tushman, Smith and Anderson (2002) report that although self-assessment measures may be prone to bias, they are commonly used because (1) the presumably more objective sources can also be biased, (2) objective data may not be available, and (3) these perceptual measures have been shown to be reliable since prior studies have showed high correlations of perceived measure with objective measures (Venkatraman & Ramanujan, 1986). We developed measurement scales for each KM concept after taking into account the recommendations put forward by Churchill (1979) and DeVellis (1991).

Following the literature review carried out in the previous section, we identify two dimensions that bring together the most relevant aspects of KM practices: (1) knowledge dissemination practices, and (2) knowledge storage systems. By means of a literature review, a pre-test, and a validation process based on Exploratory and Confirmatory Factor Analysis we obtained a measurement scale made out of seven items (Appendix). These seven items are drawn from the literature. For example, Nonaka and Takeuchi (1995) emphasize the importance of fostering employees' participation by means of techniques such as multidisciplinary teams, quality circles or improvement groups as this group interaction is required to disseminate tacit knowledge. Katz and Tushman (1981) highlight the contribution of gatekeepers to project success: they disseminate knowledge and information from the firm to outsiders (suppliers, customers, etc.) and vice versa. Wheelwright and Clark

(1992) support the use of control and revision systems for innovation projects as well as feedback systems allowing knowledge created in finished innovation projects to be applied in subsequent projects. Such KM practices are implemented in a firm-specific way. This implementation is measured by asking for the degree of use of such practices.

Similarly we operationalize KM dynamic capability through two dimensions: (1) external knowledge integration, and (2) internal knowledge development. Following the methodology previously mentioned, we obtained a measurement scale made out of eleven items (Appendix).

We measure innovation performance by means of the Oslo Manual (OECD-EUROSTAT, 1997: 70) scale for assessing the economic results of product innovation. This scale was proposed by the OECD in order to provide some coherent drivers for innovation studies. Many innovation surveys use this scale (e.g. The Spanish Institute of Statistics INE, 2004).

Before launching the survey, we conducted a pre-test with twelve members of the biotechnology association of a leading business school: seven native English-speakers and five native French speakers. The respondents had at least three years' relevant work experience in that industry. The pre-test enabled us to check whether respondents understood the questionnaire adequately as well as to measure the time required to answer the questionnaire. The final questionnaire used in the survey is shown in the appendix. Measurement scales were applied as 1 to 7 Likert scales.

Control Variables

Firm size and R&D were included as control variables in the overall model because it has been found to impact product innovation. Both factors affect the endowment of important inputs for the innovation process such as money, people and facilities and have been shown to influence product introductions (Capon, Farley, Lehman, & Hulbert, 1992;

Henderson & Cockburn, 1994). Such control variables are in line with those used by Yeoh and Roth (1999) in their study on the pharmaceutical industry. Thus, we measured firm size through a logarithmic transformation of two indicators: turnover and the total number of employees. We measured R&D through a logarithmic transformation of two indicators: the R&D budget and the number of R&D employees.

Analyses

Before testing our hypotheses, we assessed the likely extent of common method variance (CMV). This is a problem that can arise when dependent and independent variables are collected from a single informant. We checked that CMV was not a substantial problem by carrying out two complementary analyses. First, we tested the non-existence of a single factor from a factor analysis of all survey items (Podsakoff & Organ, 1986; Tippins & Sohi, 2003). Second, because this procedure has some detractors (Kemery & Dunlap, 1986), we also performed a Method Variance (MV) marker variable analysis, which consists of examining the correlations between the survey variables with a theoretically unrelated variable (Lindell & Whitney, 2001). If CMV problem does not exist, then these correlations should be close to zero. The marker variable we used is "ability to develop non-technological ideas". This item was derived from basic innovation literature: Schmookler (1966) recognizes two main sources of innovation: technology and market. Our marker variable represents the market source of innovation. This is theoretically unrelated to the survey variables because the market is not relevant source of innovation for an extremely high technology industry such as biotechnology, especially when the industry is at an incipient stage (George, Zahra, Wheatley, & Khan, 2001).

The primary analyses of the data set are based on structural equations modeling. Structural equations models have been developed in a number of academic disciplines to substantiate theory. This approach involves developing measurement models to define latent

variables and then establishing relationships or structural equations among the latent variables. Structural equations' modeling has already been used in previous RBV empirical works (Yeoh & Roth, 1999; Tippins & Sohi, 2003).

EQS 6.1 software was used to estimate the models for our research hypotheses. Confirmatory Factor Analysis (CFA) was used to check the goodness of the measurement scales; this method also provides the correlations between factors or dimensions and the construct of interest (Mueller, 1996: 125). Furthermore, EQS decomposes total effects for the endogeneous variables into their direct and indirect effects.

RESULTS

Validation of Scales

We model KM practice, KM dynamic capabilities and innovation performance as latent constructs with multiple indicator variables. Because we are introducing new measures, we examine reliability, as well as content, convergent and discriminant validity, prior to testing our substantive hypotheses (Bagozzi, Yi, & Phillips, 1991).

We assess *reliability* using composite reliabilities in addition to Cronbach's alpha coefficient reporting. The composite reliabilities and alpha reliabilities (Table 1) for our three latent constructs dimensions appear to be adequate. Then, we analyse the scale validity by focusing on content validity, convergent validity, and discriminant validity. *Content validity* is assumed to exist when the scale has been constructed according to the literature (see Appendix). *Convergent validity* is accepted when factorial loads are higher than 0.4, and t coefficients are significant, i.e., higher than 1.96 (Bagozzi et al., 1991). CFAs (Figures 2, 3 and 4) show that all factor loadings achieved acceptable levels and were statistically significant.

Finally, the *discriminant validity* of two constructs can be assessed by demonstrating that the correlation between a pair of constructs is significantly different from unity (Bagozzi

et al., 1991). Discriminant validity was tested through confirmatory factor analyses (CFA) by comparing the χ^2 differences between a constrained confirmatory factor model (where the correlation between two factors is set to 1, indicating they are the same construct) and an unconstrained model (where the correlation between two factors was free). The same procedure constraining the confirmatory factor model to 0 has been used to obtain further support for convergent validity (Gatignon et al., 2002). All χ^2 differences were significant, providing evidence of discriminant validity. In sum, the three measurement scales have been validated and constitute an appropriate measurement tool.

Insert Figure 2 about here

Insert Figure 3 about here

Insert Figure 4 about here

Test of Hypotheses

Following Tippins and Sohi (2003), we used elliptically reweighted least square (ERLS) method as the estimation procedure to test our hypothesized model because this method has a satisfactory performance regardless of the data distribution (Sharma, Durvasula, & Dillon, 1989). Adopting the approach used by Singh, Goolsby and Rhoads (1994) and followed by Tippins and Sohi (2003), we showed the presence of a mediating effect, by performing a competing model analysis. The first model (direct effect) examined the direct relationship between KM practice and firm innovation performance. This model was used to test hypothesis 1: there is a positive and significant relationship between KM practice and firm innovation performance. A second model (partial mediation) examined the same relationship with KM dynamic capabilities acting as a mediator.

Figures 5 and 6 show the results of the competing model analysis. The chi-square statistic for each model is significant, but other relevant fit indices suggest a good overall fit (Seibert; Kraimer, & Liden, 2001; Tippins & Sohi, 2003). Therefore, our research hypotheses are confirmed.

The direct effect model has been satisfactorily tested. There is evidence of a positive link between KM practices adoption and innovation performance (Figure 5). However, when KM dynamic capabilities are included in the analysis (Figure 6) we find a more detailed picture of this positive link: KM dynamic capabilities act as a mediating variable boosting this positive effect (Grewal & Slotegraaf, 2007). The mediating effect of KM dynamic capabilities on the relationship between KM practice and firm innovation performance is established because the following conditions stated by Tippins and Sohi (2003). First, there is a positive relationship between KM practice and KM dynamic capabilities. Second, there is a positive relationship between KM dynamic capabilities and firm innovation performance. And third, the significant relationship between KM practice and firm innovation performance indicated in the direct effect model becomes lower and nonsignificant in the partial mediation model. These conditions provide compelling evidence that there exists a clear mediating effect of KM dynamic capabilities on the relationship between KM practice and firm innovation performance. Thus, the partial mediation model represents a significant contribution in the understanding of the positive influence –supported both by theory and some previous empirical research– between KM and innovation performance. The positive impact of the implementation of KM practices over innovation performance is mediated by the firm's KM dynamic capabilities. This finding supports the RBV.

Insert Figure 5 about here

Insert Figure 6 about here

DISCUSSION

We have taken an initial step toward formulating a theoretical framework and empirically testing the relationships among KM practice, KM dynamic capabilities and innovation performance in the context of global high-tech firms. Some studies have explored the relationships among the three concepts, but in a partial piecemeal manner. The research provided strong support for the model presented in Figure 2 and the underlying hypotheses. The results have important implications in the fields of decision-making, strategic management and KM. Innovation is an important outcome of firm processes and has been shown to be critical for internationalization (Roper & Love, 2002; Pla-Barber & Alegre, 2007) as well as for firm performance (Calantone et al., 2002; Hult et al., 2004). This research provides evidence that KM enhances innovation performance and explains how this positive effect occurs.

This research has provided an examination of the effects of KM on innovation in global high-tech firms. Given that innovation performance may vary among biotechnology producers, we attempted to understand this asymmetry within the context of firm KM practice and KM dynamic capabilities. Results suggest that sustained competitive advantage in the biotechnology industry requires firm strategies that capitalize on KM practice. Furthermore, special attention needs to be paid to KM dynamic capabilities since we have found that the main effect of KM practices on innovation performance is indirect and is mediated by KM dynamic capabilities. More specifically, by analysing the indirect and direct effects, we showed how KM practice enhances sustained competitive advantages in innovation performance mainly indirectly through the creation of KM dynamic capabilities. When taking into account both effects, the indirect effect was the prevailing one.

This study also supports new trends in the RBV research, according to which research should not only identify the critical specific assets within a particular industry, but must also make efforts to obtain additional understanding of the whole competitive advantage creation process by considering the role of dynamic capabilities.

Limitations

Overall, our results should be viewed in light of several limitations. First, the data were gathered at one point in time, so no inferences of causality can be conclusively established, nor can we discount the possibility of reverse causality. Second, this is a mono-method study. Collecting the dependent and independent variables from a single informant is likely to favor the response rate, but it gives rise to concerns about common method bias. We have performed analyses to ensure that the extent of such problem is not substantial. Third, although biotechnology is a young industry, prior experience with KM practices and prior firm performance in terms of innovation are factors that could influence results. Such factors have not been controlled. Finally, the target population of this study was narrowly defined to include a reasonably homogeneous set of firms. While a restrictive sampling approach may limit the generalizability of the research, it enhances confidence that the findings are indeed a result of the hypothesized relationships.

Implications

Our study makes a contribution to the RBV by supporting the perspective that a firm's innovation performance and competitive advantage are a function of complex inimitable resources that are embedded within the organization (Barney, 1991). Further, it shows how dynamic capabilities provide flexibility in organizational practices. The KM practices considered in our questionnaire are all highly firm-specific in the sense that there are no standard formulas for their implementation. KM dynamic capabilities are not only firm-specific, but also difficult to imitate as they are based upon complex organizational routines.

KM practices and KM dynamic capabilities are valuable because they contribute to innovation performance. As a result, KM may be regarded as a substantial source of sustained competitive advantage for the firm. Also, taking into consideration the role of KM dynamic capabilities may provide an explanation of why certain firms that implement KM practices do not maximize innovation performance.

A second related contribution of our study is providing a clear understanding of the dynamic capability creation process. The adoption of KM practice and its daily use create a repository of KM dynamic capabilities through the routinization of KM practice and the learning inherent to the operational problem-solving process. Subsequently, KM dynamic capabilities allow practice to be more effective and assure a positive impact of KM practices on innovation performance by adapting them to change –therefore avoiding any negative effect of rigid KM practices– and by creating new KM practices as they are required. This notion is consistent with, and builds on some of the earlier work in this area (Zollo & Winter, 2002; Zott, 2003; Grewal & Slotegraaf, 2007; Easterby-Smith & Prieto, 2008).

A third contribution is to the emerging KBV, which posits that knowledge constitutes the ultimate source of competitive advantage. This study provides a clearer understanding of KM effect on innovation performance supported by an empirical test. Further, a global conceptualization of KM taking into account organizational practices and dynamic capabilities is provided and validated.

A methodological contribution of our study is in the development and empirical validation of scales to assess KM practice and KM dynamic capability. While the role of KM as a source of competitive advantage has received a great deal of interest from strategy researchers, empirical work on KM and its impact on firm outcomes is still limited.

Our study has also interesting implications for practice. It shows managers how to make the most of KM. The dual structure between KM practices and KM dynamic

capabilities is potentially useful for practitioners, as it leads to an understanding of how the adoption and use of KM practices can produce substantial benefits for the firm. However, the implementation of KM practices is necessary but not sufficient for firms to create sustainable competitive advantage. The KM dynamic capability creation process as well as its subsequent repository must be taken into account. Dynamic capabilities are the link between organizational practice and sustainable competitive advantage and, therefore, managers should take them into account when formulating the firm's strategy.

Previous studies have showed that that simply investing in KM systems is not enough to enhance performance (Tippins & Sohi, 2003; Sabherwal & Becerra-Fernandez, 2003). It is not a question of how *much* you spend, but *how* you spend your money. The KM dynamic capability must be considered and managed even if it is intangible (Grewal & Slotegraaf, 2007). Focusing on internal and external knowledge creation will enhance the effectiveness of KM systems. Regarding decision-making in KM, the results of this study suggest the following: spend on KM systems, but spend the money wisely. Managers should have in mind the connection between KM practice and KM dynamic capability.

Additionally, practitioners may find this study's questionnaire useful to audit internally their KM practice and their KM dynamic capabilities and benchmark them with competitors.

Future Research

The results of this study provide guidance for future research. The mediating effect of dynamic capabilities should be taken into account in knowledge and information systems research carried out in an organizational context. Such dynamic capabilities constitute an important step between operational organizational practices and performance that helps to improve the understanding of the global link. The relationship between KM practice and KM dynamic capability needs further analysis from a longitudinal perspective.

Furthermore, KM has been usually examined in knowledge-intensive industries for their leading position. However, its implementation in more mature industries is expected. Further research is needed to assess the extent of difussion of KM in non knowledge-intensive industries and analyse whether KM is able to explain performance differences in such contexts.

Finally, although many high-tech firms are Born-Globals (Madsen & Servais, 1997; Moen, 2002), further research is also required to offer a detailed description of how KM practice and dynamic capability contribute to their internationalization performance.

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FIGURE 1

Organizational practices, dynamic capabilities and business process performance:

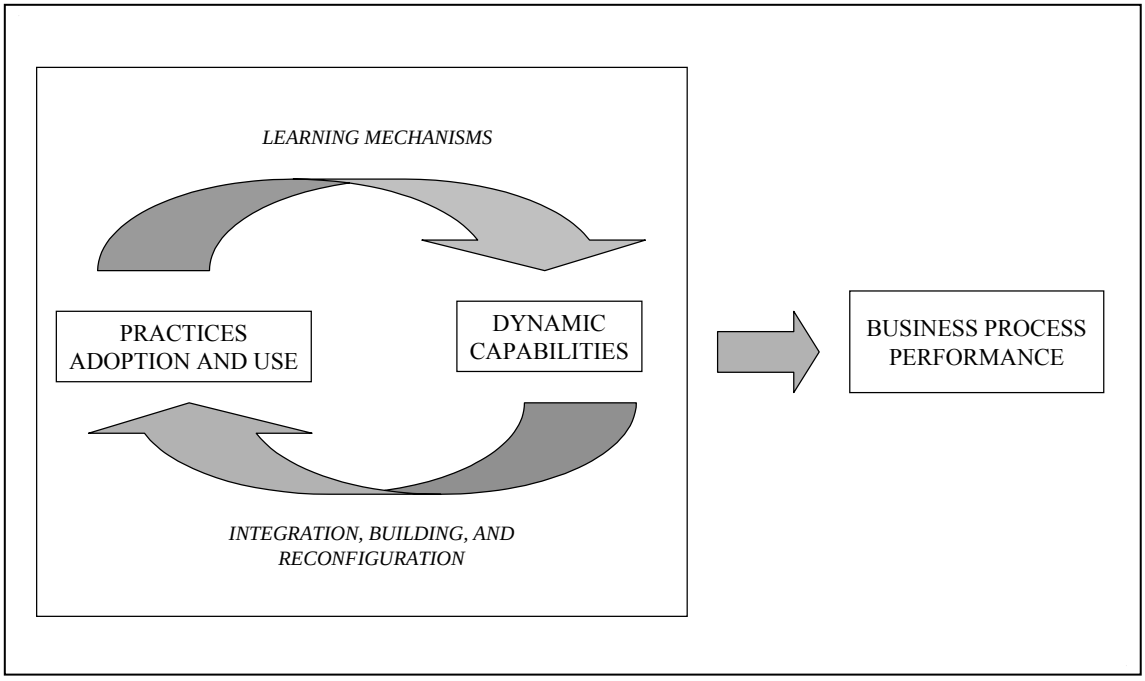


TABLE 1

Correlations, Means, Standard Deviations, and Reliabilities

Factors	Composite reliability	Mean	S.D.	1	2	3	4	5
1. Knowledge dissemination	0.78	4.598	0.818	(0.77)				
2. Knowledge storage	0.81	4.677	0.931	0.658**	(0.80)			
3. External knowledge integration	0.82	4.629	0.857	0.462**	0.445**	(0.87)		
4. Internal knowledge development	0.85	4.612	0.826	0.368**	0.449**	0.768**	(0.84)	
5. Innovation performance	0.90	4.652	0.805	0.245**	0.367**	0.625**	0.769**	(0.90)
MV marker variable: Ability to develop non-technological ideas	--	4.303	1.3073	-0.062	-0.086	0.028	-0.091	-0.091

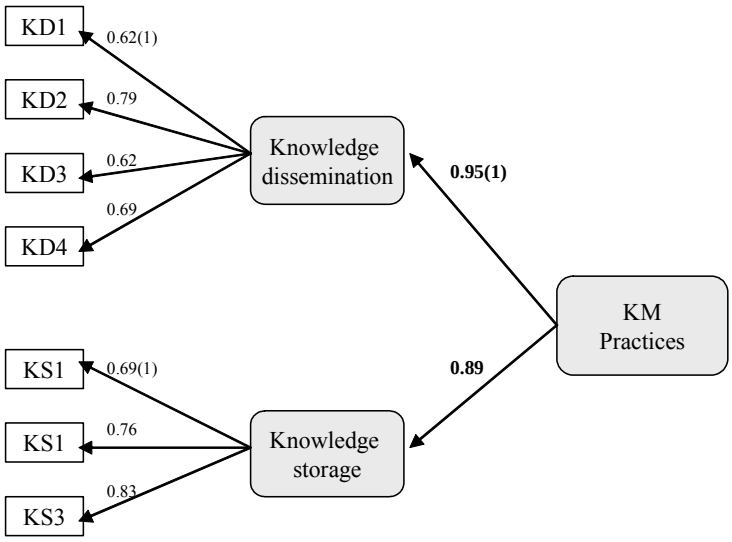
Concepts	Mean	S.D.	1	2	3
1. KM Practices	4.64	0.79			
2. KM Dynamic Capabilities	4.61	0.74	0.68**		
3. Innovation Performance	4.65	0.79	0.37**	0.73**	

N = 132; alpha reliabilities are shown on the diagonal.

* p<0.05

** p<0.01

FIGURE 2: CFA for KM Practices



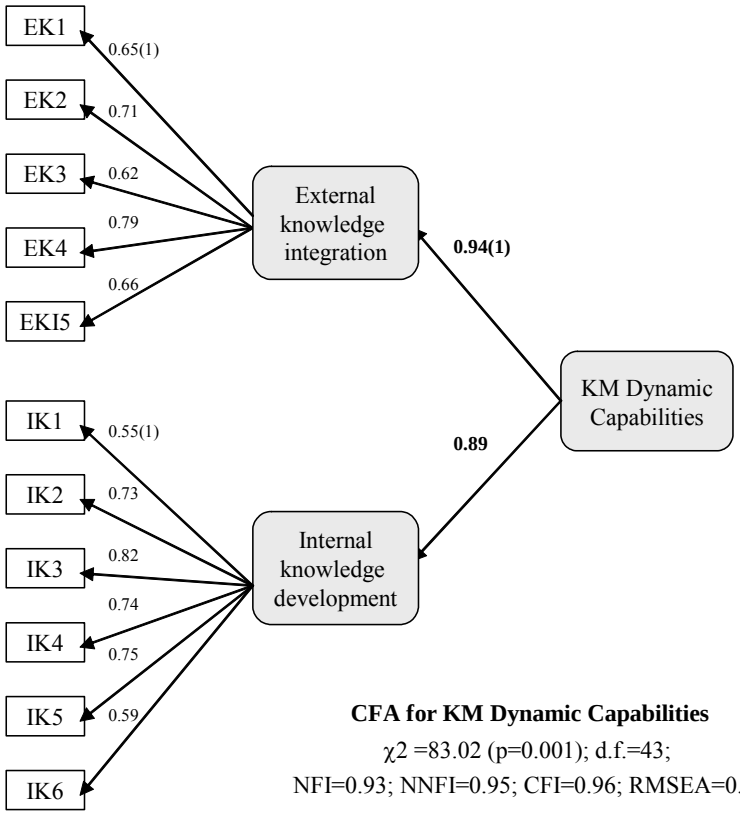
CFA for KM Practices

$\chi 2$ =18.64 (p=0.135); d.f.=13;
NFI=0.96; NNFI=0.98; CFI=0.99; RMSEA=0.06

Pairwise Confirmatory Analyses: Estimates of Correlations

KM Practices	*Knowledge Dissemination*				
	ϕ	d.f.	$\chi 2$	$\Delta\chi 2$	p
Knowledge Storage	0.85	13	18.64		0.13
	0	14	64.71	46.07	0.00
	1	14	24.65	6.01	0.03

FIGURE 3: CFA for KM Dynamic Capabilities



CFA for KM Dynamic Capabilities

$\chi 2$ =83.02 (p=0.001); d.f.=43;

NFI=0.93; NNFI=0.95; CFI=0.96; RMSEA=0.08

Pairwise Confirmatory Analyses: Estimates of Correlations

KM Dynamic Capabilities	*External Knowledge Integration*				
	ϕ	d.f.	$\chi 2$	$\Delta\chi 2$	p
Internal Knowledge Develoment	0.84	43	83.01		0.00
	0	44	126.41	43.40	0.00
	1	44	84.86	1.85	0.00

FIGURE 4: CFA for Innovation Performance

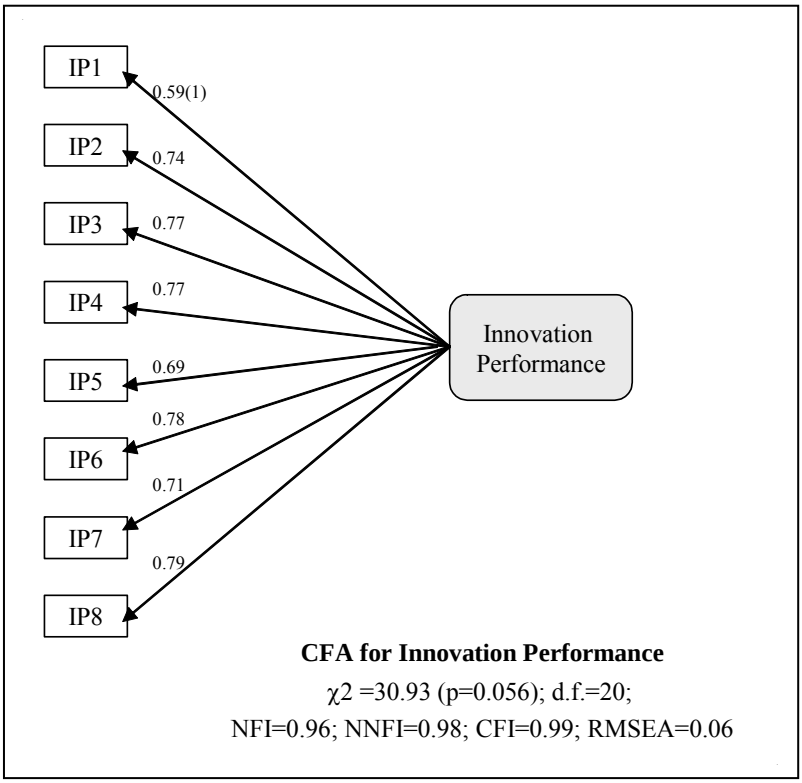
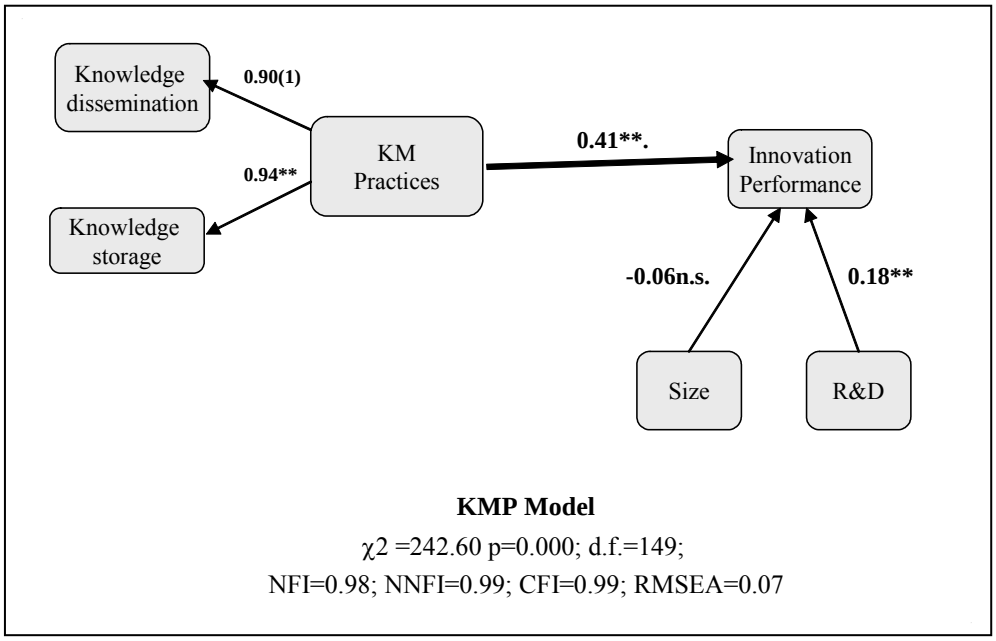


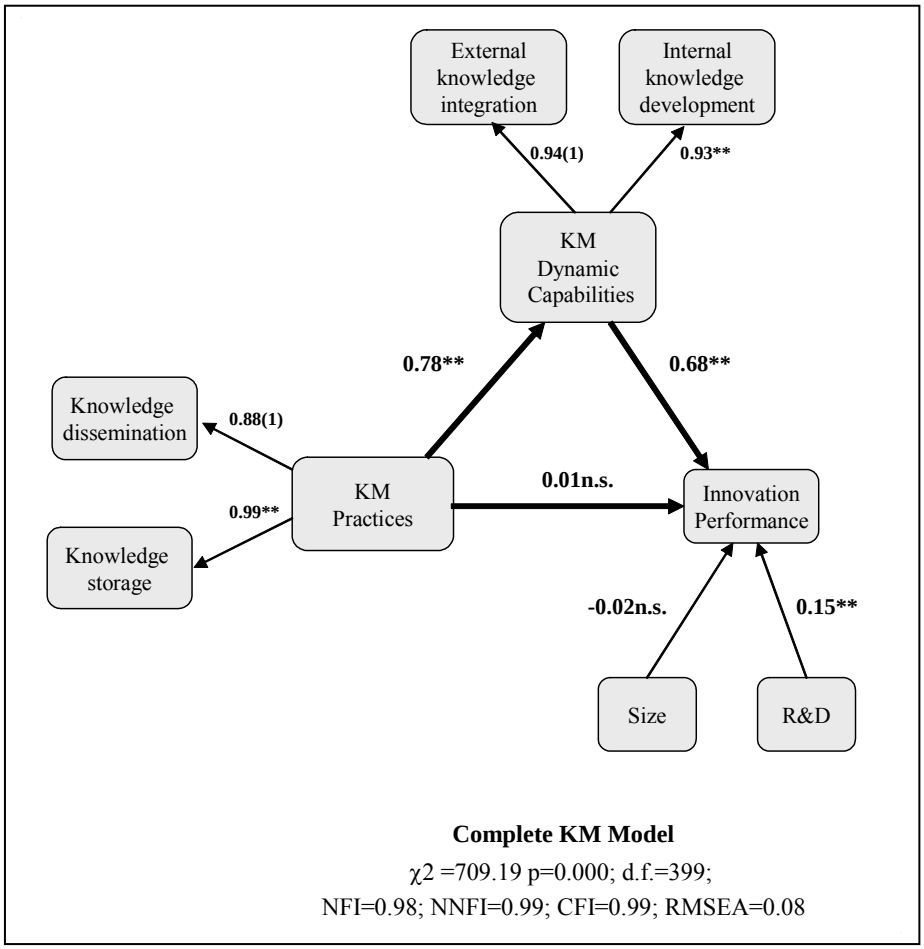
FIGURE 5: Direct effect model



KM Practice is a second-order factor. For the sake of brevity, only the first-order loadings are shown. The item loadings for these first-order factors are all significant at $p < 0.001$.

(1) The parameter was equalled to 1 to fix the latent variable scale. Parameters estimates are standardized. All parameter estimates are significant at a 95% confidence level

FIGURE 6: Mediated model



KM Practice and KM Dynamic capabilities are second-order factors. For the sake of brevity, only the first-order loadings are shown. The item loadings for these first-order factors are all significant at $p < 0.001$.

(1) The parameter was equalled to 1 to fix the latent variable scale. Parameters estimates are standardized. All parameter estimates are significant at a 95% confidence level

APPENDIX:

Questionnaire

A. USE OF KNOWLEDGE MANAGEMENT PRACTICES

Please indicate to what extent the following practices and techniques are used in your organization:

Items	Theoretical reference
KNOWLEDGE DISSEMINATION PRACTICES (α = 0.77)	
KDP1. Systems of explicit knowledge codification	Alavi & Leidner (2001)
KDP2. Mechanisms to foster information sharing by employees	Nonaka (1994); Nonaka & Takeuchi (1995); Fahey & Prusak (1998); Alavi & Leidner (2001)
KDP3. Employees' participation techniques such as multidisciplinary teams, quality circles, improvement groups, etc.	Nonaka (1994); Nonaka & Takeuchi (1995); Fahey & Prusak (1998); Alavi & Leidner (2001)
KDP4. Information distribution systems for employees, customers and suppliers	Wheelwright & Clark (1992); Alavi & Leidner (2001)
KNOWLEDGE STORAGE SYSTEMS (α = 0.80)	
KSS1. Global gathering and information processing systems	Alavi & Leidner (2001)
KSS2. Control and revision systems for innovation projects	Wheelwright & Clark (1992); Nonaka & Takeuchi (1995)
KSS3. Feed-back systems allowing knowledge created in finished innovation projects to be used in new projects	Wheelwright & Clark (1992); Nonaka & Takeuchi (1995); von Zedtwitz (2002)

B. KNOWLEDGE MANAGEMENT DYNAMIC CAPABILITIES

Please state the performance of your company compared to your competitors in the following terms:

EXTERNAL KNOWLEDGE INTEGRATION (α = 0.87)	
EKI1. Ability to obtain information about state-of-the-art scientific and technological developments through technological surveillance systems	Fleisher (2001); Chang (2003)
EKI2. Effective and updated competitive intelligence	Fleisher (2001); Myburgh (2004)
EKI3. Ability to create knowledge through co-operation with industry associations	Chang (2003)
EKI4. Ability to create knowledge through co-operation with R&D institutions such as universities and technological institutes.	Chang (2003)
EKI5. Technology acquisition (patents, equipment, etc.)	Jacobsson et al. (1996)
INTERNAL KNOWLEDGE DEVELOPMENT (α = 0.84)	
IDK1. Degree of academic qualification of employees in the R&D function	Jacobsson et al. (1996)
IDK2. Ability to be positioned on the technological front line/frontier	Wheelwright & Clark (1992); Tidd, Bessant, & Pavitt (1997)
IDK3. Ability to manage the innovation effort	Takeuchi & Nonaka (1986); Tidd et al. (1997)
IDK4. Ability to assess innovation projects	Wheelwright & Clark (1992); Tidd et al. (1997)
IDK5. Suitability of human resources devoted to the R&D function	Jacobsson et al. (1996)
IDK6. Ability to coordinate and integrate the different innovation project phases and the consequent interfunctional interphases between engineering, production and marketing	Takeuchi & Nonaka (1986); Wheelwright & Clark (1992)

C. INNOVATION PERFORMANCE

Please state the performance of your company compared to your competitors in the following terms

INNOVATION PERFORMANCE (α = 0.90)	
CACY1. Replacement of products being phased out	OECD-EUROSTAT (1997)
CACY2. Extension of product range within main product field through technologically new products	OECD-EUROSTAT (1997)
CACY3. Extension of product range within main product field through technologically improved products	OECD-EUROSTAT (1997)
CACY4. Extension of product range outside main product field	OECD-EUROSTAT (1997)
CACY5. Development of environment-friendly products	OECD-EUROSTAT (1997)
CACY6. Market share evolution	OECD-EUROSTAT (1997)
CACY7. Opening of new markets abroad	OECD-EUROSTAT (1997)
CACY8. Opening of new domestic target groups	OECD-EUROSTAT (1997)