

**THE PROCESS OF KNOWLEDGE
CREATION IN ORGANIZATIONS**

by

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The Process of Knowledge Creation in Organizations

Abstract

In their seminal work, Nonaka and Takeuchi (1995) highlighted the critical importance of knowledge creation to the long-term success of the organization. However, the scarcity of empirical work on knowledge creation has limited our understanding of the overall organizational process involved. To overcome this, we attempt a comprehensive analysis of knowledge creation within the organization, exploring the relationships between (1) knowledge acquisition, (2) problem-solving capability, (3) new knowledge creation, and (4) firm performance. We also investigate the environmental and organizational context within which knowledge creation occurs. Our study draws upon perspectives from the network, organizational learning, dynamic capabilities and innovation literatures.

Based on a survey of 317 firms, our analyses suggest that the critical linkages in the knowledge creation process occur between the four components mentioned above and, most strikingly, that the effect of new knowledge creation on firm performance is entirely mediated by innovation. The implication for managers is that by focusing on simpler processes such as problem solving or innovation they can significantly reduce the complexity of managing knowledge creation and more effectively capitalize knowledge within the firm.

Introduction

Knowledge is increasingly recognized as a strategic asset (Winter, 1987) and a source of competitive advantage (Nonaka and Takeuchi, 1995). As goods and services become more sophisticated, the foundation of competition becomes increasingly knowledge-based - developing valuable, hard-to-imitate knowledge for sustainable competitive advantage. With the advent of information technologies, the “networked” form of organization, and the need for innovation, the focus is on the generation, management and utilization of knowledge.

Knowledge-based strategy can be said to have emerged with resource-based theory (i.e., Barney, 1991; Amit and Schoemaker, 1993) and its subsets, such as “core competencies” (Hamel and Prahalad, 1990), “organizational capabilities” (Stalk et al., 1992) and “dynamic capabilities” (Teece and Pisano, 1994). These authors argue that intangible firm resources can serve as the basis for sustainable competitive advantage. Indeed, many regard intangible assets as crucial in sustaining superior performance (e.g., Itami and Roehl, 1987; Teece et al., 1997). However, the management of intangible assets (particularly organizational and individual knowledge) can be extremely challenging due to the inherent difficulties in articulating, understanding, developing and transferring them (Devinney, 1999).

The dynamic capabilities school of thought recognizes the role of knowledge development in competitive strategy and emphasizes the importance of “adapting, integrating and reconfiguring internal and external organizational skills, resources and functional competencies toward changing environments” (Teece and Pisano, 1994: 538). The essence of capability-based competition is the constant building and renewing of organizational skills and competencies. Thus, papers presented in the recent *Strategic Management Journal* special issues on “The Evolution of Firm Capabilities” (2000) and “Strategic Entrepreneurship” (2001) examined the ways in which organizations develop and change capabilities over time, enabling

them to learn and innovate. The role of knowledge featured in these studies as a source of technological competence (Yli-Renko et al., 2001) and as a coordinating mechanism for firm activities (Helfat and Raubitschek, 2000).

We build upon previous studies of dynamic capabilities and argue that the task of building and renewing the organization's stock of tangible and intangible resources involves two important knowledge-based activities: first, the *acquisition* of knowledge, and second, the *utilization* of this knowledge through organizational processes and practices (i.e., problem-solving and decision-making) to create new knowledge and innovation. We argue that a firm is constantly able to acquire knowledge, whether through external interactions or internal mechanisms (such as employee interactions, database systems, training and development, etc). We seek to determine whether such knowledge acquisition impacts on specific firm capabilities such as problem-solving skills and the generation of new knowledge and innovation. And we investigate whether these capabilities, together with the acquired knowledge, help the firm improve its innovative and financial performance.

Our study makes several contributions to the literature. Its key contribution is the investigation of other intervening variables between knowledge acquisition and firm performance. Previous studies were typically confined to the link between knowledge acquisition and performance measures such as sales growth (Lee et al., 2001) and firm survival (Miller and Shamsie, 2001) but not the impact on firm capabilities (e.g., ability to solve problems and create new knowledge). We argue that knowledge acquisition impacts on firm performance indirectly through its initial impact on firm capabilities. Our second contribution is empirical – we develop and test new measures of knowledge utilization in terms of improved problem-solving capabilities, whereas prior studies have used measures such as the number of new products (Yli-

Renko et al., 2001) and patent citation patterns (Mowery et al., 1996). Our measures of knowledge utilization have a more socio-cognitive flavor (Ginsberg, 1994). Finally, we address the issue of new knowledge creation, which, according to Nonaka and Takeuchi (1995), is not adequately addressed by many of the empirical studies. While they have addressed issues of inter and intra-firm knowledge transfer (e.g. Appleyard, 1996; Szulanski, 1996), inter-organizational learning (e.g. Steensma and Lyles, 2000) and the relationship between R&D expenditure and patents (e.g. Hall, Jaffe and Trajtenberg, 2000), little attention has been given to the process of knowledge creation *within* the firm.

This study integrates various concepts such as dynamic capabilities (Teece and Pisano, 1994; Eisenhardt and Martin, 2000), absorptive capacity (Cohen and Levinthal, 1990) and knowledge-based strategy (Spender, 1996) in developing and testing a model of organizational knowledge creation. We examine the process by which acquired knowledge is utilized through organizational problem-solving to create new knowledge, which then impacts on firm performance. In doing so, we aim to obtain a more systematic understanding of the knowledge creation process.

Theoretical Framework and Hypotheses

This study builds on the knowledge-based view of the firm, which argues that the primary role of the firm is the coordination of knowledge through mechanisms such as routines and group problem solving (Grant, 1996b). We adopt the view that employees are constantly engaged in sourcing and generating knowledge. However, to make an impact on performance, this needs to make an impact on organizational capabilities such as problem solving and decision-making. Knowledge accumulation does not automatically enhance organizational performance - hence the need to “understand the organizational processes through which firms access and utilize the

knowledge possessed by their members” (Grant, 1996b: 113). This echoes Nonaka and Takeuchi’s (1995: 6) proposition that acquired knowledge needs to be “shared widely within the organization, stored as part of the company’s knowledge base, and utilized by those engaged in developing new technologies and products”. The following discussion outlines the theoretical framework and hypotheses of this study.

Given the emerging debate on the importance of knowledge in organizations and the gaps in the existing empirical literature, we propose and test a model that investigates the process of organizational knowledge creation and its impact on firm performance. It takes into account four major aspects of the process. First, we investigate *the impact of acquired knowledge on the firm’s knowledge creating capabilities* by examining the utilization of acquired knowledge in organizational problem solving. This builds upon Iansiti and Clark’s (1994: 560) argument that “knowledge must be implemented in action-producing forms in order to create capability” and Leonard-Barton’s (1995: 8) findings that knowledge creation is dependent on four learning activities, one of them being shared and creative problem-solving processes. In this study, we define *knowledge* as Machlup’s (1980) and Ryle’s (1949) “knowing-how”, and *acquired knowledge* as that sourced through interaction with various external and internal parties. *Knowledge creating capabilities* are defined as organizational capabilities that facilitate the generation of new knowledge, and are measured by the quality of organizational problem solving.

Second, we propose that knowledge creation capabilities result in a stock of new knowledge and subsequently have a positive impact on firm performance. This is inspired by Dierickx and Cool’s (1989) distinction between “flows” and “stocks” – that is, that the accumulation of strategic stocks or assets (e.g., firm knowledge and innovation) is achieved

through a pattern of resource and skill flows (e.g., problem-solving processes) over time. Third, we investigate the impact of Cohen and Levinthal's (1990) *absorptive capacity* on both knowledge acquisition and problem-solving capability. They define absorptive capacity as "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends". As such, it is proposed that this ability will directly impact the level of knowledge acquisition and its utilization through problem-solving processes.

Finally, we investigate the impact of a number of control variables on the overall model. The process of acquiring and creating knowledge occurs within two contexts: first, the nature of the knowledge applied by the firm to its activities. We control for these by investigating the effects of Zander and Kogut's (1995) dimensions of organizational knowledge and by including industry dummies for any residual effects. Second, the differing characteristics of firms within an industry, which we control for by including factors such as size, ownership structure and R&D intensity.

Figure 1 presents the proposed model. The basic idea is simple – the knowledge creation process itself is one where (externally and internally) acquired knowledge enhances the problem-solving capability of the firm, which in turn facilitates the creation of new knowledge. New knowledge facilitates innovation, which is broadly defined (see below), and this ultimately impacts on the firm's financial/market performance. The overall knowledge creation process operates within a context where factors such as absorptive capacity, the nature of the organization's knowledge environment and the industry context also affect the role that knowledge creation plays in determining innovation and performance. In particular, both knowledge acquisition and problem solving will be affected by absorptive capacity—that is the firm's ability to assimilate acquired knowledge.

Note that the model makes a strong statement in that the effect of new knowledge on financial performance is *entirely mediated* by innovation. Thus knowledge creation itself is of no intrinsic value in this model; to be valuable to the firm it must be translated into innovation. To test this assertion we subsequently compare the proposed model with an alternative model where new knowledge directly impacts financial performance.

The model should be seen in the research setting of a cross-sectional survey, designed to examine firm differences in knowledge acquisition, problem-solving capability, new knowledge creation, etc. and the impact these have on innovation and financial performance. Moreover, we identify the impact of these differences after controlling for the heterogeneity due to the nature of organizational knowledge, and of industry and firm characteristics. The next section covers the development of the hypotheses based on this model.

Insert Figure 1 Here

Knowledge Acquisition and Problem-solving Capability

The acquisition of knowledge (and its implications for innovation and performance) has received increasing attention from scholars of strategic management and organizational knowledge. For example, both Liebeskind et al., (1996) and Powell et al., (1996) concluded that externally sourced knowledge contributed to organizational learning. Similarly, Henderson and Cockburn (1994) attributed drug discovery productivity in the pharmaceutical industry to the maintenance of extensive information flows across firms, as well as across business units within the firm. Steensma and Lyles (2000) provided a knowledge-integration perspective of international joint ventures by showing that both managerial and technical support from the foreign parent contributed to greater IJV learning and ultimately, survival. Other studies (Lane and Lubatkin,

1998; Stuart, 2000) attributed organizational learning and performance to the knowledge and capabilities of alliance partners.

Building upon these, we examine the effect of knowledge acquisition on firm performance. However, the main contribution of our work is to recognize that knowledge needs to be *applied and utilized* before it can make an impact on firm performance. Our logic adheres to the theories of organizational learning that argue “learning is the acquisition of new knowledge by actors who are able and willing to apply that knowledge in making decisions or influencing others in the organization” (Miller, 1996: 486). This is also consistent with Ryle’s (1945: 179) statement that “effective possession of a piece of knowledge, involves knowing how to use that knowledge, when required, for the solution of other theoretical or practical problems.” This implies that acquired knowledge needs to be acted upon in order to make a difference to firm performance. Adopting the views of organizational learning (Garvin, 1993; Miller, 1996) and strategic decision-making (Mintzberg, 1978) scholars, we examine the utilization of (externally and internally) acquired knowledge in a problem-solving context. We argue that the greater amount of knowledge flowing into the organization’s problem-solving processes, the greater its capability to solve problems effectively,¹ and we test this through the following hypothesis:

H1: There is a positive relationship between knowledge acquisition and problem-solving capability

Problem-solving Capability and New Knowledge Creation

The essence of Nonaka and Takeuchi’s (1995) work is the creation of new knowledge through an iterative cycle of tacit and explicit knowledge transfer. In our study we do not address the intricacies of tacit and explicit knowledge conversion and transfer, but rather, the creation of new knowledge through effective problem-solving processes. It is important to articulate what we

mean by new knowledge *creation* as distinguishable from knowledge *acquisition* or *utilization*. Access to knowledge does not necessarily lead to new knowledge being created. Rather, it needs to be processed and integrated into the organization's existing knowledge base and problem-solving processes in order to produce new knowledge. This distinction is emphasized in Pfeffer and Sutton's (2000: 243) work on the "knowing-doing gap" which argues that "organizational performance often depends more on how skilled managers are at turning knowledge into action than on knowing the right thing to do". This is supported by Levinthal and March's (1993) argument that high levels of exploration activity are needed in order to increase the pool of new knowledge into which an organization taps. The essence of Ryle's (1945) essay "Knowing How and Knowing That" is the distinction between acquisition of knowledge and being able to apply that knowledge when necessary.

Extending these arguments, we emphasize that the creation of new knowledge occurs through the application and exploitation of acquired information and knowledge, that is, it is created through *actions* and *behaviors* such as problem-solving. This is consistent with the views of March (1991) and Dierickx and Cool (1989) that knowledge *stock* is generated over time through a constant *flow* of resources and capabilities (such as knowledge acquisition and effective problem-solving). Thus, we hypothesize the following relationship:

H2: There is a positive relationship between problem-solving capability and new knowledge creation

New Knowledge Creation and Innovation

There is a significant literature supporting the argument that the very act of innovating is synonymous with the creation of new knowledge. The need to overcome various forms of uncertainty arising from innovation has contributed to the importance of creating new knowledge

from both within and outside the organization. Scholars from the network and inter-organizational relationships fields have argued that learning and knowledge transfer among firms are essential to the innovation process (e.g., Powell et al., 1996; Liebeskind et al., 1996). The work of Nonaka and Takeuchi (1995: 3) regards knowledge creation as the essence of innovation – “organizational knowledge creation is the key to the distinctive ways that Japanese companies innovate. They are especially good at bringing about innovation continuously, incrementally, and spirally.”

Theories of “dynamic capabilities” (Teece et al., 1994) also emphasize knowledge (particularly its constant renewal) as a source of innovation and competitive advantage. Central to this is the concept of “knowledge integration” (Grant, 1996a; Iansiti and Clark, 1994), that is, the ability to integrate different types of specialized knowledge to develop new innovation-enhancing capabilities. Henderson and Clark’s (1990) work on “architectural innovation” investigates the relationship between knowledge and innovation. Their basic premise is that firms need to develop and renew their architectural knowledge continually to prevent knowledge from becoming obsolete in the event of radical innovation. As an illustration of the importance of accumulated knowledge for innovative capabilities, Helfat (1997) found that during periods of environmental instability, firms with greater volumes of accumulated knowledge undertook greater amounts of R&D. Consistent with the existing literature, we hypothesize the following relationship:

H3: There is a positive relationship between new knowledge creation and innovation.

Innovation and Financial Performance

Our ultimate dependent variable is firm financial performance. There is a continuous and, as yet, unresolved debate in the strategy literature on the relative importance of industry and

organizational factors as drivers of financial performance (for example Schmalensee, 1985; Rumelt, 1991). However, in studies where authors have investigated the relationship between innovative output and performance, results have been more conclusive. There is substantial empirical evidence in the literature pointing to a positive relationship between innovation and financial performance (at both the firm and industry levels). Banbury and Mitchell (1995) found that the introduction of incremental product innovations strongly influenced market share and business survival. In other studies, innovation has been attributed to improved stock price performance (Chaney and Devinney, 1992), persistent profitability (Geroski et al., 1993), sales growth (Soni et al., 1993) and, at the industry level, productivity growth (Chakrabarti, 1990).

Building on the positive relationship between innovation and financial performance established by numerous studies, a positive relationship is hypothesized between innovation and financial performance:

H4: There is a positive relationship between innovation and financial performance

The Role of Absorptive Capacity

It is important to consider a different level of analysis, that of the *firm's own ability to acquire and apply knowledge*. Cohen and Levinthal (1990: 128) define absorptive capacity as “the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends”. They postulate that the firm’s R&D effort determines its capacity to absorb externally generated knowledge and, thus, its level of learning. Various studies have investigated the concept of absorptive capacity and its role in both knowledge acquisition and learning. March (1991) and Mowery et al. (1996) linked the firm’s level of absorptive capacity to its ability to recognize and source external knowledge. In other studies, absorptive capacity is linked to the firm’s ability to learn and utilize new knowledge. For example, Pennings and Harianto

(1992) found that prior accumulated experience in a certain technological area increased the likelihood of new technology adoption. Lane and Lubatkin (1998) concluded that the similarity of capabilities (a measure of relative absorptive capacity) between “teacher” and “student” firms enhanced inter-organizational learning.

Consistent with previous studies, we propose that the firm’s level of absorptive capacity will have a positive impact on both its propensity to acquire knowledge and its ability to learn and utilize knowledge (i.e., enhancing problem-solving capability). We test for a direct effect between absorptive capacity and knowledge acquisition and a moderating (interaction) effect between absorptive capacity and problem-solving capability. We argue that absorptive capacity will directly augment knowledge acquisition, but high levels of both absorptive capacity and knowledge acquisition are needed to have an impact on problem-solving capability.

H5: There is a positive relationship between absorptive capacity and knowledge acquisition

H6: Absorptive capacity moderates the relationship between knowledge acquisition and problem-solving capability

The Residual Effect of New Knowledge Creation on Performance

Our final hypothesis centers on the way in which knowledge is capitalized by the firm. If new knowledge creation were primarily an innovation-centered phenomenon, we would expect that the impact of new knowledge on performance flowed entirely through innovation. That is, new knowledge is capitalized through innovative activities, which in turn, impact on firm financial performance. This is consistent with Nonaka and Takeuchi (1995) for whom new knowledge creation is an integral part of firm innovation, rather than firm financial performance.

H7: There is no effect of new knowledge creation on financial performance other than through innovation.

The hypothesis has interesting empirical and managerial implications. If the benefits of new knowledge flow into firm performance predominantly via innovation, then the management of the knowledge creation process can be simplified around the better-understood and more easily measurable construct of “innovation.” However, if we find residual effects of new knowledge on firm financial performance, it implies the need for further development of the construct of “new knowledge.” It also means that managers need to pay more attention to the various ways in which that knowledge can be capitalized within the firm.

Control Variables

The extent to which an organization acquires and creates knowledge depends on the characteristics of its own knowledge base and the industry context in which it operates. For example, a law firm – with the legal demands of transparency and codifiability – will operate in a different context to that of a consulting firm – where knowledge may be more embedded and less codified. The organization’s knowledge base is developed via accumulated experience which, in turn, results in “a set of rules or higher-ordered organizing principles by which new capabilities are created, improved and transferred in the organization” (Zander and Kogut, 1995: 78). Because knowledge creation processes (as we have defined and measured them in this study) involve the interaction of firm members in a problem-solving environment (and are associated with the acquisition and sharing of knowledge), we need to take into account the effects of the firm’s knowledge characteristics. For example, if its underlying knowledge can be easily codified and taught to new employees, it is more likely to be shared and thus increase the effectiveness of its problem-solving. Hence, we control for these effects by investigating the impact of Zander and Kogut’s (1995) five knowledge dimensions on knowledge acquisition, problem-solving capabilities and new knowledge creation.²

We also use firm and industry controls – i.e., industry dummy variables, firm size, R&D intensity and ownership structure - to control for industry and firm effects that are known to exist with respect to innovation and performance (e.g., Acs and Audretsch, 1987), as well as knowledge acquisition, problem-solving, and new knowledge creation. Controlling for these, as well as the knowledge dimensions, allows us to better identify the real impact of the model's focal constructs.

Methods

To test our hypotheses empirically, we employed a questionnaire survey methodology and estimated the model using partial least squares (PLS). We first discuss our measures, then the sample of firms we obtained and finally model estimation.

Construct Measures

Given the complexity of the issues covered by the research and the fact that there is no existing single instrument upon which we can draw, we developed our own instrument based on managerial interviews and previous questionnaires (e.g., those of Zander and Kogut, 1995 and Appleyard, 1996). The questionnaire consists of both *formative* measures – i.e., observed indicators that cause or form the latent constructs – and *reflective* measures – i.e., observed indicators that are caused or formed by the latent constructs (Bollen, 1989). Formative measures are used for the constructs of knowledge acquisition and innovation with the remaining constructs (i.e., problem-solving capability, new knowledge, absorptive capacity and financial performance) measured by reflective measures. Each is discussed in detail in the sections below. All survey questions (except those pertaining to demographics) use a 7-point Likert scale.

Knowledge Acquisition (formative)

To measure knowledge acquisition, respondents were asked to rate the frequency of acquiring knowledge from a list of 15 parties such as customers, suppliers, competitors, government agencies, universities, research agencies, other subsidiaries, colleagues and so on. The aim was to construct a comprehensive and “generic” list of external and internal parties representing a network of interactions for firms across various industries. This approach is adapted from Appleyard (1996).

Knowledge acquisition is a formative measure because we are seeking to form an aggregate index that represents the underlying pattern of activities and which “forms” the construct “knowledge acquisition” for our model. The creation of this index can be done empirically—for example, through the direct estimation of weights—or theoretically—through a logical definition of the mechanics by which the individual measures are aggregated. Logically, we are concerned with two factors: (1) the number of parties from which a firm acquires knowledge (i.e., *breadth* of acquisition) and (2) the frequency of knowledge acquisition from such parties (i.e., *intensity* of acquisition). However, here we are interested in the overall level of the effect and leave it to later work to determine whether breadth and intensity have differential effects. Fortunately, there is a natural index that allows us to capture simultaneously breadth and intensity and avoid the necessity of estimating the index empirically. Entropy indices are common in industrial organization research (Jacquemin and Berry, 1979) as well as statistics. We use an entropy index to measure the constructs of knowledge acquisition and innovation.³

Innovation (formative)

To measure a firm’s level of innovation, we compiled a list of 14 innovative outputs, incorporating new (and modified) products, services and processes (organizational, administrative and production), patents, licenses, publications and conference presentations. The

aim was to construct measures generic enough to be applicable to firms from multiple industries. Respondents were asked to rate their firm's frequency of producing these innovations compared to their competitors. As before, measures are aggregated using the entropy formula.

Problem-solving capability(reflective)

In his *socio-cognitive capability model*, Ginsberg (1994) argues that strategic decision-making is often hampered by cognitive (i.e., bounded rationality, biases and cognitive heterogeneity among decision makers) and social impediments (i.e., conflicts that restrict the formulation and implementation of effective decisions). The author presents the notion of *socio-cognitive advantages* to better understand “the processes through which managers’ mental models and capabilities engender competitive advantage” (Ginsberg, 1994: 154). The three socio-cognitive advantages are: (1) *creativity* – the ability to be innovative and efficient in devising solutions and choosing options; (2) *comprehensiveness* – the ability to be exhaustive and coherent in judging situations and assessing problems; and (3) *consensus* – harmony and shared commitment to goals and decisions.

We apply Ginsberg's theoretical formulation as a means of measuring organizational knowledge creation because of its focus on the problem-solving context. The use of a problem-solving environment as a context for studying knowledge creation is evident in previous research by Nonaka and Takeuchi (1995), Leonard-Barton (1995) and Iansiti and Clark (1994). We argue that if a firm is able solve problems comprehensively, creatively and generate consensus around goals and decisions, it is thus more able to create new knowledge.

Ginsberg's (1994) article on socio-cognitive capability is a conceptual piece. To our knowledge, there have been no empirical attempts to measure and test the concepts and propositions outlined therein. Hence, we develop measures for (1) comprehensiveness, (2) creativity, and (3) consensus, that capture the essence of the author's conceptual definitions.

Items that investigated the extent to which respondents solved the problem exhaustively by using teams as well as formally evaluating different solutions to the problem, measured *comprehensiveness* in problem-solving. Items that investigated the extent to which the final solution to the problem was creative or novel, whether the decision-makers were flexible in adopting new ideas, and whether there were pressures and incentives to be creative in problem-solving, measured *creativity*. Items that investigated the degree to which decision-makers were able to integrate alternative options into an effective solution to the problem, the degree to which the solution was implemented in a timely fashion, and whether there was a high level of consensus and shared commitment among the decision making team, measured *consensus*.

We then merged the measures of comprehensiveness, creativity and consensus into an overarching construct of *problem-solving capability*. We are not concerned about the specific impact of each dimension – this will be an interesting topic for future research – but with developing a simple construct that captures the multifaceted nature of good problem solving. Our main concern is the knowledge acquisition → problem-solving → new knowledge → performance chain of relationships.

To avoid developing measures that were too general, we specifically investigated the levels of comprehensiveness, creativity, and consensus in the *context of problem solving* via the following specific instruction in the questionnaire:

Think of an incident when you were involved in solving an important problem in your organization. This must involve a problem that was actually solved. Please note that this may include solving a client's problem, as long as a substantial part of the organization was involved in solving it. Please describe the problem briefly.....

By asking respondents to describe a specific problem and directing subsequent questions to that particular situation, we were able to measure the quality of the firm's problem-solving

processes in terms of Ginsberg's "socio-cognitive capability". Our measures were constructed to allow us a degree of generalization of the firm's processes. We took precautions to ensure respondents described situations that were representative of their organization's problem-solving approach. Specifically, we asked them to rate the described situation in terms of importance (i.e., having an impact on the organization's performance) and frequency of occurrence.⁴

New Knowledge (reflective)

We measure new knowledge by examining the quality of the solution to the problem described by respondents in the questionnaire, based on the assumption that an effective solution facilitates *learning* (either by individuals or the organization) and is tantamount to *new knowledge being created*. This proposition is well grounded in the literature, especially in the context of new product development and follows directly from Ryle's (1945) definition of know-how as knowledge that is "required for the solution of.... theoretical or practical problems." Most of the cases illustrated in Nonaka and Takeuchi's (1995: 231) work are anchored in new product development projects, as these constitute the "core process for creating new organizational knowledge". Others have also asserted that problem-solving routines form the organization's platform for learning and knowledge generation (e.g. Leonard-Barton, 1995).

We constructed measures taking into account the cognitive (Argyris and Schon, 1978), behavioral (Cyert and March, 1963), and performance (Fiol and Lyles, 1985) dimensions of learning from the organizational learning literature. Our measure encapsulates five factors: (1) productivity or performance improvements; (2) new ways of doing things; (3) new projects or product ideas; (4) wider organizational thinking, and (5) increased ability to solve other problems in the organization.

Absorptive Capacity (reflective)

To measure Cohen and Levinthal's (1990) concept of absorptive capacity, we go beyond the authors' emphasis on R&D investment, recognizing that this may not be applicable across industries. Hence, in order to develop generalizable measures as well as adhering tightly to the authors' definitions, we designed measures to capture two important aspects of absorptive capacity: first, *active information-seeking behaviors*; i.e., the degree to which respondents actively seek external information, record it for future reference, use the acquired information in their work, and distribute the information to fellow colleagues. Second, we recognize that the development of absorptive capacity is essentially path-dependent; that is, it is a function of both past and on-going *investments in knowledge accumulation*. To measure this, we investigated the degree to which respondents participate in academic/industry conferences, update their skills through training and self-learning, and keep abreast with the latest technology and knowledge related to their organization's business. Our measures are organizational – i.e., the extent to which the firm has policies and procedures that encourage employees to seek external information and invest in knowledge accumulation.

It is important to emphasize that our operationalization of absorptive capacity is both broader and more direct than previous empirical work where the emphasis is on the *proxies* of absorptive capacity. For example, Pennings and Harianto (1992) measure past accumulated technological experience as a proxy for absorptive capacity. Lane and Lubatkin (1998) hypothesize that absorptive capacity is a function of the similarity between the student and teacher firms' compensation practices and organizational structures. In contrast, we employ a more direct approach by examining the extent to which a range of *actions* are taken to recognize, absorb and assimilate new external information and knowledge into the organization.

Financial Performance (reflective)

Financial performance was measured using both market measures – market share and annual sales growth – and financial measures – after-tax return on investment and growth in total after-tax profits. These are commonly used in the strategy and marketing literatures (e.g., Banbury and Mitchell, 1995) and reflect the multidimensional pressures managers face on a day-to-day basis. Following Johansson and Yip (1994) and Roth and Morrison (1990), these measures were treated as reflective indicators of an existing latent “performance” construct.

Sample

Our questionnaire was pre-tested through interviews and a pilot sampling trial. The final version was then mailed to 2,137 organizations (all with more than 20 employees) randomly selected from 17 manufacturing and service industries (based on two-digit SIC codes). The objectives of this procedure were to ensure generalizability of results across industries and to target industries where issues of information and knowledge transfer, knowledge creation and innovation are *important and relevant*. Specifically, we targeted industries facing dynamic and competitive environments - hence the need for continuous knowledge creation and learning. The issue of relevance is also crucial to obtaining a reasonable response rate and high quality responses (questions are more easily understood if they are important and relevant).

The questionnaire was addressed to the CEO or managing director of each organization. To minimize the limitations of using single informant methodology, we took precautions to ensure informant competency. First, the key objectives of the study and its central themes were outlined in a cover letter. If the CEO was unable to complete the survey, they were asked to give it to a middle/senior level manager with sufficient knowledge of the study’s objectives. Second, we included criteria for assessing informant competency, such as tenure in the organization, industry and current position.

The number of responses totaled 343 (yielding a 16% response rate). After eliminating 26 surveys due to large proportions of missing data. The final 317 used in the analysis were fairly evenly distributed across manufacturing (44%) and service (56%) sectors as well as across the 17 industries. Firm size was also well distributed, with 40% small firms (100 or less employees), 30% medium-sized firms (100 to 400 employees) and 30% large firms (more than 800 employees). The average and median sizes of these firms were 2,024 and 175 employees respectively. Tests of the distribution of returned surveys indicate that no industry or size bias existed in the responses received.

Analysis of respondent characteristics indicated that they had sufficient knowledge of the key issues of the study – all respondents occupied middle-senior management roles, and the average tenure at the organization, industry and current position were 12, 17 and 5 years respectively. Following the procedures of Armstrong and Overton (1976) we also tested for non-response bias by examining the construct means of early versus late respondents, and found no significant differences.

With surveys such as this there is always a concern about single respondent bias. In a related study, the survey was used in conjunction with six case studies (see Soo, Devinney, Midgley and Deering, 2000) and an identical model was estimated for each company. In this situation, as many as 120 responses were received from a single firm, hence we had both repeated measures of firm variables and estimates of the variance of individual measures. Although the models differed in the magnitude of various effects (as one would expect), the general form of the model and key conclusions remained valid.

Method of Estimation

The data from the survey was analyzed using partial least squares (PLS), a well-established technique for estimating path coefficients in causal models (e.g., Johansson and Yip, 1994; Birkinshaw et al., 1995). Its conceptual core is an iterative combination of *principal components analysis* relating measures to constructs, and *path analysis* permitting the construction of a system of constructs (Barclay et al., 1995). The major advantages of PLS are that it: (1) accepts small sample sizes, (2) can deal with complex causal models, (3) does not require multivariate normality and (4) produces consistent parameter estimates. It is especially suited to “situations of high complexity but low theoretical information” (Barclay et al., 1995: 288), a point that is particularly relevant given that the field of organizational knowledge is relatively new with concepts and relationships still being developed, hence the emphasis is on theory building rather than theory testing.

Results

For the PLS model, we are interested in two levels of analysis – the *measurement* model (i.e., the reliability and validity of the measures used to operationalize the underlying constructs) and the *structural* model (i.e., the relationships between the latent constructs). We present and discuss the results of the measurement model before proceeding to the latter.

Measurement model

Examining the loadings and cross-loadings of each of the constructs’ individual items assesses the reliability of the reflective measures. For an item to be reliable a minimum loading of 0.7 is required, indicating that more than 50% of the variance of the measure is accounted for by the respective construct. In our study, all items had a loading with their respective constructs of greater than 0.7. Other measures of reliability are Cronbach’s alpha and Werts, Linn and Joreskog’s (1974) measure of internal consistency (IC). Table 1 lists the alpha and IC scores for

all the reflective constructs, indicating satisfactory reliability with the IC scores ranging from 0.86 to 0.92.

Insert Table 1 Here

Finally, we assess the discriminant validity of the constructs by using Fornell and Larcker's (1981) measure of average variance extracted (AVE). The AVE measures the amount of variance captured by the construct (through its items) relative to the amount of variance due to measurement error. To satisfy the requirements of discriminant validity, the square root of a construct's AVE must be greater than the correlation between that construct and other constructs in the model. The correlation matrix in Table 1 shows that all the diagonal elements are greater than the corresponding off-diagonal elements.

Structural model

The results of the structural model are presented in Table 2 and Figure 2. From these we can see that the latent constructs of problem-solving capability, new knowledge and innovation are well explained (R-squares of 37%, 40% and 27% respectively) and those of knowledge acquisition and financial performance reasonably well explained (R-squares of 20% and 15% respectively). Furthermore, all but one of the path coefficients shown in Figure 2 are statistically significant at the 0.01 level or higher and the remaining path (between absorptive capacity and problem-solving capability) is significant at the 0.05 level. The paths that are not shown and not significant are (1) the moderating (interaction) effect of absorptive capacity on the link between knowledge acquisition and problem-solving capability, (2) the direct path between new knowledge and financial performance and (3) those relating to the various controls. Overall the model fits well and supports the majority of our hypotheses. However, before discussing these hypotheses it is useful to note the practical impact of the firm's problem-solving capability or new knowledge created as shown by this model. For example, the difference between a firm that

is one standard deviation above the mean on problem-solving capability and one that is one standard deviation below the mean, amounts to an advantage to the former of 1.08 standard deviations on new knowledge created, 0.46 standard deviations on innovation and 0.12 standard deviations on financial performance. These are substantial impacts—particularly when compared with other sources of firm improvement.

Insert Table 2 and Figure 2 Here

Factors Contributing to Problem-solving Capability

We use the process of problem-solving to investigate the knowledge creation process, employing Ginsberg's (1994) theory of "socio-cognitive resources" and forming the summary construct "quality of organizational decision-making" from the levels of comprehensiveness, creativity and consensus shown in a key decision. Knowledge acquisition impacts directly on the quality of organizational problem solving, implying that the sourcing of external expertise (both explicit and tacit) produces better solutions in problem-solving situations and supporting Hypothesis 1. This is consistent with Leonard-Barton's (1995) argument that importing and absorbing external expertise is among the essential ingredients to organizational knowledge building – "even companies with extensive internal research capabilities need to tap into complementary external sources of technology" (p175).

Factors Contributing to New Knowledge

We investigated whether effective problem-solving processes will lead to new knowledge being created. The results show that the quality of problem-solving contributed directly and significantly to new knowledge, with a path coefficient of 0.54. This supports Hypothesis 2 and suggests that patterns of comprehensive and creative problem solving together with shared commitment to the implementation of the solution are factors conducive to organizational knowledge creation. They confirm the critical role of comprehensive, creative and "congenial"

problem-solving *processes* in the creation of new knowledge, and support Cohen and Levinthal's (1990:130) claim that "problem-solving skills represent a capacity to create new knowledge".

Factors Contributing to Firm Performance

Our ultimate aim is to predict firm innovative and financial performance and we hypothesized a positive relationship between new knowledge creation and firm innovation, and between firm innovation and financial performance. The results show positive and significant relationships between new knowledge and innovation with a path coefficient of 0.43 and between innovation and financial performance with a path coefficient of 0.25. These results support Hypotheses 3 and 4 and do so after controlling for a range of firm characteristics (such as size, R&D intensity and ownership structure) and industry differences (through industry specific dummy variables). This is consistent with Nonaka and Takeuchi's (1995) argument that organizational knowledge creation is the key to innovation and firm performance. Perhaps more intriguing is the support for Hypothesis 7 – that there is no effect of new knowledge on performance other than through innovation. What this implies is that it may be possible to focus the knowledge management activities of the firm around the imperative of new and improved products/service, processes, and material outputs (patents, licenses, publications, etc.) and that managerial concerns about the measurement of knowledge could be solved through innovation as a valid proxy.

Alternate Model: Testing for Direct Effects

To check for any other alternative paths to firm performance, we re-estimated the model with two additional links – a direct link between knowledge acquisition and financial performance, and another between problem-solving capability and financial performance. Results showed no significant direct relationships, with minimal changes to the R-square value of financial performance (it increased from 0.15 to 0.16). The structure of the model (i.e., the significant

relationships shown in Figure 2) remained stable. The coefficients of these two direct paths are also noted in Table 2.

What is significant about this study is that we are able to measure knowledge creation and innovation as separate constructs and show a strong relationship between them. It is important to note that although knowledge creation is synonymous with firm innovation (by our empirical finding), it does not automatically lead to innovation. New knowledge needs to be mobilized and utilized within the organization to produce innovation. In other words, innovation (i.e. products, services, processes, patents, publications, etc.) is a tangible outcome that flows from the application of new knowledge (i.e., ideas, insights, “wider” thinking, increased ability to solve problems, etc.). In this study, we show that new knowledge that arises from an organization’s problem-solving process significantly predicts the level of its innovative output, and continued innovation leads to improved financial and market performance.

The Role of Absorptive Capacity

Absorptive capacity has significant impact on knowledge acquisition, supporting Hypothesis 5. This supports Cohen and Levinthal’s (1990) assertion that absorptive capacity is the ability to recognize the value of new, external information and is a direct influence on the level of knowledge sourced into the organization. We tested for a moderating effect of absorptive capacity on problem-solving capability in Hypothesis 6 and found that it was not supported. Indeed, we found that absorptive capacity had a direct positive effect on problem-solving capability, which implies that if the organization promotes a culture of absorptive capacity among its employees, the problem-solving team can tap into a deeper “pool” of alternative options and creative ideas when solving organizational problems, regardless of the level of individual knowledge acquisition. This points to the importance of entrenched organizational

routines and procedures in the knowledge creation process, or what Dierickx and Cool (1989) call “flows” of resources and capabilities over time.

Effects of Control Variables

We did not hypothesize any direction or magnitude for the control variables. However, for the sake of completeness we include all those coefficients with t-statistics greater than 2 in Table 2.

Conclusions

Knowledge is increasingly trumpeted as the most important competitive asset of the firm. However, there are still large gaps in our understanding of both the impact of knowledge creation on performance and the process by which knowledge is created. Indeed, a more conspicuous weakness is in our ability to apply quantitative modeling techniques to this issue. In our research, we endeavored to investigate quantitatively the process of knowledge acquisition and its impact on both the intermediate decision-making processes of the firm and its performance. In doing so we have made several contributions that enhance our understanding of this phenomenon.

First, our study provides a more comprehensive analysis of the knowledge creation process than previously existed. Rather than concentrating on a specific aspect of the overall knowledge creating process, we have examined the nature of the knowledge acquisition → problem-solving → new knowledge → innovation → financial performance chain in its entirety. This is important in the sense that we are able to show linkages between various concepts and literatures—e.g., such as Cohen and Levinthal’s work and that of Ginsberg—rather than simply inferring a link. This is particularly significant for managers because we are able to make specific managerial recommendations that relate financial performance to knowledge by examining all the intermediate steps from the establishment of knowledge acquisition activities to innovation and financial performance.

Second, in our investigation of the linkage between problem-solving processes and knowledge acquisition, we assert that knowledge is best understood in the way in which it impacts on actions. In other words, we do not rely on a direct measure of knowledge, but on the fact that knowledge, in the sense that it is a justified belief on which people act, will reveal itself through the quality of the higher level decision-making processes of the company and its management. Our approach— asking the respondent to describe and evaluate a specific problem-solving situation—allows us to simultaneously capture the contextual nature of the impact of knowledge and to study a dynamic process using cross sectional techniques. Our finding that the quality of organizational problem solving is the major contributing factor to new knowledge creation indicates that the firm’s inherent creativity and ability to gain consensus around ideas and solutions is at least as important as its ability to collect and analyze comprehensive information. We feel further validated in this belief by the fact that organizational absorptive capacity is of equal importance to knowledge acquisition in its impact on the problem-solving process.

Finally, from a managerial perspective, our study has the potential to give managers ideas on where to focus their efforts to achieve specific types of results. Working backwards from the innovation performance measure, a manager would be able to examine where in their problem-solving process they are deficient, and, having determined to what extent, where they can go next. For example, companies may discover that they have consensual decision-making and outline comprehensive options but are uncreative (the third “leg” of quality problem-solving). From there they can create solutions meant to increase the creativity of their organizational processes.

We see our study as a “preamble” to future research that will investigate in greater depth the specific factors contributing to organizational knowledge creation. Its most salient feature is to paint a picture of “what matters” in the context of knowledge creation. It tells us that we need to take into account the external network, the effects of information and know-how acquisition, the level of absorptive capacity, the nature of the existing knowledge base and the quality of problem-solving activities.

As with all studies of this kind, there are a host of limitations that present opportunities for further work. Some are methodological; for example, our measures of networking, information and know-how acquisition, and innovation are all uni-dimensional measures that hide some of the richness of the constructs. However, models with multi-dimensional dependent constructs become extraordinarily complex and difficult to interpret and we have chosen simplicity as our first pass on interpreting this data. Some limitations are conceptual; for example, although we know that the various control variables do not contribute much to the final innovation and performance constructs, we need to be more certain that our formulation is consistent across industries. This requires a series of industry models to validate whether the structure of the model is identical from industry to industry. Finally, we need to integrate our work more into the qualitative tradition in this area. Currently we are advancing the instruments used in this study and applying them in a series of case studies that match the industries studied here. This should allow us to make richer statements about what is going on in firms of this kind while at the same time providing further empirical validity of the formulation developed here.

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Figure 1: Proposed Model for Organizational Knowledge Creation

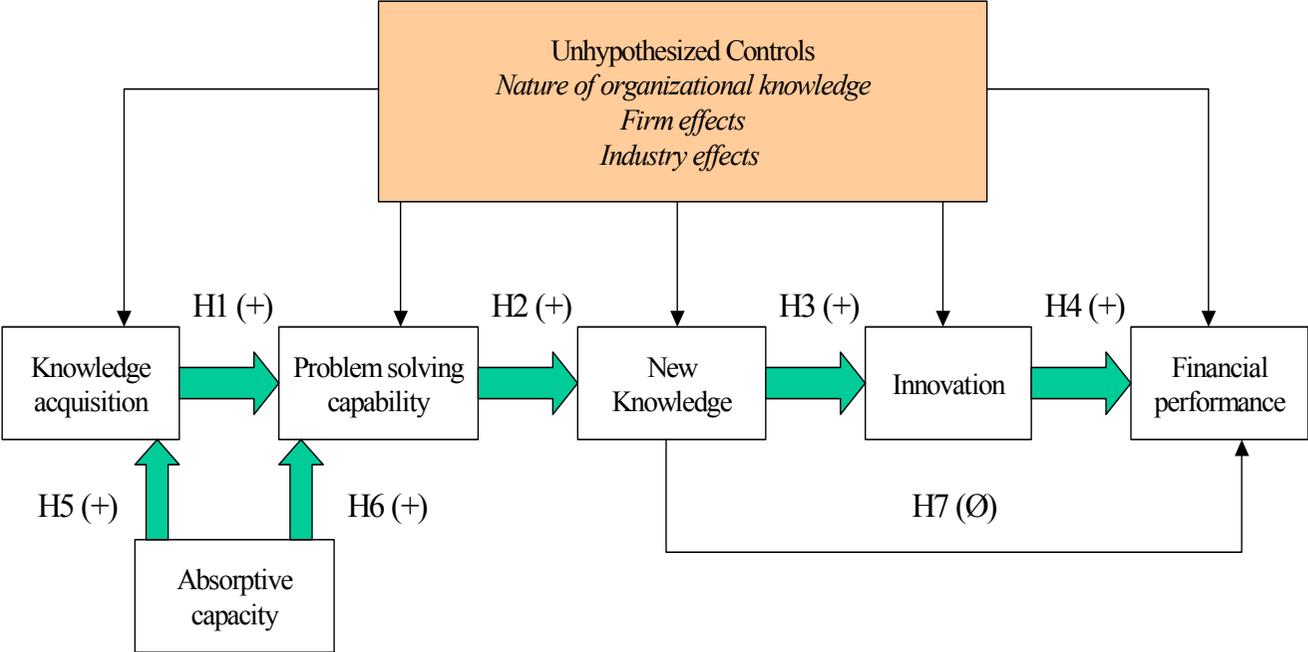
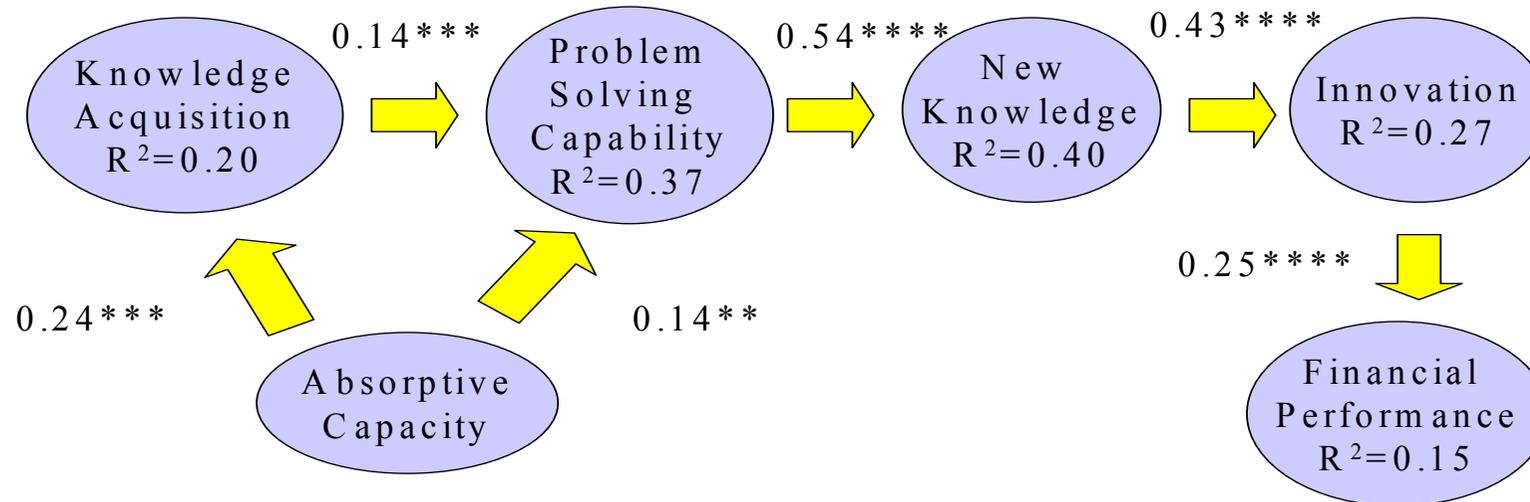


Figure 2: Structural Model Results



Significant links only are presented **** $p < 0.001$, *** $p < 0.01$, ** $p < 0.05$
R-square figures are those obtained after controlling for (1) nature of
organizational knowledge, (2) industry effects and (3) firm effects.

Table 1: Measures of Internal Consistency and Discriminant Validity (Correlations of Latent Constructs)

	Knowledge acquisition	Absorptive capacity	Problem-solving capability	New knowledge	Innovative	Performance
Knowledge acquisition (F)	1.00					
Organizational absorptive capacity (R)	0.34	0.78				
Problem-solving capability (R)	0.29	0.38	0.82			
New knowledge (R)	0.19	0.34	0.60	0.74		
Innovative performance (F)	0.38	0.37	0.36	0.42	1.00	
Financial performance (R)	0.05	0.11	0.15	0.08	0.28	0.80
Cronbach's Alpha	N/A	0.89	0.76	0.78	N/A	0.83
Fornell's Internal Consistency	N/A	0.92	0.86	0.86	N/A	0.87

(F) indicates a formative measure; (R) indicates reflective measures; Diagonal elements are square roots of average variance extracted

Table 2: Structural Model Results

	Proposed effect	Path coefficient	Observed t-value	Significance level	Hypothesis supported?
HYPOTHESIZED MODEL					
Effects Knowledge Acquisition (R² = 0.20)					
Absorptive capacity	H5 (+)	0.24	3.06	***	Yes
Industry control: banking and finance		0.20	2.10		
Effects on Problem-solving Capability (R² = 0.37)					
Knowledge acquisition	H1 (+)	0.14	2.48	***	Yes
Absorptive capacity	H6 (+)	0.14	2.03	**	Yes
Absorptive capacity*knowledge acquisition	H6 (+)	-0.08	-1.00	n.s.	No
Knowledge control: complexity		0.18	2.82		
Knowledge control: system dependence		0.23	3.61		
Effects on New Knowledge (R² = 0.40)					
Problem-solving capability	H2 (+)	0.55	10.68	****	Yes
Industry control: Machinery (non-electric)		-0.14	-2.24		
Effects on Innovative Performance (R² = 0.27)					
New knowledge	H3 (+)	0.43	7.59	****	Yes
Industry control: Petroleum, oil and gas		0.18	3.05		
Industry control: Chemicals		0.23	3.43		
Industry control: Machinery (non-electric)		0.22	2.57		
Industry control: Electrical & electronic machinery		0.21	2.79		
Industry control: Insurance		0.17	2.80		
Industry control: Business services		0.23	2.71		
Effects on Financial Performance (R² = 0.15)					
Innovative output	H4 (+)	0.25	3.59	****	Yes
New knowledge	H7 (∅)	-0.05	-0.08	n.s.	Yes
Extra Direct Paths in the Alternate Model					
Effects on Financial Performance					
Knowledge acquisition		-0.08	-1.16	n.s.	
Problem-solving capability		0.12	1.57	n.s.	

Control variables with t-statistics less than 2 are excluded for simplicity.

p-values: ** <0.05; *** <0.01; **** <0.001

Endnotes

¹ We use Ginsberg's (1995) concepts of comprehensiveness, creativity and consensus in defining and measuring "problem-solving capability". This will be discussed in detail in the later section on construct measurement.

² The five knowledge dimensions are: codifiability, teachability, complexity, system dependence and observability. From the standpoint of our model there is little reason to hypothesize any specific effect of Kogut and Zander's measures, noting only that they are a possible influence on the relevant constructs in the model.

³ The measure we use is $\sum_{i=1}^N F_i \ln(1/F_i)$ where F_i is the frequency of acquisition from i th party (F_i is computed as a percentage of the total frequency score). Soo (1999) examined the results of a related model both with the single items entered into the model (hence the weights are estimated optimally in a linear aggregation) and with the entropy measure. The effect in terms of aggregate path effects and fit are indistinguishable statistically.

⁴ Respondents were asked to rate (1) the impact of the described problem on firm performance and (2) the frequency of occurrence. On a 7-point Likert scale, the average score was 5.7 for "impact" and 3.8 for "frequency". These figures suggest that the described problems, although not frequently repeated, were critical to firm performance and hence the *process* of solving such problems constitutes the focal point for idea and knowledge generation. The types of problem described by respondents included organizational restructuring, improving product performance, process reengineering, developing marketing strategies and improving organizational culture and communication.