Applied process knowledge and market performance: the moderating effect of environmental uncertainty

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Keywords

Environment, Just-in-time, Manufacturing, Performance, Supply-chain management

Abstract

Challenges the idea of an unconditional and positive influence of knowledge on performance without regard to environmental uncertainty. Focuses on applied process knowledge spanning the supply chain (i.e. considers supplier, internal, and customer sources). A survey of 208 manufacturing firms found the association between applied process knowledge and firm market performance is positive and statistically significant when demand unpredictability is high (but not when low); statistically significant when product churning (uncertainty) is high (but not when low); and not moderated by core production or logistics process change. Firm size and production technology were also controlled. Firms that can determine the moderating effect of the different types of environmental uncertainty they face upon their knowledge-performance relationship will perform better in terms of market performance indicators.

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Introduction

Neoclassical theory postulated matter and energy (i.e. land, labor, and capital) as the factors of productivity. According to the resource-based theory of the firm, these factors have been replaced by knowledge and information as the primary wealth-creating assets of a firm (Bell, 1973; Glazer, 1991; Hunt and Morgan, 1995). Attention has turned to knowledge assets as indispensable resources and sources of competitive advantage (Grant, 1996a, b; Liebeskind, 1996; Prahalad and Hamel, 1990; Spender, 1994; Teece, 1998; Teece *et al.*, 1997; Wernerfelt, 1984). Managing knowledge creation and application has become increasingly vital to the survival and success of corporations (Hedlund and Nonaka, 1993; Nonaka, 1991). The competitive advantage of today's firms is judged by the creation and application of knowledge rather than market competitiveness based primarily on target market selection, product market positioning, or the price/performance of end products (Day, 1994; Dierickx and Cool, 1989; Grant, 1996a; Prahalad and Hamel, 1990; Teece, 1998; Teece *et al.*, 1997).

As an outgrowth of the resource-based view, the knowledge-based view of the firm concentrates on applied knowledge as the most strategically important of the firm's resources. The emphasis is on the application of knowledge, not merely acquisition and protection (Grant, 1996a, b; Spender, 1994). Any firm that does not treat knowledge as a purpose of its operations will fail, not because it could not create knowledge, but because it could not apply it to the delivery of market-valued products (Demarest, 1997). The success of firms in increasingly turbulent environments depends directly on the competitive quality of their knowledge-based assets and the successful application of these assets in operational activities to fulfill the firms' objectives (Bohn, 1994; Grant, 1996a; Spender, 1994; Teece, 1998; Teece *et al.*, 1997; Wiig, 1997). If research is to pursue knowledge assets as the most interesting resource underlying competitive advantage, it is imperative to undertake the study of the association between knowledge and performance (Hoopes and Postrel, 1999).

Despite the theoretical strength of the idea that the application of knowledge creates competitive advantages for firms, research

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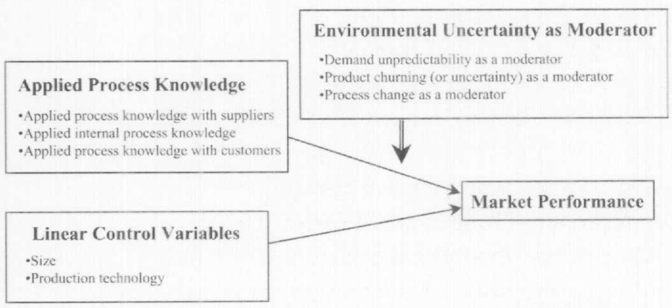
that demonstrates the influence of applied knowledge on firm performance under different environmental conditions is lacking. Contingency theory has long argued that, to remain viable, organizations in uncertain environments will adapt their knowledge-generating and application abilities to the changing contingencies in the environment (Terreberry, 1968). Thus, contingency theory argues for a challenge to the premise that the application of knowledge unconditionally results in improved performance. In this research, we propose an important contingency: the strength of the relationship between applied process knowledge and firm performance varies under different types of environmental uncertainty.

The objective of this paper is to propose and test a model of the conditional effect of applied process knowledge on market performance. We address the following research question: What are the performance implications of applied process knowledge (i.e. internal, supplier, and customer process knowledge) under different environmental uncertainty conditions (i.e. low versus high demand unpredictability, product churning, and process change)? Figure 1 presents the overall research framework. In addition to the knowledge, performance, and environmental uncertainty variables, the framework includes firm size and production technology as control variables. These variables have been shown to influence key firm variables and, therefore, should be statistically controlled in the analysis (for examples see Germain et al., 1994; Hill, 1989; Khandwalla, 1974; Kimberly, 1976; Miller, 1991; Miller and Dröge, 1986).

The paper is presented in the following format. First, we discuss the knowledge-based view of the firm and the association between applied knowledge and performance. Second, we discuss contingency theory, including hypotheses regarding the moderating effect of environmental uncertainty (i.e. demand unpredictability, product churning, and process change) on the knowledge-performance relationship. Third, we describe an empirical study in which the research framework of Figure 1 is tested. Finally, we conclude with a discussion of the results, including managerial implications and further research.

Figure 1 Research framework



Theoretical framework

Strategic management literature, following the precepts of resource-based theory (Barney, 1991; Dierickx and Cool, 1989; Doz, 1996; Rumelt, 1984; Wernerfelt, 1984) and dynamic capability (Day, 1994; Teece et al., 1997), has shifted its focus from looking outside at the industry structure to uncover the "real" basis for sustainable competitive advantage to internal, firm-level factors driving sustainable competitive advantage (Grant, 1996a). The knowledge base of a firm leads to a set of capabilities that enhances the chances for competitive growth and survival. How firms accomplish their work, and how well, has become a matter of considerable interest (Hoopes and Postrel, 1999; Jordan and Jones, 1997; Roos and Roos, 1997). Firms differ in their knowledge and these differences, when they are economically interesting, have enduring effects on relative performance (Grant, 1991; Kogut and Zander, 1992).

The resource-based perspective of the firm argues that the competitive advantage of firms is mostly attributable to differences in organizational resources and capabilities (Grant, 1996b; Roos and Roos, 1997). Knowledge has five attributes that distinguish it from physical assets. Typical firm assets are divisible, appropriable (i.e. either you have it or I have it), scarce, nonrenewable (or depletable), and exhibit decreasing returns to use. In contrast, knowledge as a resource differs:

(1) knowledge is not easily divisible;
(2) knowledge is not easily appropriable;
(3) knowledge is not inherently scarce (though it is often perishable);
(4) knowledge is essentially regenerative or "feeds on itself"; and
(5) knowledge often increases in value the more it is used rather than exhibiting

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decreasing returns (Glazer, 1991; Grant, 1996b).

Because of these, many have argued that knowledge assets can be leveraged to achieve competitive advantage (Barabba and Zaltman, 1991; Day, 1994; Garvin, 1993; Glazer, 1991; Prahalad and Hamel, 1990; Sinkula, 1994).

The application of knowledge is what endows it with these traits. Knowledge appreciates in overall value the more it is used. Knowledge has no value if it is not applied in some way. It is only in the application that it becomes valuable. Knowledge that is acquired or generated within an organization has to be crystallized into some concrete "form" such as a product or a process in order to create a knowledge asset (Demarest, 1997; Glazer, 1991; Hebeler and Van Doren, 1997; Hidding and Catterall, 1998; Nonaka, 1994; Spender, 1994). This conceptualization of knowledge is appropriate because restriction to purely cognitive aspects of knowledge would stretch the abstraction of the firm too far. It is hard to imagine a firm as solely a thinking entity, but much easier to see how it applies knowledge to develop practical skills (Hedlund and Nonaka, 1993).

Increasingly, successful enterprises recognize that performance depends on the competitive quality of its knowledge-based assets as well as the successful application of these assets in operational activities (Spender, 1994; Wiig, 1997). In applying knowledge from various sources within an operation, new knowledge is produced that can be used by more sources. The firm plays an integrating role by bringing together diverse inputs and specialized knowledge. In other words, the more a specialized application of knowledge is seen as delivering one particular source of value, its meaning to the firm is likely to go beyond its original function and provide other sources of value (Galunic and Rodan, 1998; Glazer, 1991; Hidding and Catterall, 1998; Teece, 1998). For example, a firm's expertise in just-in-time (JIT) scheduling and production is seen as an application of specialized knowledge. The original value of the JIT process is to lower the costs of production; however, it goes beyond this value by enabling the firm to provide a more customized offering to its customers and ultimately leads to better performance for the firm.

Knowledge itself does not ensure profits. Knowledge formed into valuable assets makes the difference. Ideas by themselves do not produce cash flow and rising stock value. The development and management of a network of responsibilities, patterns, rules, and scripts, applied throughout the firm, creates marketplace performance. Efficient markets provide profits only to successfully applied ideas (Demarest, 1997; Grant, 1996a; Hebeler and Van Doren, 1997). The firm that does not develop a capability for applying knowledge throughout the firm incurs significant excess costs and will suffer from lower performance outcomes (Hoopes and Postrel, 1999); a highly efficient, high-volume knowledge system that does not lead to dominating market performances has no ultimate value to the firm (Demarest, 1997). Consequently, organizational knowledge is valuable in proportion to its influence on market performance: ultimately, superior knowledge allows a firm to create or enhance customer relationships and their associated revenue streams, achieve operational efficiencies (through outright cost reductions or process refinements), devise a more productive system of work organization, or create the optimum goods and services for served markets (Demarest, 1997; Glazer, 1991).

The argument that improved market performance derives from applied knowledge of the firm depends critically on the assumption that a firm can protect its knowledge from imitation or appropriation by competitors (Grant, 1996b; Kogut and Zander, 1992; Liebeskind, 1996; Teece *et al.*, 1997). Specifically, the analysis of the profit-generating potential of resources and capabilities concludes that for knowledge to be one of the firm's most important resources and capabilities it must be relatively permanent, difficult to identify and understand, imperfectly transferable, not easily replicated, and the firm must possess clear ownership and control (Grant, 1991; Liebeskind, 1996; Spender, 1994).

Applied knowledge can exhibit these elements (and create a source of sustainable competitive advantage) for several reasons. First, applied knowledge is difficult to imitate because it requires the integration of specialized knowledge bases of several individuals. Merely learning what others know undermines gains from specialized learning. Competitive advantage is dependent on the firm's ability to access and apply the specialist knowledge of a number of individuals. Second, purchasing applied knowledge in competitive markets is difficult (unlike most capital goods, off-the-shelf technologies, and individual experts). By purchasing information in the form of facts, the theory that links facts is not transferred, and it is this theory that must be mastered if knowledge is to be applied. Furthermore, the price paid in a competitive market typically capitalizes the full profit from the knowledge asset. Finally, internal development of applied knowledge takes time and effort. A firm that does not learn to apply knowledge early is behind its rivals in developing a source of competitive advantage. Firms are generally not capable of developing new competencies quickly (Demsetz, 1991; Grant, 1996a; Hoopes and Postrel, 1999; Teece *et al.*, 1997).

If employees are mobile, application of knowledge depends more on mechanisms for applying knowledge rather than the extent of employees' specialist knowledge. The greater the span of knowledge being applied and the more sophisticated the integration mechanisms, the more difficult it is for competitors to accomplish imitation (Grant, 1997). Even if the resources that constitute the applied knowledge are transferred, the nature of the organizational routines – in particular, the tacit knowledge and instinctive coordination – makes the replication of the applied knowledge within a new corporate environment doubtful (Grant, 1991; Spender, 1994).

For example, lean production activities involved in a manufacturing process can be codified and transferred without requiring the knowledge of how the process works. A Japanese factory shop might, conceivably, be organized by rules of JIT scheduling, production, and delivery. In turn, these rules might be transferred to US manufacturing operations. Yet, the applied knowledge that results in the development of such processes is unlikely to be transferred as easily. Lean production processes often display high levels of cohesion. When this happens, imitation is difficult because of the required systemic changes within the organization and among interorganizational linkages. Being taught the explicit, codified skills of how to perform JIT processes is different than being taught how to apply the knowledge behind the processes. Imitation takes time; imitation of a best practice may be illusive, particularly in a different context or setting (Kogut and Zander, 1992; Teece *et al.*, 1997).

The role of the supply chain in applied process knowledge

Most organizations employ a mix when building the processes of knowledge acquisition and application, seeking knowledge from intra- and inter-organizational sources (Jordan and Jones, 1997). In this wider perspective, a firm's knowledge consists also of the information of other participants in the supply chain, as well as internal knowledge (Kogut and Zander, 1992). Knowledge applied to facilitate exchange within the supply chain is of three types:

(1) upstream, between the firm and its suppliers;
(2) within the firm itself, to facilitate its operations; and
(3) downstream, between the firm and its customers or distributors (Glazer, 1991; Teece, 1998).

Collaborative arrangements between firms within a supply chain are useful because it is sometimes difficult to achieve congruence between a firm's product domain and its knowledge domain (Grant, 1996b, 1997). Firms may use interfirm collaboration to gain access to other firms' knowledge assets, supporting more focused, intensive exploitation of existing knowledge within each firm (Mowery *et al.*, 1996). As the companies within a supply chain better utilize their internal knowledge resources and access the knowledge of outside firms, long time lags in developing new capabilities internally are avoided. In addition, such interfirm sharing of applied knowledge fosters the acquisition of "strategic options" on new technologies when the firm does not possess all the knowledge requirements needed (Grant, 1997). Collaborative partnerships permit ongoing, reciprocal exchanges of knowledge and play an important role in the transfer and application of explicit knowledge. Knowledge exchanges cannot be achieved entirely through codification or embodiment in products (Grant and Baden-Fuller, 1995).

Some applications of knowledge in supply chains appear simple but prove exceptionally difficult to imitate (Grant, 1991). This is especially true for applied process knowledge. Whereas applied product knowledge may be obtained through tactics such as reverse engineering, this is not the case for process knowledge because firms do not need to outwardly expose their applied process knowledge (Teece *et al.*, 1997). One of the simplest and well-known Japanese supply chain applications of process knowledge is JIT scheduling, production, and delivery. Despite the fact that it does not require sophisticated knowledge or complex operating systems, the coordination and attitudinal changes required for its effective operation are such that few US and European firms have introduced it within the supply chain with the same degree of success as Japanese companies. If apparently simple processes such as JIT are deceptively difficult to imitate, it is apparent that firms that develop highly complex capabilities can sustain their competitive advantages over very long periods of time (Grant, 1991).

Environmental uncertainty as a contingency variable

It is becoming a well-accepted dictum that in an economy faced with increasing turbulence in the external environment, applied knowledge has emerged as the most strategically significant resource of the firm for creating and sustaining a competitive advantage (Grant, 1996a; Nonaka, 1991). When demand unpredictability, product obsolescence, and technology change are all high, successful companies are those that continuously create and apply new knowledge to products and processes (Bohn, 1994; Grant, 1991, 1996a; Nonaka, 1991); however, in uncertain environments ambiguity exists over the future knowledge requirements of a product. Because acquiring and applying knowledge takes time, the firm must make knowledge investments whose returns are risky. Consequently, when facing environmental uncertainty, collaborative relationships with supply chain partners may limit risk by avoiding knowledge investments on the part of firms. Furthermore, in conditions of high environmental uncertainty, effectively managed supply chain relationships have been found to provide sustainable competitive advantage (Noordewier *et al.*, 1990). This suggests that the greater the environmental uncertainty which a firm faces, the greater the benefits of supply chain knowledge application compared with the mere internal application of knowledge (Grant and Baden-Fuller, 1995). Therefore, we hypothesize that the relationship between applied supply chain process knowledge and market performance is greater when environmental uncertainty (in the form of demand unpredictability, product churning, and process change) is high versus low.

H1. The positive relationship of applied process knowledge with market performance is greater when demand unpredictability is high than when demand unpredictability is low.

H2. The positive relationship of applied process knowledge with market performance is greater when product churning (or uncertainty) is high than when product churning is low.

H3. The positive relationship of applied process knowledge with market performance is greater when process change is high than when process change is low.

Method

Sample

The researchers obtained a sampling frame of 1,264 individuals from the National Association of Purchasing Managers manufacturer's "executive list". The "executive list" consists of those identifying themselves as having reached the upper level of purchasing in their firm or division. A goal of faxing a survey to 400 randomly selected individuals from the list was set. Each of the 400 had to meet three criteria, they had to:

(1) pass a key informant check;
(2) be willing to participate; and
(3) actually be employed by a manufacturer (as a check to catch misclassifications or changes in employment).

The criteria were assessed by phone contact. When a criterion was not met (n = 159), another individual was randomly selected from the list. From the list, 402 individuals were contacted by telephone as two returned questionnaires were discarded because of excessive missing values.

In 78 instances, a second survey was faxed to another employee who was identified by referral, contacted by phone, and met the three criteria. Of the 480 total surveys that were faxed, 227 were returned (from 210 firms). The response rate is 47 per cent (or 227/480) for surveys and 52 per cent (or 210/402) for firms. The majority of respondents were directors (66 per cent), followed by managers (16 per cent), and vice-presidents (14 per cent). Most were employed in purchasing (72 per cent), followed by materials management (10 per cent), and manufacturing (5 per cent). Average annual sales were $1.406 billion (ranging between $1.25 million and $42 billion with a standard deviation of $4.188 billion) and the average number of employees was 4,573 (ranging between 15 and 122,000 with a standard deviation of 13,132). Two-digit SIC codes were collected. The most often appearing SIC group in the sample is chemicals (SIC 28, n = 34), followed by fabricated metal products (SIC 34, n = 21), rubber (SIC 30, n = 18), food (SIC 20, n = 17), industrial machinery (SIC 35, n = 17), and electronic and electrical equipment (SIC 36, n = 14).

Measurement

Applied process knowledge was measured by 11 items. We defined knowledge on the survey as "understanding some phenomenon" (Hage, 1980). Respondents were asked to rate their firm's "application of knowledge in each of the following areas" on seven-point scales with endpoints "low application of knowledge" and "high application of knowledge". The items span the firm's entire supply chain and tap applied knowledge with and by suppliers (e.g. information from suppliers that improves inbound delivery and inventory management), internally (e.g. demand-pull support systems), and with customers (e.g. the extent to which the firm applies knowledge of customers' production plans). The items themselves were generated from literature reviews based in marketing (e.g. Frazier *et al.*, 1988), decision making (Germain and Dröge, 1997), and operations (Sakakibara *et al.*, 1993). The exact items in the applied process knowledge and in the other scales are presented in Table I.

Market performance was measured by two items tapping market share growth and sales growth. Seven-point scales with endpoints of "well below industry average" and "well above industry average" were used. Respondents rated performance over the past three years to offset particularly good or bad years due to unusual circumstances (Miller, 1991).

We controlled for two other commonly studied context variables, size, measured by the natural logarithm of annual sales (Khandwalla, 1974), and production technology, measured by Khandwalla's (1974) weighted mass output orientation scale (see also, Miller *et al.*, 1991). The latter measures reliance on five types of production technology ranging from custom production (of a single unit or a few units at time to customer specification), given a weight of one, to continuous process technology (as in the production of liquids, gases, or solid shapes), given a weight of five. The sum of the weighted items is then taken, with higher values indicating greater production routineness and lower values representing lesser production routineness. Seven items were used to measure demand unpredictability, product churning, and process change (e.g. Celly and Frazier, 1996). Seven-point semantic differential scales were used.

Reliability and validity

For the 17 instances where two respondents per firm exist, interrater agreement scores (r_{wg}s) were estimated. Values over 0.70 are acceptable and justify collapsing scores across multiple respondents; i.e. using the mean value when two respondents exist (James *et al.*, 1993). The interrater agreement scores are provided in Table I and all values exceed 0.70. The number of observations in the data set was thus collapsed down to 208 firms.

Two-group confirmatory factor analysis (CFA) was used to verify measurement adequacy. Using covariance matrices as input, LISREL was used (Jöreskog and Sörbom, 1993). Applied process knowledge is indicated by three variables: applied supplier process knowledge, applied internal process knowledge, and applied customer process knowledge. Size is indicated by the natural logarithm of annual sales and production technology by the weighted mass output orientation scale. Performance is indicated by market performance. Three two-group models were studied. In the first, the sample was split as close as possible on the median of

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Table I Scaling

Variable	r_{wg}	Items
Applied supplier Process knowledge	0.79	(1) information from suppliers that improves inbound delivery/inventory management;
		(2) suppliers' application of your production plans (shared plans with suppliers);
		(3) warehouse staging systems proximate to your firm that provides you with inbound JIT-type delivery
Applied internal Process knowledge	0.92	(1) total preventive maintenance methods;
		(2) demand-pull support systems;
		(3) methods for reducing machine set-up times;
		(4) cellular plant layout;
		(5) *kanban* support systems
Applied customer Process knowledge	0.71	(1) information from customers that improves outbound delivery/inventory management;
		(2) information from customers on their future production plans;
		(3) outbound warehouse staging systems proximate to customers to provide them with JIT-type delivery
Size		Natural logarithm of annual sales
Production technology	0.78	Weighted sum of:
		(1) custom technology;
		(2) small batch technology;
		(3) large batch technology;
		(4) mass production technology;
		(5) continuous process technology
Market performance	0.86	(1) market share growth over the past three years;
		(2) sales growth over the past three years
Demand unpredictability	0.81	(1) sales are predictable . . . unpredictable;
		(2) sales forecasts are likely to be accurate . . . inaccurate;
		(3) industry volume is stable . . . volatile
Product churning	0.82	(1) new products are introduced infrequently . . . frequently;
		(2) products become obsolete slowly . . . rapidly
Process change	0.83	(1) core production process change slowly . . . quickly;
		(2) logistics processes change slowly . . . rapidly

Note: r_{wg} = interrater agreement score

the demand unpredictability variable (α = 0.73) to form two groups: n = 115 in the low group and n = 93 in the high group. In the two-group CFA (see Table II), the factor loadings and errors were declared invariant across groups (χ^2 = 32.127; df = 21; p = 0.057; RMSEA = 0.072; CFI = 0.925) Several models were studied and these demonstrated that factor loadings and errors could be declared invariant across groups without significant loss of fit. As seen in Table II, the factor loadings all exceed 0.400 and respective t-values are all significant at $p < 0.01$. Together, these indicate adequate convergent validity. Interfactor correlations were estimated freely across groups in the CFA analysis. We then studied whether the interfactor correlation between applied process knowledge and size, between applied process knowledge and production technology, and between size and production technology could be declared equal across groups without significant loss of fit. This was the case. This finding is important because we may now declare the interfactor correlations between pairs of exogenous constructs invariant in the structural equations model (SEM).

The process for the two-group CFA based on a split in demand unpredictability was repeated for the two-group CFA on splits in product churning (α = 0.82) and process change (α = 0.83). For product churning, n = 89 in the low and n = 119 in the high group. The CFA demonstrated that factor loadings and errors could be specified invariant across groups without loss of fit. Model fit statistics are: χ^2 = 29.947; df = 21; p = 0.093; RMSEA = 0.064; CFI = 0.896. Subsequent testing revealed that all interfactor correlations between pairs of what will be exogenous constructs could be constrained to be equal across groups without a significant loss of fit. The low process change group contains 91 firms versus 117 firms for the high process change group. Factor loadings and errors could be declared invariant without loss of fit (model statistics:

Table II Two-group confirmatory factor analysis results of the measurement models

Variable	Loading (t-value) Demand unpredictability model		Product churning model		Process change model	
Applied process knowledge (SCR_1 = 0.61; SCR_2 = 0.63; SCR_3 = 0.63)						
×1. applied supplier knowledge	0.690	(8.783)	0.654	(8.477)	0.653	(8.210)
×2. applied internal knowledge	0.454	(5.883)	0.444	(5.795)	0.444	(5.628)
×3. applied customer knowledge	0.781	(9.722)	0.816	(10.224)	0.782	(9.487)
Size						
×4. natural logarithm of annual sales	0.983	(19.626)	0.983	(19.679)	0.983	(19.670)
Production technology						
×5. weighted production technology	0.982	(19.589)	0.983	(19.672)	0.982	(19.645)
Performance (SCR_1 = 0.82; SCR_2 = 0.83; SCR_3 = 0.83)						
×6. market performance	0.974	(19.256)	0.975	(19.334)	0.975	(19.281)

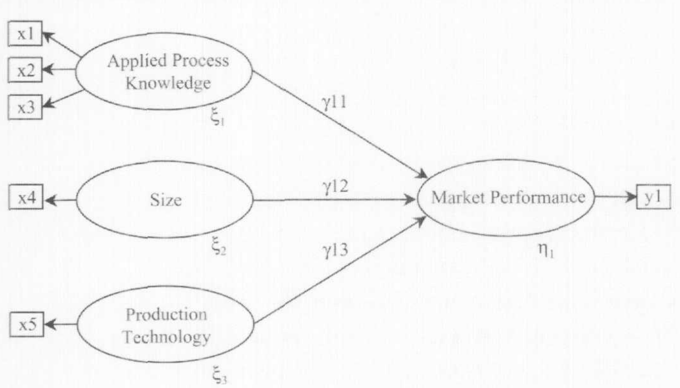
Notes: Loadings are common metric completely standardized estimates; All CFA t-values significant at $p < 0.01$; SCR = scale composite reliability for demand unpredictability, product churning, and process change models, respectively; Demand unpredictability CFA fit statistics: χ^2 = 32.127; df = 21; p = 0.057; RMSEA = 0.072; CFI = 0.925; Product churning CFA fit statistics: χ^2 = 29.947; df = 21; p = 0.093; RMSEA = 0.064; CFI = 0.896; Process change CFA fit statistics: χ^2 = 20.829; df = 21; p = 0.469; RMSEA = 0.019; CFI = 0.991

χ^2 = 20.829; df = 21; p = 0.469; RMSEA = 0.019; CFI = 0.991) as well as exogenous construct interfactor correlations.

Results

The hypotheses were tested using SEM based upon covariance matrices as input. Double-headed arrows indicating interfactor correlations between pairs of exogenous constructs are not shown in Figure 2. The process used in testing was as follows. First, a two-group baseline SEM was estimated with factor loadings, errors, and interfactor correlations between pairs of exogenous constructs declared invariant across groups, but with structural paths estimated freely across groups. Second, a nested model was estimated wherein the path from applied process knowledge to market performance was fixed equal across groups. The significance of the difference between this and the baseline model (a single degree of freedom $\Delta\chi^2$ test) represents a test of the hypothesis. For the sake of completeness, single degree of freedom $\Delta\chi^2$ tests are performed for the equality of the effects of size and production technology on market performance. Finally, a nested model is examined that incorporates the findings of the previous steps that frees, sets to zero, or sets equal across groups paths that need be. The process is performed separately for each of the two-group models based upon splits in the three environmental uncertainty variables.

Figure 2 Empirical model



Note: The model is a one-group representation of one of the 2-group models

Demand unpredictability as a moderator

For demand unpredictability, the baseline two-group model fit statistics are: χ^2 = 28.826; df = 24; p = 0.227; RMSEA = 0.044; CFI = 0.965. For each baseline model, Table III presents path estimates, interfactor correlation estimates, and t-values. Recall that the first hypothesis stated that the relationship between applied process knowledge and market performance would be greater when demand unpredictability is high versus low. The relevant path ($\gamma_{1,1}$) is not significant when demand unpredictability is low ($\gamma_{1,1}$,

Table III Summary of two-group LISREL model results

	Parameter estimate (t-value)											
	Demand unpredictability model				Product churning model				Process change model			
Parameter	Stable demand		Volatile demand		Stable products		Churning products		Stable processes		Changing processes	
$\gamma_{1,1}$	0.159	(1.363)	0.463	(3.356*)	0.089	(0.699)	0.483	(3.992*)	0.307	(2.235b)	0.317	(2.588*)
$\gamma_{1,2}$	0.022	(0.226)	0.146	(1.308)	–0.046	(–0.422)	0.115	(1.180)	0.070	(0.626)	0.033	(0.336)
$\gamma_{1,3}$	–0.008	(–0.077)	–0.030	(–0.248)	–0.045	(–0.384)	–0.027	(–0.250)	–0.076	(–0.622)	0.031	(–0.285)
$\Phi_{1,2}$	–	0.133	(1.581)	–	–	0.109	(1.317)	–	–	0.132	(1.545)	–
$\Phi_{1,3}$	–	0.353	(3.792*)	–	–	0.349	(3.716*)	–	–	0.362	(3.752*)	–
$\Phi_{2,3}$	–	0.303	(4.037*)	–	–	0.305	(4.051*)	–	–	0.299	(3.980*)	–

Notes: $\gamma_{1,1}$ = effect of applied process knowledge on performance; $\gamma_{1,2}$ = effect of size on performance; $\gamma_{1,3}$ = effect of production technology on performance; Estimates are common metric completely standardized estimates; Demand unpredictability fit statistics: $\chi^2 = 28.826$; df = 24; $p = 0.227$; RMSEA = 0.044; CFI = 0.965; Product churning fit statistics: $\chi^2 = 32.982$; df = 24; $p = 0.104$; RMSEA = 0.060; CFI = 0.940; Process change fit statistics: $\chi^2 = 26.367$; df = 24; $p = 0.335$; RMSEA = 0.031; CFI = 0.974; * = $p < 0.01$

1 = 0.159; t = 1.363), but it is significant when demand unpredictability is high ($\gamma_{1,1}$ = 0.463; t = 3.356; $p < 0.01$). The model with $\gamma_{1,1}$ constrained equal across groups ($\chi^2 = 32.21$; df = 25) is significantly different from the baseline model ($\Delta\chi^2 = 3.8384$; Δdf = 1; $p < 0.10$) suggesting that $\gamma_{1,1}$ cannot be set equal across groups without loss of fit. *H1* is thus supported.

The single degree of freedom $\Delta\chi^2$ tests to assess the equality of $\gamma_{1,2}$ and $\gamma_{1,3}$ across groups were not significant, nor were the pooled paths across groups significant. In the final nested model, $\gamma_{1,1}$ was estimated in the volatile demand group. All other paths were fixed to zero ($\chi^2 = 31.924$; df = 29; $p = 0.323$; RMSEA = 0.031; CFI = 0.974). As expected, the difference between this and the baseline model is not significant ($\Delta\chi^2 = 3.098$; Δdf = 5; $p > 0.10$). The path from applied process knowledge to market performance in the volatile demand group is significant ($\gamma_{1,1}$ = 0.471; t = 3.655; $p < 0.01$). It is important to note that the estimation of interfactor correlations between pairs of exogenous constructs means that the $\gamma_{1,1}$ estimate is a partial estimate after controlling for the linear effects of size and production technology. In summary, applied process knowledge predicts market performance, but only when demand is volatile.

Product churning as a moderator

The fit statistics for the two-group model based on a split in product churning are: $\chi^2 = 32.982$; df = 24; $p = 0.104$; RMSEA = 0.060; CFI = 0.940. Applied process knowledge predicts market performance when product churning is high ($\gamma_{1,1}$ = 0.483; t = 3.992; $p < 0.01$), but not when low ($\gamma_{1,1}$ = 0.089; t = 0.699). The nested model with $\gamma_{1,1}$ constrained equal across groups ($\chi^2 = 38.125$; df = 25) is significantly different from the baseline model ($\Delta\chi^2 = 5.143$; Δdf = 1; $p < 0.05$). The path from applied process knowledge to market performance cannot be set equal across groups without a significant loss of fit. The remaining two single degree of freedom $\Delta\chi^2$ tests for $\gamma_{1,2}$ and $\gamma_{1,3}$ were not significant and neither were the pooled paths.

In the final nested model, the paths from size and production technology to market performance were set to zero in both groups and the path from applied process knowledge to market performance was set to zero in the low product churning group ($\chi^2 = 34.232$; df = 29; $p = 0.231$; RMSEA = 0.042; CFI = 0.956). The difference between this and the baseline model is not significant ($\Delta\chi^2 = 1.250$; Δdf = 5; $p < 0.10$). The relationship of applied process knowledge with market performance is significant in the high product churning group ($\gamma_{1,1}$ = 0.486; t = 4.289; $p < 0.01$), but zero in the low product churning group, even after controlling for the linear effects of size and production technology. These tests support *H2* – namely, that the relationship of applied process knowledge with market performance is greater when the level of product churning is high as compared to low (alternatively, product churning moderates the effect of applied process knowledge on market performance).

Process change as a moderator

For process change the baseline model fit statistics are: $\chi^2 = 26.367$; df = 24; p = 0.335; RMSEA = 0.031; CFI = 0.974. The effect of applied process knowledge on market performance is significant in both groups (when processes are stable, $\gamma_{1,1} = 0.307$; $t = 2.235$; $p < 0.05$ and when processes change, $\gamma_{1,1} = 0.317$; $t = 2.588$; $p < 0.01$). For the nested model with $\gamma_{1,1}$ set equal across groups, $\chi^2 = 26.386$ (df = 25). The subsequent test of path equality across groups is not significant ($\Delta\chi^2 = 0.019$; Δdf = 1; $p > 0.10$). The path in the two groups can be set equal without a significant loss of fit. The tests of path equality for $\gamma_{1,2}$ and $\gamma_{1,3}$ across groups were not significant. The pooled estimates were not significant.

In the final nested model, the effects of size and production technology were fixed to zero in both groups, but the effect of applied process knowledge was estimated in both groups but set equal ($\chi^2 = 27.551$; df = 29; $p = 0.542$; RMSEA = 0.015; CFI = 0.993). The difference between this and the baseline model is not significant ($\Delta\chi^2 = 1.184$; Δdf = 5; $p > 0.10$). The effect of applied process knowledge on market performance ($\gamma_{1,1} = 0.316$; $t = 3.361$; $p < 0.01$) is equal in both groups. This does not support *H3* – the level of process change does not moderate the effect of applied process knowledge on market performance.

Discussion and conclusion

The current interdisciplinary literature suggests that the influence of applied knowledge on firm performance is positive and unconditional. In this study, we challenged this view from a contingency perspective. We argued that the relationship between applied process knowledge and market performance outcomes is contingent on environmental conditions. In particular, we predicted that high levels of demand unpredictability, product churning, and process change would stimulate firms to apply knowledge to increase their performance, whereas the positive relationship between knowledge and performance would be less when faced with low levels of these types of environmental uncertainty.

The knowledge-performance relationship

There is a general consensus that knowledge and performance are positively and significantly related and, furthermore, that the application of knowledge creates competitive advantages for firms. Prior research, however, has not examined the influence of applied knowledge on firm performance under different environmental conditions. Our objective was to test a model of the conditional effects of applied process knowledge on firm performance: we examined the performance implications of applied supply chain process knowledge (i.e. customer, supplier, and internal process knowledge) under conditions of high versus low demand unpredictability, product churning, and process change.

First, we examined whether the relationship between applied process knowledge and market performance is positive but moderated by demand unpredictability. In other words, does the uncertainty of the market in terms of predictability of sales, stability of industry volumes, and accuracy of sales forecasts affect the strength of the positive relationship of applied process knowledge with market performance? The two-group results show a positive and significant effect when demand is volatile and no significant effect when demand is stable. Thus we conclude that demand unpredictability moderates the knowledge-performance relationship, which is positive overall. When demand unpredictability is high, applied process knowledge is positively related to market performance, but not when demand unpredictability is low. This holds true even when controlling for the effects of firm size and production technology; that is, as firms become larger (or smaller) and as different manufacturing processes are used (ranging from custom to continuous process technology), there is a moderating effect of demand unpredictability on the knowledge-performance relationship.

Next, we examined whether the positive relationship between applied process knowledge and market performance is moderated by product churning. When products become obsolete quickly and new products are introduced frequently, applied process knowledge from the entire supply chain should have greater value, and hence firm market performance should be greater than when product obsolescence is slow and new product introduction infrequent. The results indicate that product churning is a moderator: when product churning is low, applied process knowledge has no effect on performance, but when it is high, the effect is positive. This moderating effect exists after controlling for the effects of firm size and production technology.

Finally, we examined whether the positive relationship between applied process knowledge and market performance is moderated by process change. Because we were investigating applied process knowledge, we hypothesized that changes in a firm's processes would moderate the knowledge-performance relationship. Specifically, we argued that when core production and logistics processes are stable, applied process knowledge would have a lower effect on performance, but when these processes change rapidly, the positive effect of knowledge on performance would be greater. The results of the two-group model showed a positive and equal effect regardless of the level of process change. Thus we must conclude that process change does not moderate the positive knowledge-performance relationship. This holds true even when controlling for the effects of firm size and production technology; that is, as firms become larger (or smaller) and as different manufacturing processes are used (ranging from custom to continuous process technology), there is no strong evidence of a moderating effect of process change on the knowledge-performance relationship.

The findings of this study contradict the idea that firms must continually adapt all of their internal structures and processes to deal with dynamic environments. Rather, the combination of the type of environmental uncertainty and the type of knowledge applied by the firm (in our case, applied supply chain process knowledge) determine the importance of the dynamism of the environment on the knowledge-performance relationship. The results of this study suggest that evidence of a moderating effect of the environment on the knowledge-performance relationship depends on the type of environmental uncertainty faced. For applied process knowledge, our focus, demand unpredictability (i.e. sales, industry volumes, and sales forecasts) and product churning (i.e. obsolescence and new product introduction) influence the knowledge-performance relationship but process change (i.e. rapidity of change in core production and logistics processes) does not influence the relationship.

The results suggest that for some types of environmental uncertainty, there is a conditional relationship between applied knowledge and market performance. When facing conditions of high demand unpredictability and product churning, applied process knowledge and market performance are positively and significantly related, but not when these types of environmental uncertainty are low. In contrast, the rapidity of change in a firm's operational processes does not moderate the relationship between applied process knowledge and market performance; the relationship is positive and significant in conditions of both rapid and slow process change. Hence the assumption that knowledge and performance are positively and unconditionally related is subject to challenge on these empirical grounds.

Managerial implications

Applied knowledge drives superior firm performance. In response to environmental uncertainty, firms should look inward, basing strategy on their knowledge assets as well as outward on served markets. The emergence of this resource-based approach to long-term strategy highlights the role of knowledge assets. This provides the foundation for the argument that the organization's ability to create, integrate, and apply knowledge assets is the ultimate source of competitive advantage. It is not the specialized knowledge of the organization's members which is of critical strategic importance. It is, rather, the firm's effectiveness at building, integrating, and applying its knowledge assets that is vital (Jordan and Jones, 1997).

The findings of the present study argue for recognition of the influence of uncertainty on the knowledge-performance relationship. Managers should be aware that an unconditional assumption that applied knowledge results in improved performance needs to be challenged. The type of environmental uncertainty moderates the knowledge-performance relationship. The tendency might be to assume that only when a firm faces high environmental uncertainty would it be important to apply knowledge to improve performance. The study shows it should not be assumed that when environmental uncertainty is low, knowledge has no impact on performance. When environmental uncertainty is high (e.g. sales are unpredictable, industry volumes are volatile, sales forecasts are inaccurate, products become obsolete quickly, new products are introduced frequently, and operational processes are subject to rapid change) the relationship between applied supply chain process knowledge and market performance is significant and positive; however, even in some cases of low environmental uncertainty (e.g. stable operational processes), applied knowledge is positively and significantly associated with market performance. Consequently, managers need to be cognizant of the different types of environmental uncertainty they face. From this research, managers understand that when faced with high (but not low) demand unpredictability, high (but not low) product churning, and high or low process change, applied process knowledge predicts positive market performance.

The present study investigated JIT processes implemented throughout the entire supply chain as a form of applied process knowledge. While not the only type of applied process knowledge available to firms, this manifestation of applied process knowledge shows that knowledge can be applied across the entire supply chain to the benefit of the firm. It has been suggested that effective knowledge-based companies can develop cost advantages by sharing operational improvement ideas (such as the proliferation of JIT across the supply chain) more rapidly than competitors and their supply chain partners who are not effective at applying knowledge (Trussler, 1998). Indeed, there may be synergy in applying knowledge across the supply chain as opposed to merely applying internal knowledge.

Study limitations and further research directions

In light of the constraints of the present study, further research should be considered. We examined only one type of applied knowledge. The sources of competitively advantageous knowledge and their relative mix is an area lacking research. This is an important area of investigation because the amount of knowledge generated and applied may depend not only on the specific sources to which the firm has access, but also on the proportionate representation of each type of knowledge in the firm's total knowledge base. The essence of knowledge management may be in the mix (in addition to management of each type of knowledge).

Obtaining a second respondent from a number of firms increased the reliability of the study; however, a higher number of multiple informant firms would improve further research. Furthermore, the cross-sectional nature of the data limited the degree to which we were able to study the moderating effect of environment on the relationship between applied knowledge and performance over time. Only longitudinal data would overcome this limitation.

Relatively large manufacturing firms were sampled in this study. It would be interesting to study knowledge, performance, and uncertainty in smaller firms or other types of firms (e.g. professional services, retail). Different results may be found in these different contexts. For example, professional service firms may be more concerned with different types of applied process knowledge (as opposed to JIT) than examined in the present study.

The measures used in this study offer one operationalization of each of the constructs. Other operationalizations are also appropriate. There are other types of applied process knowledge (e.g. other lean manufacturing processes) that may influence performance. There are additional environmental elements (e.g. competitive intensity, industry concentration) that should be examined. Further research should consider various combinations of different types of applied knowledge and other types of environmental uncertainty to determine those that foster performance. Similarly, while there is evidence that affirms the validity of self-reported performance measures (Dess and Robinson, 1984), our measures of market performance are self-stated as opposed to objective, archival measures. Finally, while we included two of the most common control variables, other control variables (e.g. technology use) should be considered when further research is conducted in this area.

References

Barabba, V. and Zaltman, G. (1991), *Hearing the Voice of the Market*, Harvard Business School Press, Boston, MA.

Barney, J. (1991), "Firm resources and sustained competitive advantage", *Journal of Management*, Vol. 17 No. 1, pp. 99-120.

Bell, D. (1973), *The Coming of Post-Industrial Society: A Venture in Social Forecasting*, Basic Books, New York, NY.

Bohn, R.E. (1994), "Measuring and managing technological knowledge", *Sloan Management Review*, Vol. 36 No. 1, pp. 61-73.

Celly, K.S. and Frazier, G. (1996), "Outcome-based and behavior-based coordination efforts in channel relationships", *Journal of Marketing Research*, Vol. 33 No. 3, pp. 200-10.

Day, G.S. (1994), "The capabilities of market-driven organizations", *Journal of Marketing*, Vol. 58, pp. 37-52.

Demarest, M. (1997), "Understanding knowledge management", *Long Range Planning*, Vol. 30 No. 3, pp. 374-84.

Demsetz, H. (1991), "The theory of the firm revisited", in Williamson, O.E. and Winter, S. (Eds), *The Nature of the Firm*, Oxford University Press, New York, NY, pp. 159-78.

Dess, G.G. and Robinson, R.B. Jr (1984), "Measuring organizational performance in the absence of objective measures: the case of privately-held firm and conglomerate business unit", *Strategic Management Journal*, Vol. 5, pp. 265-73.

Dierickx, I. and Cool, K. (1989), "Asset stock accumulation and sustainability of competitive advantage", *Management Science*, Vol. 12, pp. 1504-11.

Doz, Y. (1996), "Managing core competency for corporate renewal: towards a managerial theory of core competencies", in Dosi, G. and Malerba, F. (Eds), *Organization and Strategy in the Evolution of the Enterprise*, Macmillan Press, London, pp. 155-78.

Frazier, G.L., Spekman, R.E. and O'Neal, C. (1988), "Just-in-time exchange relationships in industrial markets", *Journal of Marketing*, Vol. 52, pp. 52-67.

Galunic, C. and Rodan, S. (1998), "Resource recombinations in the firm: knowledge structures and the potential for Schumpeterian innovation", *Strategic Management Journal*, Vol. 19 No. 12, pp. 1193-201.

Garvin, D. (1993), "Building a learning organization", *Harvard Business Review*, Vol. 71, pp. 78-91.

Germain, R. and Dröge, C. (1997), "An empirical study of the impact of just-in-time task scope versus just-in-time workflow integration on organizational design", *Decision Sciences*, Vol. 28 No. 3, pp. 615-35.

Germain, R., Dröge, C. and Daugherty, P.J. (1994), "The effect of just-in-time selling on organizational structure: an empirical investigation", *Journal of Marketing Research*, Vol. 31 No. 4, pp. 471-83.

Glazer, R. (1991), "Marketing in an information-intensive environment: strategic implications of knowledge as an asset", *Journal of Marketing*, Vol. 55 No. 4, pp. 1-19.

Grant, R.M. (1991), "The resource-based theory of competitive advantage: implications for strategy formulation", *California Management Review*, Vol. 33 No. 3, pp. 114-35.

Grant, R.M. (1996a), "Prospering in dynamically-competitive environments: organizational capability as knowledge integration", *Organization Science*, Vol. 7 No. 4, pp. 375-87.

Grant, R.M. (1996b), "Toward a knowledge-based theory of the firm", *Strategic Management Journal*, Vol. 17 No. 10, pp. 109-22.

Grant, R.M. (1997), "The knowledge-based view of the firm: implications for management practice", *Long Range Planning*, Vol. 30 No. 3, pp. 450-4.

Grant, R.M. and Baden-Fuller, C. (1995), "A knowledge-based theory of inter-firm collaboration", paper presented at the Academy of Management Conference.

Hage, J. (1980), *Theories of Organizations: Form, Process, and Transformation*, John Wiley, New York, NY.

Hebeler, J.W. Jr and Van Doren, D.C. (1997), "Unfettered leverage: the ascendancy of knowledge-rich products and processes", *Business Horizons*, Vol. 40, pp. 2-10.

Hedlund, G. and Nonaka, I. (1993), "Models of knowledge management in the West and Japan", in Lorange, P., Chakravarty, B., Roos, J. and Van de Ven, A. (Eds), *Implementing Strategic Processes: Change, Learning and Cooperation*, Basil Blackwell, Cambridge, MA, pp. 117-44.

Hidding, G.J. and Catterall, S.M. (1998), "Anatomy of a learning organization: turning knowledge into capital at Andersen Consulting", *Knowledge and Process Management*, Vol. 5 No. 1, pp. 3-13.

Hill, T. (1989), *Manufacturing Strategy: Text and Cases*, Irwin, Homewood, IL.

Hoopes, D.G. and Postrel, S. (1999), "Shared knowledge, 'glitches', and product development performance", *Strategic Management Journal*, Vol. 20 No. 9, pp. 837-65.

Hunt, S.D. and Morgan, R.M. (1995), "The comparative advantage theory", *Journal of Marketing*, Vol. 59 No. 2, pp. 1-15.

James, L.R., Demaree, R.G. and Wolf, G. (1993), "r_{wg}: an assessment of within-group interrater agreement", *Journal of Applied Psychology*, Vol. 78 No. 2, pp. 306-9.

Jordan, J. and Jones, P. (1997), "Assessing your company's knowledge management style", *Long Range Planning*, Vol. 30 No. 3, pp. 392-8.

Jöreskog, K.G. and Sörbom, D. (1993), *LISREL 8: User's Reference Guide*, Scientific Software International, Chicago, IL.

Khandwalla, P.N. (1974), "Mass output orientation of operations technology and organizational structure", *Administrative Science Quarterly*, Vol. 19 No. 1, pp. 74-97.

Kimberly, J.R. (1976), "Organizational size and the structuralist perspective: a review, critique, and proposal", *Administrative Science Quarterly*, Vol. 21, pp. 571-97.

Kogut, B. and Zander, U. (1992), "Knowledge of the firm, combinative capabilities, and the replication of technology", *Organization Science*, Vol. 3 No. 3, pp. 383-97.

Liebeskind, J.P. (1996), "Knowledge, strategy, and the theory of the firm", *Strategic Management Journal*, Vol. 17, pp. 93-108.

Miller, C.C., Glick, W.H., Wang, Y.-D. and Huber, G. (1991), "Understanding technology-structure relationships: theory development and metaanalytic theory testing", *Academy of Management Journal*, Vol. 34 No. 2, pp. 370-99.

Miller, D. (1991), "Stale in the saddle: CEO tenure and the match between organization and environment", *Management Science*, Vol. 37 No. 1, pp. 34-52.

Miller, D. and Dröge, C. (1986), "Psychological and traditional determinants of structure", *Administrative Science Quarterly*, Vol. 31 No. 4, pp. 539-60.

Mowery, D.C., Oxley, J.E. and Silverman, B.S. (1996), "Strategic alliances and interfirm knowledge transfer", *Strategic Management Journal*, Vol. 17, pp. 77-91.

Nonaka, I. (1991), "The knowledge-creating company", *Harvard Business Review*, Vol. 69, pp. 96-104.

Nonaka, I. (1994), "A dynamic theory of organizational knowledge creation", *Organization Science*, Vol. 5 No. 1, pp. 14-37.

Noordewier, T.G., John, G. and Nevin, J.R. (1990), "Performance outcomes of purchasing arrangements in industrial buyer-vendor relationships", *Journal of Marketing*, Vol. 54 No. 4, pp. 80-94.

Prahalad, C.K. and Hamel, G. (1990), "The core competence of the corporation", *Harvard Business Review*, Vol. 90 No. 3, pp. 79-91.

Roos, G. and Roos, J. (1997), "Measuring your company's intellectual performance", *Long Range Planning*, Vol. 30 No. 3, pp. 413-26.

Rumelt, R.P. (1984), "Towards a strategic theory of the firm", in Lamb, R.B. (Ed.), *Competitive Strategic Management*, Prentice-Hall, Englewood Cliffs, NJ, pp. 556-70.

Sakakibara, S., Flynn, B.B. and Schroeder, R.B. (1993), "Framework and measurement instrument for just-in-time manufacturing", *Production and Operations Management*, Vol. 2 No. 3, pp. 177-94.

Sinkula, J.M. (1994), "Market information processing and organizational learning", *Journal of Marketing*, Vol. 58 No. 1, pp. 35-45.

Spender, J.-C. (1994), "Organizational knowledge, collective practice and Penrosian rents", *International Business Review*, Vol. 3 No. 4, pp. 353-67.

Teece, D.J. (1998), "Capturing value from knowledge assets: the new economy, markets for know-how, and intangible assets", *California Management Review*, Vol. 40 No. 3, pp. 55-79.

Teece, D.J., Pisano, G. and Shuen, A. (1997), "Dynamic capabilities and strategic management", *Strategic Management Journal*, Vol. 18 No. 7, pp. 509-33.

Terreberry, S. (1968), "The evolution of organizational environments", *Administrative Science Quarterly*, Vol. 12, pp. 590-613.

Trussler, S. (1998), "The rules of the game", *Journal of Business Strategy*, Vol. 19, pp. 16-19.

Wernerfelt, B. (1984), "A resource-based view of the firm", *Strategic Management Journal*, Vol. 5, pp. 171-80.

Wiig, K.M. (1997), "Integrating intellectual capital and knowledge management", *Long Range Planning*, Vol. 30 No. 3, pp. 399-405.