Optimizing decisions using knowledge risk strategy

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Abstract

Purpose – *The paper aims to focus on a strategic approach for making trade-offs between knowledge and risk.*

Design/methodology/approach – *Knowledge and risk are viewed as organizational resources that have an inherent trade-off between them, so that optimal firm performance does not necessarily arise through greater accumulation of knowledge nor from reduced risk. This trade-off is represented as an efficient knowledge-risk frontier. The paper examines the dynamics of this frontier on organizational performance.*

Findings – *The concept of knowledge-risk strategy is presented which contends that non-probabilistic risk or uncertainty originates from gaps in knowledge.*

Research limitations implications – *The paper proposes a new line of research to understand decision-making in organizations, particularly those which focus on knowledge intensive products and services.*

Practical implications – *The paper proposes managerial approaches to improve organizational positioning relative to the efficient knowledge-risk frontier through greater awareness of contributors to knowledge gaps and risk in decision situations, as well as traditional strategic tools such as outsourcing.*

Originality/value – *The postulated link between risk and knowledge gaps establishes a knowledge-based view of firm risk and recognizes trade-offs for decisions regarding knowledge accumulation.*

Keywords *Knowledge, Decision making, Risk, Resource based strategy*

Paper type *Conceptual paper*

1. Introduction

There is significant focus in the management literature on the importance of knowledge and risk to firm success. Knowledge is seen as critical to competitive position (Zack, 1999), firm organization (Quinn *et al.*, 1996; Grant, 1996a) and to inter-organizational relationships (Dyer and Singh, 1998; Grant and Baden-Fuller, 1995). Extending knowledge through development of intellectual property is integral to organic firm growth and innovative capability (Cohen and Levinthal, 1990) so that efficient capture of knowledge becomes critical to expansion in domestic markets (Mahoney and Williams, 2003) and internationally (Ghemawat, 2008; Bartlett and Ghoshal, 1989). Moreover, knowledge is one of the firm's resources that must be reconfigured when extending its dynamic capabilities (Teece *et al.*, 1997). Because knowledge is so critical to organizational learning and development, its optimal deployment may be the only sustainable form of competitive advantage (De Gues, 1988) and so a lack – like limits on any resource – constrains a decision-makers' ability to develop strategic approaches.

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Regardless of the task that managers face, critical strategic decisions include which knowledge to develop and the extent to which knowledge needs to be developed to achieve a successful outcome. Two aspects of this are important.

Most evaluations of knowledge accretion assume it costlessly benefits the firm. Naot *et al.* (2004, p. 452), for instance, point out that learning "is generally assumed to produce some change in the organization" and then classify outcomes as cognitive, behavioural or normative, with no suggestion of financial consequences. Bapuji and Crossan (2004) also review the empirical literature on knowledge generation without identifying any financial consequences. In fact, most analyses of organizational learning and knowledge focus on their acquisition, dissemination and application (Grant, 1996b; Bueno and Salmador, 2003; Chiva and Alegre, 2005) without questioning the normative assumption that value will always be added.

In practice, most free knowledge is a public good that intuitively offers little competitive advantage. Acquisition of proprietary knowledge involves significant costs for its development and transfer, which can be so resource-intensive that not developing it may derive significant competitive benefits. Furthermore, once knowledge is developed, it can sometimes impede further learning by restricting the ability to respond to new or changed situations (Hedberg, 1981). Thus, firms must optimize, not merely achieve, knowledge gains and be continually alert to the inherent cost-benefit trade-off.

A second frequently overlooked caution in strategic discussions about knowledge is that a consequence of not developing knowledge is risk, with its meaning for managers as the probability and quantum of value loss. Lack of knowledge hampers management of risks and can lead to poor organizational outcomes through ineffective execution of strategy or disadvantage in quality and cost. Because the risk surrounding a particular decision comes from gaps in knowledge about alternative choices and the probabilities of possible outcomes, accumulation of knowledge should improve management decision-making.

Thus, the quantum of any risk to firm value is inversely related to the firm's knowledge about the risk's nature, and acquiring knowledge adds to firm value by improving risk management. This nexus, or inherent trade-off, between knowledge and uncertainty offers a potential competitive advantage given the obvious benefits from innovations in techniques to optimize knowledge development and deployment.

In the theoretical model presented in this paper, risk and knowledge are fungible, but, risk lies in the future, whereas knowledge lies in the past. Put differently, knowledge is a stock that has been accumulated over time, whereas risk is contingent on a future event. Thus, knowledge and risk form a continuum that breaks at the here and now, and future risk can only be reduced by accumulating further knowledge. This intuition is used to examine the implications of knowledge and risk on investments and decision-making.

Although the knowledge-risk nexus that is developed appears intuitively obvious and discussion of it trivial, observation of corporations suggests that knowledge and risk rarely meet in management theory or practice. The field of corporate risk assumes that knowledge is available, and the field of knowledge does not see its product as an input to risk. While knowledge is usually seen as an asset, most decision-makers discount risk as an unwanted occurrence to be avoided and never as an organizational resource that can improve performance. Because companies and researchers silo the two concepts, they are not functionally linked: risk and knowledge are as polarized as human resources and accounting (Trieschmann *et al.*, 2005).

The importance of risk to management should, though, be clear. For instance, firms seem unable to control risk using conventional techniques (Coleman, 2006), and they suffer poor payouts from basic corporate strategies such as initial public offerings (Ritter and Welch, 2002), mergers and acquisitions (Andrade *et al.*, 2001) and commodity hedging (Mian, 1996). Knowledge is so poorly applied and risk is so badly judged that "half the decisions in organizations fail" (Nutt, 1999, p. 75).

The concept of a return-risk nexus is leveraged to extend the literature on risk and knowledge in three ways. First, the paper proposes the concept of an efficient knowledge-risk frontier that represents an optimal set of trade-offs between knowledge and risk that will enhance performance outcomes. The key innovation is to see both knowledge and risk as organizational resources that are partially substitutable and require cost-benefit trade-offs, which suggests that knowledge accumulation and risk reduction are not invariably performance enhancing. Optimal performance is achieved by positioning the firm on an efficient knowledge-risk frontier, which is suggested to be competitively derived.

Second, the paper introduces the concept of knowledge-risk strategy, which is an approach to strategic decision-making that focuses on managing the firm's position in relation to the efficient knowledge-risk frontier. Third, the paper identifies management approaches to knowledge, risk and decision-making to help organizations come closer to an efficient frontier. This includes a conceptual outline of how knowledge gaps can emerge and methods of constraining ambiguity in decision-making.

The balance of this paper is presented in four sections. In the first, there is a review of existing literature, definition of key terms and discussion of the knowledge-risk nexus. In Section 2, the concept of an efficient knowledge-risk frontier is presented along with a series of propositions about its dynamics. In Section 3, knowledge-risk strategy is developed as a method of managing the firm's performance against the efficient knowledge-risk frontier. The focus here is on identification of different knowledge gaps and clarification of knowledge-based risks which arise in individual strategic decision-making. The paper concludes by specifically tying the knowledge-risk nexus to management practice and setting out implications for practice and suggestions for further research.

2. Integrating knowledge and risk: the knowledge-risk nexus

In most studies, knowledge is functional and constitutes sufficient understanding to form a basis for action (Saint-Onge, 1996) or to make judgments. Davenport and Prusak (1998, p. 5), for instance, define knowledge as: "a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information". At the other extreme is ignorance, which Carayannis (1999) defines as the absence of knowledge required for optimal action, which results in either inability to take action or decisions without full understanding. Knowledge is an abstraction from action because it enables action or performance but in itself is not valuable and requires application to enhance performance.

Like knowledge, risk has long been seen by scholars in multiple guises. Codification of its attributes started with Knight (1921) who drew the distinction between fundamental uncertainty and probabilistic risk, where the latter can be defined by a reliable distribution, so outcomes are drawn from a known population such as playing roulette. Uncertainty incorporates some element(s) beyond control and knowledge so that probabilities are not precisely known: betting on a soccer match or investing in equities involves uncertainty. Ambiguity describes the situation where it is not feasible to identify all possible outcomes, let alone estimate their probabilities (Camerer and Weber, 1992).

These perspectives on risk and knowledge suggest that each incorporates uncertainty, with knowledge constituting a decision's stimuli and risk encompassing its unwanted outcomes. Risks arise in the firm's assets, processes, culture, competencies and environment, and their successful management is judged by *ex post* outcomes of decisions. Firms that acquire appropriate knowledge improve their ability to manage risk, which is value building given a strong inverse link between risk and organizational performance (Bowman, 1980; Bromiley, 1991; Singh, 1986). For example, a study of US nuclear power plants showed that higher reliability was associated with higher earnings (Osborn and Jackson, 1988). The inverse profit-risk link can be seen as a function of endogeneity in firms' strategic judgment: decisions that reduce risk by promoting ethics,

safety, reliability and quality are value maximizing (Brickley *et al.*, 2002). In addition, badly judged risks induce creditors to increase borrowing costs and make investors uncertain about future earnings, both of which discount the share price. Knowledge accumulation enhances shareholder value by reducing risk, which suggests a knowledge-based view of firm risk that is comparable to the resource-based view of the firm.

Despite the intuitive importance of a knowledge-risk nexus, it has been little explored in previous literature. In particular, its strategic aspects have only been inferred and not developed. Marshall *et al.* (1996), for example, proposed that unmanaged organizational knowledge had been a contributor to spectacular financial disasters and developed some broad principles for knowledge management. From a similar perspective, McBriar *et al.* (2003) saw organization risks arising from inattention to knowledge. Pender (2001) points out that probability-based techniques to manage risks from human decisions are incomplete without incorporating knowledge availability, transmission and change. Other authors have set out the business case operationalizing strategic links between risk and knowledge. Chong *et al.* (2000) surveyed managers to show that few tracked returns from intangible assets such as knowledge, whereas DeTore *et al.* (2002) demonstrated a technique to quantify the benefits of knowledge accumulation.

A number of management researchers have tentatively linked knowledge and risk. For instance, Porter (1985, p. 470) sees risk as "a function of how poorly a strategy will perform if the 'wrong' scenario occurs", This kind of risk is clearly sourced in an absence of knowledge about the future. An example of how knowledge reduces risk is given by Delios and Henisz (2003) who found that firms with greater international experience are less sensitive to uncertain national policy environments. These firms accumulated knowledge through the act-then-learn philosophy of experiential learning (Kim, 1993), which can be deliberate or semiautonomous (Zollo and Winter, 2002). The experiential learning process helped develop knowledge that reduced their risk even when these organizations were facing new and uncertain environmental conditions.

A second stream of work that links knowledge and risk develops the concept that managers see many decisions with risks as incorporating real options (Miller and Shapira, 2004) that offer opportunities for improvement, so there can be value in delaying a decision to accumulate additional knowledge (Shapira, 1995). Clare and DeTore (2000) examine the valuation of investments in knowledge, arguing that pilot projects and other methods of breaking investments into stages allow knowledge to be accumulated about the probability distribution of the cash flows resulting from the knowledge investment. In this stream of research, risk is reduced as knowledge accumulates.

A third set of study incorporates environmental uncertainty into strategic planning and concludes that a significant factor distinguishing firms is their unpredictability and dynamism (Dess and Beard, 1984). The importance of risk and knowledge to strategy in dynamic settings was confirmed by Garg *et al.* (2003) who found that dynamism in firms' environment leads CEOs to increase their level of environmental scanning, which is a form of knowledge accumulation to deal with increasing levels of uncertainty (i.e. risk) in the external environment.

In the fourth strand of work linking knowledge and risk, Hoopes and Postrel (1999, p. 837) identify glitches or errors which arise "only because knowledge was not shared" and lead to risk and cost. Along similar lines, Grant (1996b) argues that co-location of knowledge and decision-making optimizes organizational efficiency by avoiding costs and delay in transfer of knowledge and by avoiding inferior decisions based on incomplete knowledge. Each view traces risk back to gaps in knowledge. As the concepts and tools of knowledge management mature, it has become clear that incomplete or incorrect knowledge is an important business risk.

3. An efficient knowledge-risk frontier: the trade-off between knowledge gaps and corporate risk

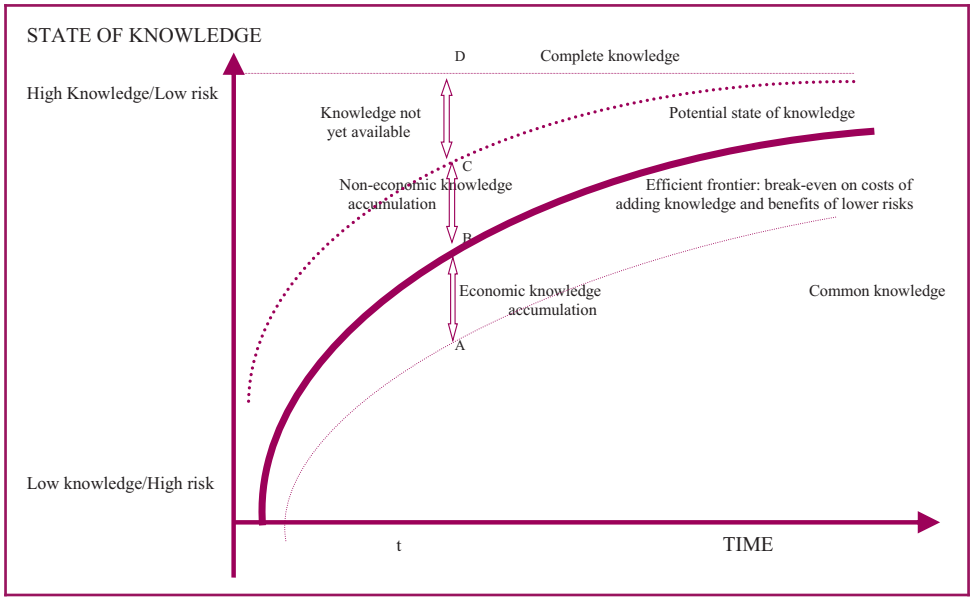
Knowledge and risk are partial substitutes. Thus, organizations' accumulated knowledge can be applied to reduce risk, whereas organizations that inefficiently apply their knowledge incur unnecessary risk. Because building knowledge increases firms' understanding of alternative actions, it can increase the probability of success. However, building knowledge has a cost and hence organizations must trade between the costs of investment in knowledge against those of higher risk.

This is a typical managerial task, and a useful concept is that of the efficiency frontier that enables a multivariate perspective by giving a competitive perspective to firms' optimization of resources that is richer than a financial or performance comparison (Chen *et al.*, 2015). The concept explains shortfalls in a firm's performance in terms of gaps to best practice that inefficiently match its inputs to outputs. Various methodologies have evolved to measure this inefficiency based on multiple inputs and outputs and the establishment of a benchmark frontier (Bessent *et al.*, 1988; Tofallis, 2001). This points not just to gaps in performance but to ways to resolve them.

It is proposed that there is an efficient frontier that represents the points at which the cost of knowledge accumulation equals the benefit to be derived in the form of risk reduction or enhanced performance (Figure 1).

The efficient frontier is competitively derived, so – somewhat counterintuitively – it shifts outward as competitors build knowledge. Most knowledge is readily available (Machlup, 1980), which sets benchmark risk levels and offers no competitive advantage. Thus, firms that do not utilize available knowledge may be penalized, and firms with proprietary knowledge are rewarded. Organizations seeking superior return from better managing risk need to develop their own proprietary knowledge, which requires time and resources and involves complex cost-benefit trade-offs. Moreover, competitors can quickly assimilate other firms' proprietary knowledge and remove any differential reward. Because proprietary knowledge and common knowledge increase with time, there are continually greater demands placed on the necessary knowledge for a company to compete. Assuming a static organization, time shifts the efficient frontier upwards and outwards (Figure 1).

Figure 1 Risk-return nexus and efficient frontier



To describe the model, it involves a management topic whose state of knowledge is static and so "complete knowledge" – D – is constant. Firms can acquire common knowledge – A – without cost apart from its implementation. In addition, they can build and deploy proprietary knowledge at the cost which brings benefit up to the efficient frontier – B. Above this point, firms can build and deploy identifiable proprietary knowledge up to point C, but its costs exceed benefits. Moving above C requires insights beyond the capability of individual firms. The three curves slope upwards on the assumption that knowledge accumulates over time and are asymptotic to the limit of complete knowledge.

An example can be seen in the development of deepwater oil exploration. This technology began with commencement of offshore drilling in US waters in 1938. Oil companies leapfrogged each other to move into ever more challenging frontiers, reaching water depths of 1,000 feet within 40 years. However, disasters such as that involving the BP Deepwater Horizon in 2010 (which was in mile-deep water) show that much remains to be learned (Graham, 2011).

To operationalize the model, firms operating above the efficient frontier may have accumulated invalid or inaccurate knowledge (Tsang, 1997), which is not economically deployed and requires effort to unlearn (Tsang and Zahra, 2008). Alternatively, they may have anticipated a shift in the efficient frontier. This will be inefficient if timing of the knowledge acquisition does not match its utilization or if it never proves relevant to the organization's operations. On the other hand, firms may use foresight to acquire proprietary knowledge in advance of its competitive utilization, and, although notionally less efficient, increase their ability to respond as competitive pressure moves the efficient frontier. Firms may temporarily maintain positions below the efficient frontier because of unrealized risk, but, eventually, this will lead to poor performance.

To summarize the implications of the model, firms face three key issues when dealing with knowledge-based risk. First, a lack of reliable knowledge generates risk in decisions. Second, there is a cost in accumulating knowledge and keeping it current, which imposes risk-return trade-offs from investment in knowledge: firms do not know the precise nature of knowledge prior to accumulating it and so may invest in the wrong knowledge, which does not lead to value additions. Knowledge-risk strategies accumulate knowledge when it provides a favourable return and discourage its accumulation when benefit is minimal. Finally, changing knowledge shifts the competitive balance, so firms need to match knowledge strategy to their environment.

These competitive dynamics imply that organizations may temporarily hold more or less efficient positions in relation to the efficient frontier. The following sub-sections develop a number of propositions regarding the efficient frontier.

3.1 Performance implications of the knowledge-risk frontier

A nexus between knowledge and risk exists because an organization's risks at any point in time are a function of the knowledge it has gained along the historical pathway set by past decisions. The authors believe that linking knowledge and risk can be achieved by firms at a slight incremental cost and will generate synergies and enhance understanding of the fundamental drivers of corporate performance.

Risk can be reduced at low cost when organizations under-utilize knowledge they possess or can access commonly available knowledge. In the case of under-utilization, most corporations build more knowledge than necessary to achieve their goals (Araujo *et al.*, 2003; Brusoni *et al.*, 2001) and consequently have a favourable cost-benefit trade-off in acquiring knowledge. For example, they typically hire widely experienced staff and sponsor education to develop their knowledge and skills beyond the requirements of current tasks. Because the gap between the quanta of knowledge that is available and used can be large (Prietula and Simon, 1989), there is a cogent argument to better utilize already available knowledge to reduce risk and move the firm closer to the efficient frontier.

Even when there is some cost to acquiring and applying this knowledge, the reduction in risk should help to reduce variability in earnings and deliver net financial benefits to the organization in the long term. This leads to the following proposition:

P1. Most firms face a favourable cost/benefit trade-off for knowledge and risk and hence can reduce risk for any given level of organizational performance through better knowledge utilization or acquisition of commonly available knowledge.

However, because most firms derive any superior competitive performance from a subset of organizational resources that are valuable, rare, inimitable and non-substitutable (VRIN) (Barney, 1991), only the acquisition of specific proprietary knowledge has the potential to affect competitive performance. While unique VRIN resources are thought to explain heterogeneous performance in firms (Crook *et al*., 2008), non-VRIN resources or strategic industry factors are seen as necessary to avoid competitive disadvantage (Amit and Schoemaker, 1993). These "necessary to play the game" resources only need to be maintained at an average industry level. For example, clean restrooms are important to a competitive restaurant but only to the extent that they do not create dissatisfaction in customers. Our view of these non-core resources is that they represent different points on the efficient knowledge-risk frontier. Additional knowledge about how much satisfaction or dissatisfaction results from clean washrooms may reduce the risk of lost customers, but the cost of accumulating and applying that knowledge may exceed the potential risk. A large portion of the knowledge accumulated by firms would relate to these non-VRIN resources. Not accumulating this knowledge may not directly impact competitive performance but it does increase risk. This leads to the following propositions:

P2a. Acquisition of proprietary knowledge has greater costs but is necessary to reach the efficient frontier and achieve superior long term performance.

P2b. Because the acquisition of knowledge has a cost, firms that acquire less knowledge may secure a profit advantage, but this is only short-term as it leads to increased risk, whether realized or implied.

3.2 Dynamic environments and the efficient frontier

Because knowledge accumulation is bounded by limits on the decision-maker's time and resources, knowledge can be available but not captured by a decision-maker. An environment where knowledge is being created is likely to expand knowledge gaps and so risk increases with environmental dynamism. Environmental dynamism has been shown to have multiple components that includes knowledge accumulation and the interdependencies between competitive actions (Castrogiovanni, 2002). Industry complexity may also make learning more difficult (Cohen and Levinthal, 1990) because of the complexity of the products (Gupta and Govindarijan, 2000) or the intensity of R&D within the industry (Lee, 2003).

A typical example involves the introduction of new products, which are often launched before their effects and consequences are fully understood. Commercialization reveals knowledge gaps, which close over time because suppliers move up the experience curve and reduce the incidence of consumer complaints and product defects. When the rate of innovation is slow and product life cycles are long, few risks arise out of knowledge gaps. However, in a rapidly innovating environment, knowledge gaps can remain large for lengthy periods: the industry is permanently running significant risks.

Milliken (1987) pointed to the genesis of risk from knowledge gaps in a changing environment with his suggestion that environmental uncertainty had three types:

1. state uncertainty when the external environment is uncertain and unpredictable;
2. effect uncertainty when the impact of environmental events or changes on the decision-maker are uncertain; and
3. response uncertainty when decision-makers cannot know the consequences of their actions.

This complements the concept of turbulence (Emery and Trist, 1965), which arises from exogenous uncertainties such as increases in social and industrial activity and technological innovation:

> Escalating complexity and change require greater adaptive capacity [which is used by organizations of] [. . .] resources and skills to process information, make sense of their environments, and act [. . .] to at least maintain their viability (McCann and Selsky, 1984, p. 461).

This can extend to hyper-turbulence where the level of uncertainty is so high that the environment is unpredictable and the decision-maker lacks sufficient adaptive capability to survive. The environment renders the decision-maker ignorant because of lack of knowledge about the decision's components and, more importantly, possible outcomes.

That is not to say that all turbulence derives from knowledge gaps: it can, for instance, be caused by knowledge acquisition (of the type depicted in Schumpeter's gales) or shocks (which can be sourced as far apart as demography and natural disasters). Even previously stable industries can have changes imposed on them through government policy or scientific breakthroughs (e.g. environmental regulations, epidemiological studies of health risks). Nor does every gain in knowledge reduce risk: knowing the identity of a murderer can simultaneously increase knowledge and probabilistic risk.

While McCann and Selsky (1984) do not link knowledge and risk, their concept of adaptive capacity is clearly akin to knowledge, and its absence threatens firm viability. To them, turbulence follows escalating complexity and brings disruptive change, much as Toffler (1970) argues that knowledge fuels change in the environment and technology drives it. In terms of our earlier discussion, turbulence is another manifestation of rapid change in available knowledge, which increases the scale of knowledge gaps and thus risks.

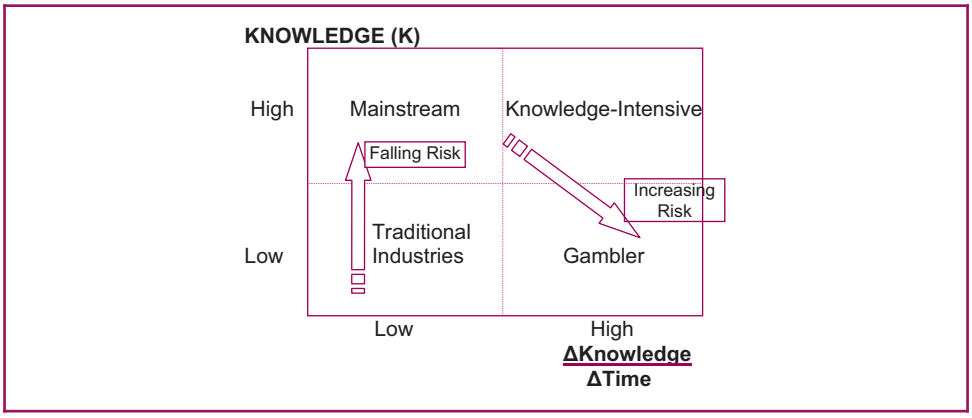
Because commonly available knowledge grows with time, a firm moves further away from the efficient frontier unless it actively acquires knowledge. In stable environments, inter-organizational learning tends to reduce variation in organizational practice (Miner and Haunschild, 1995). Organizations also are rarely static and, at the same time, actively attempt to restrict knowledge flows and disclosure to competitors (Harris, 1998). However, in dynamic environments, this growth of knowledge moves at a faster pace and hence these environments impose additional challenges for firms to maintain a position on the knowledge-risk frontier. This leads to the following proposition:

P3. Organizations in dynamic environments are subject to increased levels of risk from knowledge gaps. In other words, the efficient knowledge-risk frontier advances faster in dynamic environments.

Even without turbulence, continually growing knowledge means that the risks facing any organization will be forever evolving: thus, risk management can never eliminate risk *per se* and, at best, minimizes exposures from current risks while scanning the environment for newly emerging risks. From a knowledge-risk strategy perspective, continuous accumulation of knowledge is the only way to manage risks.

This dynamism means that environmental risk at any point in time is a function of the existing knowledge gap plus changes in knowledge and can be captured through risk vectors as shown in Figure 2. Because there is a cost to acquire knowledge, firms in dynamic environments segment themselves by competencies and existing knowledge. Specialization and cooperation allow firms to remain efficient at developing knowledge that matches the rate of change in the environment. Traditional industries such as craft-based firms or small service companies will operate in the lower left quadrant of Figure 2, whereas mainstream companies are in the upper left. Leading edge companies with large R&D resources operate in the upper right quadrant. Only firms that are willing to gamble by relying on chance in the face of an unknown future are in the bottom right quadrant. When knowledge is evolving rapidly, it can be impossible to keep up: in such an environment, it is not practicable to ever attain a high level of knowledge, and chronic gaps create

Figure 2 Knowledge-turbulence dynamic



significant risk from instability which eventually leads to hyperturbulence. Conversely, when knowledge is relatively stable, it can be amassed and reduce risk.

The important implication of dynamism shown in Figures 1 and 2 is that firms can best manage risks by matching knowledge accumulation to their environment. Knowledge-based strategies that respond to the environment include collaboration, partnering, acquisition and development of indirect capabilities (e.g. through outsourcing). These will be discussed further in Section 4.

3.3 Path dependency and the efficient frontier

At any instant, an organization is dependent on the path it has travelled: looking backwards, it is defined by the knowledge it has amassed; looking forward, the value it can capture is a function of how its knowledge can be leveraged to successfully manage risks. While decision-makers and organizations can optimize the response to different decision situations, it can be hindered by path dependency. The decision situations themselves are difficult to recognize, firms lack awareness of their given state of knowledge, interpret knowledge differently and misunderstand the most effective path in which to develop knowledge to enhance performance.

Viewing knowledge accumulation as path-dependent implies that it can be hard to determine the actual state of knowledge and how far along the path has the firm travelled. Thus, a history of accumulating knowledge can lead an organization to conclude that its decisions are reasonably well founded, but this may actually be false because more extensive knowledge would indicate a level of ignorance. Carayannis (1999) calls this latter high level awareness meta-knowledge, and, even when actual knowledge remains limited, it can reduce risk by moving the decision-maker from a state of ignorance to one of uncertainty.

The varied history of firms explains why they interpret the same knowledge differently. Some can be trapped in core rigidities (Leonard-Barton, 1992), whereas others explicitly recognize the importance of knowledge. The latter is most evident in "firms possessing entrepreneurial resources" which deliberately build processes that continually search for new knowledge (Penrose, 1999, p. 66). This, however, requires significant time and effort and also the vision to know which direction to pursue (Sartre, 1992). Even then, new knowledge may be inappropriate or not emerge as anticipated (Boulding, 1956).

Complex pathways link improved knowledge to lower organization risk and enhanced performance. Potential strategies are bounded by past decisions that determine a firm's competencies and resources such as organization structure, assets, processes, geography and markets. These define the firm's ability to improve knowledge and understanding of decision outcomes and thus influence risk (Teece *et al.*, 1997). A less

direct path-dependency is accumulated knowledge which allows organizations to discover new ways of combining existing resources and develop profitable products or services and also establishes cognitive frames to evaluate new knowledge or events (Das and Teng, 2001, Lyles and Schwenk, 1992).

Risk is path-dependent in terms of the time required to acquire knowledge and the need to develop supporting competencies. Firms that are not efficient from a knowledge-risk perspective will face time requirements to build knowledge that efficient firms will not face. Cohen and Levinthal (1990) argue that a lack of absorptive capacity leads to a situation of lockout where organizations fail to perceive the value of new information, whereas Lane and Lubatkin (1998) suggest that inter-organizational learning is impacted by differences in knowledge bases. However, even in cases where the value of knowledge is correctly perceived, the time required to acquire and assimilate the information may prevent the organization from achieving any meaningful benefit. Particularly in cases where new knowledge or innovations are created within an industry and the efficient frontier shifts, the ability of a firm to respond is subject to increased risk of poor performance from the compounding of existing knowledge-risk gaps with the newly created gaps from the shift in the efficient frontier. The ability of a firm to reach the efficient knowledge-risk frontier is slowed by the path dependent nature of knowledge. This leads to the following proposition:

P4. Organizations that face higher levels of risk from knowledge gaps will take longer to respond to industry innovations than firms with lower levels of risk from knowledge gaps. In other words, the further a firm is from the efficient knowledge-risk frontier, the longer the time to reach the frontier.

4. Managerial implications of the knowledge-risk frontier: knowledge-risk strategy

This section builds on the linkages that were established between knowledge and risk to present a practice-focused approach which is labelled *knowledge-risk strategy*. Knowledge-risk strategy identifies and manages the exposure to risk resulting from gaps in knowledge and is distinguished by the centrality of the knowledge-risk nexus, and optimizing the firm's position on the efficient knowledge-risk frontier.

Implementing knowledge-risk strategy is a dynamic process that is demanding of resources and can trigger strategic choices that have opportunity costs. This is because of linkages between organizational learning, knowledge and risk, which means that pursuing more or less of one impacts the others and firm value. Because firms operate in different contexts, their experiences are unique and there is no universal rule, such as positive trade-offs between return and risk, knowledge acquisition or organizational learning. Although, knowledge-risk strategy has few rules, it offers opportunities to capture additional value through insights related to awareness and containment.

Awareness focuses on understanding the structure of decision situations and competitive knowledge gaps or dysfunctions. Whether investments are made to close these gaps depends on the cost/benefit trade-off implied by the efficient knowledge-risk frontier. If this trade-off is favourable, knowledge accumulation is appropriate. If the trade-off is not favourable, then existing knowledge should be used to contain risk by, process improvement, enterprise risk management or risk management products such as insurance.

The trade-offs inherent in knowledge-risk strategy were set out in relation to Figure 1. Consider a sector whose knowledge is steadily accumulating. At time *t*, all firms have free access to common knowledge – A – which sets the benchmark risk. The most cost-effective risk is reached on the efficient frontier of knowledge accumulation at point B where the cost of achieving additional knowledge equals its benefits (which include risk reduction and improved financial results). Over time, knowledge accumulates through experience and invention, so that common knowledge or benchmark risk overtakes the previous efficient frontier.

To derive the strategic implications of this diagram, consider a firm at point B. Given the sector's state of knowledge, the firm has minimized its possible risk and can only reduce it further by acquiring additional knowledge, which brings no net benefit. A decision not to accumulate additional knowledge is rationally ignorant. Conversely, firms at point A have knowledge available to them that can cost-effectively reduce their risk and remove a competitive disadvantage by purchasing knowledge, developing its own knowledge or waiting until the knowledge becomes generally available. Firms below point A can add value merely by taking advantage of commonly available knowledge.

A practical application of the model can be demonstrated with a start-up firm. At inception, it sits below point A (for example) where its knowledge base is small and concentrated; thus, risk is initially high, but it falls as knowledge gaps close. Empirical evidence supporting the concept that risk is reduced as knowledge is accumulated is offered by Biggadike (1979) who sampled 200 *Fortune* 500 companies to evaluate returns from their new product launches. He found that only 18 per cent of ventures were profitable in the first two years, but this rose to 38 per cent by the end of year four and exceeded 50 per cent in year seven. In terms of our argument, start-up firms initially pay such a high price to garner commonly available and unrewarded knowledge (everything from accounting practices to production line management) that they are unprofitable for years.

4.1 Increasing awareness of the contribution of knowledge gaps to corporate risks

Contemporary risk management follows a reductionist approach that uses processes to limit hazards or products to fix the outcome.

The process-perspective of risk management looks forward at risks that might emerge or backwards to learn from risks that have emerged. It typically classifies corporate risks in terms of their loci (McCarthy and Flynn, 2004; Deloach, 2000), which are usually tangible, either as recognizable bodies such as competitors, counterparties and government regulators or specific events such as natural disasters, operational failures and organizational conflicts. The product-perspective of risk management narrows uncertainty to lock in an outcome, typically through insurance or by hedging with market-based instruments such as futures contracts.

The alternative view proposed in this paper is that many risks arise where knowledge is available but has not been captured by the decision-maker and requires a more holistic, even philosophical, approach to cost-effectively reduce knowledge gaps. This section examines firm risk in light of knowledge available to the decision-maker from their own experience, organizational processes and routines and from others in their network. This points to seven types of knowledge gaps in organizations related to decision-makers' access to knowledge and its validity which are summarized in Table I.

The table incorporates two relevant concepts. One is validity of knowledge which was developed by Pears (1972) and intuits that the strategic value of knowledge falls steadily to ignorance with removal of its three critical aspects, namely, confidence or certainty,

Table I Origins of different knowledge gaps

Type of knowledge gap	*Location of knowledge gap*	*Decision-maker access to knowledge (Yes, no or partial)*	*Validity of knowledge (Valid or invalid)*
Invalid knowledge	All types	Yes	Invalid
Process uncertainty	Organizational explicit knowledge	Partial	N/A
Knowledge uncertainty	Individual tacit knowledge	Partial	N/A
Hidden knowledge	All tacit sources	No	N/A
Cognitive bias	Decision-maker tacit knowledge	Yes	Invalid
Cognitive bounds	Decision-maker tacit knowledge	No	N/A
Knowledge transfer	Other tacit sources	Yes	Invalid
Knowledge application	Other tacit sources	Yes	Valid
Rational ignorance	All types	Yes	Invalid

credentials or justification and truth. Risk rises when knowledge is lacking or invalid. A second concept arises because most decision-makers' knowledge is tacit through their personal framework and cannot be codified but only displayed (Tsoukas, 2005). This is most obvious with complex decisions and environmental turbulence where senior managers reach strategic decisions through their tacit knowledge, such as intuition (Dane and Pratt, 2007).

4.1.1 Invalid knowledge. The most obvious risk from knowledge gaps is incorrect information that creates false beliefs or false justification. Data are prone to be incorrect when they do not have absolute yardsticks or are not subject to rigorous quality control. This can occur because they are samples or derived from other data and so become subject to revision as precision improves. This is common with complex statistics such as gross domestic product, so that historical statistics can be updated for years as underlying data become more accurate; other complex data sets such as corporate statutory accounts can prove unreliable, too. Another risk arises when knowledge is invalid because it is incorrectly applied, such as superstitious learning (Miner and Mezias, 1996). Invalid knowledge gaps can arise when firms make first use of newly available knowledge that proves either incorrect or not appropriate to the task.

Behavioural economics provides examples of invalid knowledge when decision makers fail to collect big enough samples, reduce ambiguity by relying on confirming data, and use heuristics to reduce alternative choices to a manageable number (Kahneman, 2011).

4.1.2 Process uncertainty. A second knowledge gap arises when the processes underpinning actions or expected outcomes are not understood. This is common with natural events. Weather forecasts and earthquake predictions are unreliable because of gaps in scientific knowledge and not because of the absence of data; same is the case with human systems such as economies and patterns of social behaviour such as political trends and fashion. We either do not understand the underlying processes or lack the cognitive ability to isolate their principal determinants. To complicate this issue, many important systems are chaotic or have time-varying determinants and are not capable of being forecasted.

Markets provide numerous examples of uncertain processes. These systems not only have many economic, financial and behavioural drivers but also are chaotic (Sornette, 2003), and, because they have thinking constituents, they respond to real or anticipated actions by others and so are reflexive (Soros, 1994). Poor understanding of market processes is why the global financial crisis of 2007-2009 was merely the latest in a string of market shocks.

4.1.3 Knowledge uncertainty. A third knowledge gap is uncertainty about its accuracy or comprehensiveness. This relates particularly to the future where good data, by definition, are unavailable. These gaps are not quantifiable nor easily resolved.

Knowledge uncertainty raise doubts about whether any decision or process is, or can be, correctly specified. Keynes (1937, p. 213), for instance, observed that "we have [. . .] only the vaguest idea of any but the most direct consequences of our acts" and concluded that decision-makers extrapolate present conditions and often follow the herd for comfort. This myopia sees decision-makers rely on recent or proximate information rather than building new knowledge (Miner and Mezias, 1996), whereas organizations that meet success can be equally rigid in their unwillingness to accumulate additional knowledge (Barnett and Hansen, 1996; Leonard-Barton, 1992). When knowledge is uncertain, decisions are mis-specified which leads to the wrong questions being asked and the wrong decisions being made.

4.1.4 Hidden knowledge. A fourth gap comes when essential knowledge is hidden, either because it is kept a secret or because it lays dormant and so its existence is not suspected. Hidden knowledge is common with products and processes in the early stages of commercialization: detailed understanding is not yet available, and knowledge is limited to

a few initiated experts and so risks and opportunities cannot be known to a broader circle of interested parties. An example of knowledge that can lie dormant is deterioration of equipment, where risks from wear and tear may only be established through intrusive, possibly destructive testing. In research, this is the missing variables problem where a process is only partially defined by available knowledge.

An example of hidden knowledge relates to significant shocks whose occurrence and impacts are often under-estimated, which explains why forecasts of long-term trends have generally been wrong. In a typical example, a study of 105 long-term forecasts of the level of US energy demand in 2000 found that the actual result lay outside the forecasters' range (Craig *et al.*, 2002). Hidden knowledge cannot be comprehended in a decision, and its emergence over time reveals incorrect specification of the process and data underlying a decision, which can humble the experts.

4.1.5 Cognitive bias. A fifth knowledge gap occurs when knowledge is available and provides a good understanding of the underlying systems and processes at play but is dismissed because of preference for a particular cognitive framework or to favour a preferred decision. Because cognitive biases reflect individuals' own experience and decision paradigms (Slovic and Gregory, 1999), they can lead to different perceptions of the same decision by senior executives and analysts which can see deep divisions develop between them. Executives, including political leaders, may choose policies, goals and broad strategies in light of qualitative factors, whereas analysts (particularly those operating after the event) form their judgements using quantitative inputs. This is why the recommendations of experts, everyone from Planning Departments to the CIA, are often neglected, not because they are wrong or of no merit but simply because they are not relevant to decision-making. Neglect of information, preference for particular process frameworks and more or less reliance on qualitative data produce significant biases in the use of shared knowledge. A typical lament along the lines is that "we as a [finance] profession have overestimated the rationality of investors" (Elton *et al.*, 2004, p. 262).

4.1.6 Cognitive bounds. Similar to cognitive bias, cognitive bounds reflect the inability of decision-makers to develop and process sufficient knowledge to reach a satisfactory conclusion. Simon (1957) proposed the concept of bounded rationality arising from resource constraints such as lack of adequate time, knowledge and analytical capability. These limitations from restricted analytical capability are the focus of cognitive bounds rather than motivational aspects such as satisficing. With complex decisions, restricted cognitive capabilities prevent effective processing of available knowledge and impede a decision-maker from achieving the ideal of a "fully rational man" (Selten, 2002).

4.1.7 Knowledge transfer. The seventh knowledge gap is related to its transfer and deployment. Because knowledge is only of practical use when shared, and its value is directly related to its freshness and accuracy, gaps can emerge in the timing and adequacy of knowledge transmission. There is also the efficiency of transfer: for instance, it can be difficult to quickly and accurately share knowledge across cultures or groups because of barriers of language and understanding. The weaknesses of knowledge transfer are seen most clearly in the risk and knowledge silos that characterize many organizations. Knowledge transfer difficulties may emerge at different stages of a transfer process and are not either instantaneous or costless (Szulanski, 2000). However, without effective knowledge transfer, knowledge gaps become widespread and inevitably encounter an unrecognized or unmanaged risk.

4.1.8 Knowledge application. The failure to translate knowledge into effective action is a widespread organizational problem (Pfeffer and Sutton, 2000). When the process of sharing knowledge is weak, it can be distrusted and not acted on. A topical example of this can be seen in the 2007-2009 Global Financial Crisis, where many investors built their strategy around reliance on easy liquidity and permanently rising asset prices, particularly housing, that proved flawed. Accurate knowledge about this situation and the history of markets to revert to their mean was available and recognized but not efficiently used. In a

similar vein, many corporate decisions rely on the rule of law, honest effort, lack of corruption and ethical practices. When dishonesty is common (perhaps cultural), poor application of knowledge will impose risks that are transparent to the organization. More broadly, inadequate application encompasses weak dissemination of knowledge, cognitive biases and lack of awareness of proprietary knowledge.

4.1.9 Rational ignorance. The final knowledge gap arises from rational ignorance which occurs when knowledge is not developed because the costs of doing so outweigh potential benefits. Hence, a decision-maker may have the opportunity to accumulate knowledge but deems it uneconomic, unwise or impractical. This rational acceptance of an identified knowledge gap is a consequence of value judgments about the worth of the available knowledge (Caplan, 2001). There is also a commercial trade-off between the time and cost of obtaining additional knowledge and resulting incremental benefit, which is referred to as rational ignorance or rational irrationality (Caplan, 2001; Tirole, 2002). This idea of a trade-off between the costs of knowledge acquisition and its benefits challenges the normative assumption that all knowledge adds value (Teece *et al.*, 1997) and that it can be derived costlessly. This idea is further developed in the following section.

The discussion above shows that knowledge gaps can arise either inside the firm or in its surrounding environment, and Table II gives examples of different types of corporate risks that can result. Sometimes knowledge gaps can interact and compound risks. Hidden knowledge and cognitive bounds, for instance, can throw up seemingly random events that emerge completely without warning, such as a pandemic or terrorist attack. These could not be predicted because their determinants were either invisible or hidden in the noise of available data or they were events with low probability.

In summary, a gap in knowledge introduces uncertainty into a decision and thus increases its risk. Hence, the nexus between knowledge and risk is itself one of the most significant sources of corporate risk (as discussed in Section 1).

4.2 Making decisions when facing risks from knowledge gaps

Decision-makers face risks because they lack knowledge about the nature and outcomes of choices facing them. In an ideal world, perfect knowledge would eliminate risk, but this is impractical for at least two reasons. One is bounded rationality (Simon, 1957) in which the decision-maker simply does not have adequate time and resources to gather and analyze

Table II Knowledge-based classification of corporate risks

	Examples of consequent firm risk	
Knowledge gap	*Exogenous*	*Endogenous*
Invalid knowledge	Customer demand Product quality	Performance
Process uncertainty	Political or regulatory Economy Markets	Environmental, health and safety
Knowledge uncertainty	Credit	Product costs
Hidden knowledge	Development of rival products and technologies	Operational failure Organizational failure (fraud, mismanagement)
Cognitive bias Cognitive bounds	Neglect of competitors' activities Industry and market evolution Infrastructure failure	Weak governance or risk management frameworks
Knowledge transfer	Supplier performance Supply chain efficiency	Ordering Information overload
Knowledge application		Inadequate governance Poor strategy Competitiveness Performance
Rational ignorance	Patent infringement Disruptive technology	Employee misconduct

all relevant data. The significance of this is most obvious from the fact that individuals cannot obtain complete historical knowledge because of bounds on data collection and processing, as shown by debates over relatively recent, well-documented events such as the causes of past century's world wars and various stock market crashes (Headrick, 1992). The second reason is that one can never have true knowledge of the future beyond the period when current conditions dissipate.

Managers respond predictably to different degrees of knowledge. Thus, Ansoff (1965/1987) argues that effective decision-makers retain optionality in strategy so they can respond to new knowledge and emergent situations (Mintzberg and Waters, 1985). This experiential learning approach brings the counter-intuitive result that deciding in the absence of full knowledge actually reduces risk because it generates knowledge.

Decision-makers adopt a variety of responses when facing risk from knowledge gaps. An empirical approach, which is likely to draw heavily on explicit knowledge, is appropriate in the case of probabilistic risk where the decision-maker can quantify exposures, perhaps using a methodology such as value-at-risk (Linsmeier and Pearson, 2000). When knowledge is less certain, a more qualitative response is appropriate, such as examining alternative choices through scenarios. These are 'stories of the future' or integrated depictions of plausible future developments (Ringland, 1998). They provide diversity to expectations of future developments and strategic options under consideration, so that firm strategies can be stress tested (testing their ability to function under difficult circumstances) to ensure their suitability under a range of plausible outcomes.

An intuitive response is more appropriate with ambiguous decisions. This relies heavily on tacit knowledge, eschewing analytical processes and is particularly useful in turbulent environments and when facing less-structured problems requiring judgement (Dane and Pratt, 2007).

As a decision's features become less precise, the cost-benefit trade-off to acquire additional knowledge or make knowledge more explicit becomes increasingly important. Is it worth the time and effort to accumulate or codify additional knowledge in order to further reduce the risk of an unfavourable outcome? Despite the importance of additional knowledge, managers seem to truncate its acquisition well before returns diminish. A number of studies, for instance, have shown that managers place minimal reliance upon the facts associated with a decision (Forlani, 2002; Mullins *et al.*, 1999) and prefer to choose based on anticipated or even preferred outcomes. This is also seen in well-recognized biases such as the availability heuristic (where decision-makers over-generalize from limited knowledge and recent experience) and confirmatory bias (which is the tendency to seek out evidence that supports the preferred decision) (Kahneman *et al.*, 1982). The possibility of decision biases makes it desirable to impose discipline on decision processes, such as incorporating population-based data on risks to provide an outside view (Lovallo and Kahneman, 2003).

Another example of how knowledge reduces risk can be seen in the development of production processes. As an organization gains better understanding of a process, it can begin to anticipate impacts that may derail operations and evaluate their probabilities. Once a fairly advanced state of knowledge is achieved, the process can be considered as subject to probabilistic risk so that statistical process control is possible and the outcome is reasonably certain (Bohn, 1994). The probability of an unfavourable outcome continues to fall until near perfect knowledge brings it close to zero.

A closer examination of various decision-making situations allows us to relate categories of risk with the extent of knowledge available. This leads to the conceptual model set out in Table III where risk is integrated with knowledge and thus drives a decision's components and appropriate managerial responses. A number of authors have explored various categories of risk in decision-making in relation to knowledge (Pender, 2001; Hoffman and Hammonds, 1994; Zack, 2001). One of the most comprehensive analyses was developed

Table III Decision character, knowledge and response

Decision character or situation		*Extent of determinancy in interpreting or defining a situation, event or process*	*Degree of confidence or predictability of knowledge*				
Classification	*Description*		*Interpretive frame*	*Decision alternatives*	*Outcome probabilities*	*Outcome consequences*	*Managerial response*
Ambiguity (Passive ambiguity)	Inadequate knowledge (patterns/concepts) about, no explanation for or understanding of a goal, situation or task	No framework or means to interpret or define something	None	Unknown	Unknown	Unaware	Strategy
Active ambiguity	Inadequate knowledge (patterns/concepts) about the situation but an ability to actively limit the resources involved or the consequences of the decision	No framework or means to interpret or define something, but some ability to understand resource commitments or control consequences	None	Unknown	Unknown	Aware	Strategy/options
Complexity	Too many situational elements and relationships to coordinate or consider simultaneously	One unique interpretation or frame	Single	Unknown	Unknown	Unaware	Strategy
Equivocality	Multiple interpretations of a goal, situation or task	Multiple interpretive frames and definitions	Multiple	Known	Unknown	Aware	Options
Uncertainty	Insufficient factual information about the goal, situation or task and some lack of confidence in the consequent inferences, estimates or predictions required	One unique interpretation or frame	Single	Known	Unknown	Aware	Options
Probabilistic risk (Certain simplicity)	Probabilities and consequences of different outcomes or states are known with certainty	None	Single	Known	Known	Aware	Quantify exposure

by Zack and McKenney (1988, 1999, 2001). Zack's focus is on defining an organizational knowledge processing situation, whereas the focus here is on the decision character within individual decision-making. Both approaches require the identification of different types of conditions or situations facing an organization or particular decision-maker. Zack (2001) identifies four primary knowledge processing loads: complexity, uncertainty, ambiguity and equivocality. These requirements drive a secondary problem – what he refers to as a knowledge-processing load – in which an organization must balance its capabilities with the knowledge-processing load that it is facing to maintain performance effectiveness. Zack includes a description of the interpretive frame for each knowledge-processing situation. Table III builds on work by Zack and provides a number of key areas of expansion. First, additional decision characters are added – decision alternatives and outcome probabilities that would be typical within the risk literature. Second, there is an addition of a new characteristic to the certainty of knowledge that examines the level of awareness of the outcome consequences. Decisions are often designed to limit or control the total resources involved. Third, the model distinguishes between passive and active ambiguity, where active ambiguity refers to an awareness or limitation on outcome consequences. Finally, different managerial responses are associated with each of the decision situations. These potentially include strategic responses, where the organization may be facing a knowledge-processing load that exceeds it capabilities. In these circumstances, the organization may accept the risk of taking action with limited or no knowledge processing by making trade-offs between the level of risk and the cost of developing additional knowledge.

5. Implications and further research

In summary, the concept of knowledge-risk management links knowledge acquisition to improved risk management, incorporates the link between knowledge acquisition and organizational learning, recognizes that each has a cost, as well as potential benefit and develops an optimized strategy to balance knowledge and risk. This should produce new insights for strategy and corporate governance by outlining how the relationship between risk and knowledge affects firm behaviour. The paper has also outlined a new direction for resource-based firm research: a knowledge-based view of firm risk that delivers knowledge-risk strategy.

A practical example of aggressive knowledge accumulation that reduces risk is provided by the company Cisco, which has a policy of acquiring relatively small firms (defined as having less than 80 employees) with knowledge that Cisco does not have, particularly those with "disruptive technologies" (Ferrary, 2003). This accelerates Cisco's own knowledge development and internal R&D and enables the company to respond quickly to changes in the knowledge-risk frontier that they cannot anticipate: "If the company does not have the resources to become a market leader in a targeted segment within six months, it looks to buy its way in". (DiGeorgio, 2002, p. 137). This strategy keeps Cisco close to the moving efficient knowledge-risk frontier while removing potential competitors and accelerating product development.

Effective risk management is at the heart of good governance, and this requires firms to identify and close knowledge gaps. Thus, board of directors that force accumulation of relevant knowledge and direct it towards risks can improve performance. Knowledge-based risk management is an especially important issue for firms in fast-moving industries. Best practice firms establish a framework to evaluate and accumulate knowledge and develop systems to optimize the trade-off between knowledge accumulation and risk. Even though these systems may appear haphazard and random – and in fact they can be – when properly structured they manage risk in a cost-effective way.

Although the discussion above enhances understanding of risk and knowledge and the link between them, organizational outcomes will be improved by further work in several areas.

One deficiency in this analysis is the shortage of empirical support. What, for instance, are the frequency and consequences of the various risks identified? The authors are not aware of any comprehensive evaluation of these issues, although some work has been done on the proportion of decisions involving risk by Howard (1988), Viscusi and Aldy (2002) and others. Moreover, except for an analysis by Coleman (2006), we are not aware of any meaningful evaluation of changes in risk over time. This is particularly significant for our models because they suggest that overall risk should be falling with the gradual accumulation of knowledge. It should also be recognized that there is a debate over measuring the quantum of knowledge available to firms (which is relevant to the rate of change of knowledge) and captured by them.

A second research gap is the need to quantify the relationships between the accumulation of knowledge, risk and performance. This will be challenging because of the difficulty of measuring knowledge but may be achieved through intensive survey methods directed towards how knowledge is used to measure specific risks in an industry.

A third research topic is applicability in the real world of the taxonomy that is developed. As Campbell-Hunt (2000) showed in relation to the competitive strategy model developed by Porter (1980), a conceptually satisfying theory does not necessarily explain corporate performance. The assertion in this paper that narrowing knowledge gaps reduces risks is conceptually analogous to that underpinning modern portfolio theory in which increased risk brings greater return. Thus, the various tests used for capital asset pricing model (CAPM) (Roll, 1977) may be applicable to our model.

A fourth gap is the need to further operationalize the proposed strategy model. Where conventional risk management has evolved into Enterprise-Level Risk Management (Deloach, 2000), knowledge-risk strategy needs to develop its own techniques and management guidelines.

Finally, knowledge-based risk has important implications for resource-based and knowledge-based theories of the firm which warrant further investigation. For example, do knowledge-risk trade-offs impact the nature of coordinating mechanisms or enhance our ability to understand boundary decisions within firms? In particular, the risk/return aspects of knowledge investments may provide further explanation of why organizations avoid investments in particular knowledge-based resources.

In closing, knowledge-risk strategy means that every manager should recognize that what is not known definitely has the power to hurt.

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