Risk management through learning: Management practices for radical innovation success

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A B S T R A C T

The study investigates a subset of management practices that may contribute to success of radical innovation efforts by large established firms. We focus on that subset of practices concerned with learning oriented approaches to risk management. Three such practices are examined: a) a real options approach to funding and evaluating projects, b) propensity to experiment in the marketplace, and c) commercialization of early applications quickly, which we call a harvesting strategy. Building on the learning, resource based view and dynamic capabilities literatures we argue that these three practices will facilitate radical innovation success. Industry clockspeed is incorporated as a moderator of the relationships between these practices and various manifestations of radical innovation success. Data collected from 85 high level individuals involved in radical innovation efforts in large firms indicate that real options approaches and experimental learning have strong positive effects on all measures of RI success, while harvesting strategies impact the development of new competencies, but not the other RI success measures. Harvesting strategies are more impactful when industry clockspeed is low.

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1. Introduction

It is widely understood that large established companies are capable of creating and commercializing new products that offer incremental benefits to the market. However, we also know that that established firms struggle in their attempts to develop new to the world, breakthrough innovations that confer whole new business and rejuvenation opportunities (Christensen, 1997; Dougherty, 1992; Jelinek & Schoonhoven, 1990; Leifer et al., 2000; Morone, 1993; Van de Ven, 1986). Many empirical studies have linked breakthrough innovation to superior performance (Lawless & Anderson, 1996; Christensen, 1997, Cho & Pucik, 2005; Sorescu, Chandy, & Prabhu, 2003; Zahra, 1996), however firms continue to face challenges in managing breakthrough innovations, and so the need to overcome these challenges and develop capabilities for breakthrough innovation appears to be a critical issue for established firms. Firms face several challenges in managing breakthrough innovation. First, established organizations experience path dependency (Nelson & Winter, 1982; Teece, Pisano, & Shuen, 1997). They are ensnared in what is familiar to them, in what they have always done. Their future is a direct extension of their past. New ideas cannot be very different from their present ones.

The second challenge, which emanates from the first, is established organizations’ reliance on established routines (Nelson & Winter, 1982; Grant, 1996): procedures that promote efficiency and automation over creativity and flexibility. Core capabilities become core rigidities (Leonard-Barton, 1992). Given the highly competitive environment in which firms operate, a dominant culture of operational excellence appears requisite for success (e.g. Hendricks & Singhal, 2001).
Reliance on established routines, however, reduces an organization’s ability to cope with uncertainty in any manner other than to ignore it or elect not to engage in opportunities that introduce it. This precludes most opportunities that could result in breakthrough innovations, since each breakthrough, by definition, is unique, and situation-specific knowledge must necessarily be developed. Past experience is not necessarily an aid to the current opportunity (Eisenhardt & Martin, 2000). Technical uncertainties abound for most breakthroughs, but so do high levels of uncertainty and discontinuity in markets, resources, and organizational changes required to successfully commercialize them (Chandy & Tellis, 2000; Leifer et al., 2000; Rice, O’Connor, & Pierantozzi, 2008). Yet the rents gained through innovative activities are termed Schumpeterian or entrepreneurial rents (Knight, 1921; Rumelt, 1987) because they are the rewards to firms that are prepared to act in the face of ex ante uncertainty (McGrath & Nerkar, 2004).

Given this tendency for organizations to experience path-dependency and engage in uncertainty avoidance, it is worth enquiring into how path-generation can be possible, that is, how can organizations create radically new paths? How can they develop transformational routines that work in parallel with the operating routines that form the basis of their dynamic capabilities? How can firms manage the process of creating radically new innovations? What are the structural, organizational, and cultural conditions that support the path generation process?

One aspect of this question that has been considered theoretically (King & Tucci, 2002; Sommer & Loch, 2004) but not yet empirically tested is the effectiveness of approaches firms use to manage risk and uncertainty when engaging in radical innovation activities. Risk and uncertainty are inherent in innovation activities whose objectives are path generation, i.e., breaking away from path dependencies to create new markets with pioneering technologies (Ahuja & Lampert, 2001). One solution to firms’ challenges in successfully commercializing breakthroughs may be to institutionalize practices that encourage them to deal with risk in a systematic manner, and specifically in a manner that recognizes the highly uncertain, highly ambiguous environments that characterize the domain of breakthrough innovation.

In this paper we investigate three such practices, and their relationship to Radical Innovation success. These practices are a) options thinking, b) experimental learning and c) an early harvesting strategy. We examine this subset of practices because of their theoretically compelling contribution to a learning orientation, and, thereby, their contrast with traditional operational excellence oriented approaches. Taken together, these three practices may impact a company’s culture of innovativeness by legitimizing members of innovation projects and those evaluating project progress to admit that they may not know all that is necessary to predict a project’s impact on the company. Cultures dominated by operational excellence objectives, which is the experience in most larger established organizations, are fundamentally based on ensuring that deviations from a plan are rooted out, or considered as failures of execution. The three practices we examine, however, highlight a learning by doing orientation, and explicitly recognize that, a priori, it is impossible to predict future courses of action based on past experience. These three constructs may play a significant role, we believe, in contributing to a theory of path generation for large firms. Thus, the aim of this paper is to understand management practices that mitigate risk borne of uncertainty, so the risk management approach is one of learning and interacting to shape outcomes. Our premise is that learning oriented risk management practices can address the challenges of path dependency and rigid routines that plague established firms in their attempts to effectively innovate.

Additionally, we consider the impact that environmental dynamism plays on the relationships between these learning oriented approaches to risk mitigation and RI success. Whether a firm’s environment is dynamic and fast paced, or alternatively, evenly paced and slower to change, may impact the approaches to risk management via learning that firms take to enhance the likelihood of RI success.

In the next section of the paper we discuss the relevant literature streams that inform our question of specific risk management practices that contribute to RI success, focusing specifically on practices that are appropriate for highly uncertain, ambiguous environments. We then introduce our conceptual model and detail our hypotheses and their underlying justification. Subsequently we outline our methodological approach and detail our results. We end with a consideration of what has been learned and how it contributes to a theory of path generation via radical innovation.

2. Relevant literature

In this section we consider the work to date on management practices for breakthrough innovation in established firms, and then focus specifically on the risk management and dynamic capabilities literatures to inform the idea of risk management via learning in an innovation context.

2.1. Managing breakthrough innovation

Managing Breakthrough Innovation. For the past fifteen years, academic scholarship has focused attention on understanding those conditions that face established firms in their attempts to commercialize radical innovations, and on developing theoretically based prescriptions regarding successful management practices to meet those objectives (Day, 1994; Dougherty & Hardy, 1996; Hill & Rothenberg, 2003; Kanter, 1989; Lynn, Morone, & Paulson, 1996; Mullins & Sutherland, 1998; Polley & Van de Ven, 1996; Van de Ven & Polley, 1992). O’Connor (2008), taking a systems perspective on how established firms can build a capability for sustained, rather than ad hoc, breakthrough innovation, suggests that a complete management system be developed and implemented that is specific and appropriate to an innovation objective, but distinct from the management system that supports the firm’s operational excellence objectives. Drawing on the vast literature in innovation management, the author identifies the necessary elements of such a system to include: 1) an identifiable organization structure responsible for radical innovation, 2) leadership and culture
are decision making because of the inability to know the range of possible outcomes (Edwards, 1954). For the manager, organizational memory, thinking about risk mitigation under uncertainty.

2.3. Dynamic capabilities theory and learning

We turn to dynamic capabilities theory. According to dynamic capabilities scholars, learning occurs by identifying and institutionalizing a process (a routine), observing and reflecting on its effectiveness, and modifying it. March and Simon (1958) describe an organizational routine as a fixed response to a defined stimulus, implying that, once embedded, no further learning is necessary. Zollo and Winter (2002) define a dynamic capability as “a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness” (p.340). This occurs through a process of a) identifying and codifying process, b) repeating them and c) generalizing them. According to this definition, dynamic capabilities are process-improvement techniques. They constitute the firm's way of modifying operating routines. The generation of capabilities requires enough experience that “tacit production and organizational knowledge become stored in new patterns of activity, in routines” (Teece et al., 1997). These routines help the firm integrate (Helfat & Raubitschek, 2000), reconfigure (Hargadon & Sutton, 1997), or develop and release new resources (Henderson & Cockburn, 1994).

Given the uncertainties associated with RI, which requires knowledge creation and application in novel contexts, it is not clear how codifiable, repeatable processes can be useful mechanisms for building RI dynamic capabilities (Cheng & Van de Ven, 1996;
Eisenhardt & Martin, 2000; McGrath, 2001). Other scholars note, however, that routines that preserve ongoing change processes can exist on a higher order (Argyris & Schon, 1978; Benner & Tushman, 2003; Nelson & Winter, 1982). Just as experience with operating routines preserves and entrenches those routines, experience with changing operating routines necessitates modification routines that can make similar changes in the future (Amburgey, Kelly, & Barnett, 1993; King & Tucci, 2002). One kind generates routines that reduce a firm’s dynamic capability while another generates routines that increase it (King & Tucci, 2002). Firms can thus create routines that are variety increasing, rather than variety reducing, and, by extension, are rooted in learning and influencing rather than in exploiting the known, and, by extension, are path generating rather than path dependent...

When firms operate in domains of high variety and high uncertainty, such as, for example, the exploration and enactment of RI opportunities, it is unclear how an infrastructure can be built to support change (Cheng & Van de Ven, 1996). The mechanisms for learning in these situations are not necessarily the same as they are for environments that can be reduced to straightforward relationships. While some types of activities may become routinized over time, RI is marked by novelty every step of the way. This means that, in order to minimize risk while maintaining high variation, mechanisms must be created that support the development of situation-specific knowledge continuously. In highly uncertain markets (either due to pace or ambiguity), firms cannot rely as much on existing knowledge as they can in known markets. In the latter, change may occur frequently but along predictable linear paths, so routines can be employed.

Known markets have relatively stable industry structures; market boundaries are clear and the agents in the value chain are known. Effective dynamic capabilities rely heavily on existing knowledge or “learning before doing” (Pisano, 1994). Managers can use structured, analytical approaches and tacit knowledge in their decision-making. The key to competitive advantage is efficient, well-codified and well-understood processes coupled with rapid execution. Routines can be specified to create organizational memory about their execution, and to enhance predictability and diagnosis when an error occurs.

High uncertainty markets, however, require different approaches (Eisenhardt & Martin, 2000; O’Connor, 2008). First, the end state is more central in managers’ minds than the means to getting there (Eisenhardt & Martin, 2000). In other words, achievement of the goal overrides the process, since processes vary by situation. Routines are simple rather than complex and investment in building them is minimal (Eisenhardt & Sull, 2001). Routines focus on specifying boundary conditions or priorities; they are not rigid processes. People who can solve problems become more important than any process. Creativity is highly valued.

Due to the need for situation-specific knowledge creation, and the diminished value of existing knowledge, frequent experiential actions that lead to quick learning are used to compensate for limited understanding (Eisenhardt & Martin, 2000; McGrath, 2001). Skills are required to (1) design experiments so that learning is maximized (Sitkin, 1992); (2) conduct experiments with goals in mind as opposed to processes; (3) evaluate results given the highly ambiguous action: outcome relationship; and (4) decide on the next course of action based upon strategic objectives. Iteration is critical as new information and changing conditions are uncovered.

Further, in high-uncertainty situations, dynamic capabilities are characterized by “parallel consideration and often partial implementation of multiple options” (Eisenhardt & Martin, 2000). This may be manifested through the use of prototyping and extended use trials with potential customers (Lynn et al., 1996; O’Connor, 1998; Pisano, 1994; Veryzer, 1998) to provide rapid learning by engaging the market experientially rather than analytically. Other manifestations include exploring with multiple co-development partners, or multiple potential application spaces, or multiple external and internal sources of funding (Leifer et al., 2004). In these ways, the RI effort can manage risk by proving its value in small, albeit familiar ways to managers, by validating the market’s enthusiasm for the innovation.

### 3. Theoretical framework

Based on this literature review, we identify two fundamental questions: 1) how might learning be accelerated to help reduce risk? And 2) given that there will be uncertainty, how do firms appropriately evaluate projects to mitigate risk? To address these questions, we focus on three risk management-via-learning constructs that may serve as atypical management practices, but that are appropriate for the RI environment. We identify these as a) utilizing an options mentality for RI project investment decisions, b) experimental processes that aid learning, and c) harvesting early and often. Taken together, these practices offer a learning oriented approach to risk management that addresses the two fundamental issues of how to learn faster, and how to evaluate projects characterized by high uncertainty. Table 1 contrasts these practices with those that dominate in the traditional management system whose objective is maintaining operational excellence.

<table>
<thead>
<tr>
<th>Operational excellence objective</th>
<th>Innovation objective</th>
<th>Constructs</th>
<th>Relevant literature</th>
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<tr>
<td>Develop structured processes to reduce deviations</td>
<td>Test value and gain validation simultaneously with development activities to legitimize new path internally and externally</td>
<td>Harvest</td>
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<td>Measure post hoc to evaluate performance against objectives.</td>
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3.1. Impact of environmental context

Work that examines decision making under uncertainty and risk management argues that managers will characterize and interpret the level of environmental munificence (Milliken, 1987), and that interpretation of the environment will influence the degree to which the manager will elect to pursue more information to make a better decision. Munificent environments are perceived as more tolerant of incorrect decisions, so that the cost attached to a decision making error is more easily recouped than if the environment is stringent (Milliken, 1990), thereby implying that learning is less important in munificent than in stringent, harsh, or high perhaps high velocity environments (Eisenhardt, 1989). Fast paced or high velocity environments are not munificent, and are less tolerant of pursuing more information prior to decision making due to the time pressures that require quick decisions. Adaptive learning may be more important in these environments (Eisenhardt & Tabrizi, 1995). We therefore consider the role of industry clockspeed, a measure of environmental dynamism, in moderating the relationship of learning oriented risk mitigation practices to RI success.

4. Conceptual model: key constructs and hypotheses

Fig. 1 depicts our conceptual model. We begin by describing the RI Performance constructs, and then address each of the Independent variables and their relationship to performance, incorporating the role of the industry clockspeed as a moderator throughout.

4.1. Defining RI performance

The financial returns expected from radical innovation can take many years (Chandy & Tellis, 2000; Morone, 1993; Sorescu et al., 2003) and management patience often wears thin (Fast, 1978). Interim measures of success, however, can be noted. We therefore examine four distinct performance indicators, each with a different time horizon.

First, we define legitimacy as the extent to which the radical innovation initiative is known throughout the organization and recognized by senior management as having the potential to bring value. Second, activity captures the degree to which the flow rate of projects into and out of the RI portfolio has increased, along with concomitant levels of resources. Thus activity recognizes that the RI initiative is gaining momentum. Third is competency. Since radical innovation is, by definition, fraught with unknowns and novelty, one would expect that an expected benefit to the firm of investing in developing RI portfolios is an increased expertise in new technology arenas and business domains that could then be leveraged in other parts of the organization. The fourth performance construct we identify is output, defined as the degree to which the investment in RI has brought commercial success, both financially and through market expansion.

4.2. Options mentality

By options mentality we mean the extent to which the set of radical innovation funding decisions are made with the idea that they may be funded in increments to learn more, and that decision rights for further funding at milestone points are explicitly reserved by managers and are contingent on the learning that has occurred by the project team. While this may appear to encourage path dependency (Adner & Levinthal, 2004), we note that a redirection is always a possible course of action, allowing for the possibility of path generation outcomes. Funding in small doses, based on milestone achievement helps manage risk via reducing uncertainty efficiently. The real options approach has received a great deal of scholarly and managerial attention of late (Amram & Kulatilaka, 1999; Barnett, 2008; McGrath, 1997; McGrath & MacMillan, 2000; McGrath & Nerkar, 2004; McGrath, Ferrier, & Mendelow, 2004; Trigeorgis, 1996).

Real options reasoning offers a complementary approach to normative models of investments under uncertainty borrowed from the field of finance (Fama & French, 1996), which are based on assumptions of efficient markets and static equilibrium (McGrath & Nerkar, 2004). Consideration related to the availability, or potential availability of future information is neglected in the calculation of financial options, or any NPV-based calculation (Adner & Levinthal, 2004), rendering them ineffective as tools for
aiding decision making regarding investments in R&D or innovation projects within the firm (Christensen, Kaufman, & Shih, 2008; Faulkner, 1996, 1998; Dixit & Pindyck, 1995).

Real options reasoning, on the other hand, is used to guide investment decisions under uncertainty (Abel, Dixit, Eberly, & Pindyck, 1996; Dixit & Pindyck, 1995; McGrath, 1997; McGrath & MacMillan, 1995). It explicitly recognizes that, while an investment decision is critical at time $t$, new information that informs that decision will be forthcoming in times $t+1$,...,$t+n$. Therefore, options thinking incorporates mechanisms for updating decisions based on new information, and allows for smaller investments during times when uncertainty to highest. With this approach, researchers view investing in a technology with a highly uncertain future as taking an option that may or may not be exercised, depending on how new information changes the option value of that opportunity. The objective of each funding milestone is to learn more, thereby reducing the uncertainty about the value of an opportunity.

The advantage of using options thinking to guide decision making is that it allows for managerial flexibility, and offers an evaluation process that parallels the learning objectives of the exploration and experimentation processes innovation teams may use to mature their projects. If teams use such processes, but are evaluated by their managers on the basis of conventional project planning and execution metrics (e.g. adherence to a predetermined budget and schedule, which presume that outcomes and pathways for achieving them are known at the outset), a mismatch occurs and Radical Innovation has a low likelihood of succeeding.

**Hypothesis 1a.** Use of a real options mentality to aid managerial decision making for continued investing in RI projects positively impacts a firm’s Radical innovation performance.

### 4.3. Consideration of industry clockspeed and options thinking

As the pace of change in an industry intensifies, it become increasingly important to make decisions based on most recent information. Uncertainty is high not due to the lack of information, but because of its pace of change (Eisenhardt & Martin, 2000, Brown & Eisenhardt, 1997). Under these conditions, and given the comparatively longer development cycle times for radical innovations (Leifer et al., 2000), one would expect that maintaining the decision right among evaluators to withdraw or fund based on the latest information becomes increasingly important in aiding RI success.

On the other hand, since RI lifecycles are comparatively longer, an orientation toward switching investment opportunities on short intervals may disincline evaluators to continue the dogged persistence necessary for breakthrough innovation (Leifer et al., 2000). We will hypothesize the majority view (i.e. the former) and suggest the following:

**H1b.** The positive relationship between use of a real options mentality to aid managerial decision making for investing in RI projects and RI success will strengthen as industry clockspeed increases.

### 4.4. Experimental processes

By experimental processes we refer to project management approaches that focus on strategically directed learning and the willingness to change course based on the outcome of learning experiments (Cheng & Van de Ven, 1996; Lynn et al., 1996; Mullins & Sutherland, 1998; Rosenkopf & Nerkar, 2001; Van de Ven & Polley, 1992).

Highly structured processes such as predefined phase-gating (prescribed for incremental innovation) may produce new products quickly, but those products often do not meet market conditions (Eisenhardt & Tabrizi, 1995; Sethi & Iqbal, 2008) or offer long-run competitive advantage. Process-oriented management stabilizes routines and increases efficiency in the short run, triggering internal biases for certainty and predictable results (Benner & Tushman, 2003). A focus on process management (i.e. codifiable routines) favors exploitative innovation over exploratory innovation.

The exogenous shocks and endogenous chaos is that are oftentimes present in a radical innovation development environment (Leifer et al., 2000) make it so difficult for RI project managers and their team members to plot a course of action at the outset that the route most often prescribed for decision-making is the iterative probe and learn process, which relies on experimentation combined with attention to feedback for learning (Cheng & Van de Ven, 1996; Lynn et al., 1996; Sommer & Loch, 2004). Under such highly ambiguous conditions, cause effect relationships among various alternative courses of action are not known, and, in fact, neither are outcome preferences or goals. (Cheng & Van de Ven, 1996; Sarasvathy & Dew, 2005). This prerequisite knowledge must be created in new situations. Learning in chaotic or highly ambiguous conditions is an expanding and diverging process of discovering possible action alternatives, outcome preferences and contextual settings (Cheng & Van de Ven, 1996; Pisano, 1994; Sommer & Loch, 2004). Building repertoires of action experiences, outcome preferences and contextual practices increases the likelihood of making creative connections between means and ends when actions and outcomes ultimately do become related (Cheng & Van de Ven, 1996). Simple, semi-structured routines that develop confidence, a coherent picture of the action: outcome relationships and the surrounding context for the innovation are prescribed in the literature for highly ambiguous settings (Eisenhardt & Martin, 2000).

Other researchers contend, however, that due to the lag between an organizational experiment and a complete understanding of the phenomenon, continuous experimentation has the potential to lead to organizational drift and should be engaged in at a slow pace (Lounamaa & March, 1987). In addition, large established organizations’ ongoing success is predicated on their ability to conform to tight, predictable routines. Experimentation and redirection are considered ‘mistakes’ of good project managers, who
are rewarded for developing a project plan with a timeline and a budget, and who are careful not to deviate from that plan (McDermott, 1999).

When RI is the objective, however, variety enhancement is favored over closure for much of the project’s development cycle (McGrath, 2001). Knowledge and expertise come from experience with a wide variety of cues and stimuli. New knowledge occurs through simultaneous outreach into the market, evaluation and technology experimentation (O’Connor, 1998), since market and technical development are intertwined in high-uncertainty environments (Morone & O’Connor, 1992). Under these conditions, there is a need for situation specific learning (Eisenhardt & Martin, 2000), and reliance on both feedback and feedforward loops for learning and experimentation processes (Crossan & Berdrow, 2003). In our view, the processes and tools needed to navigate high-uncertainty market, technical, resource and organizational barriers are different from those typically used in large established firms. Mechanisms for variety seeking and experimentation are critically important. Similarly, explication of latent assumptions, hypothesis generation and testing regarding the multi-dimensional uncertainty landscape (Rice et al., 2008) comprise a more appropriate approach to project management than do more typical project management tools that focus on reducing deviations from a pre-ordained and approved plan. We therefore hypothesize that:

**Hypothesis 2a.** The use of experimental, learning oriented practices in the development of radical innovations positively impacts a firm’s RI success.

### 4.5. Consideration of industry clockspeed and experimental processes

When change in the competitive and customer environment occurs rapidly, adaptability is critical (Eisenhardt & Tabrizi, 1995). Each new product release may, in fact, be considered an experiment. However, the counter argument may also be true. High levels of industry clockspeed may in fact preclude the learning oriented experimental processes that allow for breakthrough innovations to be nurtured, evolved, and elaborated over time. There may be more of a population ecology phenomenon at work, in which innovations offered at any point in time are selected from among a set of rapidly deployed alternatives, and the rest of the offerings are dropped in favor of offerings that meet the next generational requirements. We therefore propose:

**H2b.** The positive relationship between experimental processes and RI success will be diminished as industry clockspeed increases.

### 4.6. Harvesting strategy

When a radical innovation opportunity is under development, there may be choice points at which management can elect to commercialize an aspect of the opportunity, though it may be an inferior product given the technology’s promise, or though it may potentially distract the development team from the larger vision (Leifer et al., 2000; O’Connor & Rice, 2008). We call this a harvest strategy, and offer it as an approach to interacting with the market to gain confidence in the market’s demonstrated enthusiasm for the innovation’s novel benefits, as well as educating the market regarding other possible uses and applications for the technology (O’Connor & Rice, 2001).

Besides these market related interactions, a harvest strategy can provide internal organizational legitimacy for the RI function, by signaling early wins. The management of innovation literature indicates that organizational patience for the development of radical innovation capabilities does not equal the time necessary to develop it and have it bear commercial fruit (Fast, 1978; Govindarajan & Kopalle, 2004; Jelinek & Schoonhoven, 1990; Majchrzak, Cooper, & Neece, 2004; Sharma & Chrisman, 1999) Thus harvesting strategy can help manage both internal and external sources of risk via learning and interacting.

A harvest strategy may not, however, always be appropriate. In fact, research in economics on exhaustible resources of value proposes that in situations where price is set exogenously, and there is high uncertainty in pricing in the marketplace, it is often optimal to hold back production or actualization of a project in return for an option for claims on uncertain profits several years in the future as opposed to activating claims on uncertain profits in the near future (McDonald & Siegel, 1985; Pindyck, 1981). This speaks to the fact that senior managers who sense small immediate wins may pressure project teams to commercialize an early opportunity earlier than is appropriate, providing ample signals to competitors, disappointment to the marketplace with inferior offerings (Bayus, Jain, & Rao, 1997), and disappointment internally, that the expectations for RI projects may be quite high. Additionally, team members may become so distracted with the commercialization effort that progress on the long term vision that originally motivated the work may wane. Rather than treating the RI opportunity as a platform for a new business based on numerous products, early harvests treated in this manner may be rejected as failures or underleveraged once the first product form is commercialized, a phenomenon referred to as “radical innovations, incrementally executed” (O’Connor, Leifer, Paulson, & Peters, 2008).

While these latter issues may exist, we suggest that a harvest strategy can operate as a learning oriented strategy when pursued as such, and can, in fact, contribute positively to RI success. We therefore suggest:

**Hypothesis 3a.** Use of a harvesting strategy will have a positive impact on a firm’s RI success.

### 4.7. Consideration of industry clockspeed and harvesting strategy

As the pace of industry change increases, early and frequent validation in the market becomes increasingly important. Modification may be more likely to occur across product releases, no matter how ‘klugey’ the early products may be. (Brown &
Eisenhardt, 1997, Mullins & Sutherland, 1998). The risk of not harvesting likely outweighs the risks associated with doing so. We therefore posit that:

H3b. The positive relationship between harvesting and RI success will be strengthened as industry clockspeed increases.

5. Methodology

This study was performed as part of a larger research program on Radical Innovation that has been ongoing since 1995, in conjunction with members of the Industrial Research Institute (IRI), a professional organization of R and D managers, directors and Chief Technology Officers of Fortune 1000 U.S. based industrial companies.

Our conceptual model was informed by the literature, meetings with the IRI membership, and two longitudinal cross case qualitative studies. In implementing the qualitative work that informed our thinking for our survey, we followed the approach described in O’Connor, DeMartino, Paulson, and Ravichandran, (2003) for engaging a multidisciplinary research team in longitudinal prospective research. The first of these, which took place from 1995–2000, followed twelve radical innovation projects over the course of their development in ten large established companies including Air Products and Chemicals, Analog Devices, Dupont, GE, GM, IBM, Nortel Networks, Polaroid, Texas Instruments, and United Technologies. The objective of the first qualitative study was to understand the management processes that were used to develop and commercialize breakthrough innovations, compare them with those management practices that are recognized as appropriate for managing incremental innovation, and develop theoretical and practical insight into path generation development at a project level.

The second qualitative study occurred during the years 2001–2005. The objective was to understand the challenges firms faced as they attempted to institutionalize a radical innovation capability. The unit of analysis was not the project level, as was the case in the first study, but rather at the firm level, where we observed the group or team who nurtured the portfolio of all RI projects. The twelve participating companies qualified into the study because they had a declared strategic intent to develop or evolve their RI capability. They included 3M, Air Products and Chemicals, Albany International, Corning, Dupont, GE, IBM, J&J Consumer Products, Kodak, Med-Westvaco, Sealed Air and Shell Chemicals.

Research shows that the average life for new ventures groups, or new business creation divisions within large firms is approximately four years (Fast, 1978). The conclusions drawn from the first qualitative study led us to believe that companies can manage the development of radical innovation much better, but that large firms have focused their efforts most heavily on the improvement of new product development routines for incremental innovation. Thus, our objective was to follow, prospectively, a set of firms that admitted a strategic intent to develop or evolve this capability. We believed that, by tracking such initiatives we could at least describe what companies are doing, and identify challenges and their approaches to circumventing those challenges as they worked to meet their strategic objective.

The nature of these inquiries dictated a prospecitive, longitudinal research design and a multiple case study methodology (Yin, 1994). In case study research, a phenomenon is examined in its natural setting. This is especially appropriate for research in new areas, where the goal is to answer “how” or “why” questions about contemporary events, and the objective is to build theory rather than test hypotheses. Multiple cases are more robust than a single case because comparisons can be made across cases, and are therefore less tied to a particular context (Yin, 1994). This contrasts with the ethnography method (Workman, 1993), where the observer intensively studies a single company, team, or other unit to learn about the details of daily practice. Since one of our goals is to offer a degree of generalizability, we used a larger sample with a lower intensity of interaction over a longer period of time. Our prospective approach to data collection for both qualitative studies allowed us to guard against post-hoc rationalization (Loftus, 1979; Van de Ven, 1986). Firms were enlisted while these initiatives were ongoing, and data collection continued for five years for the first study, and four years for the second.

The research question “How can firms build a sustainable radical innovation dynamic capability?” is complex, multidisciplinary and requires significant lenses of interpretation. A multidisciplinary research team was used, in accordance with the methodology described in O’Connor et al. (2003), wherein collecting and interpreting data together is noted as imperative for gleaning insights that any single disciplinary approach may not perceive. Multiple investigators bring a variety of ‘thought worlds’ (Dougherty, 1992) to the research problem. Their mix of perspectives increases the likelihood of discovering novel insights. A convergence of opinions enhances confidence in the findings, while conflicting views keep the research from premature closure (Eisenhardt, 1989). A team of nine researchers and one doctoral student with disciplinary foci in entrepreneurship, strategy, marketing, finance, information systems management, risk management, technology management, organizational behavior, and political science, worked on this project. This breadth made possible a multi-disciplinary, interactive examination of the phenomenon of interest.

We used analytical induction (Miles & Huberman, 1994) to develop an understanding of management practices that appeared most appropriate for RI success. Data collection and analysis are conducted simultaneously, each informing the other. In fact, the conclusions of the first qualitative study (that RI project teams could benefit by a management infrastructure and management system to guide them, and that firms can in fact do this within the corporate organization rather than in an external incubator setting) motivated the second study. Within the second study, we realized that all of the elements of a management system would need to be considered, and so we asked questions about organizational structures, processes, metrics, governance, culture, and skills associated with the radical innovation initiative. We observed changes in each of these, and continuously questioned in each follow up interview why these changes were occurring.
This process of analytical induction is complicated in a multidisciplinary research team setting, such as ours, by the need to analyze data with the entire research team, and so scheduled debates and formal 'data analysis' sessions were held, to ensure our individual interpretations were converging.

Over the numerous meetings, conversations, and intensive review sessions of the interview transcripts through both studies, practices began to emerge early that we checked in subsequent interviews and noted across cases. We began to formalize these and check the literature for others’ views. Through this process, we identified the real options thinking and experiential processes, which are both rather widely known today in the literature, but not empirically tested. Harvesting strategy, however, is not yet widely recognized in the literature, and so we base most of our views of the importance of this construct on the observations from our cases.

5.1. Measurement development

Measures for the survey reported on in this paper were developed on the basis of three sources of input. First, the literature helped inform our conceptual definitions of Options, experiential processes, clockspeed and radical innovation. Second, the longitudinal studies described above helped inform all of the variables, but the concept of a harvesting strategy is not yet well developed in the literature. Finally, the IRI's subcommittee on Radical Innovation worked with us to refine the constructs. Measures were developed, pre-tested with the IRI membership, and refined two times. Table 2 provides the measurement items and their reliabilities. All of the measures except the dependent variable Competency achieved acceptable levels of reliability. Competency, a two item measure, is vulnerable to low reliability due to the low number of items that comprise it. Harvest also is only marginally acceptable in terms of reliability (.69). Since it is a new measure and theoretically important to the model, we opted to include it. Future work to improve the reliability of this measure is important. Table 3 provides descriptive data and correlations among the

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Scale items</th>
<th>Factor loadings</th>
<th>Cronbach's alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI performance/dependent variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legit</td>
<td>1. Our senior management believes that our RI initiatives will lead to significant growth opportunities for us.</td>
<td>.789</td>
<td>.837</td>
</tr>
<tr>
<td></td>
<td>2. Our sr. mgmt. is confident that our RI initiatives are progressing well.</td>
<td>.936</td>
<td>.871</td>
</tr>
<tr>
<td></td>
<td>3. Our sr. mgmt is confident that we have the capabilities to deal with the inherent uncertainties associated with RI's.</td>
<td>.718</td>
<td>.804</td>
</tr>
<tr>
<td></td>
<td>4. Most business units are knowledgeable about the specific RI projects that are underway.</td>
<td>.824</td>
<td>.901</td>
</tr>
<tr>
<td>Activity</td>
<td>1. There has been a steady growth in resources allocated to our RI initiatives.</td>
<td>.824</td>
<td>.816</td>
</tr>
<tr>
<td></td>
<td>2. Over the last three years, there has been a significant growth in the number of RI project that have been initiated.</td>
<td>.901</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Over the last three years there has been a significant growth in the number of RI's that have been transitioned to operating units for commercialization.</td>
<td>.807</td>
<td></td>
</tr>
<tr>
<td>Competency</td>
<td>1. During the last five years we have been very successful in creating new technological competencies.</td>
<td>.832</td>
<td>.554</td>
</tr>
<tr>
<td></td>
<td>2. During the last five years we have been very successful in developing new business/market competencies.</td>
<td>.832</td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>1. During the last five years we have successfully commercialized RI's developed by our organization.</td>
<td>.807</td>
<td>.797</td>
</tr>
<tr>
<td></td>
<td>2. During the last five years our company has successfully entered several technology/product domains that were new to us.</td>
<td>.906</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. During the last five years our company has successfully entered several market domains that were new to us.</td>
<td>.820</td>
<td></td>
</tr>
<tr>
<td>Independent variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Options</td>
<td>1. While investing in RI projects we understand that only a small percentage of the projects is likely to succeed.</td>
<td>.753</td>
<td>.779</td>
</tr>
<tr>
<td></td>
<td>2. We expect significant course corrections in RI projects and we have the flexibility to adjust project funding based on these changes.</td>
<td>.871</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Our funding strategy encourages RI project teams to probe and learn.</td>
<td>.822</td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>1. Initial market applications for RI's are chosen on the basis of how much we can learn from potential customers.</td>
<td>.611</td>
<td>.762</td>
</tr>
<tr>
<td></td>
<td>2. Insights gained in early market experiments are used to redirect RI projects.</td>
<td>.843</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. We conduct frequent, low-cost market tests to help us decide next steps in RI projects.</td>
<td>.862</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. We field test prototypes early in the development process, even if they are not yet perfected.</td>
<td>.772</td>
<td></td>
</tr>
<tr>
<td>Harvest</td>
<td>1. We seek revenues early in the process with simple versions of a RI opportunity while we continue to develop other applications.</td>
<td>.754</td>
<td>.690</td>
</tr>
<tr>
<td></td>
<td>2. Our RI projects are expected to start delivering revenues, even if they're small, as soon as any product possibility arises.</td>
<td>.888</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. We prefer to be very patient with our RI projects, and expect that, when they finally go commercial, they'll create entirely new businesses for us. (Reverse)</td>
<td>- .578</td>
<td></td>
</tr>
<tr>
<td>Moderator variable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry clock speed</td>
<td>1. The pace of new products introduced by competitors in this industry is fast</td>
<td>.820</td>
<td>.890</td>
</tr>
<tr>
<td></td>
<td>2. The rate of technological change in this industry is high</td>
<td>.864</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Changes in dominant product designs occur frequently in this industry</td>
<td>.737</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Major changes in production processes or paradigms occur frequently in this industry.</td>
<td>.797</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Radical innovation occurs frequently in this industry.</td>
<td>.788</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. There are frequent changes in current product offerings in this industry</td>
<td>.750</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7. Technological innovation is a critical competitive weapon in this industry.</td>
<td>.732</td>
<td></td>
</tr>
</tbody>
</table>
constructs. There exists some multi-collinearity among Experimental Processes and Options, but it is acceptably low (0.46) to continue with the analysis.

5.2. Sample

Respondents were Research Managers, Directors and Vice Presidents, who had oversight on the entire innovation system throughout the firm. U.S. based large industrial firms comprised the population of interest, since these firms are known to struggle with the problem of radical innovation due to their firmly established practices and necessary focus on operational excellence. Firms chosen for selection into the sample had revenues greater than US$750 million and represented a broad cross section of industries. Service and utilities firms were excluded from the sample since our understanding of RI practices to date has been driven by studies of industrial companies. Average revenues were US$8.4 billion, and median revenues were US$3.1 billion. Companies ranged in number of employees from 200 to 160,000, with mean number of employees equal to 23,625. Nine industries comprised 70% of the sample, including aerospace (7%), automotive (6%), chemicals (14%), consumer goods (6%), electronics (7%), material sciences (8%), paper and packaging (7%), pharmaceuticals (6%) and telecommunications (6%).

5.3. Data collection procedure

Eighty-five surveys were finally qualified. Dillman’s (2000) approach to data collection was followed. An initial mailing to 850 potential respondents began in spring 2004, with 2 follow up mailings occurring over the next several months. Two percent of the mailings were returned due to incorrect addresses or the respondent having left the firm. Thirty-five non-respondents were contacted to understand their reason for refusing the survey. The majority indicated that they were either not interested in the topic (15), or were interested, but did not have time (15). The remaining five, or 14% of the 35, however, indicated that it was against company policy to respond to such enquiries. Based upon this information, we reduced the potential respondent pool by 14%, or 136, leaving 714 and placing the effective survey response rate for this effort at slightly less than 12%.

6. Results

The hypotheses were tested using hierarchical moderated regression analysis. Moderated regression is similar to multiple regression except that cross-product terms for independent variables thought to interact are entered into the equation after the main effects are determined. The moderating effect is examined by comparing the multiple correlation coefficient ($R^2$) of the equation without the cross-product terms to the equation with the cross-product terms. The increment in $R^2$ is then tested for statistical significance. Since we have four measures of RI success, we ran regression models with each RI success measure as a dependent variable. Moreover, we ran the regression models separately for each of the two sets of moderators in our research model.

Table 4 summarizes the results of the statistical analysis. It is seen that the main effects of learning oriented practices on RI success are significant with one exception. Options mentality and use of experimental and learning processes have a significant positive effect on all dimensions of RI success lending support to hypotheses 1 and 3. Harvesting strategy has a positive effect on competency but did not have a significant relationship with the other three measures of RI success. Thus, the support for Hypothesis 2 is modest. Examination of adjusted $R^2$‘s indicates that, overall, the learning oriented practices explain substantial variance in RI success (28.9% for legitimacy, 27.1% for activity, 29.7% for competency and 18.4% for output) and all four models show significant $F$ statistics at $p < .01$ levels.

Examining the interaction effects of industry clock speed on RI success, results in Table 4 indicate that the interaction between options thinking and industry clock speed has a significant positive relationship with legitimacy but no significant relationship with activity, output and competency. This suggests that for firms operating in high clockspeed environments, adopting an options approach wherein funding for radical innovations are made with real options considerations enhances the legitimacy of the innovation initiatives among the organizational members more so than in industries characterized by low clockspeed levels. It does not aid, however, in gaining new competencies or more effective output differentially across higher and lower velocity industries.

The interaction between industry clock speed and harvesting strategy has a negative effect on activity and output suggesting that a strategy of harvesting early and often is more valuable for firms operating in less dynamic environments.
The interaction between use of experimental processes and industry clockspeed does not have a significant relationship with any of the RI success measures perhaps because experimental learning is inherently necessary in the context of managing radical innovation irrespective of the industry characteristics.

Overall these results provide strong support for the central premise of this paper that learning oriented risk management practices will have a positive effect on success of radical innovation efforts in firms. The results also provide modest support for the notion that the effects of the learning oriented risk management practices will vary based on the industry clock speed. We interpret and discuss these results in the next section.

7. Discussion and conclusions

With regard to the main effects model, Options mentality and Experimental processes appear to be strong risk management-by-learning practices that promote RI success measured in any manner. Adopting a harvest strategy, however, is only directly and positively related to new competency development as a measure of RI success.

7.1. Harvest strategy as a risk management by learning practice

Harvest strategy as a risk management by learning practice: These results are particularly surprising. We hypothesized that harvesting small wins along the way would help reduce organizational doubt about the RI initiative, and we expected to see it correlate with legitimacy most strongly. What may be occurring is a serial development in ability to demonstrate success across these measures. We expect legitimacy to be one of the initial hurdles that an RI portfolio manager would need to overcome, but, in fact, competency development may be the initial path. Harvesting as a learning oriented risk management tool is equally effective under all levels in terms of attaining new competencies, but equally ineffective (main effect is not significant) in gaining legitimacy internally.

7.2. Options orientation as a risk management by learning practice

As noted, project and portfolio evaluation and ongoing oversight using an options orientation is strongly and directly related to RI success. This relationship is strong under all levels of industry clockspeed for all measures of RI success except Legitimacy. There,
the relationship between options orientation and legitimacy is even stronger when industry clockspeed is high. It may be that RI oversight boards are more credible when they use processes that recognize that, since futures are unpredictable, funding incrementally may save money in the long run.

Finally, experimental processes have strongly significant direct impacts on all indicators of RI success. These hold regardless of industry clockspeed, indicating the universality of experimental processes as a learning based risk management tool.

In summary, we find that both options mentality and experimental processes have been shown to directly impact RI success, and that harvesting strategy impacts RI competency. The contributions of this study are twofold. From a theoretical perspective, we have conceptualized the notion of path generation for organizations as opposed to path dependence, and have identified a set of practices for dealing with risks associated with path generation activities, which are fraught with high uncertainty.

Secondly, we have contributed to the growing body of work that is beginning to empirically test the rich collection of conceptual frameworks and theories that is burgeoning in the literature on radical innovation. We find that the development of dynamic capabilities for managing highly uncertain phenomena such as radical innovation includes a risk management-by-learning capability. Further research is necessary to replicate our findings and extend them to other high uncertainty venues.

References


