

WHAT IS NOT A REAL OPTION: CONSIDERING BOUNDARIES FOR THE APPLICATION OF REAL OPTIONS TO BUSINESS STRATEGY

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We argue that the greater the extent to which choice sets evolve as a consequence of firms' exploration activities, the less structured the firms' abandonment decisions become and, in turn, the less distinguishable a real option is from more generic notions of path dependence—a sequential stream of investment in and of itself does not constitute a real option. While organizational adaptations can extend the applicability of real options, they impose tradeoffs that may lead to the underutilization of discoveries made in the course of exploration.

The concept of real options has created considerable excitement in the management literature in recent years (Kogut & Kulatilaka, 2001; McGrath, 1997). The appeal of real options is quite natural. Firms face uncertain futures, and the investment opportunities they face are, to an important degree, a function of their prior investment commitments. Thus, at a surface level, the real options framework appears to precisely fit firms' strategic challenges by linking current actions to uncertain futures. In addition, relative to other justifications for exploration, such as rationales for slack search (March & Simon, 1958), real options provide a rhetoric that comfortably fits the standard language of corporate finance. Less obvious than the benefits offered by the real options framework but equally important are its inherent limitations in guiding organizations' decision making under uncertainty.

The underlying logic of the real options framework is based on the realization that future investment opportunities are contingent on prior investment commitments. Thus, in contrast to net present value analysis, real options analysis accounts for the sequential nature of choice processes. Such an observation is not alien to researchers working within the tradition of the

behavioral theory of the firm (Cyert & March, 1963) or evolutionary economics (Dosi, 1982; Nelson & Winter, 1982; Penrose, 1959) who have long been sensitive to path dependence. What is distinctive about the use of real options as both an analytic tool (Dixit & Pindyck, 1994; Trigeorgis, 1997) and a strategic heuristic (Luehrman, 1998; McGrath, 1997) is that the real options logic offers the prospect of assigning actual values (cardinal in the former case or ordinal in the latter case) to stage-setting investments.

However, while the logic can always be used to generate values and orderings, the validity of these results depends on some key assumptions. The technical violations of strict real options assumptions and the methods for their accommodation are, by now, well known (e.g., Copeland & Antikarov, 2001). More subtle, however, and more limiting to the validity of real options as a tool in organizational decision making are violations that stem from organizational processes in the face of different modes of uncertainty resolution.

The real options framework is intended to exploit the flexibility inherent in sequential investments. We argue that this flexibility stems from the possibility of abandoning investment initiatives, rather than from the simple substitution of a stream of smaller payments for a larger lump sum payment. This implies that the effective management of real options requires a high degree of rigidity in the specification of the agenda of the initiatives and the criteria for

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their success. We consider the implications, positive and negative, of such constraints and compare them to more generic path-dependent approaches to managing investment under uncertainty.

In the next section we briefly lay out the formal structure of real options. We then examine some of the critical assumptions that underlie the application of options to firms' investment decisions. When uncertainty resolution emerges as an outcome of firm action, the sharp temporal demarcation made in the options literature between "Stage 1" and "Stage 2" investments is called into question. In such settings, beyond learning about a specific initiative, the flexibility associated with later investment decisions often stems from the possibility of discovering a wide variety of related opportunities, even in the face of unfavorable initial outcomes. We show that the greater the extent to which initiatives are open ended, the more problematic the application of the real options framework is. Flexibility in search can undermine the flexibility associated with abandonment. Abandonment is essential for limiting downside risk, a key virtue attributed to real option investments. We consider how organizational processes, such as the allocation of decision rights that limit the range of possible action and the specification of well-defined temporal boundaries, can extend the applicability of real options reasoning but force strategic tradeoffs of their own. We conclude by considering differences between real options

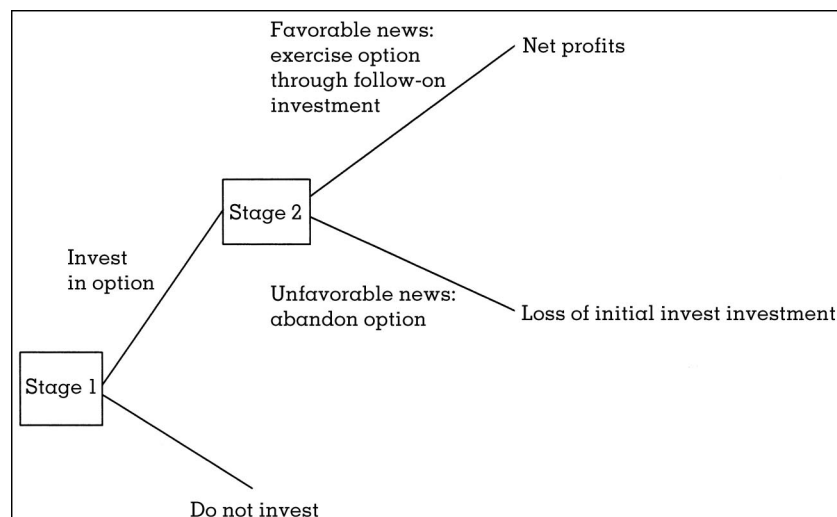
approaches and more generic path-dependent processes, and we suggest how they might be distinguished empirically.

REAL OPTIONS

Real options investments are characterized by sequential, irreversible investments made under conditions of uncertainty (Dixit & Pindyck, 1994). The framework suggests that purchasing a real option on a strategically important opportunity allows firms to postpone commitment until a substantial portion of the uncertainty about the opportunity has been resolved. After making an initial investment, management is then to turn its attention to other matters and wait for a signal as to whether or not it is appropriate to harvest or cultivate the initial investment.

Consider the events that transpire prior to the exercise of financial options, on which the real options model is based (Figure 1). First, an investor purchases an option (Stage 1). Then, during the course of the holding period, the value of the option changes in response to external events. Throughout the holding period, the financial markets provide a clear signal as to the current value of the option. Finally, events transpire so that the investor chooses to exercise the option, or, alternatively, the expiration date specified in the option contract is reached and the option expires (Stage 2). Investments with this structure are optionlike in that Stage 2 investments are not a necessary consequence of

FIGURE 1
The Structure of Real Options



having made an initial Stage 1 investment but, rather, can be conditioned on the realization of interim information.

Note two critical features of this process: (1) the value of the option (and the underlying asset) is exogenous to the investor's activity—the investor cannot take steps to make the intrinsic characteristics of the asset more attractive; (2) the market signal of option value is readily observable and is independent of the investor's behavior. If these properties carry over to an investment of a nonfinancial sort (such as in plant and equipment, or in technology licenses), then the logic of options can directly carry over. The greater the extent to which these properties are violated, the more problematic the application of an options framework is.

The "wait and see" setting of financial options represents the extreme case of investment environments, but one for which the methodology is ideally suited. Because much attention in the management literature is focused on the ways in which the firm can affect outcomes and variances (e.g., McGrath, 1997), it is important to examine what happens to the applicability of options logic as we move away from a world of wait and see to a world of "act and see," in which uncertainty resolution is endogenous to firm activity.

BOUNDARIES OF REAL OPTIONS

The boundaries of the logic of real options are often considered in relation to the breakdown of net present value analysis: to the degree that investment choices have the property of high uncertainty and irreversibility, a real options valuation provides a better characterization of the investment's true value than does a net present value calculation because of the latter's inability to account for the value of delaying commitments (see Figure 2a).

Less examined but no less important are the boundaries along which real options logic is itself strained. As we move from a world of real options on tradable assets, in which the firm has no hand in resolving uncertainty and the set of possible actions in response to this uncertainty resolution can be specified at the time of the initial investment, to real options on strategic opportunities whose outcomes are intimately linked to firm action, the clean demarcations between investment stages begin to blur and

FIGURE 2a
Boundaries of Applicability for Net Present Value and Real Options

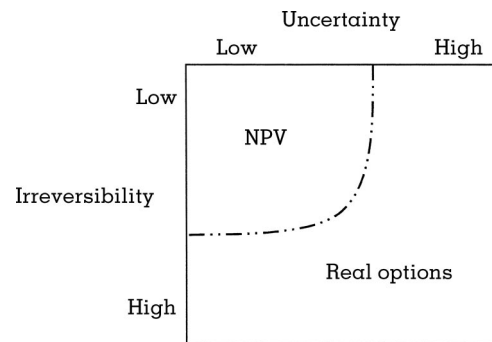
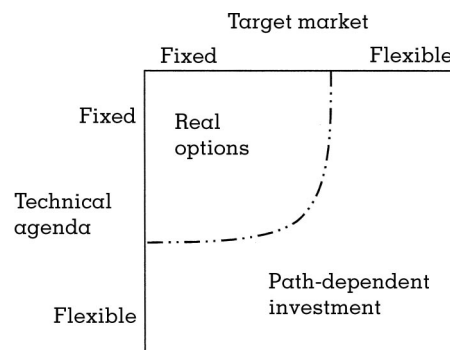


FIGURE 2b
Boundaries of Applicability for Real Options and Path-Dependent Opportunities



the application of real options becomes more challenging analytically and, focal to this paper, organizationally.

When target markets and technical agendas are flexible (see Figure 2b), the discrete investment logic of real options is eroded, and activities may be characterized more appropriately as more generic path-dependent processes that fall under such labels as *probe and learn* (Lynn, Morone, & Paulson, 1996), *incremental search* (March & Simon, 1958; Nelson & Winter, 1982), or *innovation journeys* (Van de Ven, Pollery, Garud, & Venkataraman, 1999). Alternatively, if the scope of the option investment is fixed a priori—that is, if the opportunities on which one is taking an option can be clearly specified at the inception of the option—then the decision to abandon an initiative can be clearly articulated and the flexibility associated with an option investment can be readily maintained.

In the context of financial options, one can clearly state a priori when a given option will be

"in the money" and worth exercising. However, in the case of real options on strategic opportunities in which new possibilities are identified as a consequence of a firm's actions, such a prior specification may not be possible or even desirable. Experiments, even unsuccessful ones, not only provide information about intended investment paths but also provide information about other possibilities—possibilities that may not even have been envisioned at the time of the initial investments. Outcomes that are negative vis-à-vis the initial proposed initiative may still suggest or engender other possible actions. For instance, the failure of a technology development effort to reach a given technical hurdle in a specified time horizon does not preclude additional efforts or different approaches; similarly, if a new product fails to win acceptance in a given target market, it may still be successful in other possible target markets.¹

At a basic logical level, the boundless set of possibilities associated with a strategic investment initiative presents a problem analogous to that posed by Popper (1959) in the context of hypothesis testing. Popper's proposition is that a hypothesis is never proved; rather, it is not disproved in any given test. Conversely, in a given attempt to realize an opportunity, we can only prove that an initiative can be successful in a particular setting; we cannot use negative outcomes to preclude the possibility that it will be successful in other target markets or with further technical refinements.

This "impossibility of proving failure" is an inherent feature of firm initiatives under uncertainty and poses a fundamental challenge to the applicability of the real options framework. Further, because actors at different levels of an organization have different perspectives on the attractiveness of a given opportunity, they will disagree as to the proper framing of termination decisions. Thus, the open-ended nature of the search for success raises organizational chal-

lenges to abandoning options that can deter firms from exercising the very flexibility that made the real options approach attractive in the first place.

The degree to which an initiative is circumscribed is itself dependent on organizational choices concerning project scope. If an initiative is highly circumscribed in terms of what appropriate target markets are and what temporal and technical boundaries must be respected, then the degree of flexibility in the potential directions of the initiative is limited, but at a price. Imposing rigid criteria for abandonment may result in the underutilization of discoveries made in the context of initiatives that are failures with respect to their initial agenda but that introduce promising possibilities not previously imagined.

This highlights the need for proponents of real options logic to consider a more nuanced organizational perspective that incorporates the different views that exist within an organization. The firm cannot be regarded as a unitary actor. Managers charged with pursuing an opportunity and executives charged with evaluating a portfolio of opportunities will differ in their beliefs as to when an option ceases to be attractive. Such differences are a function of their incentives and opportunity structures, and they serve to compound the psychological biases regarding sunk costs and escalating commitment that can act to deter strategic redirection.

These considerations are largely overlooked in the theoretical (e.g., Dixit & Pindyck, 1994; Trigeorgis, 1997) and managerial (e.g., Amram & Kulatilaka, 1998; Luehrman, 1998) work on real options in strategy, in which researchers tend to treat the firm as a monolithic actor. They are also largely overlooked in empirical work in which scholars tend to look at investment decisions that are not integrated within the firm's organizational activities (e.g., investments in acquisitions and joint ventures). The importance of organizational factors in determining the applicability of options logic increases as real options theory is extended from the evaluation of investments in physical assets, for which the resolution of uncertainty is exogenous to firm action and the scope of possible firm response to this uncertainty is relatively constrained (e.g., making use of a plant in a foreign country to potentially take advantage of swings in relative wages), to the evaluation of investments in stra-

¹ Knight's (1921) distinction between risk and uncertainty, which lies at the heart of notions of entrepreneurship (Kirzner, 1997), is closely related to the distinction we are making here. Real options are well suited to incorporate risk, an uncertain realization from a well-specified probability distribution. In contrast, the inherent unknowability that characterizes Knightian uncertainty poses a significant challenge to characterizing means and variances of key option analysis parameters.

tegic opportunities, for which the resolution of uncertainty is largely endogenous to firm action, and the scope for possible modifications in the initial initiative is vast.

CHALLENGE OF ABANDONMENT

Ambiguity of Stages in Real Options

An investment's flexibility is revealed in the project abandonment decision. Options are flexible not because they substitute a stream of smaller payment for a larger lump sum payment but because the payment stream can be abandoned in light of negative outcomes. The less well-defined the abandonment decision, the less valid the perception of flexibility and the less appropriate the nominal application of real options logic. In the absence of proofs of failure and strict, structured abandonment deadlines, firms face a difficult organizational challenge to exploit the flexibility offered by the sequential nature of optionlike investments. As noted earlier, there is an important asymmetry between positive and negative signals that is analogous

to the asymmetry of proving and disproving a hypothesis in empirical research. Popper (1959) argues that it is logically impossible to prove that a hypothesis is true; we can only show that it is not false, up to a specified probability level. In contrast, a managerial initiative can only be shown to be successful in that some market or technical criteria are met; an initiative, such as the development of a new technology, cannot conclusively be shown to be incapable of succeeding.

Consider what we learn when a new technology is "tried." We may learn that, in a given time period and with a given level of investment, researchers were not able to meet certain technical milestones. Similarly, we may learn that a particular market context was not receptive to the technology in its current form. However, these results are not impossibility theorems. They do not demonstrate that, with more time and more resources, these technical milestones could not be met. Nor do such results demonstrate that other market settings might not respond positively to the technology in its current form or that enhancements to the technology or

FIGURE 3
Malleability of Technical and Market Focus to Firm Activity

	Target market fixed	Target market flexible
Technical agenda fixed	<p>Oil production capacity</p> <p>Multinational production for currency arbitrage</p>	<p>Patented materials (technical properties fixed, but different markets may yield different outcomes—e.g., Viagra, which failed to reduce angina but was found efficacious elsewhere)</p>
Technical agenda flexible	<p>Artificial heart (application is fixed but different development approaches may yield different outcomes)</p>	<p>Wireless internet</p> <p>Solar panels</p> <p>Artificial intelligence</p>

a reduction in cost will not lead to success in the current market setting.

Thus, the significance of any specific market response is constrained in market space to a specific segment, and constrained in time to a specific development state. Figure 3 maps the potential malleability of a project to interim feedback, in terms of the opportunity to affect the technical agenda of the project and the markets in which the project will be evaluated, after an option has been purchased. Again, what is critical is that these new directions need not have been identified at the time of the inception of the initial option investment. They were not part of the justification for the initiation of the option, but they became critical for the continuation of the investment effort. The greater the potential for ex post discovery of possible new directions for the original initiative, the greater the difficulty in deciding when to abandon the opportunity.

The problem of abandonment is compounded by the fact that most options on strategic opportunities do not have an explicit, exogenous expiration date. How long the firm can keep the option open, whether in persisting in development efforts in nominally promising pharmaceuticals or in market creation efforts for emerging technologies, is often difficult to specify ex ante.² When there is no explicit time limit on

² The fact that a real option may lack an explicit expiration date need not imply that the option persists indefinitely. In particular, competitive forces may result in the effective expiration of an option. However, even in cases where the competitive environment drives option expiration (e.g., McGrath, 1997; Trigeorgis, 1997), the timing of expiration cannot be specified ex ante. In addition, when the opportunity can be exploited in multiple markets, a rival's entry into one market does not necessarily lead to the expiration of the option in other markets, so even in these settings ex post endogeneity is present. Strategic interactions also present another dimension of endogeneity to the problem of evaluating options that leads to an additional set of challenges. As opposed to "standard" real options settings, where expected payoffs are exogenously determined, "competitive" real options analysis requires an accounting for the ways in which the firm's actions affect rivals' responses. The benefits of delay and exploration that are derived from sequential investments must be weighted against the potential benefits offered by commitment and preemption (Ghemawat, 1991).

Although still in infancy, theoretical attempts to marry real options with game theory (e.g., Grenadier, 2001; Kulatilaka & Perotti, 1998) suggest that analytic results can be obtained. These results, however, are very sensitive to underlying assumptions about parameter values — values that

efforts to enhance the value of the initial initiative, time to expiration becomes an endogenous choice. From a valuation perspective, longer option durations lead to higher option values and increase the risk of overvaluation. From an organizational perspective, flexibility in duration leads to negotiations over termination criteria, which increase the risk that firm investments will be governed by influence processes and idiosyncratic justification, rather than by a coherent portfolio strategy.

A fundamental difficulty raised by broad flexibility in response to interim signals is that while real options valuation techniques are well tailored to offering go/no-go guidance on project initiations, they are relatively equivocal regarding what to do after an initial "go" recommendation.

Clearly, the real options valuation framework can be reapplied to the evaluation of a given initiative at a future time, when some uncertainty is resolved (e.g., compound real options). Structured reevaluation, however, becomes increasingly difficult as uncertainty gets resolved in increasingly incremental steps that are a function of firm activity.³ Incremental discovery leads to difficulty in drawing precise distinctions among a series of independent options, a single compound option, and more generic path-dependent search activities. The division of time into discrete decision points is typically artificial. Does the pharmaceutical firm that started a research project on Monday make a conscious choice on Tuesday to continue with the project? Ultimately, the structure of the discovery activity

are impossible to assess with accuracy for many strategically important opportunities. Furthermore, for analytic tractability, these models necessarily ignore many important factors, such as the complexity and duration of competitive responses, identified in recent work on competitive dynamics (e.g., Ferrier, Smith, & Grimm, 1999).

³ Trigeorgis (1997), for example, notes that a rich set of compound options poses analytic and computational challenges to the actual evaluation of real options. Consider that of the six factors that determine option value (value of underlying risky asset, exercise price, time to expiration, volatility of the value of the underlying asset, foregone cash flows, discount rate), the first four are especially difficult to specify with confidence for the case of strategic opportunities. See Bowman and Moskowitz (2001) for a reexamination of the effectiveness of the application of option analysis at Merck, and Lander and Pinches (1998) for a discussion of the modeling challenges to making real options analysis "practical."

FIGURE 4
“Option Traps” That Hinder the Abandonment of Opportunities

	Target market fixed	Target market flexible
Technical agenda fixed	Option trap: in the absence of expiration, the firm can maintain the option indefinitely until conditions improve “Things will get better”	Option trap: negative market signals may lead to a search for new potential markets or market interventions rather than abandonment “We can try it somewhere else”
Technical agenda flexible	Option trap: further development efforts always hold the potential for overcoming any negative market signal “We can try harder”	Option trap: too many degrees of freedom for ruling out success “We can make this work”

and the scope of the authority of the project team define these distinctions and thereby draw the boundary of applicability for options logic.

Organizational Factors

Because holding options open entails both organizational and financial maintenance costs (Garud & Nayyar, 1994), managing abandonment has direct implications for firms' success in managing real options. The “option traps” presented in Figure 4 highlight the forces that undermine timely project abandonment in different uncertainty resolution regimes. The challenge of project abandonment is complicated by the nature of organizational resource allocation (Bower, 1970) and the different perspectives and incentives of stakeholders at different levels in the organization.

This contrast is most succinctly characterized as the difference between “holding the option” and “being the option.” For executives at high levels in the organization within whose purview lie a number of distinct initiatives, an individual initiative may have an optionlike quality in that the abandonment of the particular project may not entail significant consequences. However, the managers focused on that particular project may see greater potential in its pursuit, both because they are not aware of the larger set of alternative investments available to the firm and because of the career consequences associated with its abandonment. These considerations, in turn, act to increase these managers' dedication to achieving success with respect to a particular initiative. This dedication, while

positive in the sense of increasing the likelihood of success, clearly hampers their ability to abandon initiatives when the learning outcomes are negative (Garud & Van de Ven, 1992). For this reason, the way in which the selection and resource allocation mechanisms are manifested throughout the organizational hierarchy is fundamental to the challenge of exploiting the flexibility inherent in real options.

These organizational drivers are compounded by psychological deterrents to abandonment. Given the difficulty firms have in incorporating the logic of sunk costs (Russo & Schoemaker, 1989), their tendency toward escalating commitments (Staw, 1981) and overconfidence (Camerer & Lovo, 1999), the political impetus not to show failure (McGrath, 1999; Sitkin, 1992), and the natural desire to succeed, the challenge of abandonment—giving up on an opportunity that has a chance for success—is a large one.⁴ This, essentially, is the dark side of managing projects with product champions (Maidique, 1980) and skunk works (Kanter, 1988), where the systems and support mechanisms put in place to create an impetus for starting innovations act directly against their objective reassessment and termination. Indeed, the challenges associated with abandoning projects can be

⁴ Investment in joint ventures creates an organizational boundary that should make it easier to monitor, separate, and abandon an option investment (e.g., Kogut, 1991). Even in this ideal setting, however, the evidence of firms' effectiveness in managing exit and minimizing downside risk is mixed (Reuer & Leiblein, 2000).

greater than those associated with initiating them (Brunsson, 1982; Garud & Van de Ven, 1992).⁵

Real options logic makes a fundamental contribution to the structuring of risk. When deployed in real organizations, however, this logic must be complemented with appropriate controls (Block & MacMillan, 1993; McGrath & MacMillan, 2000). These controls need to reflect the evaluation traps created by flexible sets of possible responses to interim signals and the way in which initiatives may be usefully redirected. Given the vast set of possible paths that an investment effort may take, the "flexibility" of abandonment that is central to the evaluation of real options calls for an off-setting rigidity in specifying the set of allowable courses of action at the time of the initial investment.

The degree of flexibility in response to interim signals is likely to vary with the unit of analysis being considered and where the boundaries of the decision-making entity lie. At the level of the firm, it is difficult to presume that the firm can commit itself to a narrow range of response to information that may emerge for an initial "option" investment. Indeed, such a commitment may not be sequentially rational (Selten, 1975). However, at lower levels of the organization, subunits may be constrained in the range of initiatives that they pursue (Galunic & Eisenhardt, 1996), whether limited in the range of target markets that can be addressed or the set of technical approaches that can be explored. It is at these lower levels that real options may reside. Disciplined project management can foster organizational environments that facilitate real options strategies. Projects can be artificially constrained through milestones, strict deadlines, and regimented market focus to overcome the challenge of the impossibility of proving that all possible avenues of opportunity are unpromising and, in turn, that the abandonment of the initiative is appropriate. Such practices, however, run the risk of under-

exploiting the lessons learned from unsuccessful or only partially successful initiatives (e.g., Sitkin, 1992).

Our aim is not to dispute the importance of continued search activity. Indeed, we note that it is at the heart of well-admired processes such as skunk works, probe and learn, and so forth. Rather, our aim is to highlight the difficulty such processes raise for conceptualizing and managing real options. Specifically, the more freedom afforded to an option manager (i.e., the more active his or her role is in resolving uncertainty), the more likely the option is to take on a life of its own, independent of the requirement specified by the logic governing the firm's portfolio of options. When the selection and evaluation criteria differ across levels of the organization, which is increasingly the case as managers have more control and are more vested in their projects, freedom of action at the level of the project is not consonant with the consistent approach to portfolio management at the level of the firm. Making investment decisions under the assumption of clear-cut abandonment points, when organizational conditions are such that abandonment is unlikely to occur or unlikely to be timely, is likely to render an initial real options valuation to be quite misleading. Since real options framework is a theory of allocation and control, this raises a question as to the merits of its application under such conditions.

In sum, firms invest in the active development of technology, and not in passive bets as to winners and losers. Given the impossibility of proving failure and the absence of formal expiration dates for an option investment, a firm's internal selection regime dictates its ability to manage options. A well-managed real options strategy must necessarily guard against the natural momentum that builds up around hopeful activity.

Another way of characterizing our argument about the importance of abandonment is to recognize that, from the perspective of the option initiative, the key is to avoid false negatives (type II errors), in which valuable opportunities are foregone. However, from the perspective of managing the option portfolio, the key is not to forget about avoiding false positives (type I errors), which tie up resources that are better used elsewhere.

⁵ In our own conversations with managers in high-technology firms known for the depth and breadth of their innovative capacity, they consistently spoke of the challenge of shutting down projects. At one firm, "death row" was used to describe a set of projects that the organization had formally recognized as in need of termination but that, for various reasons, kept getting stays of execution and surviving.

ALTERNATIVE SEARCH PROCESSES

While the notion of real options as a way to frame decision makers' choices under uncertainty is relatively new to the management literature, the problem of organizations confronting uncharted worlds is well established. A long-standing strand of the literature has highlighted the role and importance of search processes. Search may be local and problem driven, but it also may comprise more opportunistic, and less local, exploration. This latter notion of slack search (March & Simon, 1958) has been picked up and interpreted in terms of ideas of autonomous innovation (Burgelman, 1983) and skunk works (Kanter, 1988)—ideas that have not only been offered to capture existing behavior but also held out as normative suggestions for how organizations may cope with uncertain futures.

These images of search efforts, relatively loosely controlled but modest in financial commitments, lack the procedural rationality of real options decision making. No explicit decision is made as to what constitutes the appropriate amount of slack search at a given time; rather, the organization is viewed as having, or is encouraged to develop, a heuristic or norm regarding the appropriate level of resources to be allocated to such efforts.

Another clear distinction between this broad category of path-dependent principles and the real options framework is that specific initiatives are not endorsed or necessarily examined by higher-level actors within the organization. Slack is introduced into the resource allocation system such that modest initiatives can occur without direct corporate oversight. Of course, if such initiatives identify opportunities that appear to be worth pursuing and worth commercial development, it is likely that greater resource commitments will be necessary, and, as a result, higher-level organizational actors will need to be convinced of the initiative's merits. This commitment of more substantial resources and the organizational approval of such commitments is akin to the "striking" of an option. Again, though, it is important to note that the initial initiative was never chosen by the organization; rather, the organization chose to allocate sufficient slack such that such initiatives might emerge.

A natural question to ask is when might such less specified discovery processes be preferred to the more explicit decision calculus of real options? One complexity in considering this contrast is what one is to take as a characterization of a real options process. In our view, as a behavioral matter, the use of real options may not vary so greatly from the behavior that stems from slack search. Indeed, one of the merits of the real options framework is that it provides a procedurally rational justification for processes of slack search. In that sense, real options are a powerful tool for the "technology of foolishness" (March, 1988).⁶

Alternatively, we can make the reference point decision processes that more closely adhere to the precepts of real options decision making. One virtue of the real options approach is that since the initial stage-setting investments are more explicit and, in turn, more visible to higher-level actors within the organization, the organization will have a better sense of its portfolio of initiatives. An organization may feel that it wants some initial exploration in a variety of technologies or markets and would have a better sense of its overall exposure under the real options approach than under a system of slack search.

The tradeoff to this benefit is, as we have argued above, that to make exploration initiatives conform to the structure of a real option, the boundaries of these initiatives should be tightly specified *ex ante*. If an initiative to explore the value of a particular technology or particular market application wanders in response to feedback from initial efforts or shifts in markets and technologies, the discipline required by real options is lost. However, such discovery processes are often heralded as valuable means by which innovation occurs (Adner & Levinthal, 2002; Day, 1990; Lynn et al., 1996). While these more generic path-dependent processes of exploration do not address the abandonment challenges we have highlighted, unlike real option approaches, they do not make implicit assumptions about termination that are critical to their validity.

⁶ By "technology of foolishness," March (1988) refers to mechanisms that legitimate the allocation of resources for search and discovery processes.

Clearly, to the extent that the potential paths a stage-setting investment may take are inherently limited, the real options framework is more readily applied. In addition, in such settings the potential downside of its application in terms of foregone opportunities that are discovered *ex post* is sharply diminished. Such a perspective suggests that real options may be better suited to well-specified investments, such as overseas production facilities and innovation licenses, than to less structured opportunities, such as the development of new product technologies in the face of a wide set of possible technical solutions and market applications.

CONCLUSIONS

In some sense, our argument simply places the notion of real options in the broader context of sequential decision making. Actions are taken, beliefs are revised, and subsequent choices are made. One is then left with the empirical question of how to distinguish real options from the broader class of sequential decision-making processes. Demonstrating that firms' investment paths involve a sequential process of scaling up is, in itself, insufficient. There are a wide variety of processes that would generate such a pattern, such as adjustment costs and time compression diseconomies (Dierickx & Cool, 1989), and incremental learning (Cyert & March, 1963), that are not directly linked to ideas of real options.

As a result, we must move beyond measures of the performance characteristics of firms' project portfolios, whether average project losses at real options firms are smaller (because they have limited downside risk) or average project gains relative to losses are larger at real options firms (because losses are limited but upside risk is unbounded). Rather, we should examine the way in which the portfolio is adjusted over time and, in particular, firms' approaches to abandonment.

Thus, in terms of observed behavior, we would expect real options firms, relative to their traditional counterparts, to

1. abandon projects earlier and
2. have higher project abandonment rates.

Similarly, in terms of organizational processes, we would expect real options firms to have

1. stricter action mandates for business units and project teams;
2. formalized milestones and go/no-go procedures;
3. incentive systems, organizational cultures, and allocation mechanisms that are more tolerant of failure; and
4. review procedures that are more sensitive to the presence of different incentives at different levels of the organization.

More broadly, in terms of empirical research on the use of real options in organizations, we would hope to see demonstrations of patterns of systematic and structured decision making that demonstrate divergence from *both* net present value analysis *and* unstructured path dependence, as well as data that consider project termination, not just the initiation and pacing of investment.

Firms face complex and highly uncertain investment environments. The real options framework usefully highlights the links between current actions and the set of future possibilities. However, to the extent that exit criteria are not well posed in a world of action and open-ended search, this framing can be overly seductive. While real options logic may justify investments that would be rejected under the calculus of net present value, these "justified" investments may well destroy value when implicit assumptions about abandonment flexibility are wrong. In settings where the range of responses to the resolution of technical and market uncertainty is largely unconstrained, the utility of applying options logic is unclear. For such strategic investments, in contrast to financial options, exit criteria are not self-evident. Rather, in such circumstances it may be more useful to identify the possible sequence of experiments that will test the most promising market and technical paths available to the firm.

To be clear, our purpose is not to question the internal logic of real options. We do feel, however, that grouping all path-dependent activity under the real options label overextends real options logic as tool, framework, and even as metaphor, and undermines its effective application. We believe that understanding a theory's boundaries serves to make it more powerful and more precise. We argue that the cause of options thinking is best served in considering the boundaries of the domain of applicability of this logic for business strategy, and in defining its place within the broader set of tools that are

available to address decision making under uncertainty. In this regard, we suggest that the answer to the question "What is (and is not) a real option?" has as much to do with the organization as it does with the opportunity.

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