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RESPONSE

REAL OPTIONS AS ENGINES OF CHOICE AND HETEROGENEITY

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Four characterizations of options exist: (1) as a component of total firm value, (2) as specific projects, (3) as choices, and (4) as a heuristic for strategic investment. Option value exists when two conditions apply: future choices and potential for proprietary access to outcomes. Narrower boundary conditions are inconsistent with theory and incomplete for application. The option lens has promise for its power to shed economic insight into behavioral processes.

It is a testament to the significance of real options theory in strategy that critiques and refinements are emerging (Adner & Levinthal, 2003; Coff & Laverty, 2001; Garud & Kumaraswamy, 1998; Miller, 2002; Reuer & Leiblein, 2000). Elaboration of the theory's essential elements is crucial to its development, and we welcome vigorous debate, better definitions, and particularly better advice for the application of options concepts to practical problems in organizations. Real options reasoning is poised to occupy a central conceptual position in the development of theory that offers guidance for strategic decision making under uncertainty. Some authorities even believe that options technologies may dramatically change established theories, suggesting, for instance, that they "may even lead to a revisiting of the industrial-organization model" (Merton, 1998: 343).

In the field of management, however, application of real options theory is preparadigmatic. Scholars have not yet been freed "from the need constantly to re-examine its first principles" (Kuhn, 1970: 163). This developmental stage of the theory suggests that it makes sense to determine the characteristics of strategic decisions that would benefit from using the real options perspective. Triggered by Adner and Levinthal's (2004) thinking, it seems to us that five issues are of particular importance:

1. the definition of what a real option is,
2. the definition of the sources of flexibility,
3. the imputed processes of cognition and uncertainty reduction operating in the theory,
4. the concept of "effective resource allocation," and
5. the organizational implications of using options reasoning.

We build a discussion around these topics to structure a commentary on Adner and Levinthal's article, "What Is *Not* a Real Option: Considering Boundaries for the Application of Real Options to Business Strategy." We suggest points of enthusiastic agreement, as well as points of critique.

DEFINING KEY CONCEPTS

What Is a Real Option?

The title of Adner and Levinthal's article draws our attention to a fundamental problem with the theory as it stands—namely, little consistency regarding what is meant by the term *real option*. Although most views have in common the idea of a limited commitment that creates future decision rights, the option in question varies. Four different but often conflated

concepts can be identified in the real options literature: (1) the idea of option value as a component of the total value of the firm, where it represents growth opportunities; (2) a specific investment proposal with optionlike properties; (3) choices that might pertain to one or more proposals; and (4) the use of options reasoning as a heuristic for strategy.

Option value as a component of the total value of the firm. Early interest in the concept of real options in the field of finance is often traced to Miller and Modigliani's (1961) observation that a firm's market value comprises two components. The first is the present value of those cash flows that will be generated by assets that are in place. The second is the present value of growth opportunities.

Myers (1977) and Myers & Turnbull (1977) proposed the existence of real options by suggesting that the first component stemmed from existing units of productive capacity, whereas the second represented intangible assets or "options to purchase additional units of productive capacity in future periods" (Myers & Turnbull, 1977: 331–332). They presaged later research that found that failing to account for option value can systematically exert downward bias on return calculations. They observed that the presence of valuable growth options might lead to an overestimation of the appropriate hurdle rate for capital investment, wryly concluding that this creates "practical and theoretical difficulties" (Myers & Turnbull, 1977: 332). The relevant option construct in these early treatments was the set of undefined growth opportunities possessed by a firm that stemmed from its bundle of resources and capabilities.

Specific investments with optionlike properties. Investment models in the field of finance often confine the application of options analysis to decisions regarding a single project. A common objective is to derive a robust valuation method for real options, as Black and Scholes (1973) did for financial options. Scholars in finance thus have assessed discrete projects, such as a specific investment in R&D or in an asset with uncertain payoffs—for instance, the right to drill for oil or develop land (Dixit, 1992; Majd & Pindyck, 1987; Triantis & Hodder, 1990; Williams, 1991; see also Dixit & Pindyck, 1994). This body of literature has grown very rapidly and now encompasses several hundred studies in the field of finance.

The definition of a real option as a specific investment also has been widely used in the management literature, and it is the definition most commonly employed in empirical studies. These include growth options (Kester, 1981), joint ventures (Kogut, 1991), investments in R&D (Kumaraswamy, 1996), venture capital investments (Hurry, Miller, & Bowman, 1992), and governance choices (Folta, 1998; Folta & Miller, 2002). In these studies option value is related to the preservation of choices, meaning that a firm can take a variety of actions (scale up or down, abandon, change direction, or delay) when more information is available, rather than make a full commitment to a given path at the outset of the project or initiative. As Merton points out:

> The common element for using option-pricing here is . . . [that] the future is uncertain (if it were not, there would be no need to create options because we know now what we will do later) and in an uncertain environment, having the flexibility to decide what to do after some of that uncertainty is resolved definitely has value (1998: 339).

In conducting empirical work, scholars in this tradition typically theorize that a decision sequence is consistent with options reasoning, forming a prediction of what is likely to occur if the decision maker is using options reasoning. They then examine whether the actual decisions appear to conform to the theorized sequence. Options reasoning is often found to be more consistent with the pattern of choices made by organizations than are other investment alternatives (typically, discounted cash flow models). For instance, firms impose higher hurdle rates for investment than would be dictated by the net present value (NPV) rule, and they stick with investments that are underperforming longer than the rule might suggest (see Dixit, 1992, for a discussion of hysteresis effects).

Choices that might pertain to one or more proposals. In another approach to defining options, researchers focus on the decisions or choices that executives might make as the option, rather than the asset or resource about which the choice is being made. Hence, Trigeorgis (1993) describes the following as real options: the option to defer, the option to stage and sequence investment, the option to alter operating scale, the option to abandon, the option to switch inputs or outputs, growth options, and multiple interacting options. In his review of the literature on each of these types of options, Tri-

georgis notes that each has a different level of importance for organizations facing different types of challenges.

Further, in most real-life contexts, multiple choices are possible; thus, multiple options pertain. "Real-life projects in most industries," he observes, "often involve a collection of various options, both upward-potential enhancing calls and downward-protection put options present in combination. Their combined option value may differ from the sum of separate options values, i.e., they interact" (Trigeorgis, 1993: 204).

Much of the research using this definition of an option consists of analytical attempts to determine the effects of making different choices on valuation. For instance, in constructing a new power plant, a firm might face the choice of whether it should be designed to use a single fuel or whether it is worth investing in flexibility so that it can operate on multiple fuels. Options analysis is used to determine whether the additional cost of building in switching capability is likely to be worthwhile (Merton, 1998). Childs, Ott, and Triantis (1998) consider project interrelationships, particularly the tradeoff between parallel or sequential development of major projects. In another analysis Baldwin and Clark (2000) assess whether the investment to create modularity in production is worth the additional complexity of the design.

Options reasoning as a heuristic for strategy. A final way options are defined in the literature is as a process heuristic for understanding the economics of sequential resource investment choices. Bowman and Hurry, for instance, propose that "the lens offers an economic logic for the behavioral process of incremental resource investment" (1993: 760). Key to this perspective on options is the premise that resources create the future potential for decision makers to act in ways that could not have been foreseen at the time a specific investment decision was made.

What distinguishes options from other firm resources, according to Bowman and Hurry, is that resources with option value "generate choices" and "allow preferential access to future opportunities" (1993: 762). These researchers propose that decisions regarding individual options are actually best understood as a sequential "option chain," involving the recognition by managers that an option exists, and sequential investments, each investment conferring preferred access to a subsequent investment opportunity. Bowman and Hurry (1993) go to some lengths to distinguish incremental options—the consequence of simple puts and calls—from flexibility options, which generate strategic change. Their focus is on the "underlying choice mechanism" for the observed cumulative and path-dependent change in organizational resources.

A few scholars in management have studied whether options logic appears to be at work in the pattern of path-dependent investments that build on and create a firm's bundle of resources. For instance, in a longitudinal study of patenting in the pharmaceutical industry, McGrath and Nerkar (2001) found evidence for the presence of options logic operating at the portfolio level in R&D investments. Kogut and Kulatilaka (2001) found that options logic served as a building block in a formal descriptive model for evaluating capabilities. In the normative literature on real options, options as strategy heuristic has been proposed as a way of constructing business portfolios and pursuing the development of important capabilities (see Courtney, Kirkland, & Viguerie, 1997; Kogut & Kulatilaka, 1994; McGrath & MacMillan, 2000).

It is also important to note that, in some studies, researchers have found little support for predictions emerging from options theory. For instance, Reuer and Leiblein (2000) found no containment of downside risk as a result of firms' decisions to operate internationally, as might have been expected from options theory. They conclude that there is less flexibility in international expansion investments than might be anticipated.

The finance literature and strategic management literature thus provide precedent for four complementary but distinct definitions of what a real option is as a unit of analysis. Adner and Levinthal focus only upon one definition—that of a real option as a project, more or less in isolation from other projects or firm resources. Their proposal that the definition of a real option be narrowed to a subset of even this single definition does not address the fundamental problems that scholars working on a better theory of real options are attempting to resolve. Thus, that element of firm value that cannot be calculated with reference only to resources in place would not fit the definition, nor would the best way to assess alternative choices about a specific investment, nor would the use of options

reasoning as an alternative to rational actor models of a series of interdependent strategic choices. In defining boundaries for the application of the theory, we believe it is important to bear in mind the issues that real options reasoning can help management scholars address. The reason the theory attracted so much attention in the first place is that extant theories have not proven adequate.

What Creates Option Value?

Despite differences in the definitions they have chosen, scholars using the various definitions are consistent regarding the properties that lead to enhanced or diminished value stemming from the presence of real options. These are the by-now-familiar constructs of substantial upside potential and downside loss containment. Valuable options possess an asymmetrical performance distribution, skewed toward the upside. This is achieved when the options-oriented investor pursues opportunities that appear to have significant upside potential in a manner that permits costs (downside risk) to be contained.

Mechanisms for enhancing upside potential include expanding potential markets served, improving margins in those markets through better performance of the offering, and facilitating rapid market entry. Isolating mechanisms and processes that prevent appropriation of the proceeds of an options-influenced strategy further expand upside potential. Mechanisms for containing downside loss include a variety of strategies for limiting investment (such as partnering or leveraging existing resources) and preserving the possibility to abandon or redirect a project. (See McGrath [1997] for a discussion of these properties for technology positioning projects and Rumelt's [1987] concept of "entrepreneurial rents," in which he theoretically specifies conditions under which a firm can claim excess profits by acting under uncertainty.)

With financial options, the containment of downside loss typically is a function of abandonment, or, as it is usually described, expiration in the face of a decision not to exercise the option. Thus, the most an investor can lose with a financial option is the price of the option. Although this is true at the level of a single option and is the point of departure for Adner and Levinthal's discussion, important caveats emerge when more than one option is held in an investor's portfolio. Sophisticated users of financial options in practice often engage in advanced forms of arbitrage—balancing the risks of one class of investment against risks in others. As the complexity of such portfolios increases, so too does the potential for enormous downside loss as unobserved interdependencies are created. The inventive application of financial options theory did not render investors immune from massive losses; recall the implosion of hedge fund Long Term Capital, which prided itself on its sophisticated options modeling capabilities (and which, in fact, employed many of the brilliant minds behind the development of options theory in finance).

As interdependency and interaction within a portfolio are created, the challenge of managing downside risk increases. The abandonment decision in financial options is often described as occurring formulaically, as Adner and Levinthal characterize it. Thus, when the exercise decision must be made, if the option is not in the money, one allows it to expire. The introduction of portfolio considerations, however, makes it clear that such a simple formula does not guarantee the downside loss prevention that is integral to option value, even for financial options.

Instead, judgment and active management must be deployed to design and reformulate portfolios. The same conditions of alertness, foresight, and anticipation of uncertain outcomes that appear to be important for the management of real options also apply to the successful management of portfolios of financial options. Under these conditions, management of a bundle of financial options has perhaps more in common with the challenges of managing bundles of real options than is typically articulated.

Where Does "What Is *Not* a Real Option" Fit?

Adner and Levinthal essentially propose that any strategic investment in which rigid abandonment criteria cannot be specified ex ante should not be classified as a real option. As our brief review of scholarly perspectives on options suggests, this is a rather abrupt departure from the extant literature. To have no option value (and thus not represent a real option), an investment would have to meet two tests: (1) the resource in question would generate no future choices, and (2) the resource would allow no

"preferential access to future opportunities" (Bowman & Hurry, 1993: 762).

Adner and Levinthal claim that situations with flexible market application or flexible technical agendas, or both, are nonoptions (their Figure 2b). We find it difficult to see how such projects could not have option value. Flexible mandates by definition suggest future choices. Further, exploration in uncertain new areas is strongly associated with heterogeneity in resource accumulation, creating the potential for preferential access (March, 1991). Indeed, as Myers concludes, "Options are at the heart of the valuation problem in all but the most pedestrian corporate investments . . . . it is hard to think of an investment project that does *not* include important real options" (1996: 99).

Let us consider Adner and Levinthal's proposed refinement to the theory of real options in application. As has become conventional in the real options literature, they begin their analysis with the sequence of activities involved in purchasing and exercising a single financial option and apply this logic to the decisions involved in purchasing a real option on a strategically important opportunity. They lay out a familiar decision-tree structure for how such staged investments can create value, mimicking the process that unfolds for financial options (their Figure 1). Their analysis is consistent with those who have applied options reasoning to understand individual projects.

In a sharp departure from most previous arguments about the nature of flexibility, however, they contend that the flexibility associated with the notion of real options has to do primarily with abandonment. Their focus on abandonment omits the many other attributes of a project that contribute to option value, such as changing scale or designing for different later usage, without providing a compelling argument as to why these other forms of flexibility are not relevant to the analysis.

Their emphasis on abandonment as the key driver of flexibility that creates option value is essential to their major theoretical points. These are that, in order to abandon a project, decision makers must specify, ex ante, rigid criteria for making the abandonment decision—specifically "a high degree of rigidity in the specification of the agenda of the initiatives and the criteria for their success" (pp. 74–75). Cases in which such rigid criteria cannot be applied are not, they argue, suitable for real options analysis, creating a boundary for the application of options theory.

THE NATURE OF FLEXIBILITY

We have several concerns with the positioning of abandonment and the accompanying rigidity at the center of Adner and Levinthal's theoretical argument. The rigidity construct is incorporated in the theory because Adner and Levinthal explicitly assume that, without rigidly defined criteria for success and failure of an initiative, abandonment cannot occur. We concur with and respect the authors' reiteration of organizational properties that tend to promote escalation of commitment or avoidance of project termination (see Bowen, 1987; Brockner, 1992; Keil & Flatto, 1999; Staw, 1976). However, we believe that Adner and Levinthal's views of abandonment are unnecessarily restrictive. Rather, we argue that a more liberal view of abandonment is more consistent with the thrust of much of the previous literature—for instance, Bowman and Hurry's (1993) assertions about options as a vehicle for path-dependent strategic change and choice.

It is also important to recognize that any good theory can be misused in practice. Achieving flexibility has more to do with effective project management and appropriate organizational structure than with inadequacies in or misapplication of real options theory. Indeed, specifying success and failure criteria in advance is but one practice among many associated with the ability of an organization to terminate projects.

Abandonment and the Growth of Knowledge

Adner and Levinthal place primacy emphasis on the need to specify and weight the set of option theoretic abandonment criteria a priori. Our concern with this argument is that it presumes that knowledge is static and ignores the role of proactive learning. In other words, the a priori specification of abandonment criteria (to be invoked at time t_n) is based on the firm's stock of knowledge, assumptions, and its option-signal interpretive framework at t_0—that is, what executives in the firm think they know and

what they think might happen in the future. However:

> Given that economic agents base their [assumptions and] actions on their individual stocks of knowledge and that they cannot predict their own future knowledge, it follows then that they cannot predict their own future actions [or optionlike parameters for future actions] in any detail at the time of formulating their initial plans (Harper, 1994: 51).

Thus, we allow that at every point in time between t_0 and t_n, the firm's stock of knowledge, upon which the initial abandonment decision was made, will likely change, partially owing to the exogenous resolution of uncertainty and partially owing to the firm's own trial-and-error search initiatives to test its assumptions and perhaps bring new action alternatives into view. We adopt here Penrose's view that "the growth of knowledge is not simply a Bayesian process of induction from unambiguous facts, but a process of interpretation of the events to which members of the firm are exposed, often as a consequence of their own business initiatives" (1959: 40).

Following the carrying out of an optionlike strategic initiative, learning affects the firm's own framework for observing and interpreting exogenous signals related to the option's exercise or abandonment (O'Driscoll & Rizzo, 1985). This, in turn, gives rise to the possibility, if not likelihood, that the abandonment criteria themselves may be subject to continual changes over time. Bowman and Hurry (1993) thus place "recognition" processes at the center of their theoretical argument. We concur with those learning theorists who argue that "a dynamic theory of agents' learning is a prerequisite to *any* satisfactory explanation of sequential economic decision-making" (Harper, 1994: 50; emphasis added). In other words, a rigid specification of ex ante stopping conditions takes inadequate account of learning.

Fully incorporating the role of knowledge growth and proactive learning into options theory also allows for potential surprises among both predecision assumptions and option investment outcomes. This means that some firm actions may be carried out with the explicit intent to probe the boundaries and limitations of the firm's stock of knowledge at any given point in time—that is, proactive attempts to figure out what those in the firm know and do not know. Here we depart from Adner and Levinthal by arguing that the growth of knowledge, in and of itself, may also be a legitimate option theoretic "dependent variable" or "underlying asset."

In other words, when executives in a firm proactively test their assumptions and conjectures by comparing the outcomes of predicted market events with those that actually occur, then falsity is transmitted back to the system (Harper, 1994). If decision makers are disappointed or surprised, one or more of the assumptions governing the a priori specification of abandonment criteria must be flawed. Therefore, "economic agents must continually be open to revising their conjectures and plans in light of new experiences, especially the unintended consequences of past actions" (Harper, 1994: 51). Flexibility, strategic change, and resource redirection often result from surprises among either intermediate or ultimate option investment outcomes. Admitting the potential for such post hoc recognition of opportunity is antithetical to Adner and Levinthal's strict go/no-go abandonment framework, yet is well accepted as part of the evolution of a firm's strategy.

Time and Time Again

The passage of time is another central feature within both financial options theory and real options reasoning. Adner and Levinthal adhere rigidly to calendar or clock time in specifying termination conditions. We suggest that this unduly limits their perspective in two important respects. First, they require the a priori specification of well-defined temporal boundaries for option exercise and expiration, citing that the longer the duration and/or the more open ended the option is, the higher the risk of option overvaluation will be. Second, they require a sharp temporal demarcation between investment stages. Interestingly, they acknowledge that the specification of time to expiration becomes an endogenous choice and is difficult to specify ex ante. Further, the division of time into discrete decision points is artificial. This suggests that meaningful adaptation or application of financial options theory to real options reasoning and strategic choice must be accompanied by the

adaptation of clock/calendar time to real/strategic time.[1]

As an illustration of the manifold impacts of real time on knowledge, decision making, strategic choice, and abandonment, consider the strategic challenge illustrated in Figure 1. Assume a hypothetical firm whose overarching strategic intent is to extract long-run economic value from gold mining operations within a suspected gold field located in hitherto uncharted territory. Among all potential inland water routes, top management makes an optionlike investment in exploring this particular waterway with the intent to explore inland—an investment that may be characterized by a set of general yet a priori specified strategic bearings. Top management also has specified a general yet flexible time-to-abandonment/exercise guideline.

Yet, even before the vessel gets underway, it is anticipated that strategic time (and all that takes time) is multidimensional and unknowable: How does the river meander? Is the river passable entirely by boat? What is the ultimate waterborne inland distance of the gold field from the river's mouth? How fast is the river's current? Is wind speed constant? How long will the quest actually endure? How many days' supplies is the crew capable of storing on board?

The answers to these questions can be partially anticipated but can be fully confirmed or refuted only with the passage of time and proactive learning. Further, there may be many other unanticipated challenges that impact the set of a priori assumptions and timeline, which may require adjustment of the same.

As the journey proceeds, the captain (manager) must make a series of "nested" optionlike choices over time that fall within the broader domain of the initial higher-order option (i.e., the initial investment to search for gold in this particular waterway).[2] Some choices indeed involve waiting for the uncertainty associated with the river's direction or the appearance of new landmarks, hazards, and opportunities to emerge. Here, exogenous uncertainty results from unforeseen geographic and navigational facts or truths.

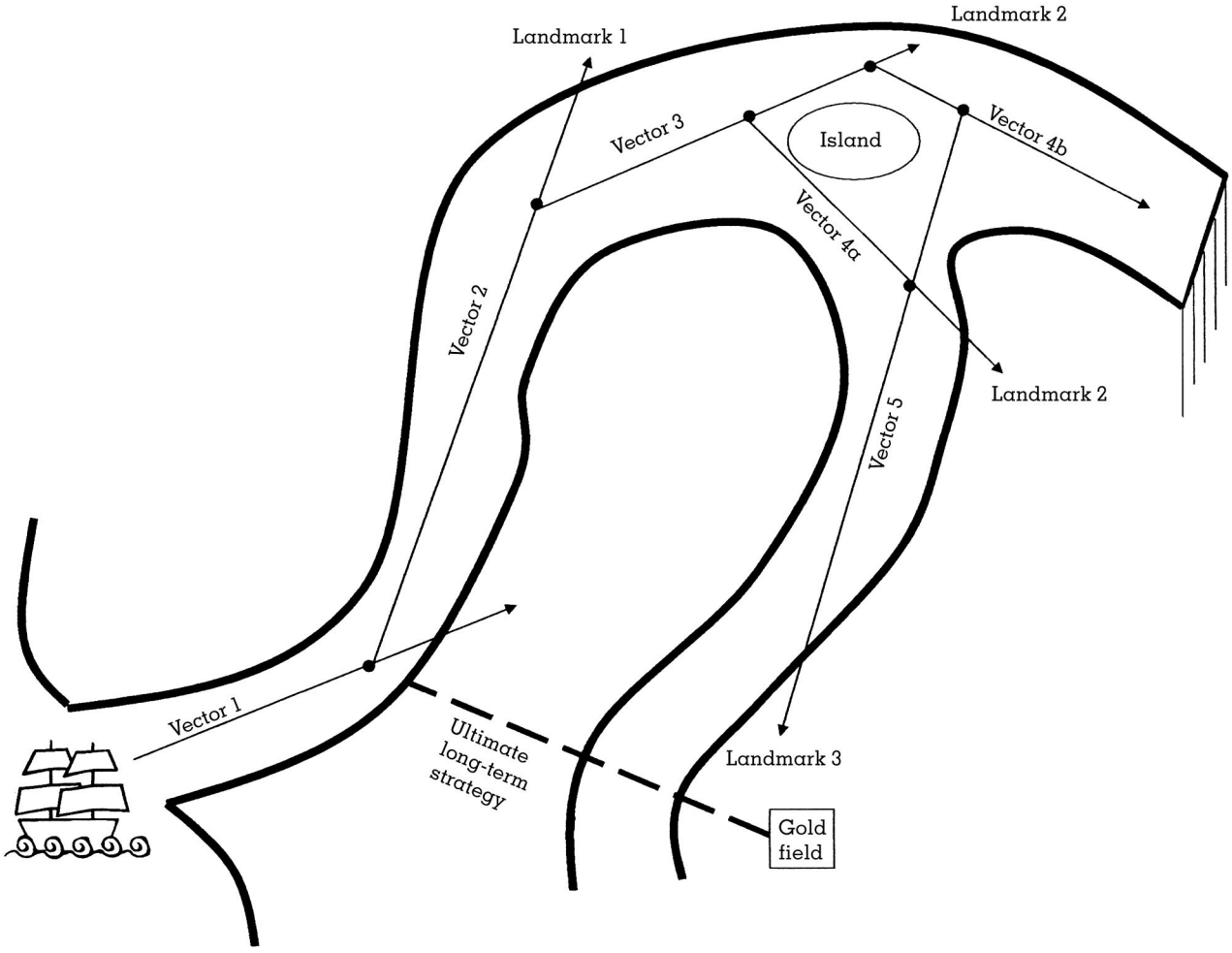
More important, however, other choices (and outcomes) involve proactive learning. In particular, the captain's choice set along Vector 3 il-

[1] O'Driscoll and Rizzo (1985) explain the key differences between clock/calendar time and real/strategic time along the following key dimensions: homogeneity, continuity, and causal efficacy. Clock/calendar time (i.e., Newtonian time) is absolute and objective; it is also mathematically divisible and regularly homogeneous. Each point in time is the same as any other; the passage of time is causally inert. Real/strategic time, in contrast, is relative and subjective. Individuals' memory and expectations differentiate each successive moment. Memory and expectation also shape continuity, which adds value as time passes (e.g., hearing a short sequence of individual notes in a melody shapes expectations and interpretation of successive moments in time). So, each unit of time elapsed is linked with the previous and the expected.

Further, Ramaprasad and Stone (1992) use the passage of time in American football as an intuitive illustration, in which there are several distinct time frameworks at play, some of which are based on clock time and others on real/strategic time. The total clock time of a game is sixty minutes, yet the total aggregated time of actual play is significantly less, because the duration of each play is a function of what happens as the play unfolds. Some plays last only a second or two, whereas others may last up to, say, fifteen seconds. Moreover, the maximum time allowed between successive plays is thirty seconds. However, this time elapsed need not always account for the total time elapsed for the game as a whole, and teams may begin play at any time prior to the expiration of the thirty-second play clock. Furthermore, the duration of a match oftentimes nears four hours, because a game consists of an unpredictable mix of clock-timed play activities, clock-timed nongame activities, and strategic-timed game activities. Finally, consistent with O'Driscoll and Rizzo's (1985) ideas about nonhomogeneity of real time, the elapsing of successive time periods has differentiated "meaning" that depends on a number of possible factors. Time becomes more precious, for instance, under some conditions—how much time is left in the game, how close the score is, etc.—under which a flurry of activity can occur quickly (in strategic time) with little time passing on the game clock (clock time).

[2] Once underway (along Vector 1), it becomes obvious that the vessel must change direction or risk running aground. So, after the passage of an unspecified period of time, the vessel adjusts it course and proceeds along Vector 2 toward Landmark 1, then changes course along Vector 3. At several unanticipated/unspecified points in time, prior to landing ashore at Landmark 2, new navigational information becomes available: two mutually exclusive alternatives to navigate around an island. The first alternative is to change course quickly to Vector 4a, and the second is to proceed along Vector 3 until a new landmark comes into view. The former decision brings the vessel safely to Vector 5. The latter decision forces the vessel along Vector 4b, where a waterfall emerges into view and necessitates either abandonment or a change of course to Vector 5. It is worth noting here the equifinality of arriving at Vector 5. Yet choosing Vector 4b results in exposure to an entirely new potential outcome that will not be experienced if Vector 4a is chosen. Near Landmark 3, telltale signs of a nearby gold field emerge into view.

FIGURE 1
The Role of Time, Uncertainty, and Choice in Stepping Stone Options



lustrates how strategic time, strategic choice, and outcomes are linked. The choice of when and how to change course is a function of the passage of strategic time relevant to the geographic and navigational facts associated only with Vector 3, not the duration of the entire journey. Here, strategic time, choice, and learning associated with the nested option both inform and are governed by the overarching a priori abandonment/exercise framework. Further, allowing the vessel to simply drift with the current along Vector 3 (i.e., to set a course and wait) is untenably deterministic from the captain's point of view. Instead, the captain enacts what Popper (1972) describes as *plastic control*—a zone of creative response to a given context that lies between exogenous determinism on one end of the spectrum and pure chance on the other.

At journey's end, the higher-order exogenous uncertainty associated with the presence and location of the anticipated economically feasible gold field is resolved. However, what is learned is that the gold field is located closer to the coast line than first anticipated. Consequently, the means (strategy) to extract economic value changes from reliance on a waterborne technology to reliance on a landborne technology (with the help of unanticipated investments in a railroad and bridge).

In sum, the passage of real/strategic time associated with a series of nested or "stepping stone" options (McGrath & MacMillan, 2000) plays a significant role in the abandonment/exercise decision of the higher-order option. Further, recognizing real/strategic time necessarily

gives rise to blurry temporal boundaries between successive stages within a project. In contrast to Adner and Levinthal, we view such blurriness as a facilitator of learning and as a useful, if not critical, feature of real options theory.

Abandonment and Principles of De-escalation

The de-escalation of commitment literature offers many other factors that facilitate ending a project, besides the specification of success or failure in advance. At issue is the process by which projects are managed—not their underlying economics (Staw & Ross, 1987). Montealegre and Keil (2000), building on the work of Brockner, Shaw, and Rubin (1979), Northcraft and Neale (1986), and Heath (1995), offer a substantial list of conditions associated with the process of de-escalation (termination or redirection), including

- making changes in top management or project championship,
- publicly stating limits on expenditure,
- making available alternative internal investments,
- setting minimum target levels for achievement,
- making negative outcomes less threatening,
- engaging in regular evaluation,
- separating responsibility for initiating and evaluating projects,
- appealing to stakeholders from externally affected parties,
- applying external pressure on the organization,
- giving unambiguously negative feedback,
- making project costs visible, and
- deinstitutionalizing.

Montealegre and Keil (2000) observed a four-step process of de-escalation in a longitudinal field study they conducted of the implementation of the baggage handling system at Denver International Airport: recognizing a problem, re-examining the prior course of action, searching for alternative courses of action, and implementing an exit strategy. Only one element of their process model involved reassessing the value of the investment by comparing it to previous expectations. The rest involved management actions that created a context for de-escalation.

As Adner and Levinthal recognize, within established organizations, processes such as stage/gate approval for R&D projects, "discovery-driven" planning for new ventures, and milestone planning with peer or outside review have been proposed to counteract the tendency toward unwarranted escalation (Block & MacMillan, 1985, 1993; Christensen, 1997; McGrath & MacMillan, 1995, 2000). In some forms of investment—for instance, private equity or venture capital investment—these criteria are explicitly incorporated in funding agreements.

Flexibility involves stopping and considering alternatives to the original course of action and the necessary investments that make this possible (as in designing for alternative uses). These alternatives might cover a broad range of actions, one of which is exit. Part of the skill of strategically creating flexibility is to build the mechanisms for flexible choice into the design of a project and to manage that project so that alternatives are preserved, while keeping costs contained.

On Unwarranted "Hope"

None of this is to say that unwarranted hope is not a significant organizational issue. Creeping commitment and excessively optimistic bold moves are both highly dangerous. Indeed, major flops—the Iridium project, Disney's original foray into France, London's Millennium Dome, investment by telecom operators in so-called third generation licenses, the Webvan venture, major mergers gone awry, and any number of other organizational catastrophes—certainly can and do occur. A key reason for this is that options reasoning was *not* applied to the management of such projects in a disciplined way. It does not suggest a shortcoming in the developing theory of real options.

In many cases of major failures, the projects were launched with a "damn the torpedoes, full speed ahead" approach, rather than the staged and sequenced approach prominent in applications of real options theory (see Folta, 1998). Even with clear mandates for success and failure, too long a time delay before assessment can still lead to overcommitment. The issue is whether projects are effectively designed to preserve decision rights, which in many of these cases, we would argue, they were not.

Perhaps a specific example consistent with the gold-seeking journey described above would be appropriate here. McGrath recently (in the spring of 2001) interacted with a project team from a large organization tasked with identifying an entry

strategy for devices deploying Bluetooth, a wireless communication technology that enables messages to be sent inexpensively within a local area. The team's original project plan called for significant, irreversible investment in software and systems to deliver Bluetooth connectivity in public places, premised on the idea that in three years millions of devices with the enabling technology would be in use. Applications envisaged were, for instance, providing information on local products and services in city centers or using Bluetooth devices instead of credit cards or other forms of payment.

After some discussion, it became clear that the project had properties that resembled what McGrath and MacMillan (2000) term those of a *stepping stone* option—namely, high uncertainty with respect to future technological standards and high uncertainty with respect to market acceptance of solutions. In addition, the costs to provide the solutions envisaged were extremely high for the focal organization and dependent on similar investments being made by partners and complementors. The team was challenged to develop an entry strategy that was more optionlike than the full commitment to a single course of action with which they had originally begun.

The Bluetooth team redesigned the launch strategy to meet several criteria: the overall investment would be sequenced, as many assumptions would be tested with as little investment as possible, and the developmental path would not require either invention of new technology or codevelopment by partners. In the end, the launch plan was revised specifically by focusing on developing solutions for small initial markets in which the company would be paid to solve a demonstrated problem with the technology as it currently existed. As the technology matured and key uncertainties with respect to scale, performance, and economics were resolved, the scope of target markets could be expanded and more ambitious strategies envisaged.

What changed here was the way in which the project was designed, *not* the assessment of its long-term value. In other words, options logic suggested a launch strategy different from what had emerged from the probabilistic search process in place within the firm prior to the redesign. The project was explicitly authorized in a manner entirely consistent with slack search. The team was originally charged to explore what the possibilities for Bluetooth might be and was allocated slack resources to explore the market space. Their lack of progress prompted McGrath's involvement. Incidentally, the options-influenced launch strategy made redirection of the project at an early stage *easier*, because lower sunk costs and overall commitment were now smaller. In fact, as of this writing, the project has been redefined from a stand-alone venture with an independent business model to a complement to an ongoing business unit, and the "venture" per se has been shut down as an ongoing concern.

Adner and Levinthal offer no better alternative to options reasoning as an economic rationale for making tough termination decisions under uncertainty. The heuristics of slack search, although descriptively useful, do not distinguish rational project continuation from dysfunctional escalation, nor do they suggest actionable heuristics in application. Options reasoning does, namely,

- keep costs down, when uncertainty is high, until major uncertainties are resolved,
- approach development in stages and sequence investment,
- pursue opportunities with significant upside potential,
- design projects around key milestones,
- reassess projects' potential in a disciplined way, and
- maintain divisibility between projects so that risks are not correlated.

Absent the discipline of project management, allocation of resources to decentralized units engaging in serendipitous search could create more problems for organizations than it resolves.

COGNITION AND UNCERTAINTY REDUCTION

The Role of "Recognition" Processes in Options Chains

A major strength of Adner and Levinthal's argument is their observation that firms are not unitary actors, which has indeed tended to be overlooked in most applications of options theory. We are in complete agreement that the organizational factors determining the effectiveness with which options are managed increase in importance as specific investments become more strategic and capability oriented and less

discrete and tactical. Indeed, in a multiproject firm there are likely to be major disagreements between those who "own the option" and those who "are the option." The sensitivity to intrafirm differences in perspective, however, also suggests the need to clearly specify the units and levels of analysis to be assessed in developing options theory. A particularly thorny problem is that failure of a particular initiative may produce insights with immense value at the level of the firm (McGrath, 1999).

Much of Adner and Levinthal's criticism of the applicability of options reasoning relative to other approaches to understanding search stems from their narrow interpretation of the key task of options reasoning as the assessment of particular projects in isolation for purposes of making the exercise choice. They do not take into account a central concern of options reasoning—namely, the sensemaking activities that cause decision makers within a firm to recognize that a potential opportunity exists.

Bowman and Hurry (1987) refer to the process of mobilizing options as the recognition of "shadow options" within the bundle of resources tied to a firm, followed by investments to convert shadow options to real options. They acknowledge that the process is likely to be idiosyncratic to the firm-specific context in which it occurs, but they argue that this is one way in which firms create inimitability in their resource combinations. Bowman and Hurry (1993) point out that the linkage between investment decisions over time is both cognitive and economic.

Adner and Levinthal's argument is quite different. They propose that options analysis must precede investment, and they dispute whether post hoc recognition of opportunities is appropriate for the operation of the theory. Most other scholars would argue that such discoveries are essential to the operation of the theory. Adner and Levinthal (footnote 5) further argue that real options evaluation should take place under conditions of risk, not Knightian uncertainty (Knight, 1921). The question this raises is why a firm would need to use options reasoning to make judgments on such opportunities, since they are amenable to conventional analysis (Dixit & Pindyck, 1994). Part of the appeal of options models is that they allow for judgment under uncertainty rather than risk (see Rumelt, 1987, on the gains to entrepreneurial actors under uncertainty).

Adner and Levinthal suggest that the mechanism of slack search, which promotes "modest initiatives" in the absence of direct corporate oversight, is a totally different mechanism from that used in real options reasoning. They characterize real options reasoning as endorsement and examination by higher-level actors within the organization, presumably before any expenditure of resources is involved. The distinction between slack search and real options reasoning has two problems.

First, the level of slack resources and approval authority from more senior to less senior levels in an organization have to do with organizational design decisions, such as the degree of operating autonomy of the units. This differs from the set of decision considerations needed to determine whether the investments managers pursue make economic sense. Second, extant options theory comfortably accommodates the concept of "recognition," in which resources are found to be valuable at some stage subsequent to the investments that created them (see Bowman & Hurry, 1987, 1993). Bowman and Hurry (1993) are very clear that some exercised options continue an existing strategy, whereas some change it by moving into new areas not evident at the time the original investment was made. Some authors have placed even greater emphasis on post hoc recognition processes as central to firm-level adaptability in the face of change (McGrath & Boisot, 2003).

Endogenous versus Exogenous Resolution of Uncertainty

A core concept in the real options literature is that some forms of uncertainty reduction are a function of exogenous forces outside a firm's influence. Others, however, are influenced, if not determined by, endogenous activity on the part of an organization's management (Majd & Pindyck, 1987; Roberts & Weitzman, 1981). Dixit and Pindyck (1994), for instance, specify differences between what they term *input cost uncertainty*, which is largely exogenous, and *technical uncertainty*, the resolution of which will be largely endogenous to the firm (and perhaps others working in a similar technological arena).

The two kinds of uncertainty create opposing pressures. On the one hand, exogenous uncertainty suggests the desirability of waiting for

uncertainty to be resolved prior to making an investment, thus delaying potentially irreversible expenditures and preserving resources for the future—essentially, an investment in preserving flexibility (McDonald & Siegel, 1986; Pindyck, 1991). Endogenous uncertainty, on the other hand, creates pressure to invest (to speed the discovery process that will resolve the uncertainty), although most likely sequentially—to indeed preserve the option or to abandon it in the face of exogenous shocks (see Folta, 1998).

Adner and Levinthal, while acknowledging the distinction between endogenous and exogenous uncertainty resolution, question the applicability of options reasoning to cases in which endogenous uncertainty resolution is important—the "act and see" rather than "wait and see" condition. When coupled with their observation that firms are not unitary actors, the distinction becomes extremely murky. For instance, if a given future state is well understood by one subgroup within a firm but not by another, from the point of view of the firm, is this endogenous or exogenous uncertainty? Even in the case of a pure "wait and see" option (e.g., bidding on rights for future oil distribution), the prevalence of the winner's curse (Samuelson & Bazerman, 1985; Thaler, 1992) suggests that the winning bid will tend to exceed the returns to be gained on the investment. In this instance, the endogenous choice ("How much should I bid?") is as much a determinant of the economic outcome as the exogenous force ("How much are the oil rights ultimately worth?"). In sum, when also explicitly accounting for the role of knowledge and learning, we believe that both forms of uncertainty are likely to remain important to the future development of real options reasoning.

EFFECTIVE RESOURCE ALLOCATION: PORTFOLIOS OR BUNDLES VERSUS SINGLE OPTIONS

The implicit dependent variable in Adner and Levinthal's analysis is identifying a superior mechanism of resource allocation. The authors offer no specific test for how such a superior mechanism would be identified but suggest that one indicator might be the presence of a "coherent portfolio strategy" (p. 79). They analyze option traps and the suitability of options logic at the level of a particular option, yet they draw implications for the firm as a whole.

One of the management challenges Adner and Levinthal point out is that as individuals working on projects at an operating level gain freedom, they are less likely to be constrained by the logic governing the portfolio of options at a firm level. Thus, projects operated as "skunk works" or those that fly below the radar of headquarters' control systems can avoid conformity to the organization's policies. This problem, they suggest, makes application of real options theory to corporate portfolios problematic.

While we don't disagree at all, we would suggest that this is a problem involving the implementation of corporate policy, not the economics of options analysis. To the extent that a firm's internal ecology (to use Burgelman's [1991] phrase) is well designed, there will be a balance between local autonomy and central control. As Bowman and Hurry note, "Different organization structures influence the extent to which decision makers are left free to strike options," (1993: 770), thus distinguishing between the organization structure and the decision. Incidentally, Bowman and Hurry further suggest that a firm is likely to be better off under uncertainty promoting greater local autonomy, a point of intersection with Adner and Levinthal.

Some early evidence suggests that portfolio factors do influence investment in options. McGrath and Nerkar (2001), for instance, found that firms with portfolios in which many options had been successfully opened were less likely to persist in opening new ones. They argue that this is consistent with a view that says the value of an option to defer erodes and, moreover, that the risk of option expiration elsewhere in the portfolio dictates a shift from exploration to exploitation, consistent with March (1991).

Adopting an options approach does not dictate the adoption of a particular organizational form, such as more or less centralized decision making. It may well be that implementing options logic across a firm's diverse activities has implications for organizing, as Adner and Levinthal propose in their characterization of what a real options firm would look like. We believe that it is important to distinguish the two constructs. Options logic does have implications for which construct would be more effective under different levels of uncertainty, suggesting, for instance, that firms with more decentralized operations would have a wider range of potential responses to an exogenous

shock when contrasted with firms that were more centralized. This would arise because more decentralized operations would encourage greater internal variety and, thus, access to a wider range of possible future actions.

CONCLUSION AND IMPLICATIONS

Adner and Levinthal's central argument depends on a distinction between decisions that are amenable to real options analysis and those that are not. The authors propose that real options are merely a subset of generic path-dependent developmental processes. This is because, in their view, the primary flexibility created by real options consists of the choice to abandon—a choice that becomes more difficult to make as project stages blur and potential uncertainties within a project interact. Thus, they suggest that real options analysis should be confined only to market and technical opportunities that are fixed and identified in advance (their Figure 2b), because it is only under these circumstances that an organization's members will effectively abandon a failing option. Under other circumstances (flexible market application and flexible technological agenda), firms presumably should use whatever mechanisms they have used previously to make decisions regarding path-dependent investments. Adner and Levinthal, however, are silent on what those mechanisms might be.

The problem here borders on the philosophical. We see options reasoning as appropriate to apply where investments in the present create choices in the future, while recognizing that there is no consensus at this point as to the optimal methods of application. Key to the concept is the idea of differential management: more conventional approaches for more certain circumstances; more optionlike reasoning for less certain circumstances.

We see no particular advantage to dichotomizing uncertain path-dependent investments—some as amenable to options reasoning and others as not. We also take a far broader view of the potential for flexibility created by options investments than abandonment. Instead, we concur with Bowman and Hurry, who propose that "the [options] lens offers an economic logic for the behavioral process of incremental resource investment" (1993: 760).

In other words, incremental path-dependent processes reflect firm behavior. The options lens embeds a logic for anticipating whether that behavior makes economic sense or not. We do not see the two at odds with one another; in fact, we see them as entirely different constructs that are, in fact, complementary.

What scholars intrigued by real options reasoning are after is not a displacement of behavioral theories of organizational learning and development, such as slack search. Indeed, we see no conflict between applying options reasoning to such search processes. What has been missing in such theories, and what real options reasoning offers, is insight into the economic logic for how path-dependent processes can be managed intelligently. We seek to develop a better mechanism for understanding the strategic effects of resource accumulation and learning processes and, hopefully, provide alternatives to tools and concepts for which scholars largely assumed a more certain environment than the one in which most organizations are forced to compete.

Indeed, our discussion suggests a fertile stream of research to uncover which of Adner and Levinthal's proposed boundary conditions to pure options theory influence its effectiveness in practice. In addition, the question of strategic versus real time and its relation to time to expiration needs to be investigated, as does the extent of flexibility that can be tolerated once an option has been selected. Thus, for instance, scholars might seek to determine the impact that abandonment difficulty, timing, and flexibility have on an option's investment outcome. In this way researchers could test the strength of the purists' theoretical argument against the pragmatic need to attenuate some of the characteristics of the pure options theory.

Real options reasoning, we believe, offers a further advantage to theories of organization. For some time, organization theorists have pitted the concepts of "rational actor" thinking against the messy realities of real organizational behavior, often concluding that the rational model is unrealistic (and, by implication, that so too are many of the theories and empirical tests associated with it). Options reasoning offers a new way of considering the differences between these two conventional counterpoints. If one admits that, under uncertainty, it is rational to keep options open, to hesitate when uncertainty is beyond one's ability to influence it, and to try

to move fast when one believes an opportunity for idiosyncratic uncertainty reduction exists, some behaviors that have been criticized as irrational might turn out to be quite sensible.

We began this discussion by observing that real options reasoning, although attracting significant scholarly attention, has not yet developed to the point where consensus on its main properties has emerged. Thus, we strongly welcome debates such as this one, through which the outlines of the emerging theory become clearer and through which the points of convergence and dispute among ideas are drawn in sharper relief. The definition of an option itself is not yet a settled matter, as our review of previous literature suggests. Unlike Adner and Levinthal, however, we believe that the outcome of debates such as this one will reveal options reasoning to be a valuable addition to established theories of learning, decision making, and organization.

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