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Can real-options analysis improve decision-making? Promises and pitfalls

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Executive Overview

Managers are faced with uncertainty in nearly every aspect of their decisions. Reducing uncertainty, then, often leads to better decisions and greater potential firm success. The real-options literature provides one tool to reduce uncertainty. A real option is commonly defined as any decision that creates the right, but not the obligation, to pursue a subsequent decision. Used effectively, these options can minimize losses while preserving potential gains. Real options are used both formally, as a modeling tool for specific decisions, and informally, as a perspective for framing decisions in a different light.

We separate real options into four distinct types—immediate entry, immediate exit, delayed entry, and delayed exit. We then provide additional understanding into how they differ and how each can reduce uncertainty. We also suggest that firms should use all four types of real options to search for additional benefits beyond uncertainty reduction. We identify several pitfalls to avoid, as well as processes to help avoid such pitfalls as escalation of commitment. In addition, we show that real options are as vulnerable to the frailties of managers as are other types of decision tools, frailties which may affect both the appropriate writing and exercising of a real option.

A real-options perspective encourages both low-cost trials, where failure is not catastrophic, as well as a conscious search for benefits that may emerge from the learning embedded inside the option.

What is the difference between an advertising slogan for a famous credit card and decision-making under uncertainty?[1] One is everywhere you want to be, while the other seems to be just about everywhere else! Managers may well have a more difficult time making decisions today than ever before. It seems that there are more decisions to be made today, and they are more complicated and expensive. These decisions must be made in an environment of uncertainty, about technology, marketplaces, competitors, legal issues, and so on. So what is a manager to do? Let us take a look at one decision-making tool that has become more prevalent in recent years: real options. A real option is a decision that creates the right, but not the obligation, to pursue a future decision.[2]

Real options don't solve every possible decision-making problem, nor are they meant to. Rather, we encourage managers to think of real options not only as a formal decision-making modeling tool but also as a different way in which to frame decisions, a perspective for resolving uncertainty. Using this different framework can generate some powerful insights.

We are concerned that the term real options has become a catch-all term for any effort to reduce the uncertainty that accompanies a decision. In this article we provide a more concise definition of real options, defining them as falling into four specific types. With this clarity in place, we can better examine some steps that may help managers to avoid the many pitfalls that can occur when using real options. In the following section, we identify the dimensions that create a real option. Then, we define four different types of real options and how they can be effectively deployed. To illustrate, we have developed a two-by-two matrix. We discuss some pitfalls that may accompany using real op-

tions, such as escalation of commitment, as well as ideas for avoiding them. We then offer some concluding comments and suggestions.

What Is a Real Option?

A real option is commonly defined as any decision with at least two parts in which the initial decision creates the opportunity, but not the obligation, to make a subsequent, beneficial decision, built upon the first. The firm makes an initial decision that has a "wait and see" feature built in. The second decision often occurs when new information becomes available after the first decision, thereby reducing uncertainty. In many ways real options are similar to financial options because the initial decision is akin to writing (buying or selling) an option and the subsequent one to exercising or refusing to exercise it. Real options emerged from the insight that many managerial decisions share common characteristics with decisions resolved by buying or selling options traded in financial markets. In Figure 1 we compare and contrast financial and real options.

A key insight to understanding real options is that there is economic value to resolving the uncertainty associated with any decision.[3] Therefore, it is often worthwhile to spend some money now to gain the necessary time to resolve uncertainty about a major decision. As uncertainty increases, the value of resolving it obviously increases as well. Using real options creates a subtle shift in a manager's perspective on uncertainty: from knowing how to avoid uncertainty to knowing how to minimize or resolve it. In resolving it, managers leave open the upside potential for decisions, while capping losses. This may lead to new opportunities emerging, often favorable outcomes for managers, which we shall discuss later in this article.

Unlike financial options, real options do not require formal contracts. A firm may "write" an option without putting it in writing. As an example, consider a firm facing a hiring decision. An application of the real-options approach would be to hire a summer intern with the specific goal of using the internship time as a lower-cost probationary and training period. The firm has the right, but not the obligation, to offer a permanent position and does so only if the intern performs at an ap-

Definitions and Characteristics	Financial Options	Real Options
Writing the Option	A formal contract that sets down all the legal transaction terms.	The initial decision that creates the opportunity to make a subsequent beneficial decision. No requirement for a formal option contract.
Exercising the Option	To formally activate the terms of the legal contract established when the option was written.	The subsequent beneficial decision made in light of new information.
Strike Price	The transaction price for the option.	The decision rule that informs the manager to make the subsequent decision.
Exercise Price	The underlying asset's price when the decision to exercise is made.	The cost of making the subsequent decision.
Call Option	An option to acquire the underlying asset at a predetermined price.	An option to enter a decision (now or in the future); an option to defer.
Put Option	An option to sell the underlying asset at a predetermined price.	An option to exit a decision (now or in the future): an option to abandon.
Liquidity and Tradability	Extremely liquid. Markets exist just for financial options.	Rarely liquid, difficult to trade.
Timing	Pre-determined, precise, finite expiration date.	Sometimes pre-determined, rarely a precise, finite expiration date, can last indefinitely.
Compound	Two separate transactions.	A three (or more) part decision, whereby exercising one option creates additional options for future decisions.
Portfolio	A collection of options.	A collection of decisions.
Underlying asset	A publicly held stock only.	Can be both tangible and intangible assets.

FIGURE 1
Comparing and Contrasting Financial Options to Real Options

propriate level. The promise of the permanent position need not be formalized in writing.

What Type of Real Option Is It?

Firms do not always spend a little now (e.g., hiring an intern), with the right to spend more later (e.g., hiring permanent staff). Several other types of options are available. It is helpful to describe the different real options in terms of entry and exit decisions, as well as in terms of timing (immediate action versus delayed action). In Figure 2 we array a two-by-two matrix of the four types of options. Across the top row we have a choice between immediate action and delayed action, and on the sides we have a choice between entering and exiting a decision.

Immediate Entry: The Benefits of Early Involvement

We shall first discuss an option that provides for an immediate-entry decision. Immediate-entry options allow a firm to spend a relatively small sum right away to create or acquire the right to pursue a full commitment later. Options for immediate entry are especially valuable when firms can acquire beneficial rights based on timing and exclusivity. As an example, the Apple iPod music player enjoyed a two-year lead over competitors by locking up the rights to miniature hard drives that were integral to the iPod design. Early development proves to be valuable if in doing so you can create a standard, develop loyal customers, or mine lucrative niches before competitors emerge.

Immediate entry to a proposed standard may enable your firm to influence the standard's development to your benefit or prevent other firms from enacting tollbooths for the standards to be used. Similarly, immediate entry can allow the firm to lock up the rights to valuable resources in the future by either shutting others out from their use or by guaranteeing a lower resource acquisition cost for the firm. Returning to the summer-intern example, firms often find that job offers to interns are more likely to be accepted than offers to candidates who have never worked at the firm before. A key benefit, in fact, is using the early commitment to learn more about not only the current op-

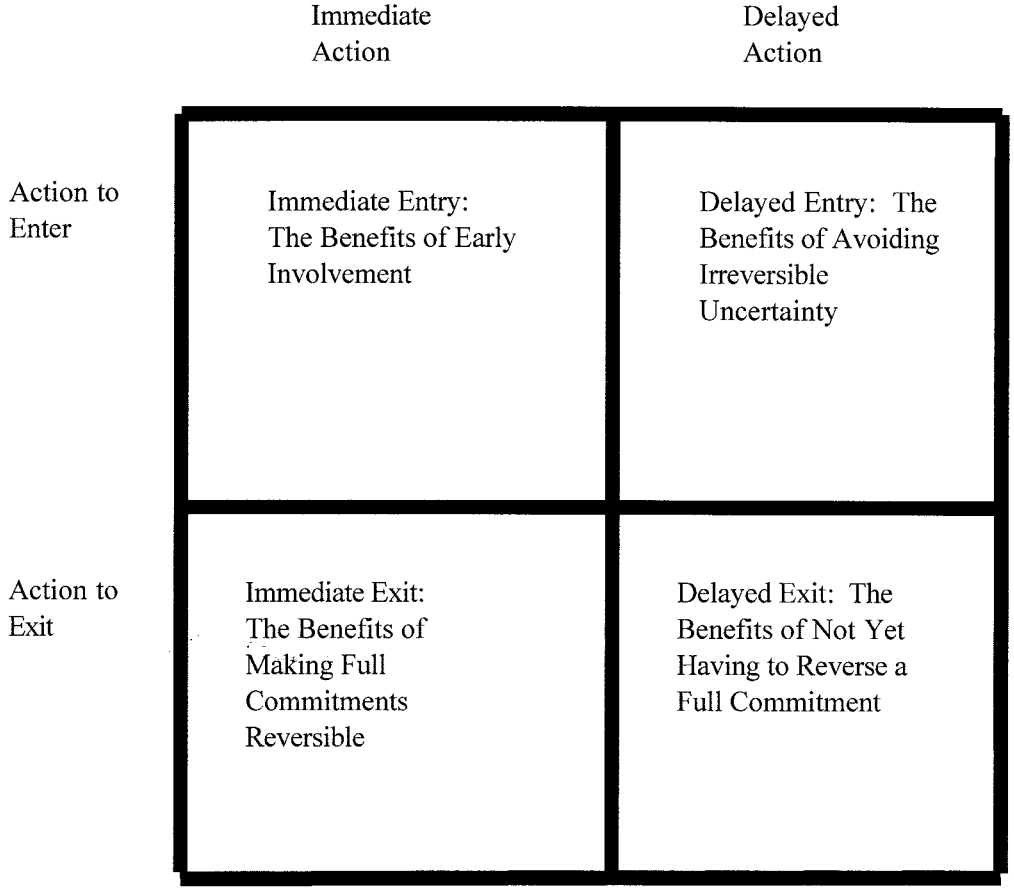

FIGURE 2
The Four Different Types of Real Options

portunity but also about processes to explore future ones as well. We shall discuss this concept later.

Immediate Exit: The Benefits of Making Full Commitments Reversible

The second type of option is an immediate exit.[4] Here, firms make a full commitment with their first decision, while at the same time acquiring or retaining the right to quickly reverse that decision later. Contrast this to an immediate entry, where firms make an initial partial commitment, followed by the right to a full commitment later. In an immediate exit, a firm fully commits funds up-front but acquires the right to later terminate the decision quickly. In fact, the firm often pays a premium up front for this right. It acquires the right to avoid an irreversible decision.

For example, consider an advertising agency seeking a new client. Once it is invited to bid, it must quickly have a full contingent of employees on board to produce a full trial advertising campaign—even though the account has not yet been awarded. An immediate-exit approach would be to hire some temporary professionals at full pay. If the agency loses the bid, the employees are immediately let go with little or no severance compensation. Hiring the temps creates an option to exit downstream quickly and at a lower cost than would be the case with permanent hires. This example differs from the case of our summer intern in that the cost of the temporary professionals, on a periodic basis, is actually higher. Unlike an immediate-entry option, firms pay more now to the temporary professionals in order to buy the right to walk away later (akin to a put option in the financial markets). Savings occur by being able to lessen the cost and time of termination, if it becomes necessary.

The downside to immediate-exit options is that they are more expensive. Because the temporary professionals shoulder an unemployment risk, they demand a premium for doing so. This premium emerges when they demand higher wages (i.e., to cushion them when there isn't any work) and show less loyalty (i.e., they are quite willing to move on to a different firm if it offers a permanent position). Like put options, firms pay for the right to make someone potentially suffer a financial loss. The more critical and specialized these skills are, the more an immediate-exit option costs.

Delayed Entry: The Benefits of Avoiding Irreversible Uncertainty

The third type of option enables delayed entry. These options occur when firms take steps now to acquire the right (but not the obligation) to enter the market at a later date. In contrast, an immediate-entry option creates an initial entry into the market. Delayed-entry options are appropriate when a firm cannot "tiptoe" into the market—it is either all the way in or all the way out. Making a decision means making a major and largely irreversible commitment.

Delayed-entry options are appropriate when a firm cannot "tiptoe" into the market—it is either all the way in or all the way out.

Delayed entry is a defensive maneuver, to protect the firm from the disadvantages of being a late mover. Delayed-entry options are also characterized by relatively higher exit costs. Hence, the best way to avoid massive exit costs is never to enter in the first place. For example, consider an oil firm contemplating a new refinery project to meet a demand that is expected to emerge in five years. Both the costs to build it and the exit costs are enormous. Under an immediate-entry option, the firm would build just a small part of a refinery, but that is not possible. In a delayed-entry option, the oil firm might acquire the land, zoning permits, and so forth necessary for the refinery. Actual construction, however, would be delayed until more information about the refinery's long-term potential emerges. Construction costs will likely be higher after delay. But this is acceptable because the oil firm wants to avoid making an irreversible decision until it is much more confident that the refinery is a good investment.

Delayed Exit: The Benefits of Not Yet Having to Reverse a Full Commitment

The last type of option is for a delayed exit. Just as a delayed entry permits a firm to buy time before making an irreversible entry decision, a delayed exit allows the firm to buy time before making an irreversible commitment to abandon an investment in a prior decision. Like an immediate-exit option, the exercise costs money. Delayed exits differ from immediate exits in that the cost of actually exiting is substantially greater. Costs are so high that firms only make the exit decision once they are sure they do not wish to ever change their minds. They seek to avoid regrets in making the decision. Return to the oil firm and its refinery decision. Suppose they build the refinery, but ten years later, due to eroded market conditions, it is

no longer profitable to run. They cannot easily sell the refinery to someone else. No one knows whether or not market conditions will ever improve such that the facility can be profitable in the future (were this known, the decision would be easier to make). Under a delayed-exit approach, they might "mothball" the plant—spending just enough to keep it operational but otherwise letting it sit idle. This option costs them money, but it permits them to avoid making an irreversible exit for now. The most expensive decision is to close the facility, only to reopen it later. In a complete exit, the firm may lose access to critical resources, or it may take too long to eventually re-enter the market.

One way to create a delayed-exit option might be for a firm to offer a union contract that provides for generous layoff benefits. This allows the firm to go into a semi-hibernation mode, idling the facility at a cost lower than keeping it fully operational, while still avoiding the long-term decision to close it permanently. Should market conditions improve, they can return to the market more quickly than before. Firms may benefit if the environment favorably changes again in the mid- to long-term future. Alternatively, if market conditions worsen and appear likely to remain that way, the firm can then make a full-exit decision.

Decisions to write delayed-exit options are not based solely on physical resources; for example, firms that launch a new product must take care not to strand early-adopting customers if they decide to kill off the product later. So such a firm's decision to knowingly operate at a loss for now, until it better understands future conditions, can be viewed as a delayed-exit option. The downside is that delayed-exit options are most prone to irrational escalation of commitment. This is because the exercise decision reverses a prior full-commitment decision, complete with all the struggles that accompanied it. Reversing again is a very difficult decision; thus delayed-exit options frequently lead to an irrational escalation of commitment, a topic that we shall expand upon later.

Modifying the Four Real Options Types with Portfolios and Compounds

In addition, all four types of options can be bundled with two modifiers: *portfolios* and *compounds*. A *portfolio* is simply a grouping of options related to the same decision. Portfolios work especially well under conditions of technological uncertainty, such as markets that have yet to adopt one of many competing standards. A firm may agree to support multiple standards for now, fully committing to a single standard once it has been established. Returning to our summer-intern option, a portfolio approach would consist of hiring not one but several interns, evaluating them, then retaining those who best fit the firm's needs. In Figure 3 we examine a hiring decision and illustrate how the various types of options and modifiers can lead to different solutions.

***All four types of options can be bundled with two modifiers:* portfolios *and* compounds.**

A *compound real option* is created when the decision to exercise an existing option also writes a new option at the same time.[5] Instead of a decision with only two parts (A and B), a compound option has at least three parts (A, B, and C), where exercising B creates the right to exercise C at a later date. Compound options make sense when it is generally not possible to get to point C from point A without going through point B. This is often seen in technology firms, where they must continue to invest in ongoing projects in order to remain technologically up to date. Doing so allows them to enter new markets in the future.

All four types of options can be modified with both portfolios and compounds. Consider a professional football team with an injured backup quarterback. It is uncertain if the backup will be ready in time for the season, should the starter be injured. To create a portfolio, they could sign three prospects, with plans to keep only one. By providing a signing bonus but not guaranteeing the contract, teams can provide themselves with an immediate exit to any (or all) of the prospects. By requiring prospects to repay their signing bonus if they are cut and then sign with another team, they create an informal non-compete clause with each prospect. This increases the likelihood that the prospect will be available later in the season, even after being cut, creating a delayed-entry option. If the team has the right to guarantee the contract, they can lock in the prospect, creating a compound delayed-entry option. Our point is that contractual terms which create various options can be bundled together to create different options.

Real Options and Learning: The Embedded (and Often Overlooked) Value

Real options are beneficial not only for reducing the uncertainty surrounding existing decisions facing managers, but also as a tool to explore for new

The Situation:
Hiring someone under conditions of performance uncertainty, when mistakes may prove costly. Here are some solutions that emerge from each type of real option (as well as the two types of modifiers used in real options).

Immediate Entry:
Hire an intern (at less cost than hiring a permanent employee), evaluate performance, then offer a permanent position only if the intern's performance is acceptable.

Immediate Exit:
Pay extra for temporary professional empoyees, retain them only as long as there is work for them to do, lay them off if there is insufficient workload.

Delayed Entry:
Establish a joint venture with a supplier. Attain a right of say in the employees to be hired by the joint venture. Sub-contract work to the joint venture, but acquire the joint venture only if favorable conditions exist long term.

Delayed Exit:
Offer existing employees generous layoff benefits to keep them available while work is unavailable. Terminate them only if long-term forecasts turn unfavorable.

Portfolio (Immediate Entry):
Hire several interns (at less cost than a permanent employee), then offer a permanent position only to the most promising intern(s).

Compounded (Immediate Entry):
Hire interns at lower cost. If they perform well, promote them to a probationary position at full pay. Then offer a permanent position (with a long-term contract) only if their performance is acceptable and if market conditions are favorable, long term.

Compounded, Portfolio, for both immediate entry and immediate exit
Hire a group of employees, but guarantee them only a specific amount of work over a set period of time (a "min-max" contract). Attain a non-compete contract clause for the duration of the contract. Attain the right to extend the contract time frame (and amount of work to be performed). Provide tenure based on the amount of work completed, and hire employees only if long-term conditions are favorable.

FIGURE 3
Example of Different Real-Options Solutions to a Personnel Problem

opportunities.[6] We highlight this often-overlooked benefit in this section.

While managers are gathering and analyzing information related to one decision, they can apply this information to new situations, identifying potential growth opportunities. As an example, consider joint ventures as a real option. They are frequently structured so that one partner can buy out the other within a certain time frame, creating an immediate-entry real option for the acquiring firm (it is often a quicker way to enter a new market).[7] A key benefit, however, lies in learning how to create and structure future joint ventures, not only with the current partner but with future partners as well. Furthermore, both joint venture/alliance partners can write this option. At first it appears that the firm with the right to acquire the other has all the benefits in the joint venture, but that overlooks the learning value of the joint venture, which accrues to both parties. This type of information sharing is often undervalued, especially when it is not written down.

The value of learning about a new market prior to full commitment to entry is tremendous. By investing in new learning, firms can decide *at an earlier time* whether or not to commit to a new market,[8] consistent with an immediate-entry option. These are often referred to as "shadow options," that is, options which emerge and are unanticipated.[9] Firms can increase their stocks of knowledge and learn more quickly how to acquire resources in the future more efficiently or cheaply. This new knowledge, combined with the firm's existing knowledge, enables it to increase its value.

The value of learning about a new market prior to full commitment to entry is tremendous.

Consider a pharmaceutical example. In 1984, Eli Lilly invested in a start-up biotechnology firm, Hybritech. Within two years, Eli Lilly acquired Hybritech outright, acquiring full access to drugs that Hybritech was pursuing. The first and primary benefit for Eli Lilly was access to a drug before it had been approved by the FDA, allowing them to acquire it at a much lower cost than if they had

waited for FDA approval. They also acquired access to Hybritech's management and existing knowledge—another benefit. The benefit easiest to overlook, however, was learning how to partner with a biotechnology start-up with different expertise (i.e., Eli Lilly was engaged in chemical-based science; Hybritech was genetically based). This enabled them to learn how to better work with their biotechnology partners and how to transmit that information inside Eli Lilly more efficiently. They wrote an option to acquire Hybritech and also wrote an option to learn how to partner with other biotechnology firms. Long term, the latter appears to have been the more valuable real option. Lilly has brought more drugs to market from its collaboration with its partners than has nearly anyone else. Lilly's latest FDA-approved drug, Cialis, resulted from a partnership with another biotechnology firm, Icos.

Potential Pitfalls Accompanying Real Options

Real options cannot solve all of the problems associated with uncertainty. In addition, failing to understand the limitations of options can lead to some perilous pitfalls, leading to unsupported confidence in the decisions made. In Table 1 we provide a summary of these potential problems and pitfalls, as well as some ideas to help avoid them.

The Net Present Value (NPV) Trap

A concern that develops when formally modeling real options involves setting appropriate parameters for the model. A key variable for modeling real options is the amount of statistical variance estimated for potential outcomes.[10] How variance is estimated has enormous implications for a real option's decision-making value. Therefore, great care must be taken in making variance estimates.

Variance is a formal way of modeling uncertainty. Simplified, variance describes for any decision how wide the range is between the worst-case and best-case outcome scenarios. Variance is generally measured in terms of standard deviations. In a real-options model, the worst-case scenario is generally limited to the cost of the initial decision. The best-case scenario, however, is rarely limited

Table 1
Potential Pitfalls and Guidelines to Improve the Use of Real Options

Potential Pitfalls That Accompany Real Options	Avoiding Pitfalls: Some Guidelines for Writing and Exercising Real Options
The NPV Trap Expected results fluctuate significantly with small changes in variance estimations, similar to the appropriate-discount-rate problem in NPV analysis.	**Institutionalize the Use of Real Options** Develop a process for managers to create consistent proposals. This may result in better sharing of learning that comes from writing real options.
Agency Theory and the Back-Solver Dilemma Managers can back-solve formal models to determine what variance estimates are necessary to provide support for their proposals.	**Identify the Sources and Types of Uncertainty** With multiple forms of uncertainty present in decisions, more specificity in framing the issue can lead to clearer solutions.
Managerial Adventurism—Overconfidence and the Illusion of Control Managers believe they have special talents that allow them to influence outcomes when they actually cannot.	**Identify the Potential Benefits That Can Occur Within the Decision** Look beyond uncertainty reduction to identify additional benefits that may emerge from employing a real option.
Managerial Adventurism—Escalation of Commitment Exercising a real-option decision may lead to similar concerns as under escalation of commitment.	**Select Which Real Option to Use** By examining issues using all four real-option types, new insights may emerge, and one solution may appear better than others.
Portfolio Pitfalls Writing several small real options may lead a manager to manage them less carefully, overlook problems, or accept greater risk in aggregate, relative to a major decision.	**Identify the Resources Needed to Develop or Maintain the Real Option** Many options require maintenance to retain their future value—a key cost to keep in mind.
Missed Opportunities By writing the wrong type of real option, managers may overlook valuable benefits.	**Develop and Announce in Advance the Decision Rule to Be Used** Publicly stated decision rules make it more difficult to "game the system."
	Separate the Role of the Real-Option Writer From the Role of the Real-Option Exerciser Employing outside auditors reduces problems that arise from escalation of commitment.
	Enter the Exit Champion Someone inside the firm not invested in the real option can more easily recognize concerns for escalation of commitment.

and represents potential blockbluster results. As the upside potential gets larger, so does the estimate of variance. And as the amount of variance increases, the value of effectively addressing the situation increases even more.

While variance can be measured on past outcomes, it must be estimated for future ones. Unfortunately, such subjective variance estimates may yield wildly changing expected results as the estimated amount of variance changes just slightly. Stated differently, depending on the amount of variance you assume in your decision model, it may yield either an approval or a disapproval decision. Choose too low a variance rate and more projects get rejected—too high a rate and the opposite occurs. Clearly, this sounds similar to the criticisms often raised against using NPV for evaluating investment options.[11] We raise this point not to discourage the use of formal models but rather to caution managers to understand how sensitive outcomes are to subjectively selected inputs.

Depending on the amount of variance you assume in your decision model, it may yield either an approval or a disapproval result.

Consider the pharmaceutical industry. On average it takes nearly eight years and $200+ million to move a promising drug treatment through the FDA's approval process.[12] When a drug fails in this process, there can be no sales, and losses equal the amount of money spent to date. But because so few drugs do make it through to approval, those that do often face limited competition and generate enormous profits. Blockbuster hits can generate upwards of $5 billion. As a result, the variance for pharmaceutical drug decisions is higher than for virtually any other industry. Accordingly, most pharmaceutical firms fund only one stage of the FDA process at a time. This strategy truncates losses to the cost of the current stage, while preserving all future potential gains. It also means that variance associated with the approval process is greatest at the time of entering the FDA process. Compared to the variance of the decision to pursue a drug, the variance of a decision about whether to outsource its production or not becomes much smaller, as firms are now estimating only potential sales, not whether or not the drug will actually be approved.

The significant differences between real options and options traded in financial markets lead to issues with variance estimates. First, financial options are assumed to be liquid, or tradable. Many real options suffer from illiquidity and firm uniqueness (the option is more valuable to the firm than to someone else). Second, financial options have expiration dates whereby the value of the option turns to zero if it is not exercised. Many real options are indefinite in length. Finally, the potential upper value of a real option may simply not be known at the time the initial decision is made (e.g., investments in learning). Valuing an outcome that has never happened before is tricky. This is especially true if the firm has had no prior experience with a similar decision and has no historical record to use for estimating variance. Together, these elements make real-option variance estimates more difficult to use.

Agency Theory and the Back-Solver Dilemma

Let us assume for the moment that companies adopting a real-options perspective invest heavily in training and that their people understand how to estimate variance well. This training can help them address the concerns noted above. However, it does not solve another inherent problem: managers who have an incentive and the know-how to "game the system." Most electronic spreadsheets permit users to simply back-solve any formula. That is, you can type in the answer you want and ask what values are needed in a formula to get that answer. If managers know that a certain option value must be met in order for the proposal to get approved, they can back-solve the model to find a variance estimate needed to arrive at the answer that upper management desires. What would be a manager's motive to do this?

Investment decisions are pregnant with agency-theory problems, where the interests of managers and owners are not co-aligned. Agency theory suggests that as managerial and owner interests diverge, managers will follow the path of their own self-interests. At times this involves securing better compensation. At other times, those interests involve exerting less effort. In terms of securing better compensation, agency problems arise because managers who propose projects may believe that if their projects are approved, they stand a much better chance of getting promoted. So while managers have an incentive to propose projects that *should be* successful, they also have an incentive to propose projects that *might* be successful. And, because of the subjectivity involved in formally modeling a real option, managers may have an incentive to choose variance values that increase the likelihood of approval.

In terms of managerial effort exerted, agency

concerns suggest that managers are less likely to exercise a real option.[13] Specifically, exercise decisions typically require more commitment and effort than do decisions that initially create the option. Left unchecked, managers who, in effect, don't want to do anything (except "collect a paycheck") may well never exercise an option. In the case of entry options, this can lead to managers failing to grasp valuable opportunities. They may, for example, let promising interns go because it is too much trouble to hire them for a permanent position. They may overlook shadow options by failing to document any learning that has occurred. And they may fail to exercise a decision to exit an option.

Exercise decisions typically require more commitment and effort than do decisions that initially create the option.

Under-investment is potentially a problem for real options, especially if the benefits from an option are embedded in knowledge assets or occur via hard-to-document values, such as organizational learning.[14] Managers may focus on "hard numbers" (such as the explicit costs) and underrely on intangible benefits, which may lead to under-investment. We suggest that the problem is a two-edged sword. That is, it is just as easy to overestimate the value of hard-to-document assets as it is to underestimate them. Overestimating is especially likely if managers believe they are more apt to get promoted for proposing investments that get funded. Given the subjective nature of valuing "soft assets," we would argue that agency concerns leading to over-investment would be as prevalent as those leading to under-investment.

Managerial Adventurism—Overconfidence and the Illusion of Control

Much has been written about traps that ensnare decision-makers. Many poor decisions come about because of such traps as biases, blind-spots, and other human frailties. Much of this literature falls under the concept of *managerial adventurism*.[15] Understanding how these traps affect decision-makers can help to improve decision-making. We think several aspects of this concept are appropriate for understanding real options.

First of all, managerial adventurism occurs when managers who have made successful choices in the past may come to believe that they possess superior expertise for managing uncertainty. They believe that their abilities can, therefore, reduce the risks inherent in decision-making to a much greater extent than they actually can. Such managers are more likely to shift away from analysis to trusting their own judgment. In the case of real options, they can simply declare that any given decision is a real option and proceed as before. If asked to formally model their decision, they are more likely to employ variance estimates that support their viewpoint.

Managerial adventurism leads to other concerns as well. Employing the real-options perspective can encourage decision makers toward a bias for action.[16] Such a bias may lead to carelessness. Managerial adventurism is as much a problem (if not more so) for small decisions as for big ones. The cost to write the first stage of an option is much smaller than the cost of full commitment, and managers pay less attention to small decisions than to large ones. Because real options are designed to minimize potential losses (while preserving potential gains), any problems which arise are likely at first to be smaller, causing less concern for the manager. Managerial adventurism could suggest that managers will assume that those problems are the easiest to solve and control, a concern referred to as the *illusion of control*. Managers may fail to respond appropriately because they overlook the problem or believe that since it is small, they can easily resolve it. Thus, managers may approach each real-option decision with less care and diligence than if they had made a full commitment to a larger investment.

Managerial Adventurism and an Irrational Escalation of Commitment

A strength of a real-options perspective is also one of its Achilles heels. Both real options and decisions involving escalation of commitment require specific environments, with sequential decisions. As the escalation-of-commitment literature indicates, simply separating a decision into multiple parts does not guarantee that decisions made will turn out well. This condition is potentially present whenever the exercise decision retains some uncertainty (which we would argue that most still do). Of the four types of options, we suggest that both options for exit are more prone to concerns of irrational escalation of commitment than are the two entry options. The decision to abandon also has strong psychological factors associated with it that affect the ability of managers to make correct exercise decisions.[17]

First, an option to exit requires reversing an initial decision made by someone in the organization. Organizations typically encourage managers to

"own their decisions," in order to motivate managers. One result is that as managers invest themselves in their decisions, it proves harder to "lose face" by reversing course. In effect, for managers making the decision, it feels as if they made the wrong decision in the first place (even if it was initially a "good" decision). The more specific the manager's human capital becomes, the harder it is to transfer it to other organizations. Hence there is a greater likelihood that managers will stick around and try to make an existing decision work. They are more likely to continue an existing project even if it should perhaps be ended.[18]

Similarly, we note that the literature on decision framing suggests that managers will pursue riskier choices if their efforts fall below a specific aspiration level. In terms of real options, the greater the potential outcome, the more valuable waiting to make a decision becomes. For managers falling below their own aspiration levels, giving up the potential gains (if the endeavor should turn around and prove profitable) makes it even more difficult to abandon an effort.

In terms of real options, the greater the potential outcome, the more valuable waiting to make a decision becomes.

Next, organizational issues can also lead to an irrational escalation of commitment. Consider an organization in which one unit bears the entire cost of the option, while others share in its benefits at no cost. If the decision to exit resides within a unit that receives benefits at no cost, it is less likely to exercise an exit option even if exercising is in the organization's best interest. This could lead to valuable resources being wasted, a concern akin to the "tragedy of the commons" issue.[19] One example of this type of problem relates to benefits that emerge from organizational learning which can create a tragedy of the commons if one unit pays for the cost of learning while others benefit from it without cost. As long as a decision is going well, conflicts will remain hidden. When the decision goes bad, however, conflict emerges.

We shall conclude our thoughts on real options and escalation of commitment by examining what happens when decision-makers confuse process and outcomes. That is, what happens when good decision-making processes still lead to poor outcomes, and vice versa? It has been argued that decision-makers assume that good (or bad) outcomes occur *because* good (or bad) processes were employed. This line of thinking leads to the perception that the difference between a calculated risk and a risky gamble is nothing more than whether or not the decision turned out well (calculated risk) or not (risky gamble).[20] We suggest that the same perception holds true for real options as well. If managers look only at outcomes and not processes, they are more likely to label a successful decision as the use of a real option (especially if they made the decision) and to criticize the unsuccessful outcomes of other decisions as an irrational escalation of commitment. Perhaps using an option is when a decision turns out well, and escalation of commitment is when it turns out poorly! We think this is especially true for compound real options, where an exercise decision includes writing a future option and not all uncertainty has been resolved. Emphasizing outcomes over process may limit learning from failed opportunities, while successes may lead to more managerial overconfidence.

Portfolio Pitfalls

One common application of the real-options perspective has been to combine it with a portfolio approach—a "scattering seeds" strategy. Firms pursue several decisions, because of the low initial costs associated with each potential decision. Firms then go forward only with the most promising decisions in the portfolio. Drawing on the managerial-adventurism concept, we argue for a counterintuitive perspective: that a portfolio of small decisions may actually be more risky than a single decision. Paradoxically, a portfolio of real options can lead to greater risk, not less. As we argued in the previous section, smaller decisions are easier for managers to overlook and for managers to assume that they can control. The magnitude of downside loss for each individual investment may be small enough that managers accept them. However, in aggregate, they may amount to more than the manager would be otherwise willing to risk in a single decision. Since managers may assume that they can handle small problems more easily, they may not take as much care in monitoring each individual decision. They may find their attention dissipated, attending to only a few decisions, while ignoring the balance.

Missed Opportunities

We find it interesting that while options can be used to explore for opportunities, their use can also preclude firms from creating opportunities. Consider a firm which makes a complementary good

for a product whose market standard has not yet been established. One options approach—using a portfolio-based/immediate-entry option—might be to produce products for all the standards. Once one standard finally emerges, the firm then drops the other efforts in favor of it. So far so good. But what if making a full commitment up front shifts the outcome for a standard?

To illustrate, there is currently a battle to develop a digital music encryption standard. Firms making portable digital music players have to select one standard (from several incompatible ones). This is the decision facing Hewlett Packard. Rather than tiptoeing into the marketplace, they have thrown their support behind the AAC standard created by Apple for the iPod. Their goal is to make this the industry standard and thus enjoy greater profits from partnering with Apple. The problem of missed opportunities emerges from employing the wrong type of option. In this example, rather than tiptoeing into the marketplace, HP wrote an immediate-exit option, fully committing to one standard in hopes of influencing its final outcome. If that fails, HP can exercise their option to exit.

Avoiding Pitfalls: Some Guidelines for Writing and Exercising Real Options

We have noted many pitfalls that can occur with the use of a real option. The difficulty of avoiding all these pitfalls may cause managers and firms to throw up their hands and dismiss such options from consideration. We think this is a major mistake. So in this section we shall talk about steps managers can take to lessen these real-options pitfalls. In Table 2 we provide a list of our guidelines, arrayed against the pitfalls mentioned above. We do so to make more clear when specific decision rules are appropriate to address a given pitfall. As an example, the use of an exit champion lessens the concern for an irrational escalation of commitment. However, we encourage managers to develop a holistic process, employing all of these steps consistently. Most importantly, the time to establish these steps is in advance, not when a

Table 2
How Guidelines Can Help Alleviate Potential Pitfalls in Using Real Options

	Pitfalls					
Guidelines	**The NPV Trap**	**Agency Theory and the Back-Solver Dilemma**	**Managerial Adventurism—Overconfidence and the Illusion of Control**	**Managerial Adventurism—Escalation of Commitment**	**Portfolio Pitfalls**	**Missed Opportunities**
Institutionalize the Use of Real Options	X	X				X
Identify the Sources and Types of Uncertainty			X	X		X
Identify the Potential Benefits That Can Occur Within the Decision		X				X
Select Which Real Option to Use					X	X
Identify the Resources Needed to Develop or Maintain the Real Option					X	X
Develop and Announce in Advance the Decision Rule to be Used	X	X	X	X		
Separate the Role of the Real-Option Writer From the Role of the Real-Option Exerciser	X	X	X	X		
Use an Exit Champion			X	X	X	

project is off course and employees wonder if it has been a mistake.

Institutionalize the Use of Real Options

One of the primary means for reducing these pitfalls is to employ a common evaluative technique, so that decision-makers feel they are comparing "apples to apples." Eliminating differences in how various values are calculated makes answers more comparable. We encourage firms to decide in advance how variance will be estimated, as well as how the value of resources to be used with a real option (e.g., equipment, land, as well as intellectual property) will be determined. Doing so helps reduce the pitfalls associated with the NPV trap, as well as the back-solver dilemma. The goal is to employ a common language and arrive at a shared agreement on what to measure.

We also recommend creating categories of potential benefits and asking managers to list potential benefits in each category, as well as attempting to value them, at least informally. While not every category is applicable to all decisions, some common categories can include the following.

- Timing
- Cost avoidance
- Technological learning
- Process learning (e.g., making this type of decision better in the future)
- Acquiring resources at lower cost
- Market leadership
- Opportunity recognition

This does not mean that unusual ideas cannot emerge. However, benefits that deviate from common categories can be set aside and held for further questioning. Additional exploration may reveal that a unique benefit resides within a given decision. In addition, when unusual but valuable benefits emerge, other proposals can be re-evaluated to search for similar benefits.

We recommend training managers to systematically search out opportunities and potential benefits. This analysis can be given to others, to jumpstart their own thinking about real options. The first few times a firm makes decisions using a real-options process, we recommend that formal feedback be made available to all involved, so they can see what projects were approved and why. For managers not involved in these decisions, firms can create mini-case studies on projects familiar to managers, having them formally identify potential benefits and opportunities. Providing such feedback should improve submissions in the future. Perhaps writing a proposal for an option now is also writing an option for better decision-making in the future.

Identify the Sources and Types of Uncertainty

Because there are many different sources of uncertainty (e.g., market, technological, cost), it helps to first identify the primary source of uncertainty influencing a given decision and to ask if reducing it may reduce other types of uncertainty. We believe this guideline is most effective in helping to avoid missed opportunities, in that it encourages managers to better examine other aspects of uncertainty. Some firms might have to accept greater cost uncertainty to avoid technological uncertainty. In the case of competing standards, it is understanding the cost of backing the wrong standard versus the cost of having to support multiple standards for an interim period. In some situations, there is no exclusivity involved, so delaying entry has limited cost. This limits the value of an immediate-entry option. In other environments the inverse may be true. Access to key resources, however, may be a major concern, leading to an immediate-entry option. Our point is that if questions are asked about multiple forms of uncertainty, potential benefits are more likely to be observed.

Because there are many different sources of uncertainty (e.g., market, technological, cost), it helps to first identify the primary source of uncertainty influencing a given decision and to ask if reducing it may reduce other types of uncertainty.

Identify the Potential Benefits That Can Occur Within the Decision

Beyond reducing uncertainty, what other benefits do you hope to gain? We recommend that managers examine solutions created from using all four types of real options. By doing so, we believe that insights into additional benefits are more likely to emerge. We recommend making this a conscious search process because it better enables managers to think creatively about how to solve specific problems. Consider a consumer example: homeowners seeking to refinance their mortgage as interest rates decrease. While this is not a real option, consumers can reduce uncertainty by purchasing an interest-rate lock (freezing the rate until closing time). Not a bad strategy, but we pon-

der whether or not homeowners have sought out other benefits as well. Could using a real option improve this decision? What if the homeowners buy an immediate-exit option on the rate lock, allowing them to cancel it any time before closing? Thus, if rates plummet, the homeowners get an additional benefit (a lower rate), while retaining all the protection as before. Asking how the four real-option types would affect the decision reveals that one of them would indeed improve it.

Consciously brainstorming to identify all of the potential benefits makes different option approaches more relevant. A firm may be seeking exclusivity, or it might be trolling for new customers in undiscovered niches. In one approach, an immediate-entrance option might prove most valuable, whereas in another the combining of a portfolio approach with a delayed entry might generate additional shadow options. Similarly, an option that generates learning might involve specific pieces of knowledge that might drive profitability, or it may be just general observation, allowing the firm to scour the environment looking for opportunities. We think this is a crucial step in reducing the missed-opportunities pitfall.

Select Which Real Option to Use

Once the concerns associated with uncertainty and the potential benefits have been identified, it is important to assess the appropriateness of each option type to the decision. For example, depending on the information identified, an immediate exit may be preferred to a delayed one, or vice versa. In addition, other tools for reducing uncertainty may work even better for a given decision. Some other tools to consider include hedges, futures, and portfolios. As a brief example, HP's photo printers for digital cameras faced a technological-standards issue; there are four common standards for compact memory—all incompatible with each other. HP has chosen a portfolio approach; their photo printers contain input slots for all four memory types. Rather than trying to predict a winner, they simply support all four standards with one product. While this strategy increases production costs slightly, it is probably the lowest-cost way to reach consumers using any of the four memory types. We note that in this case, a portfolio has an added benefit: it should appeal to consumers who think they might switch cameras in the future, by freeing them from having to buy a new printer if they buy a camera with a different memory medium than they currently use.

We suggest a process of identifying the solutions that applying each of the four options approaches might generate for a given problem. This type of brainstorming activity is an iterative process, as subsequent discussions should, in turn, lead to new ideas about potential benefits that the firm can capture. We also encourage combining this process with the modifiers discussed previously, and even with other tools for reducing uncertainty, as briefly mentioned above. Such a process, we think, should go a long way toward reducing the problems that emerge from portfolio pitfalls. Approaching each decision from multiple perspectives keeps those decisions, even though they are smaller, within a conscious decision-making process.

Identify the Resources Needed to Develop or Maintain the Real Option

Estimating resource requirements for writing an option may seem simple, but in reality it involves identifying all of the costs involved in writing the option. In both the NPV trap and the back-solver dilemma, a failure to identify costs can lead to highly inaccurate decisions. The best way to estimate costs is to examine past decisions and study the common costs found in each case. Through such a systematic approach, managers are less likely to remain unaware of the resource requirements that their decisions demand.

Estimating resource requirements for writing an option may seem simple, but in reality it involves identifying all of the costs involved in writing the option.

As an example, in the case of technological uncertainty, a firm may have to participate in each round of technological development in order for it to be available for subsequent decisions. As a result, a firm may not have the luxury of leapfrogging rounds of development.[21] It also may find that it cannot abandon a new product without stranding customers, and so it must commit to remaining with them. Similarly, if learning is a primary goal, then investments in documenting the learning become an important requirement. It may require restructuring the organization to ensure that learning flows to appropriate decision-makers. For example, in Xerox's PARC division, there were inadequate linkages between their ability to invent new technologies and their ability to get them into the marketplace.

Develop and Announce in Advance the Decision Rule to Be Used

Ambiguity and vagueness may crop up in decision-making, paralyzing the decision process. In terms of entry options, this means that missed opportunities occur, and in exit options it means that the firm endures unnecessary losses. One way to lessen the pitfall of paralysis is to state in advance the decision rule for any given option and to prescribe a process for following it. While this may appear obvious, stating and agreeing upon what the exercise decision actually involves make it more noticeable when managers do something different. This one step helps address several pitfalls, not only the NPV trap and the back-solver dilemma but also the two concerns of managerial adventurism. Clearly, the more specific the decision rule, the less likely managers are to fall into escalation of commitment.

Decision rules, however, can also be written to allow for a more effective exploration of "soft" benefits such as learning and knowing-how-to-do partnerships. Such benefits are relatively more difficult to articulate in advance of an option being written, often requiring greater reflection in order to discern their true value. Paradoxically, while it may be better to be vague at the time of writing the option (in order to capture benefits from such options), being more specific with the decision rule typically proves more important. We think it is especially valuable before evaluating "soft benefits" to spend extra time deciding how to evaluate them. It is useful to ask if they can be codified or how they will be disseminated to others. We strongly recommend developing a knowledge database of learning that has been identified as a benefit to acquiring any real option. The database entries should include not only the outcome but also the decision rules employed, as well as insights into how the benefits were discovered. Such knowledge can spur new searches into existing options, possibly providing new shadow options from the existing efforts.

Separate the Roles of the Real-Option Writer and the Real-Option Exerciser

While identifying and stating decision rules helps, the process can be improved further by relying on external audits to ensure that the decision rules have been followed. Of the many pitfalls we have identified, we see irrational escalation of commitment as the most serious. Avoiding such escalation requires more than just being specific about costs and benefits, and formally stating the decision rules and process to be followed. While these are helpful, we also suggest that external audits be done. External audits often help firms make more objective decisions about when to exit a decision. As we have noted, formally stating decision rules and identifying the parameters by which a decision should be made help any manager recognize when to make a decision, *assuming that managers can remain rational enough to make such a decision*. Rotating managers may also help since newer managers may not be as invested in a decision as previous managers may have been. Social pressures within the firm, however, may still encourage managers toward an escalation of commitment. External audits help to overcome the psychological investment that managers may have made in a decision, as external auditors should have no investment in decisions.

Of the many pitfalls we have identified, we see irrational escalation of commitment as the most serious.

The Department of Defense tried this approach with its BRAC (Base Realignment and Closure) commissions. BRAC had the unenviable job of identifying military bases that should be closed, despite the fact that over 98 per cent of the communities near these bases desperately wanted their bases to remain open. BRAC brought in individuals unaffiliated with these bases to make a decision on which to continue and which to shutter.[22]

Use an Exit Champion

In addition to external auditors, we also recommend using internal auditors or "exit champions" to complement the external audits. While product champions shepherd projects through the firm, exit champions resolve issues with both immediate-entry and delayed-exit options. In both situations, they provide arguments for killing off the firm's commitment to a decision. Exit champions reside within the firm and serve functions similar to those of product champions. As a matter of fact, both types of champions often come from similar backgrounds and have similar goals.[23] A key difference is that exit champions often have to ensure compliance with the agreed-upon decision processes or to even develop those processes in the first place. They need to walk a fine line—being sufficiently involved with a project to recognize concerns but remaining sufficiently disinvested to identify problems that can lead to irrational escalation of commitment.

One benefit is that it is often cheaper and

quicker to have an exit champion within the firm than to rely solely on an external auditor. Speed may prove critical as too long a delay in evaluating a decision may itself lead to escalation of commitment. Frequent periodic reviews and checking against agreed-upon guidelines may eliminate option exercise occurring by default or by accident. Another benefit is that an exit champion may resolve several agency concerns, both those associated with a lack of effort to truly pursue the exercise of an option and those of an irrational escalation commitment.

The Future of Real Options

In this article we have tried to improve the general understanding of real options by delineating and explaining four different types of real options. Our hope is that managers should now have a better idea of the conditions that lead to the appropriate use of each. As part of this discussion, we have also provided some guidelines to inform managers how best to deploy real options in their decision-making.

In addition to this overview, a great many other aspects of real options would repay exploration. For example, we see a potential linkage between the real-options literature and different types of capital, such as social capital and intellectual capital.[24] While we have explored real options at the level of the individual manager and the firm, they also can be created by a network of individuals and/or firms. That is, the actions of an initial individual or firm embedded in a network can create learning opportunities that others in the network can exercise as real options at a later date.

As an example, consider the PDA industry. Back in the 1980s, firms sought to build a small handheld computer that could accept handwritten text that could be manipulated by a computer. Some early "failures" in this space included Go! Computing, Grid, and the Apple Newton. The founders of the highly successful PalmPilot were veterans of other failed ventures who gained some key insights when developing the PalmPilot (and later a second company called Handspring). The "failures" of the prior ventures were viewed as beneficial learning. We suggest that a real option for the PalmPilot was written initially by the community of firms and individuals involved in the prior PDA-type efforts.

To the extent that an individual is embedded into a network (such as the community that was engaged in making a PDA) that can provide a "safety net," that person will be more willing to explore for new opportunities and to exploit them as they emerge.[25] However, the potential downside is that managers might sense a diffusion of responsibility and accountability on the part of the network member.

While we have provided a simple set of guidelines to improve the effectiveness of employing real options, we recognize that they can be further refined and made of greater use. This can occur by comparing and contrasting them to other tools for reducing uncertainty such as simple incremental decisions, hedges, and futures.[26] Just as differentiating between types of real options allows for greater understanding in their use, we think greater clarity between real options and other tools for reducing uncertainty will provide for improved decision-making as well. We think options may differ from other tools in providing additional benefits beyond uncertainty reduction. For example, an important benefit of real options is the learning that is generally associated with experimentation. Such learning adds to the firm's stock of knowledge resources and potentially enables firms to form new combinations or "unique bundles."[27]

Finally, although we have inferred some linkages, we believe the real-options literature provides a natural fit for an improved understanding of how entrepreneurs identify and pursue opportunities.[27] Both real options and entrepreneurship can strongly emphasize opportunity. Most efforts to help entrepreneurs are designed to reduce failures, whereas the real-options literature is designed to encourage them based on the notion that smaller losses are preferable to larger ones. Reconciling these opposing goals would prove especially valuable to our understanding of entrepreneurs but also of decision-making in general.

Endnotes

[1] The earliest insights on this topic emerge from Frank Knight's efforts to define a meaningful difference between risk and uncertainty. Knight, F. 1921. *Risk, uncertainty, and profit.* New York: Harper and Row.

[2] McGrath, R. G. 1997. A real options logic for initiating technology positioning investment. *Academy of Management Review,* 22(4): 974–996.

[3] McGrath, op. cit.

[4] Berger, P. G., Ofek, E., & Swary, I. 1996. Investor valuation of the abandonment option. *Journal of Financial Economics,* 42: 257–287.

[5] Bottoron, P. 2001. On the practical application of Real Options Theory. *Thunderbird International Business Review,* 43(3): 469–479.

[6] Huber, G. P. 1991. Organizational learning: The contributing processes and literature. *Organization Science,* 2(1): 89–115.

[7] Bruce Kogut was among the first to explore corporate-level real options, with his work on internal joint ventures. Kogut, B. 1991. Joint ventures and the option to acquire and expand. *Management Science,* 37: 19–33.

[8] McDonald, R., & Siegel, D. R. 1986. The value of waiting to invest. *Quarterly Journal of Economics,* 101: 707–727.

[9] For an early but valuable treatment on this topic, see Bowman, E. H., & Hurry, D. 1993. Strategy through the option lens: An integrated view of resource investments and the incremental-choice process. *Academy of Management Review,* 29: 74–85.

[10] One of the better discussions on the various limitations to formally modeling real options comes from work by Dixit and Pindyck. For reasons of parsimony, we discuss only one of the four elements whereby valuations can be mis-specified. Dixit, A. K., & Pindyck, R. S. 1995. The options approach to capital investment. *Harvard Business Review,* 73: 105–113.

[11] One of the authors formerly worked as a financial analyst for the Federal Government. The parties could not agree on the appropriate discount rate for capital investments—so an executive decision (A-11) was made to use 7 per cent, "because historically that rate has been used in the past." At least it was consistent.

[12] On the uncertainty involved in the FDA drug-approval process, the FDA has provided many valuable reports, including the following: From test tube to patient: New drug development in the United States. *FDA Consumer,* Special issue, January 1995.

[13] Agency theory suggests that managers might engage in adverse selection, where they promise what they cannot provide, and moral hazard, where they pursue their own interests because those efforts cannot be easily monitored. John Hendry provides an insightful extension on this concern. Hendry, J. 2002. The principal's other problems: Honest incompetence and specification of objectives. *Academy of Management Review,* 27(1): 98–113.

[14] There have been some good efforts to link a real-options perspective with managerial decision-making, such as escalation of commitment. Russell Coff and Kevin Laverty provide an especially insightful analysis of the topic. Coff, R. W., & Laverty, K. J. 2001. Real options on knowledge assets: Panacea or pandora's box. *Business Horizons,* 73: 79.

[15] For understanding the differences between how managers say they approach decisions and how they actually do, March and Shapira's work is among the best. March, J. G., & Shapira, Z. 1987. Managerial perspectives on risk and risk-taking. *Management Science,* 33 (11): 1404–1418.

[16] McGrath, R. G. 1999. Falling forward: Real options reasoning and entrepreneurial failure. *Academy of Management Review,* 24(1): 13–30.

[17] Coff & Laverty, op. cit.

[18] Zardkoohi, A. 2004. Do real options lead to escalation of commitment? *Academy of Management Review,* 29(1): 111–119.

[19] The tragedy of the commons describes a situation where users of a good aren't responsible for its maintenance, leading to overuse. It originated to explain the benefits of property rights and why privately held lands suffered less erosion than publicly held grazing lands. Staw, B. M., & Ross, J. 1987. Behavior in escalating situations: Antecedents, prototypes, and solutions. *Research in Organizational Behavior,* 9: 39–78.

[20] March & Shapira, op. cit.

[21] Grenadier, S. R., & Weiss, A. M. 1997. Investment in technological innovations: An option pricing approach. *Journal of Financial Economics,* 44: 397–416.

[22] Ironically, this didn't always eliminate escalation of commitment. Two of the major criteria for considering a closure were the impact on the local community and the outlay cost for closure. As a result, some bases which suffered higher operational costs remained opened, even though the overall cost to the Department of Defense was greater.

[23] Royer conducted a study of two major firms that had technological programs with very long durations and concluded that exit champions shortened decisions by several years! Royer, I. 2003. Why bad projects are so hard to kill. *Harvard Business Review,* 81(2): 49–56.

[24] Nahapiet, J., & Ghoshal, S. 1998. Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review,* 23(2): 242–266.

[25] In addition, firms and societies which accept failure see more exploration attempts. Our perspective in this article could have important implications for networks that exist within society as well as beyond the boundaries of the firm. See, for example, McGrath, R. G. 1999. Falling forward: Real options reasoning and entrepreneurial failure. *The Academy of Management Executive,* 23(2): 242–266.

[26] We note the concern that all of these approaches have been described as being real options. As more and more types of decisions are considered to be options, it can lead managers into several of the pitfalls we described. We think they are also valuable tools, and a better understanding of each should lead to improved decision-making.

[27] For an insightful perspective, see Kogut, B., & Zander, U. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science,* 3(3): 383–398. Such resources often represent specialized knowledge that can, in turn, be used to generate future opportunities. Thus, managers should strive to take into consideration the cumulative effects of learning associated with the application of real options—as opposed to considering each one in isolation.

[28] Shane, S., & Venkatraman, S. 2000. The promise of entrepreneurship as a field of research. *Academy of Management Review,* 25: 217–226.

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