Real Options on Knowledge Assets: Panacea or Pandora's Box?

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"Minnesota Mining & Catchall: 3M has sexy technology and sleepy earnings. Solution: Bust it up....3M operates on the philosophy that if you throw enough money at enough scientists they will come up with something interesting—but the strategy is something of a dud on the bottom line" (Tatge 2000).

How can firms make the right investments to create a competitive advantage in the high-velocity environment of the new economy? The broad consensus is that they must invest in knowledge assets, which form the basis of a dynamic capability. Unfortunately, standard investment tools taught in business schools, such as discounted cash flow (DCF) models, discourage investments in intangible and uncertain assets such as knowledge.

The problems with DCF fuel the excitement around applying *real options models* to evaluate strategic investments. Drawing on the analogy to financial options, the logic of real options is that firms can make small investments (establish options) that provide an opportunity for, but not the commitment to, pursuing full investments (exercising options) later. Because a firm can wait until uncertainty dissipates before making a full commitment, it can capture potentially huge gains while avoiding the risk of devastating losses.

Acknowledging the benefits of real options, we shall nevertheless explore here how *the nature of knowledge assets* itself may end up costing a firm dearly if the wrong decision is made on whether to option them. Knowledge-based options differ from financial options in at least two important ways: (1) significant uncertainty remains at the exercise decision, and (2) the value of knowledge depends on its transfer and integration within the firm. Thus, managers may erroneously exercise options (as in the provocative statement above regarding 3M) or drop options that would lead to a competitive advantage. Either choice can be very costly.

Despite the benefits, the very nature of knowledge assets could lead to costly errors when deciding whether to exercise real options on them.

The Logic of Real Options

Firms *establish* options by making an initial investment (a test market, an exploratory joint venture, a pilot R&D project) that grants them an opportunity to invest further. At a later date, they may choose whether or not to *exercise* the option and implement a full-scale project (a broad product launch, a wholly owned subsidiary, a major R&D program).

The key to options logic is the flow of information that reduces uncertainty in the time between establishing the option and facing the exercise decision. If new information casts doubt on the project, the firm can avoid losses by letting the option expire. On the other hand, if the new information is favorable, the firm can exercise the option.

By purchasing an option rather than making a full-scale investment, a firm can retain the upside potential while minimizing its downside risk. So it is often appropriate to establish an option even if a full-scale investment is unwise. This is

because the *option value* may be well above the net present value (NPV) used in DCF models. In fact, the value of using an options approach, in lieu of DCF, increases directly with the degree of uncertainty at the time the option is established.

Options logic seems particularly compelling for knowledge assets. Unlike physical or financial assets, knowledge can be transferred throughout the firm and applied to various projects and processes. That is the essence of core competence as the basis for strategy, say Prahalad and Hamel (1990). Thus, *investments in knowledge assets typically create options.* An important role of management is to recognize these options and make the appropriate exercise decisions.

Here we emphasize options *logic* as a framework for analyzing opportunity. We do not limit our discourse to the formal calculations characterized in option pricing models. In other words, managers can apply the logic behind the models without the formal mathematics developed for financial options. An intuitive application of options logic helps decision-makers value flexibility in uncertain and turbulent environments. Brown and Eisenhardt (1997) note that "successful firms rely on a wide variety of low-cost probes into the future" in these situations. The concerns we raise hold for firms applying real options heuristics and for those using formal options models.

THE IMPORTANCE OF THE EXERCISE DECISION

Interestingly, exercise decisions have received scant attention, perhaps because they are trivial when it comes to financial options. A financial option to purchase should be exercised if the cost of doing so—the exercise price—is below the current market price; there is no uncertainty. The situation is similar for a real option on a commodity such as gold, or an option on a marketable asset such as land. However, as we shall explore, uncertainty about the value of knowledge assets creates important problems.

In making the exercise decision, the firm relinquishes its option by letting it expire or making a full commitment. Either way, the flexibility created by the option is terminated. Because of the importance of such a decision, the firm must be free of systematic biases toward over- or under-investment at this stage. *The exercise decision determines whether a real options approach is better than standard DCF models.* If a firm is prone to bias at this stage, it may waste resources by investing (exercising options that appear to be failing) or by dropping options that could lead to an advantage. There are various settings in which managers should guard against these errors.

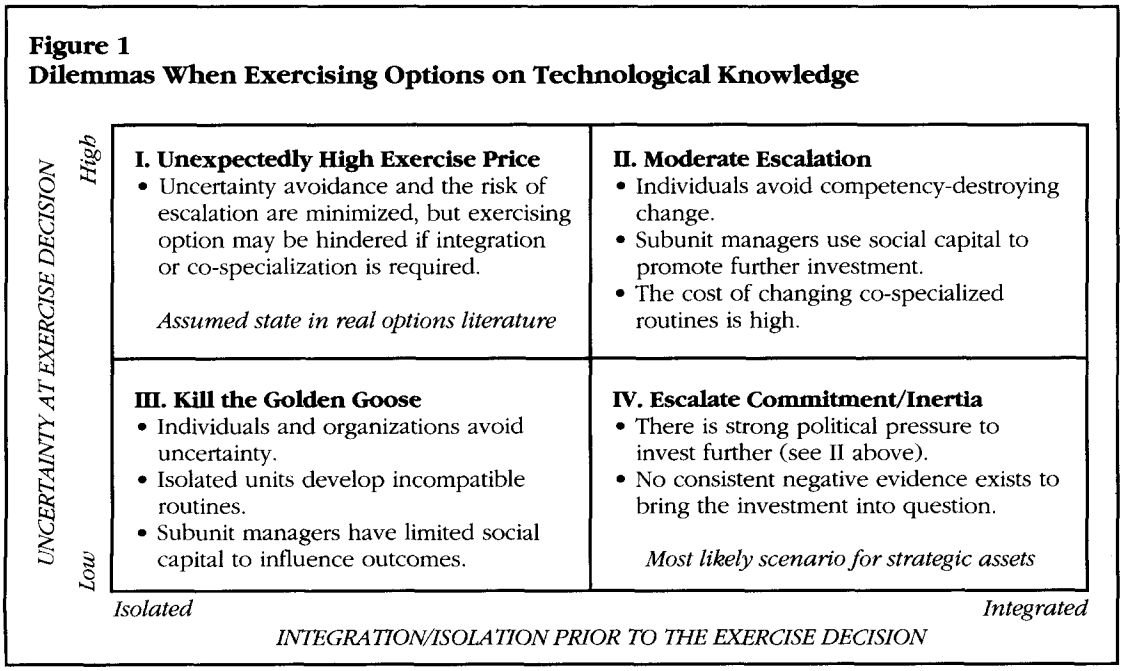
Two separate characteristics distinguish real options from financial options, as shown in **Figure 1**: (1) the degree of uncertainty remaining when the exercise decision must be made, and (2) the extent to which the assets created by establishing the option are initially integrated with other resources in the firm or kept isolated.

Uncertainty at the Exercise Decision Stage

While greater uncertainty increases the value of establishing a given option (unlike the situation with DCF models), it creates dilemmas when making the decision on whether to exercise the option. As noted, real options theory is based on an analogy to financial options, and managers do not face uncertainty when exercising financial options. However, significant uncertainty may remain at that stage for real options, especially when it comes to knowledge assets.

When this is the case, managers do not face the straightforward choice associated with exercising financial options. In fact, under great uncertainty, the decision is much like a "standard" DCF application. Seen this way, it may be subject to the same problems identified with DCF models, including biases toward short-term,

Figure 1
Dilemmas When Exercising Options on Technological Knowledge



low-risk payoffs and tangible products. This pattern seems to have plagued a number of firms.

Consider the example of RCA. The corporation was a world leader in LCD technology in the 1970s, but then it killed the research program. Using DCF, this may have been a sound choice, given the uncertain (at that time) future for LCD technology and the amount that would have been required for full development. However, RCA had effectively created an option by developing LCD technology capabilities. Subsequent developments in notebook and hand-held computers demonstrate that this option could have led to a competitive advantage if exercised.

The RCA example illustrates how we normally think of options—the exercise price is much higher than the initial investment. However, some options on knowledge assets may be thought of as involving a series of exercise decisions, each with a relatively small price. For example, many R&D programs involve capabilities that create future opportunities to update or expand. Each of these decisions, in turn, creates other options, yet the firm never faces a decision on a single large investment. An investment opportunity in which no single decision involves a large resource commitment may overcome biases in favor of short-term, low-risk payoffs.

Another factor that comes into play under uncertainty is the reputation of a project's "champion." When firms must invest under uncertain conditions, the champion's reputation and ability to influence others signals the project's efficacy. The champion is most influential when clear evidence of project performance is lacking. Thus, firms may be less likely to terminate projects sponsored by managers with good reputations or sound networks (that is, it would be more likely to exercise the option). In contrast, managers with lesser reputations may find it hard to get even extremely promising though uncertain projects funded without strong evidence of their efficacy.

Uncertainty, the magnitude of the exercise price, and the reputation of the project champion all interact in the exercise decision. For example, a project with a low exercise price supported by a high-reputation manager may not be subject to critical review at all. In contrast, a project with a high exercise price supported by a low-reputation manager might be dropped with little review in the absence of compelling evidence of its efficacy. Through these factors, uncertainty affects the likelihood that a firm will exercise an option on a given knowledge asset.

Integration and Isolation

Unlike physical or financial assets, says Nonaka (1994), the value of knowledge is ultimately contingent on its transfer, integration, and recombination with other knowledge-based assets in a firm. However, when establishing an option on knowledge assets, the firm may have the choice of integrating new assets initially or keeping them isolated. In some cases, an incompatible culture, routine, or technology must be kept isolated from other assets in order to thrive. In others, knowledge must be integrated so that its potential may be evaluated. Either way, problems arise that are absent in the decision on financial options.

Problems with Integration. If a knowledge asset created by an option is integrated, the firm may be more likely to exercise the option than if the asset were isolated. Individual, structural, and institutional factors create pressure to maintain existing social networks created by new projects, setting the stage for a bias to exercise the option and, effectively, to escalate commitment. Under these conditions, clear evidence of failure may be necessary to achieve project termination. Uncertainty is the great enabler here. If an outcome is uncertain, and particularly if failure is not clearly evident, it may be hard to derail a project once it has taken hold in the firm.

Integration may encourage firms to exercise options on poor investments. As our opening quote suggests, 3M has been held up as a model for innovation because of practices that have seemed a heuristic approach to real options. However, recent poor performance has sparked a closer look. Sporting the new moniker "Minnesota Mining & Catchall," 3M promoted innovation and variation without killing many unprofitable "options." So McKinsey & Company recommended that the company be broken into separate pieces. Despite poor performance and this clear recommendation, 3M chose to hold most of its divisions. If it had killed the options that lacked promise all along, it would not have been stuck with an "abrasive" portfolio.

A bias toward exercising options due to escalated commitment could be a critical weakness for a firm using real options logic. Indeed, says McGrath (1999), "options must be extinguished ruthlessly when they no longer promise high upside potential." This is no easy task for assets that are integrated into the core fabric of a firm.

At an extreme, overcoming such a bias may require a new management team that lacks ties to the firm's social network. This may be happening at 3M. New CEO W. James McNerney, Jr., has decided to eliminate about 800 of a total of 1,500 R&D projects, with the cuts allowing additional funding for projects with the most potential. McNerney's actions are apparently consistent with the underlying analysis of the McKinsey report: too many unprofitable projects. It may be that, as 3M's first "outsider" CEO, McNerney is in a position to take these steps, whereas his predecessors, who grew up in the firm, were not.

Problems with Isolation. A firm may limit the bias toward exercising options by keeping "experimental" knowledge assets isolated from existing units. In some cases, an incompatible culture, routine, or technology must be kept isolated from other assets in order to thrive. Isolation also serves to limit the development of social networks that may lead to the escalation of commitment, as described above. But it can also create another set of problems for the firm.

If a knowledge asset created by an option is kept isolated initially, the firm may be less likely to exercise the option than had the asset been integrated. Exercising an option on an isolated knowledge asset may be hard because the asset may possess (or develop) characteristics that are incompatible with the rest of the firm. This may be an important limitation on the application of real options for knowledge assets. If competing but incompatible options that ultimately require integration (such as firm-specific technologies or routines) must be kept isolated if the assets are to thrive, the firm may face insurmountable problems integrating the key assets.

Integration may prevent firms from fully exercising options on good investments. Xerox Corporation's Palo Alto Research Center (PARC) and GM's Saturn division are illustrative. In each case, the isolated subunit has developed unique skills and routines that flourish apart from the rest of the firm. Xerox is famous for being unable to take advantage of the options created at PARC, such as PCs, networks, and mouse interface. Here, the innovations did not build sufficiently on the firm's core knowledge and skills in marketing and xerography.

Similarly, Saturn's isolation created a unique team-based culture. This can be seen as an option on a cultural change throughout GM. However, GM faced serious implementation problems because the changes were incompatible with existing routines and values. Similar interventions, such as at the Van Nuys plant, failed largely because they were not adequately isolated from the rest of the firm. To exercise the Saturn option fully, GM might have to allow the existing divisions to wither while creating new divisions that espouse the new culture.

Monsanto's option on a biotechnology capability also illustrates the difficulty of integrating different types of knowledge. Initially, managers assumed that biotechnology was compatible with the existing chemical business. Both were research-oriented, and biochemistry is a subfield of chemistry, so the new business seemed complementary. However, the knowledge needed for the core chemical business differed from life sciences. Chemistry research was mature and best conducted with close ties to market applications; biotechnology required basic research that was best centralized to share emerging knowledge. Ultimately, Monsanto had to spin off its core chemical business to exercise the biotech option.

The Monsanto example shows that when a new isolated division represents a better way of doing things, older divisions that are highly entrenched may have to be purged in order to exercise the option and take full advantage of the knowledge assets created. It goes without saying that spinning off or eliminating the core business is a difficult path. Still, it may be required to take full advantage of establishing an option on a knowledge asset. This type of radical strategic shift often requires a new management team.

From a political standpoint, managers in isolated subunits are less apt to be well connected (a low social capital), and decision-makers may feel less bound by implicit contracts. This may mean that the managers in the affected subunit have little political influence and the rest of the firm is biased against exercising because of the significant change it would require. In essence, this is the opposite of the situation with integrated options.

DCF OR REAL OPTIONS?

So in light of the various problems that may plague exercise decisions for knowledge assets, should a firm use the DCF model or real options? Unfortunately, as mentioned earlier, the application of real options logic to knowledge assets is just beginning, and almost no attention has been paid to the exercise decision.

Real options logic is an improvement over DCF if it both promotes investment in beneficial projects and helps the firm avoid poor projects. Greater use of it will probably increase "initial" investments—firms establishing options on projects that would have been rejected through DCF. Some projects that would have been inappropriately rejected through the use of DCF analysis may be funded if an options framework promotes *both* the initial investment (establishing the option) *and* the correct exercise decision. However, not all options should be exercised. An options approach may lead to poor decisions, failing either to capitalize on opportunities for long-term profit or to terminate investments in losing projects. The question, then, is whether the dilemmas associated with options logic are more or less serious than the problems of DCF models in a given setting.

In this context, real options could lead to lower performance under two scenarios. First, the framework may encourage firms to initiate many options under the assumption that they can simply choose to kill them later. A hidden challenge is that top management must be able to pull the plug on projects against opposition that ultimately

stems from the attributes of knowledge assets. Resources such as company-specific routines and social networks do not go away easily even if the firm's best interests dictate their demise. Successful investment in strategic assets requires more than applying the logic of financial options.

At the most basic level, *financial options cannot vote on whether their owner should exercise them*, whereas purchasing an option on a strategic capability creates a constituency that will advocate further investment. Even with a marginal tendency to escalate, this problem may be amplified if using options logic leads the firm to undertake a large number of projects.

Conversely, managers must realize that without the ability to integrate knowledge assets, exercising such options may range from challenging to nearly impossible. Indeed, without considering the exercise stage at the time of establishing options, managers may be less able to carry out long-term investment programs than they would if they used standard investment models. Further, using options logic, the firm would be losing the amount of the investment (to establish the option) that would not have been made if a DCF approach had been used.

PUTTING THE LOGIC TO WORK

Options logic is poised to take its place in the mainstream of strategic management. This situation is in response to the fundamental problem associated with "standard" investment approaches: that firms must commit to expenditures without key information about the future—the acceptance of new technologies, the actions of competitors, or economic fluctuations.

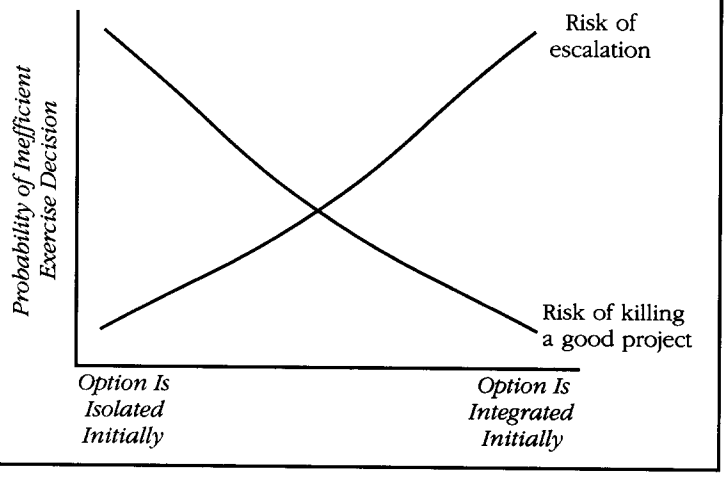
Our focus on the problems of applying real options logic is not intended to discourage the spread of its application. On the contrary, we believe that *managers must identify and understand the problems with applying options logic in order to solve them*. For knowledge assets, we expect that initial integration of the option will increase the probability that the firm will exercise it. Conversely, initial isolation of the asset will increase the probability that the option for future investment is allowed to expire. Again, we emphasize that these effects are enabled by uncertainty, the essential element that allows political processes to fill the void caused by imperfect information on a project's efficacy.

Figure 2 depicts the dilemma managers face in applying real options logic when there is uncertainty at the exercise stage. The risk of higher commitment to a failing project increases with the degree of integration. Managers can minimize this risk by keeping a project isolated. However, isolation raises the risk that a good project will be killed, and that the firm will fail to exercise the option on an asset.

The importance of the elements we have discussed is that they may lead to *systematic* tendencies to underinvest or overinvest at the exercise stage, tendencies that cannot be corrected without creating other problems. For example, it might appear that a bias toward underinvestment (say, by relying on DCF models) could be corrected by establishing options that are integrated, thereby creating pressure to exercise these options. Can this pressure—essentially, a tendency to escalate commitment—be used strategically to overcome the bias toward underinvestment? We think not. The problem is that the bias to escalate commitment to integrated options does not just correct mistakes; it does not simply result in investing in "good" projects. We expect that an increase in the tendency to exercise options will result in a new set of poor decisions—projects that under DCF would have been, and should be, rejected. As long as uncertainty is present, the firm cannot simply correct a set of poor investment choices without creating another type of problem.

It might appear from Figure 2 that the optimal degree of integration is at the intersection of the two lines, where the two probabilities are equal. However, this would presume that the cost of escalation (exercising an option on a failing project) and underinvestment (killing an option on a promising project) are equal. In fact, which problem creates worse consequences for the firm depends on the specifics of its competitive and technological context. Moreover, as in the critique of DCF models, managers may care more about costs—relatively certain and short-term—than the intangible benefits of knowledge assets. Firms therefore may choose to approach deci-

Figure 2
Competing Risks of Escalation and Underinvestment



sions on options with an eye toward reducing the likelihood of one outcome or the other. The structure for options on new knowledge assets—isolated versus integrated—is the obvious strategic choice in this regard.

Which of the two problems is more costly is also likely to vary among the firm's stakeholders. For example, the cost *to managers* of killing a promising project may not be as high as the cost of investing in a "dog." This may be a form of agency problem in which the firm penalizes failure in a way that stifles innovation. Nevertheless, it illustrates how managers may not wish to seek the exact intersection point on Figure 2.

Mitigating Potential Escalation

Perhaps the most important question is how can companies overcome the barriers we have described. The nature of knowledge assets may lead to commitment escalation becoming a particularly vexing problem. We believe firms must integrate knowledge assets at an early stage, in order to evaluate whether a full-scale commitment should proceed. If escalation cannot be mitigated with isolation, and if replacing top management (à la 3M) is too drastic, is there anything else to do?

The academic model may be quite instructive, since universities formally and informally specify that they are "buying an option" on junior faculty. The fact that the relationship may be of limited duration is made explicit at the outset, and the tenure process clearly culminates in an "exercise" decision. Universities use rigorous external review as part of this process. Although junior faculty may develop social capital that would allow them to influence exercise decisions, the external review limits the impact these ties can have on the decision. Review at the university level, where junior faculty are less likely to have social ties, further limits the risk of escalation.

In this way, universities focus great effort on limiting that risk. In the context of our discussion of Figure 2, this presumes that the cost of escalation far exceeds the risk of "killing" a promising "project." Given that tenure creates colleagues for life, this may be the case. It may or may not be consistent with business settings, in which the cost of killing a promising project may be substantial.

We are cautious in suggesting that businesses emulate universities in the matter of tenure decisions. However, some practices in the business world share the essential feature of external review. For example, cutting-edge technology firms often have scientific advisory boards to review their project portfolios. While often serving to grant status and legitimacy to the firms (by involving eminent scholars), the review process may also provide useful information much like the external review in a university setting. Interestingly, Boulding, Morgan, and Staelin (1997) assert that one way to limit the escalation of commitment to failing new products is to introduce an external decision maker. The implication is that the escalation problem at the exercise decision can be mitigated if managers will allow outsiders who are not "invested" in a project to provide input.

Firms should also attend to internal processes that may make escalation less likely. Simonson and Staw (1992) have found that escalation is less likely if specific targets are agreed upon beforehand. This recommendation may be difficult to implement for knowledge assets, where the contribution to performance of a particular asset is hard to assess. Staw and Ross (1987) argue that companies could ward off escalation if they were to encourage honest admission of poor outcomes. Simonson and Staw suggest much the same, arguing that evaluating the decision process, rather than the outcome, would limit escalation.

When it comes to knowledge assets, the decision to exercise an option can be a real dilemma for a firm. It may be driven by politics as much as a rational assessment of the return on investment. Uncertainty grants degrees of freedom for managers who can push their agendas in the absence of perfect information. Integrating the project means some managers may be in a position to use their social ties to promote continued investment. Integration also suggests that the changes resulting from the decision may be felt broadly throughout the firm, resulting in resistance to change. Isolation avoids these problems, but may result in the inability to fully realize the potential created by a pilot project or an innovative division.

Attention to implementing strategies based on knowledge assets is overdue in both management research and practice. Real options models offer great promise in promoting investment in these assets. However, if the nature of knowledge assets is the source of investment dilemmas, a real options framework is not a panacea. In fact, attempts to use the logic may generate formidable challenges in avoiding under- or over-investment when pursuing strategies based on knowledge assets and dynamic capabilities. ❐

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