# STRATEGY AND SHAREHOLDER VALUE CREATION: THE REAL OPTIONS FRONTIER

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We live in a period of heightened uncertainty. Our current business environment is being shaped by large-scale and long-term trends, such as deregulation and increased global competition, as well as the more recent arrival of the Internet. The convergence of these factors has sparked a search for strategic frameworks and capital budgeting tools that can help managers evaluate and manage uncertain opportunities.

At the same time, a promising new tool known as "real options" has attracted attention. Viewed narrowly, the real options approach is the extension of financial option pricing models to the valuation of options on real (that is, nonfinancial) assets. More broadly, the real options approach is a way of thinking that helps managers formulate their strategic options, the future opportunities that are created by today's investments.

Academics have long recognized that real options can bring the discipline of the financial markets to bear on internal strategic investment decisions. Glimmers of this thinking can be seen even in the earliest papers on financial options, including the now famous papers by Fischer Black, Myron Scholes, and Robert Merton in 1973. Another early and consistent advocate of this way of thinking has been Stewart Myers, the MIT finance professor who coined the term "real options" in an article published in 1984. In that article, Myers went so far as to say that real options has the potential to close the wide gap between strategic planning and finance. In Myers's words,

> *Strategic planning needs finance. Present value calculations are needed as a check on strategic analysis and vice versa. However, standard discounted cashflow techniques will tend to understate the option value attached to growing profitable lines of business. Corporate finance theory requires extension to deal with* real options.[1]

So why the *recent* wave of interest in real options? The short answer is, an increase in both supply and demand. On the supply side, there has been a growing body of academic literature illustrating applications of the real options approach.[2] A book by Avinash Dixit and Robert Pindyck published in 1994 codified this body of work and linked it to the larger literature on investment decisions under uncertainty.[3] Lenos Trigeorgis, who also

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1. Stewart Myers, "Finance Theory and Financial Strategy," *Interfaces*, January/February, 1984. pp. 126-137.
2. See www.real-options.com for a starter bibliography.
3. See Avinash Dixit and Robert Pindyck, *Investment Under Uncertainty*, Princeton University Press, 1994.

surveyed and synthesized the research on real options, organizes annual academic conferences on real options that further research efforts around the world.[4] Our own book, which attempts to make the insights of real options accessible to the general manager, was published in 1999.[5]

While the authors of these books would be happy to attribute the surging interest in real options to the power of their logic and prose, the underlying driver has been the times we live in. In an earlier era, most corporate investment decisions were made using discounted cashflow (or DCF) analysis—the right tool for the problem at hand. Analysts had a reasonably high degree of confidence in their forecasts of the future. And just as important, they could operate with the assurance that, once the project was accepted, the firm would attempt to run it pretty much according to plan. This does not mean that the business world was without uncertainty. But most product markets were stable and predictable, and there was seldom need for a sudden and major change in corporate strategy. When the risks on a project were larger than those incurred in the normal course of business, the most common practice was to increase the discount rate.

In the current environment, by contrast, there is greater need to understand how corporate strategy and execution interact with each other—and how that affects the value of business opportunities. Today's investment decisions often require analysts to accept that:

- they cannot, with confidence, see very far into the future;
- the company will make a first round of investment with the clear expectation that either the investment will need to be expanded or modified in the future if the project goes forward, or abandoned if things turn out poorly;
- management must consistently communicate to the public markets news of project success or disappointments, even before the project has generated positive cashflow.

In sum, the heart of the current demand for real options is management's need to position the firm to benefit from uncertainty and to communicate—both inside the firm and to the financial markets—the firm's strategic flexibility.

In this paper we provide perspective on both the supply and demand for real options. First, we tackle two questions we are often asked: "What is really new about real options?" It would be not just arrogant, but wrong to assume that we are the first generation of researchers or practitioners to have grappled with uncertainty. Much work has been done on this subject by applied mathematicians, in particular by those who study and practice in the well-established field of *decision analysis*.

We start by offering a definition of real options that is based on those risks in a corporate investment that can be tracked by portfolio of traded securities. So defined, real options are a subset of a company's strategic options. We argue that, under this definition, the applicability of real options is determined by industry and project features that allow tracking. When project and industry features lend themselves to the tracking of risks, such as in oil exploration, the real options approach is able to link the value and exercise of real options to shareholder value creation. But, when the value and exercise of investment options cannot be linked to risks priced in the financial markets, such as in pharmaceutical drug development, the value of strategic options is better captured by other frameworks such as decision analysis. In between these two polar cases are applications that require "hybrid" frameworks, a tailored mix of real options and other tools. We also argue that, as markets continue to securitize various risks and bundles of risks, there will be increased opportunity to track risk and thus link management's exercise of the company's real options to shareholder value.

The purpose of the first part of this paper is not to argue for one managerial tool or another, but to connect the appropriate choice of framework, and the reasons that drive the choice, to insights about investment decisions, valuation, and strategy. Understanding the when and how of tracking is an important issue at many companies that have built up large internal capabilities in decision analysis, and whose managers continue to ask "Why real options?"[6]

4. See Lenos Trigeorgis, *Real Options—Managerial Flexibiltiy and Strategy in Resource Allocation*, MIT Press, 1996. Conference information is at www.realoptions.org.

5. Martha Amram and Nalin Kulatilaka, *Real Options: Managing Strategic Investment in an Uncertain World*, HBS Press, 1999.

6. Although it may seem to some readers that we are drilling rather too deep into what is really a question of tools, we argue that by answering the tools questions, we better understand strategy under uncertainty.

In the second part of the paper, we look at another important issue for managers—the framing of real options applications. We illustrate our arguments by examining the valuation of Internet companies. Internet companies are of interest for two reasons. First, the need to value these profitless companies has created strong demand for real options. Second, these companies represent the same kind of investment opportunity faced by most "bricks and mortar" companies—opportunities that appear to be the key to value creation, but are far from generating positive cashflow. In the absence of positive cashflow, traditional tools don't work well.

Framing a real options application for Internet companies is a challenge because their options are less visible than in our two previous examples. The lack of visibility and prior industry investment experience increase the role of individual judgement in developing the frame. We use the example of Webvan, an online grocer, to illustrate three alternate frames that address the firm's future uncertainty. Which of the three approaches is most suitable depends on the focus of the analysis, whether it be valuation, identification of the logic behind the exercise of the real options, or analysis of the risks and consequences associated with specific scenarios.

The two main issues we tackle in this paper, market tracking of risk and framing, are also important in other sectors where there has been strong interest in real options. Conferences are now filled with practitioners speaking about their experiences in applying the concepts in industries ranging from cable television to biotech to venture capital. Academics have published studies of applications across a range of industries such as real estate development, forestry, and high-tech strategy.[7] In this wide range of applications, clarity about market-priced risk and framing will prove helpful.

Because of our focus on these two issues at the frontier of real options, this article is intended for readers with some basic knowledge of real options. Before moving on in this article, we encourage those new to real options to read the article by Aswath Damodoran that immediately follows.

## FROM STRATEGIC TO REAL OPTIONS

Although not a new concept, strategic options—the future opportunities that are created by today's investments—have recently attracted considerable attention in both the strategy and decision science literatures. For example, Ron Howard, one of the pioneers of modern decision science, commented in 1994 that "the prerogative to recognize and create options is too frequently overlooked in the framing and structuring of decision problems. This is a failure to recognize the sequential nature of most decision situations."[8]

Financial economists, who have labored for the most part independently of strategists and decision scientists, have struggled to make the broad sweep of strategic option thinking conform to the rigors of financial option valuation. When attempting to apply financial option models to real assets, academics and practioners immediately run up against a problem: some of the most significant sources of uncertainty that affect the value of strategic options are not "priced" in the financial markets. For many, the confusion on this issue sometimes gives the appearance that real options is nothing more than window dressing on concepts already explored in other fields.

We would like to propose that real options be defined as *the subset of strategic options in which the exercise decision is largely triggered by market-priced risk*, a risk that is captured in the value of a traded security. For example, oil price fluctuations are a market-priced risk because they are captured in the value of oil futures contracts. Risks not captured in the price fluctuations of traded securities are known as *private risks*. Assets with market-priced risk are associated with a wider set of opportunities because one can always acquire, reduce, or reshape the risk through a position in traded securities.

Our definition of real options may appear a bit fuzzy, but this is intentional. Securities markets are changing rapidly. What is private risk today may well be securitized in the future. Witness recent developments like telecommunications bandwidth trading, the creation of weather derivatives, and the wave of IPOs of young firms without profits. Each reflects the forces of

7. See the conference listing at www.realoptions.org and the bibliographies at www.real-options.com for further detail. Other useful introductions to real options for managers are Lenos Trigeorgis and Scott Mason, "Valuing Managerial Flexibility," *Midland Corporate Finance Journal* (Spring 1987) and Nalin Kulatilaka and Alan Marcus, "Project Valuation Under Uncertainty: When Does DCF Fail," published in this journal in Fall 1992.

8. Ron Howard, "Options," in *Wise Choices*, HBS Press, 1996, pp. 81–101.

securitization, the pricing of additional risk and return in the transparent public arena.

Securitization also has the effect of deepening existing markets, creating liquidity, and lowering transaction costs. Transactions costs and market liquidity affect one's ability to *economically* maintain a tracking position. There will be instances in which tracking will be imperfect and the decision to exercise an option will require judgment—instances in which the difference between a real option and a strategic option becomes blurred. A key question, then, for real options—one that arises from the presence of private risk in most applications—is the extent to which hybrid models are aligned with the pricing of risk in the financial markets.

**An Illustration of Perfect Tracking**

Tracking plays a central role in our definition of market-priced risk and in the accuracy of option valuation models. We provide an illustrative example of perfect tracking over one period to make the concept more concrete. To further simplify, we show the logic behind a portfolio that tracks a financial option, so as to avoid momentarily the complexities surrounding the tracking of real options. We then return to the tracking of real options immediately after the example.

A stock currently trades for \$20 and at the end of three months it will trade for either \$18 or \$22.[9] We are interested in valuing the option to buy the stock for \$21 at the end of three months. The option will pay off \$1 if the stock price is \$22 or \$0 if the stock price is \$18. The value of the option can be found by establishing the value of a portfolio of the traded stock with exactly the same payoffs as the option.

The first step is to find $\Delta$, the number of shares of the stock in the portfolio. To solve this problem, create a portfolio by writing (selling) an option and holding the stock. Construct the portfolio by choosing $\Delta$ such that the portfolio value at the end of three months is independent of the change in the stock price. In this case the portfolio has no stock-price risk and should earn the risk-free rate of return over the three-month period.

If the stock goes up to \$22, the portfolio is worth $\$22\Delta - \$1$. If the stock goes down to \$18, the portfolio is worth $\$18\Delta - \$0$. Choose $\Delta$ so that the two portfolio values are equal under the two price outcomes: $\$22\Delta - \$1 = \$18\Delta - \$0$, which simplifies to $\$4\Delta = \$1$ and so solves for $\Delta$ equal to 0.25. Thus, the portfolio consists of holding 0.25 shares of stock and writing (shorting) the option.

With $\Delta$ known, calculate the value of the portfolio in three months. This turns out to be \$4.5 for either stock-price outcome. The next step is to discount the portfolio by the risk-free rate to obtain its present value. If a 10% per annum rate is assumed, the present value of the portfolio is \$4.367.

Now find the value of the option. Since the value of the stock is \$20 and there are 0.25 shares in the portfolio, the value of the long stock position is \$5. Let f equal the current value of the option: $\$4.367 = \$5 - f$; and thus f is equal to \$0.633.

In this example the stock and the option are held in offsetting positions. Using the same logic, the value of the option can be tracked by holding a combination of the stock and risk-free securities, which creates a leveraged position in the stock. As the value of the stock changes, one repeats this type of calculation to update the number of shares to hold. This is known as "rebalancing" the portfolio. In a multi-period setting, the number of shares in the portfolio will change with both the stock price and the passage of time.

As this example illustrates, the quality of the option valuation depends on the opportunity to track market-priced risk. For example, if poor tracking leads to errors in the calculated number of shares in the tracking portfolio, there will be errors in the calculated value of the option. Real options are found in markets in which tracking is not as easy or cheap as for financial options, and thus it is important to have a clear understanding of when and why tracking might break down.

**Tracking Real Options**

To illustrate the difficulties in tracking market-priced risk, consider the real option to expand three assets, none of which is a traded security.

*(1) Copper Mine*. The option to expand will depend on the price of copper, and its net convenience value, which trades in liquid and well-functioning international markets that in-

9. This example follows that of John C. Hull, *Options, Futures and Other Derivatives*, Fourth Edition Prentice Hall, 2000, pp. 201–203.

**TABLE 1**
THE FOUR PHASES OF OIL EXPLORATION

| | Phases: Early Exploration | | Late Exploration | | Development | | Exploitation |
|---|---|---|---|---|---|---|---|
| Option Structure | Option on Option on Option on Underlying Asset | ⟵ | Option on Option on Underlying Asset | ⟵ | Option on Underlying Asset | ⟵ | Underlying Asset |

clude spot, futures, and a host of derivative instruments. The option to expand the mine can be well tracked.

*(2) Electric Power Generation Plant, Natural Gas Fuel.* The option to expand will depend on the spark spread—the price of electricity minus the price of natural gas adjusted for burner efficiency. While there are established gas and electricity markets that list spot, futures, and options, there is typically a large difference between local pricing and the market benchmarks. The valuation and execution of the option to expand the power plant will be imperfect and the quality of real option analysis will depend on the size of the tracking error.

*(3) Semiconductor Memory Plant.* The option to expand will depend largely on the price of memory chips. The chip market has a small number of key buyers and sellers, and the spot and the forward market transaction prices can be observed only sporadically. The option to expand the memory plant cannot be readily tracked by a portfolio of traded securities.

As this three-part progression suggests, there is a continuum of applicability for real options valuation models. The farther we move away from financial markets, the more difficult and costly to track the option. For many real assets, however, the distance between real and strategic options will shrink over time as more markets are completed. Partly because of this steady evolution of markets, assessing the extent to which a real option can be tracked in financial markets will remain an operational and subjective judgment.[10]

## The Real Options of Oil Exploration

Having defined real options, we now show why and how this definition can be implemented in the case of oil exploration.[11] There are lots of options in oil exploration—investments that open up opportunities to make additional investments in the future—and market-priced risk has a large influence on all exploration decisions, including those made in the earliest stages.[12]

Table 1 shows the stages of an oil field investment from exploration to extraction. This sequenced structure is common to many strategic option applications. In the oil and pharmaceutical industries, this sequence might cover a long period of time, as much as 12 to 30 years, and only a small fraction of projects—estimates range from 7-12%—actually reach completion. Each box in Table 1 indicates a stage of activity, and one makes the choice whether to continue or not at the beginning of each stage. Today, in most large oil companies the decision to continue at each stage is made using decision trees.

From the options perspective, the sequence has a very specific valuation structure. The first stage of exploration investment purchases the option to continue with the second stage of exploration investment, which in turn purchases the option to continue with the development stage, and so on. This is known as a "compound option" structure. When viewed as part of a sequence of options, each stage can be seen as a call option on the value of continuing with the exploration, a value that includes the value of all future options. There is a

10. Note that financial markets also operate with a degree of subjectivity. For example, before trading, professional traders not only look at the price, but the depth of the market, the direction of liquidity, and so on.

11. Oil exploration was one of the earliest applications of real options, with pioneering work by Paddock, Siegel, and Smith, "Option Valuation of Claims on Real Assets: The Case of Offshore Petroleum Leases," *Quarterly Journal of Economics*, 1988.

12. Our approach is to let the application at hand drive the use of the real options approach. An alternate approach is taken in papers by Jim Smith and Robert Nau,"Valuing Risky Projects: Option Pricing Theory and Decision Analysis," *Management Science*, 1995 and Jim Smith and Kevin McCardle, "Valuing Oil Properties: Integrating Option Pricing and Decision Analysis Approaches," *Operations Research*, 1999, which structure their analysis so that real options and decision analysis arrive at the same answer. While their results are correct, we find that clarity about real options requires an understanding of the differences and the source of overlap.

quantitative solution for valuing compound options that managers can use to answer two questions:

- Value: After accounting for the optimal exercise of all options, is the value of this property greater than the amount we will pay to acquire it?
- Optimal exercise: Given what we know now, is the best strategy to continue, to abandon, or to delay?[13]

We will argue below that oil exploration options should be treated as real options because, even after fully accounting for private risk, oil exploration decisions are strongly affected by market-priced risk and oil exploration options can be valued with reasonable accuracy by tracking portfolios comprised of oil securities.

**The Quantity of Oil is Unknown.** To make these ideas more clear, let us first examine the most simple case—that in which the quantity of oil is known and the only source of uncertainty is oil price fluctuation. Later we add complexity by letting quantity be uncertain as well. Also for simplicity we assume that, at the end of each stage, the choice is between continuing on to the next stage or abandoning. Often the option to delay is more valuable than the option to abandon—mainly because the option to delay contains the option to abandon—and our argument extends to this richer choice structure as well.

When quantity is known, one decides at the end of each stage whether to exercise the call option or not, whether to continue or abandon. The option value and exercise decision will be driven solely by oil prices, which can be tracked by a portfolio of traded oil securities in a manner similar to our illustrative example above.

The "prize" at the end of the option sequence is the extraction phase. At the start of the extraction phase, there is still uncertainty about oil prices that could change the extraction decision, but for simplicity we will ignore the option to cap the well when oil prices are low.[14] In this case, using discounted cashflow (DCF) to value the extraction phase is entirely appropriate. The operating rule "go under all states of the world" is correctly captured by DCF. The DCF of extraction functions as the underlying asset for the development option, and we return to the issue of how the underlying assets can be tracked below.

With quantity known, all risk in oil exploration can be tracked by a portfolio of oil securities using techniques standard in the financial markets. Hence this artificial example falls under our definition of a real option.

**Introducing Uncertainty about the Quantity of Oil.** Now let's add a dose of realism, uncertainty about oil quantity—after all, increasing quantity is the purpose of oil exploration! We will now show that, even with this private risk, real options offers important insights for oil exploration.

In this case, oil exploration effort produces two results: a revised estimate of quantity and a reduction in the range of uncertainty about the quantity estimate. Unlike learning about oil price volatility, in which one simply sits back and watches oil prices change, learning more about oil quantity costs money. And the results are not always good news. For example, one outcome of exploration is that, although one is more certain about the quantity, the estimate of quantity is now lower.

Methods for tracking a derivative security with price and quantity uncertainty are well established in the literature. For example, a 1984 paper by Alan Marcus and David Modest provides a model for tracking production decisions in the agricultural sector in cases when quantity uncertainty is a private risk, entirely uncorrelated with any traded security.[15] Consistent with this model, one might think of the release of oil quantity information as providing the basis for adjusting the scale of the tracking portfolio to the new reserve size. Thus the exploration decision, even in the early stages, remains highly exposed to oil price uncertainty. And since the exploration options are largely triggered by market-priced risk, oil exploration with price and quantity uncertainty falls under our definition of real options.

**Adding Another Uncertainty and a Choice of Technology.** As the final step, let us now add one last bit of realism to our oil exploration example by introducing an additional source of uncertainty as well as a choice of oil exploration technologies. The

13. Why would one delay exploration? To wait for oil prices to increase. Delay alone does not improve geological estimates of the quantity of oil, since that type of private uncertainty is resolved only by making exploration investment.

14. In practice price and quantity uncertainty remain at the start of the extraction phase, but for a number of industry-specific reasons, the option to temporarily shut down production is seldom used. This is an area in which a greater understanding of the value of the temporary shutdown option might change investments and behavior over time.

15. See "Futures Markets and Production Decisions," *Journal of Political Economy*, 1984. This paper assumes a simple form of quantity uncertainty. Two papers that incorporate Baysian learning about oil quantity are Robert Stibolt and John Lehman, "The Value of a Seismic Option," *Society of Petroleum Engineers*, #25821, 1993 and Bjorstad, Hefting and Stensland, "A Model for Exploration Decisions," *Energy Economics*, 1989.

additional source of uncertainty is known as chance of success (COS), which is the probability that oil can be extracted out of the geological formation. There are two exploration technologies—throwing out seismic sound waves (seismic) and drilling a set of oil wells (drilling)—that gather somewhat different bundles of information. Both generate a revised estimate of the reserve size. As a rough characterization, we assume that these technologies differ in that seismic exploration more effectively reduces uncertainty about the quantity of oil in the ground, while drilling exploration more effectively provides information about the COS.

How does the availability of two exploration technologies change the value of the exploration option and affect the exercise decision? What calculations are required to value the exploration option? The solution method is to start with the first stage of exploration. Value the project using each technology and choose the technology with the highest project value. Because the technology used in the first stage is one of the factors determining the optimal technology in the second stage, there is a simultaneous selection of the first-stage technology and the decision tree that displays the possible technology decisions in the second stage and beyond. Once the highest-valued exploration technology has been selected, the real options analysis proceeds much as before until the next technology decision.

Now think back to the tracking portfolios and the real options apparatus we have been building. None of it is helpful in making the exploration technology decision. Each technology produces a bundle of information, and choosing between information bundles is a "value of information" type problem—one that has long been studied in applied mathematics and decision science.[16] In a value of information problem, one pays to learn. The learning effort is designed to create the highest valued information in the shortest amount of time or with the lowest possible investment. The choice of exploration technology will depend on the relative size of various parameter values, such as the current estimate of the reserve size, the anticipated reduction in the range of uncertainty from exploration, the cost of each effort, and so on. These data are necessarily based on the judgment of experts.

Adding a choice of exploration technologies creates the need for a hybrid model for valuation and decision-making. First, decision analysis or another analytical tool is used to make the exploration technology decision. Then, with that choice in place, one implements the real options valuation model. At the end of the first exploration stage, the two-step model is repeated.

The particular structure of the oil exploration application makes each option exercise decision largely subject to oil price risk. Even when years away from producing revenue, the expected value of early-stage exploration decisions will change with oil price movements. Similarly, the value of oil exploration options is well-tracked by a portfolio of traded securities, even after including the private risk of exploration. Thus, while the overall structure of oil exploration with these three sources of uncertainty is that of a hybrid model, once the choice of technology is made, the option to explore is a real option.

**Tracking the underlying asset**. We would now like to return to a common concern in the application of real options—the ability to track the underlying asset. The underlying asset for the development option is the value of extraction, which we have argued is best calculated using DCF. When the analysis reaches this point, many real options papers simply assert the existence of "a twin security" that perfectly tracks the DCF value and then move on. The volatility estimate of the return to the twin security is used to estimate the expected volatility of the real asset's DCF value. This twin security approach feels very artificial to corporate practitioners, who often assume that if they can't readily identify the twin, the entire real options analysis breaks down.

Robert Merton, in his 1997 Nobel Prize address, provides a more transparent framework for establishing the value and risk of an underlying asset. Merton shows that even if the underlying asset is not securitized, its value can often be tracked by a portfolio of traded securities.[17] He also reviews the effect of market

16. David Skinner, *Introduction to Decision Analysis*, 1999, and Robert Clemen, *Making Hard Decisions*, 1996, are introductory references to decision analysis and the value of information. In decision analysis, the maximum value one would pay for information is the value gained from clairvoyance, the ability to see the future perfectly and thus make the optimal investment today. We note that this simple rule may not work well in a compound option. First, one may want to preserve future flexibility because the current investment will not fully resolve the private risk. Second, in a real options application, market-priced uncertainty will also affect the value of information—one would only pay to resolve uncertainty for all future states in which the follow-on-option is in the money.

17. See Robert C. Merton, "Applications of Option-Pricing Theory: Twenty-Five Years Later," *American Economic Review*, 1998, for a guide to the literature on how to implement this concept.

**TABLE 2 ■** THE FOUR PHASES OF PHARMACEUTICAL DRUG DEVELOPMENT

| | Phase I | Phase II | Phase III | NDA* |
|---|---|---|---|---|
| Years | 1 | 1.5 | 3 | 1 |
| Cost ($ mil.) | 15 | 30 | 200 | 7 |
| Probability of Success | 75% | 50% | 65% | 65% |
| Key Questions | Is the compound safe in healthy humans? What is the target condition? | Is the compound effective for the target condition? Is it safe? What is the right dose? | Is the compound safe and effective for large groups with the target condition? | Do the regulators think this is safe? What can we put on the label? |

Source: Navigant Consulting/SDG.
*New Drug Application.

imperfections on tracking options and underlying assets. These imperfections, which include infrequent trading, infrequent observability of trades or prices, and illiquidity, abound in real asset markets.

For practioners, there are two key insights from Merton's Nobel address. First, even with market imperfections, it is very likely that some kind of tracking can be established for the underlying asset. Real options novices often believe that the market imperfections and lack of an identifiable twin security are "showstoppers," but Merton's framework is a reminder that the logic behind options pricing can prevail. Second, Merton's arguments provide a rigorous definition of private risk. In many real options applications, the analyst subjectively determines which sources of uncertainty are private risk and which are market-priced. In the Merton framework, private risk is objectively defined and measured as the size of the tracking error on the underlying asset.[18] Thus, the identification of private risk is a question that can be resolved by the data, and the amount of private risk will be reduced over time with securitization. Merton's logic puts the burden of proof on the analyst. Instead of making assumptions about private risk, the analyst must dig deep and consider whether the risk might be even partially correlated with a portfolio of traded securities.

## Pharmaceutical Drug Development: Not Real Options

Table 2 shows the four stages of pharmaceutical drug development. As with oil exploration, the four stages can take years to complete and there is only a small chance that a project will make it through all four stages and on to sales. This structural similarity has suggested to many that pharmaceutical drug development is also a good candidate application for real options. And, as in the oil industry, most companies have internal staff trained in decision analysis—which again raises the question: "What's new about real options?" In this section we review the decision structure of drug development and the roles of private and market-priced risk. We find that we don't see lots of options in drug development, nor do we see a large role for market-priced risk to influence investment decisions.

Although pharmaceutical drug development has a sequence of decision points, as in oil exploration, there are two industry-specific features that affect its decision structure. The first is the assignment of decision rights—that is, who gets to exercise the option to continue. In drug development each stage is marked by a go/no go decision based on two parts. First is a ruling by the regulatory body, such as the FDA in the United States, as to whether the drug is safe enough to continue testing. The FDA's decision rights represent a large exogenous risk to the drug developer.

The second industry-specific feature is the lack of project abandonment. At the end of each phase, the developer will evaluate the results on a scientific basis. If the project, once completed, is expected to be hugely valuable (as is often the case in drug development), only a bad science result will

18. While this private risk may be sizable, it is not correlated with any market security (by definition), and is appropriately discounted at the risk-free rate.

keep the developer from continuing.[19] The probability of continuing with a given drug shown in Table 2 is determined by regulatory approval and promising scientific results—and there is little role for economic factors.

This analysis suggests that the four-stage pharmaceutical investment sequence should be seen as having two main decision structures. Before the large expenditures of Phase III, money is best spent gathering information to clarify whether the investment in Phase III should be made. In Phase III and after, drug development continues unless deterred by a bad regulatory or scientific outcome.

Turning now to the uncertainty of drug development, we think there are three reasons why a pharmaceutical drug development project does not lend itself to a real options application:

- There is no traded underlying asset or portfolio of traded assets that tracks project value reasonably well.
- A large amount of private risk is not resolved until just before launch, and thus the prior go/no-go decisions are largely triggered by the consideration of private risk.
- The most important questions in drug development are centered around the value of information, and in such applications real options has nothing to add beyond current tools.

The "prize" of drug development is the value of the drug once sales begin. Once in revenue, there are very few fixed costs associated with an individual drug. An operational rule of thumb in the industry is to raise advertising and marketing support commensurate with sales: if sales are trending up, spend more; if sales are weak, spend less. Hence, much of the value of a drug in revenue is driven by the level of sales.

Can a tracking portfolio be established for the value of a drug in revenue? We think it would be hard. First is the difficulty in building a tracking portfolio. Over two-thirds of drugs are sold in countries with managed health care expenditures.[20] These governmental programs have the effect of separating consumer drug spending from price signals, and so neither quantity or price is sensitive to industry or macro conditions. There are country-specific risks associated with managed care—such as the recent decision by Germany to cut payments for prescription drugs by half—but these are private risks, uncorrelated with other economic indicators.[21] Pharmaceutical stocks themselves are not good candidates for a tracking portfolio for the underlying asset because pharma companies are portfolios of drug projects. The private risk of each project is naturally diversified away at the portfolio level and pharma stocks have lower stock price volatility (about 25% annually) than most major industries. Also, the information revelations that move pharma companies' stock prices will be fairly different than the revelations that would cause revisions in the value of a single drug project. While our reasoning suggests building a tracking portfolio for a drug in revenue will be very difficult, ultimately this issue will be decided by the data.

A second reason that this application does not lend itself to real options is that there is an enormous amount of private risk that affects decisions in all stages of development. For example, in examining proprietary data for one of the blockbuster drugs of the past decade, we found that one year before launch the range of uncertainty about the present value of sales was ± 100%. The reason? The drug maker did not yet know the wording the regulatory body would allow on the label. The wording can dramatically enlarge or restrict the market potential for the drug. Other private risk that significantly affects value includes uncertainty about safety, efficacy, dosage, formulation, side-effects and so on. The effect of these private risks for development decisions is larger than the effect of fluctuations in the market-priced risk, even if the latter was well-established.

The third reason we don't believe real options applies to drug development arises from the type of information that is gathered in each phase.

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19. There is an exception to this statement in that typically a handful of drugs projects are killed for economic reasons at the end of Phase II. This is the first juncture with sufficient information for value-based decisions. Also there is strong desire to avoid the high costs of Phase III for marginal projects. Projects abandoned by one company may be of value to another, and hence there is a licensing market for Phase II drug projects.

20. Data provided by James Kierns, Ph.D., Boehringer Ingelheim Pharmaceuticals, Inc.

21. This risk is also diversified away at two levels. The multinational sales effort of most large pharmaceuticals will naturally reduce the exposure to country-specific risk. In addition, investors can further diversify it away.

Eduardo Schwartz and Mark Moon take a different approach in their paper, "Evaluating Research and Development Investments," which appears as Chapter 6 in *Project Flexibilty, Agency and Competition*, edited by Michael Brennan and Lenos Trigeorgis, Oxford University Press, 2000.. They assume that the value of a drug in revenue can be tracked by the value of a biotech firm, as often these firms have only one product in revenue. Their assumption can be tested empirically.

As we have mentioned, in the later phases the expected value of the drug is hugely positive, and drugs are seldom abandoned for economic reasons. From Phase III on, there are no significant options—just points of sudden death. Before Phase III, information-gathering investments are designed to rapidly seek the most valuable product performance and positioning in a multi-dimensional "white space." While the early phases of pharmaceutical drug development have some of the features of a strategic option—in the sense that today's investment creates a set of future choices—the real options toolkit seems largely irrelevant to decisions in pharmaceutical drug development. The industry has been using decision analysis to quantify its strategic options, which is an appropriate tool for searching out value and assessing the value of information. We don't see any pressing need for change.

## IMPLICATIONS FOR STRATEGY

Having examined two applications from the tools perspective, what insights can we gain about strategy in these uncertain industries? The risks and set of investment opportunities at the project level help us identify the skills required to manage the corporate portfolio of projects. In oil exploration we saw that market-priced risk is a trigger for early-stage decisions. Managers can make operational and strategic decisions that are fully aligned with market pricing; indeed, those who persist in basing decisions on private price forecasts and private estimates of volatility will find that, on average, they lose their company money. (If this is not the case, they should be in the oil securities trading business, where their insights can lead more directly to financial rewards!)

In addition, because the value and returns of the real options can be replicated by a portfolio of traded securities, there are significant opportunities to amplify or shed risk through financial engineering. Oil companies can be seen as portfolios of highly correlated projects, with limited opportunities to reduce corporate risk through diversification at the project level.[22] But they do have opportunities to hedge their oil price risk with derivatives. And because it is often more costly to create flexibility in physical assets than to purchase the same contingent payoff through a financial contract, oil exploration companies will find it important to have financial engineers on staff as well as geologists.[23]

How does strategy in pharmaceutical drug development differ? Because of the large private risk component, drug development projects are largely uncorrelated. Managing the stream of independent projects is key to maximizing corporate value. Investments are made to generate information and marginal projects are triaged to increase the value flowing through the system. Licensing opportunities—whether to acquire or cast off a drug in development—are often key to increasing the flow of value. Overall, the key corporate risk is the potential shortfall in the number of high-value projects. Project creation and selection are the critical skills, and the most valuable managers are those who can design investments to deliver the type of information that provides decision clarity.

As we suggested earlier, oil exploration and pharmaceutical drug development can be viewed as the two endpoints in the spectrum of market risk and private risk, with other companies and industries falling in between. In mining and other commodity industries, there is a high degree of market-priced risk, but also a larger amount of private risk than in oil companies. Consumer goods companies, which appear to be more like pharmaceuticals, also have market-priced risk. For example, the recent product introductions of Procter & Gamble (P&G)—a new mop, home dry cleaning, a vegetable spray—suggest that the company's key strategic skill is to create and select projects that command value in the consumer product space. Many of its product development investments are made to capture premium pricing for unique attributes. But P&G recently announced that its earnings have suffered due to a rise in the cost of two inputs, pulp and oil. This suggests that P&G, along with many other firms and industries in the middle of the spectrum, will need strong skills in financial engineering as well as the design of information-gathering investments.

22. There is a second source of correlation across projects: the cost of oil services. Oil services are a large component of the cost of exercise for exploration options and are also highly correlated with oil price. Thus, for example, rising oil prices may not lead to more valuable exploration options as the cost of exercise will have also increased.

23. The article by AlexanderTriantis on real options and risk management in this issue further addresses issues of real options and risk management. The article by Steve Grenadier on real options and game theory suggests that when private risk information flows across projects, the value of the exploration options may change significantly.

## VALUING AN INTERNET COMPANY

In the final section of this article we examine a topic of great current interest, the value of an Internet company. These companies, which often go public before becoming profitable, cannot be valued using the cashflow and EPS-based methods typically used by financial analysts.[24] Because traditional metrics don't work well, some have looked to real options to value the companies' growth opportunities.

To begin, it useful to distinguish between two types of Internet companies. For the first type, one has a clear idea of the industry and the business model for the firm when it reaches maturity. Amazon.com will grow up to be a cyber-Wal-Mart, Etoys promises to become a cyber-toy store, and so on. Real options can help both to value such firms and to think through their major risks because the value of the "prize"—the underlying asset for the growth options—can be replicated (albeit imperfectly) in terms of traded securities. The quality of the tracking will depend on whether the profitability and market structure of mature cyber-retailing will be similar to the current retail market.

The second type of Internet company is searching, but has not yet secured its business model or place in the value chain. Firms of this type include business-to-business exchanges such as ChemDex and PaperExchange and content sites such as iVillage and Slate. Searches by young Internet companies for profitable products and payment schemes are more open-ended than the information searches undertaken by drug and consumer goods companies. While pharmaceutical companies can't forecast the sales of a new drug, they do have strong expectations about how it will be sold, the level of the profit margins, and so on. In contrast, searches by Internet companies are rather unbounded, and a lengthy search process can put the company at risk. A successful search has two components. First, there must be a vision—in advance of the industry—about the new business model and competitive landscape. Second, as the firm conducts its search, it must retain the flexibility to adapt as needed, and even to change the business model if necessary. Thinking through the strategic options may be helpful in laying out these challenges, but we don't see a place for real options as we have defined it.

For Internet companies with an established business model at maturity, we argue that the underlying asset can be tracked and the growth options can be valued. The challenge in applying real options, however, is that the growth options are not terribly visible to outsiders, and prior experience in other industries may not prove a useful guide. From an external vantage point, the framing of Internet growth options—their number, time to expiration, cost to exercise, and so on—has a larger component of judgment than in established industries. In contrast to Internet growth options, financial options have terms that are well-specified and transparent. Financial option pricing models can be quickly and readily tested against market movements, and the feedback from such tests can be used to reduce model error. For real options in established industries, where the underlying economics, opportunities, and constraints are well understood, errors in the real options model can be also be bounded to some degree, although market imperfections and differences among real assets increase the role for judgement and the size of the model error. For real options present in Internet companies, there is potential for even larger model error since the options are opaque and the markets are new.

### The Case of Webvan

To illustrate our points, we now provide the outline of a real options valuation of Webvan, a firm whose expansion strategy is well understood by the financial community. After introducing Webvan, we first lay out a sequence of compound growth options, similar to the compound option structure discussed above. The compound option perspective highlights the requirements for successful exercise of each option. We then show an alternate frame appropriate for the high-level valuation of options-laden firms. A third framework, based on scenario analysis, highlights the interaction of financing and execution scenarios and helps to demonstrate how financial constraints may prevent the exercise of real options.

24. Elisabeth Demers and Baruch Lev study the non-traditional measures analysts are now using the establish the value of Internet companies. See "Rude Awakening: Internet Value-Drivers in 2000," working paper, Stern School of Management, New York University, April 2000.

Webvan is one of several companies that serve consumers who would like to order home-delivery of their groceries through the Internet. The traditional grocery market exceeds $400 billion in revenues per year, and online penetration is expected to reach $17 billion by 2004. Webvan and three other online grocery services are publicly traded. Webvan currently operates in two cities, and plans to expand to 26 metro areas by 2003. Webvan's strategy is centered around high-tech, and hopefully ultra-efficient, fulfillment centers built to its specifications in each metro area. Eight times the size of a typical grocery store, the fulfillment centers have the potential to generate 18 times the revenue.

Through fulfillment center efficiencies, Webvan aims to have higher-than-average grocery margins. Webvan's investments to this end include a $1 billion contract with Bechtel to build their fulfillment centers and a 10% stake in a conveyer belt company. In both cases, Webvan extracted an exclusive supply relationship in an attempt to preserve any proprietary fulfillment know-how.

Webvan's competitors in each metro area include head-to-head competitors that are also building infrastructure from the ground up, as well as regional grocery stores that are adding online services to their existing infrastructure. In one metro area a food distributor has developed an online presence. Most of the large, traditional grocery stores chains are hanging back or undertaking small experiments. They are expected to enter rapidly once the on-line model is sorted out, capitalizing on their available cashflow, supplier relationships, and distribution infrastructure.

What does Webvan's valuation look like when it grows up, when it is a mature cyber-retail store? Suppose Webvan is successful in expanding to 26 fulfillment centers by 2003. Revenue per center is expected to be $300-$400 million per year, for a total revenue of $8-$10 billion. Given that grocery stores trade for 0.5 to 1 times revenues, let's use an average market value to sales multiple of 0.75. This gives Webvan a valuation of $5-8 billion in 2003, at standard grocery store margins. Market value to sales ratios for discount retailers and express delivery services (UPS and Wal-Mart excluded) are also in the same range, so expansion across these products and services would not change the terminal value significantly. The "prize"—the underlying asset for Webvan's options to expand—can be tracked by a portfolio of grocery store and Internet stocks. The average annual stock price volatility of public grocery stores is about 50%.

## The Compound Options Frame

The art of the real options frame is to capture, at the right level of detail, the opportunity and tentative path for growth. This path has been a point of important discussion at Webvan.[25] In early 1999 Webvan's founder recognized that the then current expansion plan (12 cities in three years) would lead to a slow, steady rollout of fulfillment centers, with profitability in each, but would only result in one to two million online customers. As this was considered too few customers to provide a stable and defensible position, the company decided to accelerate nationwide expansion (26 cities in three years), and lined up a construction contract with Bechtel. In late June 2000, Webvan announced the purchase of one of its online rivals, HomeGrocer. Webvan's CEO commented that the merger would further accelerate expansion, increasing the number of metro centers served from six to 13 by the end of the year. The metro center rollout forms the basis of the series of expansion options. The cost of exercise for each option is expected to be $25 to $45 million for infrastructure and $3 to $5 million in working capital. Each option in the series can be exercised separately, so in any period Webvan can choose to stop expanding.

By specifying the options, we can obtain one of the most important benefits of the real options framework—identification of the risks that will prevent the full series from being exercised.[26] We see two big risks. The first is that revenue by metro area does not rise to a level that supports metro-area profitability, or that this growth is too slow. Among the most important drivers of this growth are penetration of online grocery shopping, the ability to add non-grocery store items to customer purchases, and the ability to create a customer

25. See Randall Strouss, *eBoys: The True Story of the Six Tall Men Who Backed eBay, Webvan and Other Billion-Dollar Start-Ups*, Crown Publishers, 2000.

26. Al Rappaport also used this type of real options logic to decompose the value of Amazon.com, and found that the value of the current business plus the value of the expansion options, on a broad-brush stroke basis, could not justify Amazon's valuation at that time. See "10 Pointers for Investing in Internet Stocks", *The Wall Street Journal*, February 24, 2000.

experience that establishes a unique reason to purchase online. These drivers are a mix of factors shared by other Internet firms and factors specific to Webvan. A fully fleshed-out compound option model would more fully specify these market-priced and private risks.

The second risk for Webvan is the possibility of financial distress. Two possible causes are slow revenue growth by metro center or an increase in interest rates that leads to a higher cost of funds, which in turn increases the cost of exercise of expansion options. (Webvan plans to issue high-yield debt to pay for the Bechtel work.) Again, a more full specification of the link between interest rate uncertainty and the cost of exercise would be required to make this framework operational.

Although we have not built out the full detail, the compound options framework generates important insights about value and risk. For example, it suggests two reasons we should expect relatively high volatility for Webvan and other Internet companies. First, compound options always amplify the volatility of the underlying asset. The amount of amplification depends on the time to maturity of each option, the cost to exercise, and other factors. But if the underlying asset has 30-40% annual volatility, it would not be unreasonable for an early-stage growth option to have nearly 100% volatility. Hence, one would expect Internet companies to be more volatile than their mature counterparts.

Second, changes in key inputs to an options-based model can lead to large revisions in value. Option value falls significantly when new information (for example, a disappointing quarterly earnings report) suggests that the current growth option might not be exercised, that the growth option is more expensive to exercise than previously anticipated, or that the mature business is less valuable than previously forecast. All three of these factors were present for Internet companies at the end of 1999, and the bad news broke the sequence of options, destroyed the layers of value, and resulted in a sharp downward revision in value across the sector. Note how difficult it would be to capture the affect of these factors in a traditional DCF analysis.

## Two Alternate Valuation Frameworks

We now briefly turn to two alternate views of Webvan's uncertain future that illustrate how the choice of frame drives the type of results obtained.

In a recent working paper called "The Rational Valuation of Internet Companies," Eduardo Schwartz and Mark Moon develop a "bird's eye view" of the valuation of an Internet company using an options approach.[27] In their framework, they specify the stochastic forms of revenues and revenue growth that reflect the exercise of real options, but without detailing the real options themselves. For example, revenue may spurt up in the short run—consistent with a burst of growth immediately after the exercise of an expansion option—but is expected to revert back to a lower long-run growth level. This top-level modeling strategy implicitly summarizes both investment behavior and market conditions.

Their second top-level modeling strategy is the treatment of bankruptcy. Schwartz and Moon's model assumes that the Internet firm becomes bankrupt when cash balances reach zero. Cash balances are a lagged function of past revenues, and thus their modeling approach introduces "path-dependency" into the option valuation—that is, current cash balances depend on past revenue. By comparison, the compound option approach we briefly described above does not explicitly model bankruptcy; it simply assumes that the firm stops expanding when conditions are poor.

The underlying assets in the Schwartz and Moon model are the value of revenues and the value of revenue growth. These are not assets per se, but the authors assume that in a market equilibrium the cashflows from revenues and revenue growth can be priced as if they were assets (and thus that investors can obtain the risk premium they would require for holding assets of this risk level).[28] Implementation of their model, as they demonstrate in a case study of Amazon.com, requires estimation of more than 20 parameters, highlighting a tradeoff present in all valuation models, precision and insight gained from detail versus additional model error introduced by a large number of parameter estimates.

Another strategy for understanding the value and risks of Webvan is to use a scenario-based

27. This paper will be published by the *Financial Analysts Journal* later this year.

28. As with the introduction of a twin security mentioned earlier, this type of assumption feels artificial to practioners—although it is frequently made in the academic real options literature.

approach. In recent work, Jay Goldman of Navigant Consulting/SDG examined the value and risk of Webvan using the tools of modern decision analysis.[29] Goldman examined potential online grocery strategies for three types of players:

- *National.* Capital-intensive, high-tech, large rollout.
- *Regional.* Less capital, less automation, small rollout.
- *Local.* Pick-from-the-store.

The cost structure and expansion plan are determined by the choice of strategy, and Goldman calculates the effect of a large number of uncertainties on the value of each strategy and its probability of execution success.

This type of analysis is one way to identify the risks that most strongly influence value. For example, Goldman found that capacity by metro center and fulfillment costs were the strongest drivers of upside potential or downside losses, not other often-cited factors such as online penetration, long-term market share, or start-up costs by metro center. In addition, Goldman found that the national strategy had the highest expected value, largely due to its potentially higher profit margins. The scenario-based approach also makes clear the risk created by Webvan's accelerated expansion plan. For example, Goldman finds that there is a significant chance (greater than 50%) that Webvan will need more than $1 billion in funding to meet its expansion plans, given all other uncertainties. (Concern about potential financial distress remains high in the financial markets, as analysts reportedly greeted the HomeGrocer announcement with a "big yawn" and were still looking for the path to profitability.) While not options-based, this type of analysis helps to rethink the expansion options and funding needed to execute them fully.

## IN CLOSING

Real options provides a powerful way of thinking about future business opportunities and what is required to obtain a fully mature business or fully developed project from an initial investment. For applications with a large component of market-priced risk, real options provides a complete quantitative framework. But when the application is largely driven by private risk, we find that real options cannot add insight beyond what is provided by other decision tools.

Our intent, however, is not to have a conversation about which tool applies where and when, but to think through the implications for corporate strategy. What is the right set of investment alternatives? How can the project or business model be redesigned to reduce risk? How tightly can we calibrate our thinking with information in the financial markets? These types of questions are informed by our tools-based discussion, but they ultimately take us to the frontiers where finance and strategy meet—exactly where Stew Myers put real options years ago.

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29. Copies can be obtained from Jay Goldman at jgoldman@sdg.com.

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