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Real Options and Their Impact on M&A

INTRODUCTION

This chapter explores one of the important frontiers of valuation: *real options*. Chapter 9 ("Valuing Firms") argues that the value of the firm is the sum of the present values of predictable cash flows and option value. Chapter 10 ("Valuing Options") explores the logic of simple financial options and their valuation using the Black-Scholes option pricing model. But in the broader perspective of M&A, finance, and business administration, financial options are a relatively small subset of the options a decision maker encounters. Financial options are distinct in that they are standardized, derived from an underlying financial asset, exchange traded, and therefore relatively easy to value. Real options are often unique, derived from nonfinancial (or "real") assets such as land, plant and machinery, patents, artistic property—these assets tend to be illiquid, and real options on these assets tend to be complex. Therefore, real options tend to be relatively hard to value. Real options remain a young subject; Stewart Myers introduced the term in 1977. Since then, real options thinking has emerged as a powerful influence on analysis in M&A. Today analysts and executives should strive to master real options thinking for at least four reasons:

1. Real options are *pervasive*. Whenever you hear a manager discuss notions such as "rights," "*flexibility*," or "commitments," that manager is describing a real option.
2. Real options will probably have a *big influence on firm value* where the firm growing, has the ability to do things other firms cannot, and/or has unique sets. Given the pervasiveness of real options in some industries such as gh technology, pharmaceuticals, defense, aerospace, and entertainment, e ratio of real option value to the total value of the firm could easily ex- ed 50 percent.
   ecutives and M&A deal designers *easily create and destroy real option lue*, with a potentially large impact on careers.
   timately, real options analysis *captures effects that DCF doesn't* as managers' d investors' behavior seems to show.[1] The common complaint about dis- unted cash flow valuation is that it fails to capture qualities about an asset

that are not reflected in the projected cash flows. Therefore, DCF alone misestimates the value of an asset. Managers' intuition tells them that there is more to many assets than meets the DCF analyst's eye. Real options treat the missing qualities. In addition, options thinking focuses on total risk (i.e., not just systematic risk), which most managers worry about.

The bad news about real options is that they can be complicated to value rigorously. This is because the kinds of contingent rights that businesspeople face may have these features:

- Exercise price may be contingent rather than fixed. It may be driven by a complicated formula, may vary over time, and/or may be subject to future negotiation.
- Expiration date may be contingent, rather than fixed. Many real options expire in stages.
- The value of the underlying asset may not be clear. Trading in the underlying asset may be limited or nonexistent, preventing the ability to observe the asset value. This implies that one must rely on imperfect estimates of value and volatility.
- Transaction costs may be high and/or contingent.
- The option may actually consist of a cluster of options, or a time-series of options, or options on options.

There are no simple approaches to modeling option value in these cases. Unless the problem can be broken down into simple pieces and analyzed using a familiar option pricing model, one must resort to using numerical methods that must be custom-tailored to each new valuation problem.

These difficulties notwithstanding, best practice in M&A draws on real options theory to:

- ***Estimate the value of optionality*** where the problem can be structured clearly and reasonable assumptions applied.
- ***Structure critical thinking*** about company values and/or deal design. Even if one cannot derive estimates of value in which one might have some confidence, real options thinking can lend discipline to a qualitative assessment of an M&A transaction, and help anticipate how options will affect value.
- ***Guide negotiation and problem solving.*** An understanding of real options can prepare one to adjust to proposals and arguments in the midst of a deal negotiation and to look for solutions when parties are at an impasse.

The aim of this chapter is to present an introduction to the subject of real options as applied to the M&A context. Specifically, it illustrates the kinds of situations where real option valuation may be warranted, as well as the kind of analytical work that a businessperson might strive to perform. More detailed presentation of analytic techniques is given in a number of resources recommended at the end of this chapter.

Some Generic Types of Real Options

Real options cluster into four common categories. This section describes these and considers their impact on shareholders and managers.

Entry or Growth Options

In 1977, Stewart Myers suggested that the value of the firm could be decomposed into two components: the value of assets in place and the value of growth options—rights to undertake new investments. Options to grow are like call options on new and uncertain businesses.[2] Perhaps the most prominent example of *entry or growth options* is investing in R&D projects. To invest in R&D is to buy an option on an uncertain, yet-to-be-discovered business.[3] Consistent with the concept, Chan, Martin, and Kensinger (1990) found that announcements of increased R&D spending are associated with a significant 1.38 percent gain in share value. Pharmaceutical companies face the opportunity to invest in these options every time a research scientist proposes a new product development project. A second example would be purchasing a territorial franchise for restaurants—this is the right to expand a business geographically. A third example would be purchasing drilling rights for oil or gas over a geographical range.[4] It would be rational to exercise these options when the present value of uncertain expected future cash flows exceeds the exercise price (i.e., the investment to commercialize the drug discovery, the cost of building the restaurant, or the cost to drill). Growth options, or options to enter a business, are *call options* on the underlying business activity. They are more valuable the longer the life of the option, and the greater the uncertainty about the value of the underlying asset.

Here's a simplistic example of how one might value an entry option. Suppose it costs $1 million to conduct the R&D necessary to prepare a prototype for market testing. Given the R&D efforts of competitors and the fickleness of consumers, you believe there will be a 20 percent chance that the product will succeed in the market, and that, if it does, it would be a business worth $10 million in present value terms. If the product fails, you would not proceed to bring it to market but rather write off the investment, at which point the value of the business will be zero. Should you proceed?

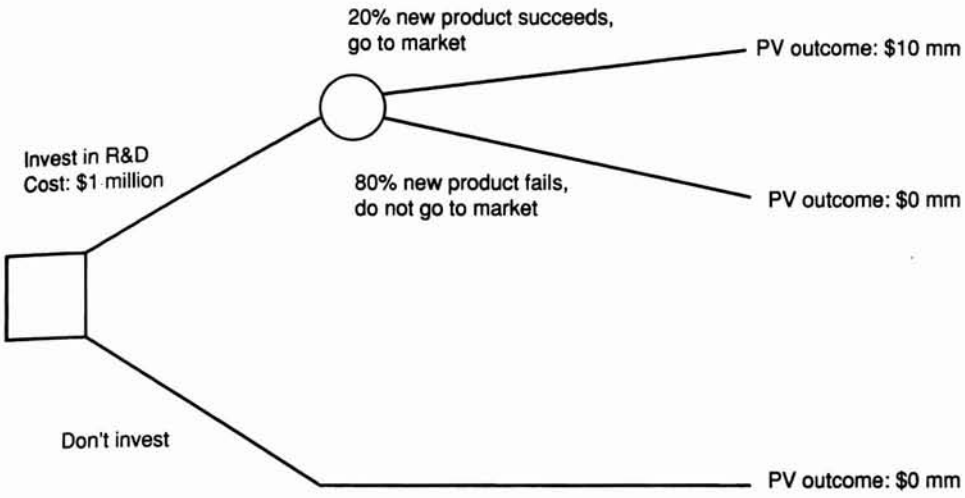
Exhibit 14.1 gives the problem expressed as a decision tree: "go/no-go." The calculation reveals that the decision to invest in the R&D creates more value than the decision not to invest. How can this be? The project is costly, and the odds of success are low. The answer lies in the asymmetry of outcomes: You have a right, not an obligation, to proceed once the R&D and product testing are complete. You will choose to exercise the option if it is in the money, and otherwise won't exercise it. Investing in the R&D gives you the right to invest later in a new research breakthrough if such an investment appears to be in the money.

Exit or Abandonment Options

Being stuck in an unattractive business without a viable exit is one of the worst situations for a firm. For instance, a diversified firm owned a coal tar refinery that had operated for over 100 years. The facility was inherited in an acquisition many years earlier. The plant was antiquated and inefficient. Furthermore, the market had

EXHIBIT 14.1 The Growth Option

Problem: You must decide whether to invest $1 million in a research and development program. If the program succeeds, you believe it will generate a business worth $10 million in present value (PV) terms. If it fails, the PV will be zero. You believe the program has only a 20 percent chance of success.



The decision to invest will be decided in this example on the basis of value maximization: invest if value is created. The value of the "invest" branch of the decision can be modeled:

$$\text{Value} = -\$1 + (0.20 \cdot \$10) + (0.80 \cdot \$0) = \$1 \text{ million}$$

turned highly competitive, making the refinery extremely unprofitable. The firm wanted to exit the business, but couldn't because doing so would trigger environmental cleanup obligations from chemical leakage over the years.[5] Nuclear power plants, petrochemical plants, and many manufacturing plants face exit costs that can ruin the economics of a business as it approaches its end. Another example of being stuck is encountered by a minority investor in an underperforming private firm—even if a minority investor wanted to exit, his or her investment could be stranded if the securities are illiquid. Such would be the case until the majority investor decides to sell the entire firm.

The right to sell an asset or abandon a business (*exit or abandonment option*) is valuable—such is the case with all insurance policies, exit or termination clauses in business contracts, and government guarantees of pension obligations. All of these are *put options*, valuable to the option holder and a liability to the counterparty. Put options are discussed in Chapter 10.[6]

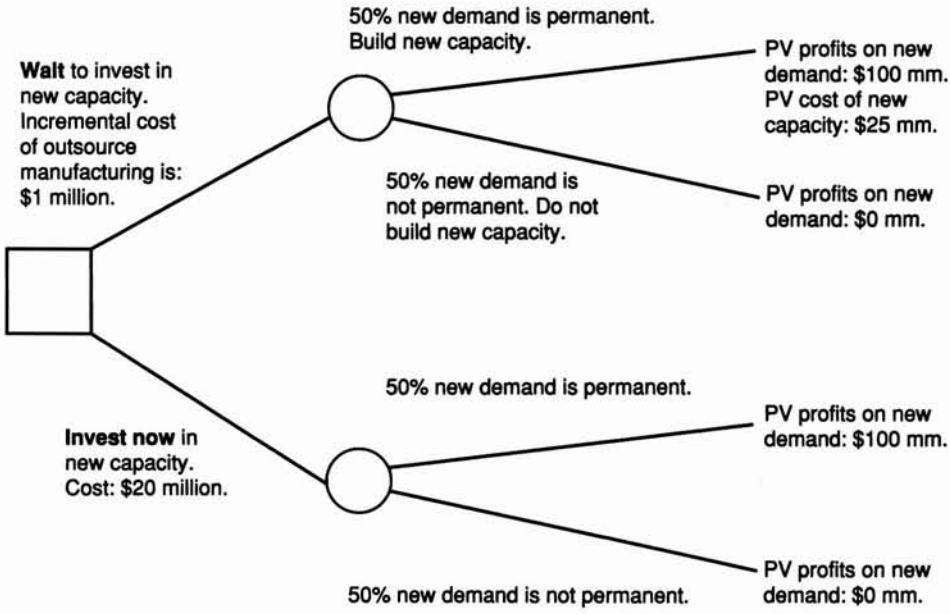
Timing Options: Rights to Delay or Accelerate

The rights to delay or accelerate the investment in an asset (*timing options*) are valuable, and exist in an American option, which may be exercised at any point up to expiration. European options are exercisable only at expiration.

- Consider the *right to defer*: Suppose your firm needs to meet growing demand and contemplates construction of a manufacturing plant. Demand is uncertain; you harbor doubts about the firmness of the increased demand and believe that with a year's experience you will learn whether the increased demand is permanent or temporary. By negotiating an outsource manufacturing contract with another firm for the new product, you can essentially buy the right to wait on investing in the new plant until uncertainty about the new demand has been resolved.[7] The value of delay is evident simply in the impact of time on option value: The longer the time to exercise, the more valuable the option. Exhibit 14.2 gives an example of comparing investing now versus after a delay.

EXHIBIT 14.2 The Option to Delay

Problem: You must decide whether to invest now in new manufacturing capacity, for an outlay of $20 million, or wait a year. If you delay, you must engage a contract manufacturer that will cost your firm $1 million more to produce goods than if they were produced at the new plant. To further complicate your reasoning process, demand for the product is uncertain. There is a 50–50 chance of the demand generating a new business with either a present value of $100 million or a present value of zero. If you delay, the new plant will cost $25 million next year.



The decision to go now or delay will be decided in this example on the basis of value maximization: delay if value is created. The value of the two branches of the decision can be modeled:

$$\text{Value of "wait"} = -\$1 + [0.50 \cdot (\$100 - \$25)] + (0.50 \cdot \$0) = \$36.5 \text{ million}$$

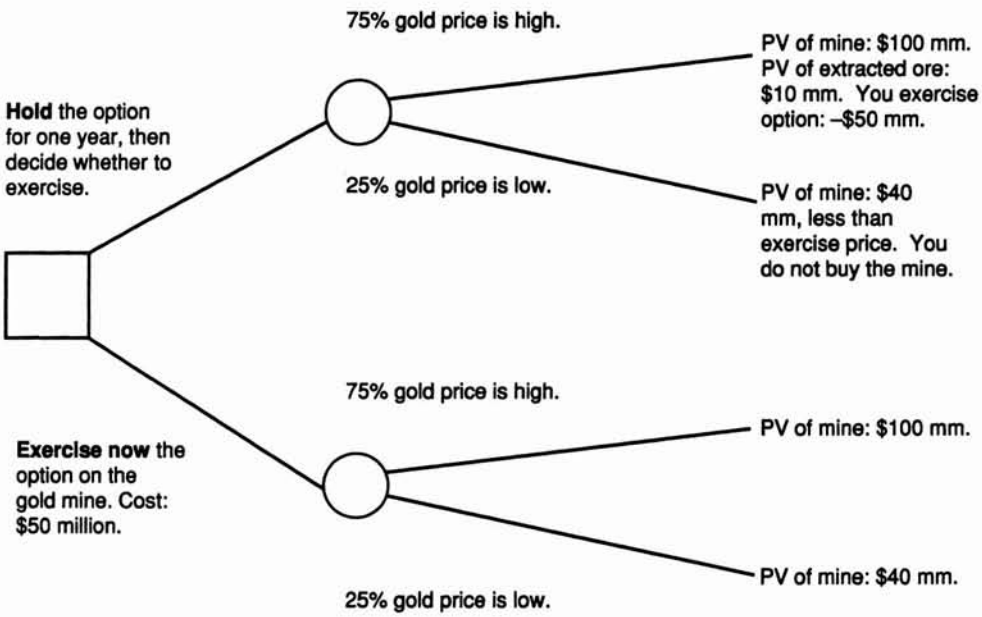
$$\text{Value of "invest now"} = -\$20 + (0.50 \cdot \$100) + (0.50 \cdot \$0) = \$30 \text{ million}$$

In this example, it pays to wait because of the high uncertainty about the value of the underlying asset (i.e., new demand).

- The *right to accelerate* may be valuable where the underlying asset throws off a high cash flow or is a wasting asset. This is a problem of leakage of value in the underlying asset, and could result from dividends paid out, costs of storage and insurance, taxes, and licensing or royalty fees. Leakage of value is a classic problem in the analysis of options. For instance, suppose that you have an option to purchase a gold mine, and that you strongly believe the price of gold will remain stable over the life of the option. Until you decide to exercise the option, the owner of the gold mine will extract the richest lodes of ore first, imposing on you a cost of the lost opportunity. Depending on the price of gold, it might be rational for you to buy the mine immediately in order to enjoy the high current flow of cash. Exhibit 14.3 offers an example of comparing

EXHIBIT 14.3 The Option to Accelerate

Problem: You already own an option on a gold mine, exercisable at $50 million. You believe the mine has a present value of $100 million if the gold price is high, and $40 million if the gold price is low. The price of gold is uncertain with a 75% chance the price will be high and a 25% chance that the price will be low. The current owner will continue to extract ore worth $10 million during the life of the option.



The decision to hold the option or exercise now will be decided in this example on the basis of value maximization: delay if value is created. The value of the two branches of the decision can be modeled:

$$\text{Value of "hold"} = [0.75 \cdot (\$100 - \$10 - \$50)] + (0.25 \cdot \$0) = \$30 \text{ million}$$

$$\text{Value of "exercise now"} = -\$50 + (0.75 \cdot \$100) + (0.25 \cdot \$40) = \$35 \text{ million}$$

In this example, the wasting value of the asset is decisive. Given the relatively high confidence about the value of the underlying asset, it pays to exercise now and appropriate the value of the ore that will be extracted over the next year.

the purchase of the gold mine now versus later. Another example would be where a competitor threatens to enter the same business, by adding new capacity or product features, for instance, and thereby decreasing the attractiveness of that business to your firm. In such a context, early exercise of real options on capacity or product features could serve a strategic purpose of preempting the competitor.

The decision to defer or accelerate a transaction is driven by an assessment of the value of the underlying asset over the life of the option. In the first case, the "asset" is the present value of cash flows—where uncertainty of demand is large enough, it will pay to wait and see how things turn out. In the second case, the "asset" is an ore body that will decline in value with reasonable certainty over the life of the option—the question is who will capture that change in value, you (the option holder) or the current owner?

Switching Options

The flexibility to switch from one operating mode to another can also be valuable.[8] For instance, consider an electric power company that must choose whether to build a plant that runs on coal only, versus a plant that will run on coal and natural gas. The coal-only plant is cheaper by $200 million, but the option to switch is valuable. The question is, does the value of the *switching option* compensate for the higher cost of the plant? Exhibit 14.4 gives an example that shows that the right to switch more than compensates for the cost of the option—here, the uncertainty is high enough to make the opportunity to switch highly valuable.

WHERE REAL OPTIONS APPEAR IN M&A

Real options are pervasive in the field of M&A in strategic planning, deal design, and postmerger integration.

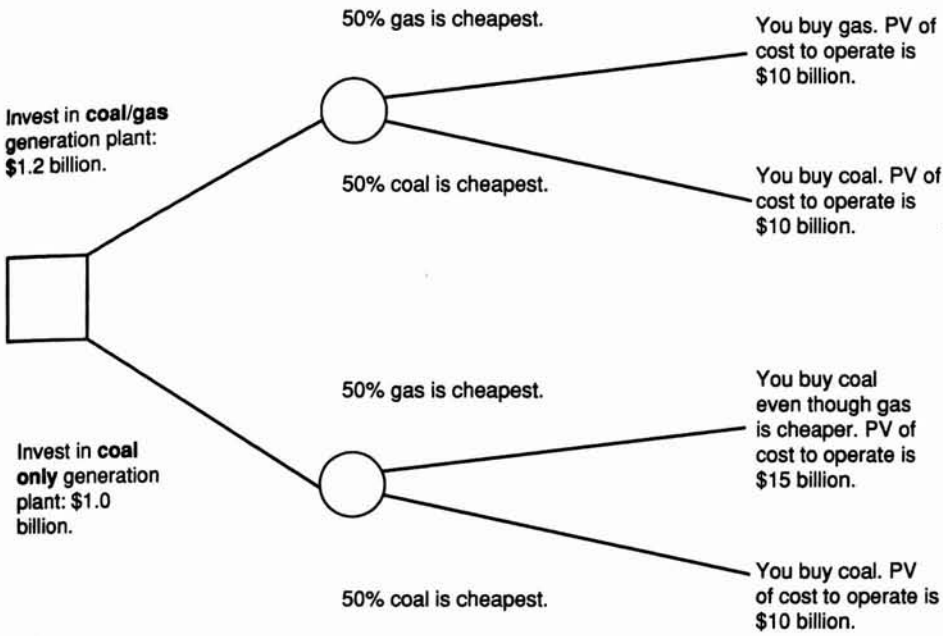
Strategy

Perhaps the most fertile area for application of real options thinking is in the area of strategic design. In general, real options valuation can add rigor to strategic thinking by virtue of its ability to assess the economic consequences of creating (or destroying) flexibility or making (or relaxing) commitments. For instance, strategists are concerned about:

- ***Flexibility versus irreversibility of actions.*** Acquisitions can create or destroy flexibility. Irreversible investments entail commitments that expose the firm to risks. In contrast, flexible investments can be altered as conditions change. Flexibility is an option on an alternative strategy and is enabled, for instance, by holding excess manufacturing capacity, excess inventory, or excess cash. Womack et al. (1990) emphasize that management techniques such as lean manufacturing grant strategic flexibility. The valuation of flexibility using real option theory has been the focus of extensive discussion.[9]

EXHIBIT 14.4 The Option to Switch

Problem: You contemplate investing in a power plant. The question is whether to commit only to coal-fired generation or to another configuration that is fueled by either coal or natural gas. The coal-fired plant requires an investment of $1 billion. The coal/gas plant requires an investment of $1.2 billion. You believe that in half the future states of the world coal will be cheaper, and in the other half, natural gas will be cheaper.



The decision to hold the option or exercise now will be decided on the basis of value maximization—in this case, revenues are assumed to be the same under both alternatives, so we focus only on cash outflows such as investments and operating costs. Thus, the decision reduces to minimizing cash outflows. The value of the two branches of the decision can be modeled:

$$\text{Value of "coal/gas"} = -\$1.2 + (0.50 \cdot -\$10) + (0.50 \cdot -\$10) = -\$11.2 \text{ billion}$$

$$\text{Value of "coal only"} = -\$1.0 + (0.50 \cdot -\$15) + (0.50 \cdot -\$10) = -\$13.5 \text{ billion}$$

In this example, the ability to switch between coal and gas is more valuable than the marginal cost of the right. Given the relatively high uncertainty about the value of the asset underlying the option, it pays to buy the coal/gas configuration.

- ***Insurance.*** Some strategic actions can hedge a firm's exposure to risks. Insurance is analogous to a put option.
- ***Learning and competencies.*** Training and learning by doing create a more flexible workforce, and this flexibility constitutes a valuable real option. Similarly, at the corporate-wide level, gaining more know-how creates strategic competencies that are valuable. Acquiring strategic capabilities through M&A is a common motive for transactions.[10]

- ***Planning.*** Boer (2002), Tufano (1996), and Sahlman (1997) argue that options thinking generally can advance corporate strategic planning. For some firms, the option value as a portion of total value will be high; for others it will be low. The proportion may vary by industry and by phase of the firm's life cycle. For instance, Exhibit 14.5 provides a matrix based on Boer's theories and findings. In the northeast quadrant, eBay and Human Genomics hold rights to unusual new intellectual property that has yet to be fully developed but that has high commercial potential. In the northwest quadrant, Microsoft and Dell have unusually strong market franchises that grant them some annuity-like business, but also have high option value because of strong flexibility. In the southwest quadrant, Duke and General Mills have strong franchises that grant economic value. And in the southeast quadrant, two bankrupt firms have relatively low economic value and option value. Boer argues that firms can migrate from one quadrant to the next and that strategic planning is about the migration process.

Consider these possible applications of real options. Common to many of these is an expression of the value of learning incrementally before jumping fully into a field:

- ***Buying a toehold minority interest before completing the acquisition.*** Some buyers prefer to get to know the target by buying an interest in the firm, taking a board seat, and generally observing the target up close before completing the full acquisition. Arnold and Shockley (2001) showed that Anheuser-Busch effectively exploited this strategy in overseas acquisitions.
- ***Buying a built-up company versus building up the same assets yourself.*** The buildup approach (also known as the "platform acquisition strategy") makes a series of acquisitions that lets you learn about the business as you go.[11] This process of staged investing permits the buyer to decide at each point whether to expand or stop.
- ***The virtue of being a second mover.*** While the "first mover advantage" and "winner take all" were much touted during the Internet bubble, the more sober perspective in recent years has been the benefit of watching someone else make

EXHIBIT 14.5 Matrix of Hypothetical Economic Value and Option Value

	Economic Value	
Option Value	**High**	**Low**
High	Microsoft 2002 Dell Computer 2002	eBay 2002 Human Genomics 2002
Low	Duke Energy 2002 General Mills 2002	United Airlines 2002 Bethlehem Steel 2002

Note: This suggests that firms can differ greatly in their composition of assets, that is, between real option value and the value of assets in place.
Source: Author's analysis, after a framework presented by Boer (2002), page 142.

the laborious market discovery—and then following rapidly. Excel followed Lotus and Visicalc. Cottrell and Sick (2001) and Tufano (1989) explore the reputed virtues of the first mover advantage.

- ***Rights to exploit an uncertain resource.*** This is especially important in fields such as natural resources, talent, and intellectual property. In two separate studies, Weatherford and Bodily (1988) and Bruner (1988) valued the right to drill in a natural gas field using option valuation techniques and illustrated that the value of the right varies directly with the volatility of gas prices.
- ***Acquisition search.*** Real option theory may offer an avenue for identification of attractive targets based on undervaluation. The equity of a levered firm can be modeled as a call option on the assets of that firm. Rappaport and Mauboussin (2002) use this approach to compare potential and imputed real option values to determine buy and sell strategies.

Deal Design

Transaction structures are usually studded with rights and commitments—these are options.[12] The formal contract is structured as a contingent right: If terms and conditions (i.e., laid out in the representations, warranties and covenants) are satisfied, then the buyer may proceed to acquire the target. Real options in deal design appear in many guises:

- ***Exchange offer.*** A buyer typically approaches target shareholders with an offer to buy the shares at a stated price, and within a given time—the buyer in effect grants a put option to the target shareholders. The shareholder (typically an arbitrager) must implement a strategy to manage the option value inherent in the offer.
- ***Breakup terms.*** Topping fees and penalties for not completing the deal are rights to payments in the event of nonperformance by one party or another. These are contingent payments and therefore options.
- ***Liquidity and control features.*** Chapter 15 argues that the ability to sell an asset on demand is like holding a put option. Having control is like holding a call option on future strategy.
- ***Contingent payment schemes.*** Chapter 22 describes the use of earnouts. Generally, contingent payments are call options on uncertain future performance.
- ***Transaction risk management.*** Caps, collars, floors, and contingent value rights are protections given to selling and/or buying investors to limit the uncertainty they may face in concluding the transaction. Chapter 23 describes transaction risk management in more detail.
- ***Takeover tactics.*** Chapter 33 illustrates that defenses such as poison pills, lockups, and control rights are options.

Postmerger Integration

Many of the options embedded in the transaction structure expire when the deal is consummated. But these are replaced with other options that are created on closing. Chapters 36 and 37 outline practices associated with successful integration efforts. Real options appear in postmerger integration in various guises:

- ***Designing organizational and operational architecture.*** Integration may entail designing a new architecture for a firm. Architecture can create or destroy flexibility and commitment, two overarching dimensions of optionality. An illustration of the creation of flexibility is apparent in the trend toward "modularization" of manufacturing. Complex business processes and products can be organized into subunits, called "modules," that permit specialization, encourage greater innovation, and promote efficiency. Baldwin and Clark (2000) argue that modularity confers flexibility through operators such as splitting a system into two or more modules; substituting one module design for another; augmenting (adding a new module to a system); excluding a module from the system; investing to create new design rules; and porting a module to another system. The innards of any personal computer and the success of Dell Computer illustrate the fruits of modularity: Architectural flexibility pays.
- ***Structuring contracts for human resources.*** Incentive compensation may explicitly employ options, or less directly embed contingent payments into an employment agreement. Investments in training and knowledge transfer systems may create flexibility for the organization.
- ***Selection among competing capabilities.*** Capabilities create flexibility and therefore option value. Especially in mergers of equals, integration planners will face tough choices among business plans, practices, facilities, and so on within the merging firms. Real options analysis may be relevant to illuminating the consequences of alternatives.

IF OPTIONALITY IS SO PERVASIVE, WHY NOT VALUE EVERYTHING AS AN OPTION?

Option valuation is costly to do well and therefore not frequently employed. Other valuation techniques are widely used. And most importantly, not all investment decisions regard options. Real options analysis may not be worth the trouble unless options are clearly present and they are *incremental* to the decision (i.e., when they may make a difference in a go/no-go or either/or choice). Otherwise, DCF or some other valuation technique will probably satisfy the analytic need.

When are options present? The simplistic answer is that an option is present anytime one hears the words "rights," "flexibility," and "commitment." Given that these are such broad terms, it is worthwhile to sharpen our definition of options by considering what options are *not*. Let's distinguish options (where it is appropriate to use our option valuation tools) from opportunities (where it is less useful to do so). Here are five criteria that distinguish an option:

1. ***Identifiable underlying asset.*** An option is a right regarding some other asset or good. Can you identify it?
2. ***Exclusive.*** Options give the owner a special right that others do not have. Is this right exclusive to you?
3. ***Contingent.*** The value of an option derives from the value of an uncertain underlying asset. Can you identify the contingency or uncertainty?

4. *Costly to acquire.* Options are valuable, and are costly to acquire. Was the right costly to acquire?
5. *Time constrained.* An option has a finite life.

Real options may not affirmatively meet all five criteria, but the closer they come to doing so, the more appropriate it will be to use the valuation techniques outlined in this chapter. Exhibit 14.6 summarizes the differences seen in *options versus opportunities.* To illustrate the logic involved in parsing options from opportunities, consider these two situations. Would you use option valuation in these cases?

1. *Right to sell lemonade at your street curb.* Children experiment with this simple act of market entry that is virtually free, unregulated, and with no entry barriers. Cheap and nonexclusive market expansions like these are opportunities, while costly and exclusive market expansions are options. This illustrates the importance of *exclusivity and cost* as distinguishing features of an option.
2. *Franchising versus generic.* Exhibit 14.6 sketches two food service situations. One is a costly franchise right, and the other is the regular opportunity to open a generic restaurant. The franchise right is an option: costly, exclusive, finite-lived, and contingent; the right is distinguishable from the eventual investment. In the case of the generic restaurant, there is no cost to acquire the opportunity; it is not exclusive; its life is not finite; and the opportunity is indistinguishable from the underlying investment.

The point is that despite the pervasiveness of choices, not all are options. Some options (such as deep-in-the-money no-brainers) may not even be worth valuing. Real option valuation is challenging but worthwhile when the asset values are uncertain, the rights are exclusive, the decision can be freely and rationally made, and the rights are costly to acquire.

HOW TO ASSESS THE IMPACT OF REAL OPTIONS

This section of the chapter gives a practical overview of real option valuation. The critical first step is to identify real options present in the situation. Next, one values the real options drawing on any of four approaches. Finally, one must interpret the results carefully.

Find and Specify the Option

One of the limitations of discounted cash flow valuation is that it does not necessarily capture well the strategic aspects of capital investment. Such strategic elements include the right to make future investments, the right to sell or liquidate in the future, the right to abandon, and the right to switch investments. All of these rights are indicators of *managerial flexibility*; flexibility is analogous to a long call or long put position: It gives the holder rights to take action.

EXHIBIT 14.8 Comparing Options and Opportunities

	Option	Opportunity
Identifiable underlying asset. An option is a right regarding some other asset or good. Can you identify it?	The underlying asset can be identified and is separate from the option.	The focus of the opportunity can be identified, but is indistinguishable from the right.
Contingent. The value of an option *derives* from the value of an uncertain underlying asset. Can you identify the contingency or uncertainty?	Whether you would exercise the right before expiration is uncertain. The sources of uncertainty are identifiable. The value of the right is contingent.	The value of the opportunity *is* the value of the underlying asset. Whether you will exploit the opportunity depends on whether the NPV > 0.
Exclusive. Options give the owner a special right that others do not have. Is this right exclusive to you?	A right held by one or only a few. Options are exclusive rights.	Opportunities are not exclusive.
Costly to acquire. Options are valuable and are costly to acquire. Was the right costly to acquire?	Resources are deployed to gain the option.	Opportunities are free.
Time constrained. An option has a finite life.	The life of the option is finite and identifiable even with reasonable guesswork.	Opportunities are often not time constrained.
Example	Right to start up a business under an exclusive fast-food franchise that you purchased, that expires within three years unless you open one or more outlets, and that requires further spending to exercise. You are the exclusive franchisee in your territory. Whether and where you exercise the right is contingent on the results of a market survey, on zoning rulings by government, and on actions by competitors.	Opportunity to open a restaurant in your community under a generic name, "Downtown Grille." You didn't pay to acquire this opportunity. There is not much uncertainty: You can rent the perfect location that will deliver a steady clientele. It looks like a good deal already.
Valuation	This is an option-valuation problem. Value the franchise right using an option valuation methodology.	This is an investment-valuation problem. Value the investment opportunity using a conventional method such as DCF.

Another class of strategic elements appears when managers promise to do certain things in response to others—for example, invest more heavily if a competitor enters a market or acquires a new technology, buy if others choose to sell, sell if others choose to buy, and so on. These promises amount to *managerial commitment*; commitment is analogous to a short call or short put position.

Flexibility can be characterized as rights to "get" (i.e., call options) and rights to "give" (i.e., put options). Flexibility creates an economic asset; commitment creates an economic liability. All simple real options can be classified on these two dimensions—Exhibit 14.7 gives a two-by-two matrix that can help the practitioner classify a real option in technical terms. For instance, flexibility to acquire new technology amounts to a long call; flexibility to sell the new technology amounts to a long put. On the other hand, commitment to sell the new technology to someone else whenever the other party desires amounts to a short call position; commitment to buy the new technology from someone else whenever the other party desires amounts to a short put position.

Options and their values can be assessed in general terms for three considerations:

1. ***Direction.*** Who holds the option? Who is the counterparty? Does the option create or destroy value for your position? These questions of *direction* fundamentally seek to establish whether the position is long or short and put or call.
2. ***Materiality.*** Option valuation is complicated, and not something to launch into without a high probability that the answer to the analysis will make a difference. Where the decision is important, the valuation analysis based on discounted cash flow seems close, and/or the assets under option are sizable, the option values will be likely to have *materiality* and make a difference.

EXHIBIT 14.7 Classification of Real Options in Technical Terms

	Flexibility (Long Position)	Commitment (Short Position)
Right to "Get" (Call Option)	You have the flexibility to "get" or buy an asset from someone else at a predetermined price. You have a *long call option position.*	You have committed to someone else the right to "get" or buy at a predetermined price. Thus, you have a *short call option position.*
Right to "Give" (Put Option)	You have the flexibility to "give" or sell an asset to someone else at a predetermined price. You have a *long put option position.*	You have committed to someone else the right to "give" or sell to you at a predetermined price. Thus, you have a *short put option position.*

Note: This table suggests some of the economic consequences of different real option positions. All flexibility creates economic assets (long positions). All commitment creates economic exposure or liabilities (short positions).
Source: Author's analysis.

3. *Key value drivers.* Options are more valuable the deeper in the money, the greater the uncertainty, and the longer the life. Attributes of the assets underlying real options may also create a host of key *value drivers.*

Model and Value the Option

The analyst has four general alternative approaches for valuing real options:

1. ***Value the real option in the framework of an existing equation.*** Equations that solve for option value are partial differential equations. The Black-Scholes equation is the first, simplest in its class, and best known. Using the Black-Scholes model is fairly easy, since with the aid of a standard program in a spreadsheet or handheld calculator, the answer is a few keystrokes away. The problem is that few real options correspond to the assumptions of this venerable model: European call option with a finite life, known value of the underlying asset, and independent of other actions. Since the Black-Scholes model was published in 1973, numerous other equations have been published that correspond more clearly to real options situations. However, most of these newer models will be beyond the reach of the trained business analyst. Therefore, many analysts simply default to using the Black-Scholes model and accept that the resulting estimates may be imperfect. Chapter 10 illustrates the application of the Black-Scholes model to value call options.
2. ***Fit the option in a framework of a binomial lattice.*** Cox, Ross, and Rubenstein (1979) outlined an option valuation approach based on the assumption that the value of the underlying asset follows a *binomial lattice* (branching) process. If the valuation is risk-neutral, the probabilities implied in the branching process permit the analyst to discount the ending values to the present at the risk-free rate, a rather convenient assumption. The binomial approach entails six steps:

    1. Grow the lattice (or "tree") of the underlying asset value over time.
    2. Assess the probabilities of an up or down movement. These will be driven by the risk-free rate of return and the volatility of the underlying asset.
    3. Assess the states in which the options will be exercised.
    4. Estimate the payoffs associated with these end-states.
    5. Calculate the present expected value of future payoffs. This will entail multiplying the probability of up or down movements times the outcomes, and then discounting the expected value back one period at the risk-free rate.
    6. Interpret the results.

    The case study of EM.TV's partial acquisition of SLEC Holdings (later in this chapter) summarizes the steps of the binomial option valuation approach and gives an example of valuing put and call options.
3. ***Fit the option in a decision tree framework.*** A decision tree invites the analyst to look ahead to the full range of ultimate outcomes, and then come back to the present to make the decisions that pursue the optimal outcome. The technical term for this is *dynamic programming.* This is the approach illustrated in the brief examples of Exhibits 14.1, 14.2, 14.3, and 14.4. It is highly versatile

and because of its transparency proves to be a very good discipline on one's thinking. Finally, it permits the analyst to depart from the assumptions of the binomial probability distribution and to custom-tailor an analysis that accounts for the quirks of the option. Exhibits 14.1 through 14.4 give examples of the use of the decision tree framework to value rights.

4. ***Value the option using simulation analysis.*** Boyle (1977) discussed the application of *Monte Carlo simulation* to the valuation of options. For a detailed exposition, see Law and Kelton (1991). Intuitively the executive should understand that a spreadsheet model represents merely one outcome of what might be a wide range of outcomes. Simulation analysis (through spreadsheet add-in programs such as Crystal Ball) instructs the computer to recalculate the spreadsheet model many times, each time using different randomly chosen input parameters—the end result is an entire probability distribution of a key result such as the value of a firm or an option. In essence, software-generated simulation recognizes the unique kind of uncertainty that the decision maker likely faces at each decision point and permits the analyst to visualize the probability that the option will be in the money. Several mini-cases in this book give examples of the use of Monte Carlo simulation to value rights.

Exhibit 14.8 compares and summarizes the four methods. The four methodologies for valuing real options will likely arrive at four different values, which are all approximately similar with one another, but not exactly so—the differences originate from subtle variations in assumptions. This is a telltale about the state of the art in real option valuation: It is a young field with much more analytical development still in progress.

Interpret the Results and Develop Implications

Simply calculating estimates is insufficient. The first step of interpretation is to examine real option estimates against some test of reasonableness. This may entail comparing the estimate to observed values in other cases. Or one could simply test the sensitivity of the result to variations in assumptions or scenarios. And finally, one could backsolve for assumptions that will produce desired outcomes.

Another step of interpretation is to examine one's confidence level in the estimated values. Sensitivity analysis helps in this regard. And simulation analysis can produce formal confidence intervals around means of distributions. But even at a qualitative level, one can take a "gut check" to consider one's relative confidence in results and parameters.

The first two steps will suggest a third: considering how the estimates might be improved through refinements in modeling, sharper assumptions, and so on. This creates an iteration in the estimation process.

Finally, one needs to ask "so what?" Analysis generated purely for its own sake is worthless; it needs to be interpreted within a practical context. One must develop the ability to identify and understand the business implications of the real options analysis *and* consider carefully how to best communicate the analysis and implications to colleagues who may not share one's mastery of real options.

EXHIBIT 14.8 Comparison of the Four Methods of Estimating Real Option Value

	Black-Scholes Equation	Binomial Lattice	Decision Tree	Monte Carlo Simulation
Approach	Choose real option assumptions corresponding to the five parameters of the model: exercise price, underlying asset value, time, risk-free rate, and volatility. Estimate value.	Represent the evolution of option value in simple up or down movements in each period over time. Identify the resulting value at the end of each lattice. Determine the profit or loss from exercise of the option, and calculate the present value of the probability-weighted average.	Model the choices and uncertain events through time (branches) and the outcomes associated with those branches. "Fold back" the outcomes to the present, making optimal choices along the way.	Model the rights and uncertain events, accounting for the probability distribution of uncertain outcomes along the way. Estimate the option value as the present value of expected future outcomes.
Significance and application	The intellectual forebear of all option pricing theory. Useful in valuing European call options on financial assets.	As time periods grow infinitely small, the binomial approach converges into the Black-Scholes model. The big workhorse of real options valuation. Widely applied.	Another tree, like the binomial but that differs in assumptions about uncertainty. Easily applied to real options that are not complex. Excellent for modeling and communicating the framework of a real options analysis.	Most flexible of all methods in handling complexity and various assumptions about uncertainty. Used in the valuation of large capital projects, mines, drilling programs, etc.

Advantages	Simplest to use, drawing on widely available programs.	Uses simple representation of volatility. Relatively easy to describe to clients.	Flexible: can tailor decision tree to the features of the real option. Transparent to the analyst and client. Therefore easy to check logic and results.	Most adaptable to a range of assumptions about uncertainty. Creates appealing visual representations of uncertainty.
Disadvantages	Rigid about assumptions. Not very flexible to adapt to real option features. Can be hard to explain to client.	Can be tedious to use for large problems. Is the binomial uncertainty distribution the best representation of risk for your real option?	Can be tedious for large problems. Requires probability assessments for outcome branches—some of these assessments may be heroic.	Time-consuming to use. Complicated: It can be very difficult to model a stream of decisions, especially distant future ones. Assumptions may be unrelated to markets, arbitrary, and heroic—these risk "garbage-in, garbage-out" results. Challenging to explain to the uninitiated.

Source: Author's analysis.

FOUR MINI-CASES IN THE ANALYSIS OF REAL OPTIONS

This section of the chapter illustrates how one might apply real options valuation techniques in M&A problems, in areas such as spin-offs (Lucent), target valuation (Agouron), staged acquisitions (NCNB), and partial acquisitions (EM.TV).

Spin-off Value of Lucent: Assessing Latent Optionality

Usually the analyst discovers a gap between the actual market value of a target and its intrinsic value. There are many possible reasons for this,[13] but real options value would be a likely suspect. The analyst uses discounted cash flow to value the target, and therefore really assesses only the value of the assets in place. Thus, the valuation gap might be due to the value of growth or other options that DCF does not consider. The solution is to assess the real option value (*optionality*) in the target. As an outsider to a company, you may doubt your ability to produce a detailed analysis of option value. By backsolving for option assumptions that produce the gap value, however, you can begin to envision the conditions under which option value might explain the gap—Rappaport and Mauboussin (2002) offer this approach as one avenue for investment analysis and stock picking. A computer model such as "Option Valuation.xls" (found on the CD-ROM) can afford a basis for this analysis. Through the solver function in Excel, you can highlight assumptions that merit more research.

To illustrate the approach, consider the following case problem. Lucent Technologies was spun off from AT&T in 1996. Shortly after the spin-off, the firm traded at $60 per share. Yet the value of its assets in place was arguably in the neighborhood of $11.[14] What real option assumptions might account for the $49 gap? One begins by assessing the Black-Scholes parameters:

- Current stock price: begin by considering $60 per share, the post spin-off value.
- Life of the option: three years. Since much of Lucent's optionality derived from new technology, and since the design cycle of technology in telecommunications equipment was rapid, one could reasonably assume a life of three years.
- Cost to exercise the option: indicated by Lucent's very high rate of capital spending,[15] about $15 per share annually. At a discount rate of 15 percent, this yields a present value over three years of $34.24.
- Project volatility: uncertain. The volatility of Lucent's equity in its first year was 75 percent. This is probably an understatement of the real option volatility, since stock price volatility will be a weighted average of assets in place and real options.
- Risk-free rate of return: known. The three-year Treasury note yield was 3 percent.

The estimated value of a call option (using the Black-Scholes model and these assumptions) is $38.70 per share. It would appear from this point estimate that real options do not explain entirely the $49 gap. But given the uncertainties surrounding several of the assumptions, it makes sense to backsolve for the kinds of assumptions necessary to produce real option value equal to the $49 gap.

The analysis reveals that for real option value to explain the $49 gap, it must have:

- ***A much longer life.*** If volatility equals 0.75, the life implied must be 8.5 years. This exceeds the likely life of real options within Lucent, given the rapid rate of technological change.
- ***Extremely high volatility.*** If the life of the option equals three years, the volatility must be in the neighborhood of 135 percent—compared to the volatility of about 20 percent for the S&P 500 Index.
- ***A much lower exercise price*** (relative to the resulting economic activity) on the order of $13 per share.
- ***Very high value*** of the resulting economic activity (relative to the necessary investment).

The last condition is possible, judging from the incredible profitability of some software, hardware, and drug firms. The analysis exposes the aggressive assumptions necessary to justify the high stock price. Taken together, these assumptions seem implausible and should motivate close scrutiny of the technology bets within this firm—or better yet, reexamining beliefs about DCF valuation of Lucent, market efficiency, and rationality. Lucent's share price, along with other telecommunications equipment manufacturers, declined sharply in the market bust of 2000–2001. In December 2002, Lucent's shares were trading around $1.50, well below the $60 level following its spin-off from AT&T. The kind of analysis here, while far from precise, could have raised flags that would have helped prevent disastrous investment.

Agouron Pharmaceuticals: Valuing the Pure Research Firm

In January 1999, Warner Lambert Company acquired Agouron Pharmaceuticals for $2.1 billion. Up to 1997, Agouron had no operating income, and by 1999 was still reporting large negative net income. The target had focused on discovering new molecular entities (NMEs) for treating cancer and HIV. In 1994, the firm had two drugs in Phase I clinical trials and one in preclinical development. Kellogg and Charnes (2000) estimated the value of Agouron shares using decision tree and binomial lattice methods of real option valuation during the period 1994–1996 when the firm's activities were entirely focused on R&D and the firm was almost solely a growth option. Casting their analysis into the framework outlined earlier, the highlighted steps of the valuation are:

1. ***Identify the optionality.*** Investing in R&D is like buying a call option on uncertain future discoveries. The exercise price equals the investment necessary to commercialize the discovery in the future. In Agouron's case, the firm had three ongoing R&D projects, each with its own stream of options. For instance, a pharmaceutical research project consists of several stages,[16] and at the completion of each stage Agouron faces the decision of whether to terminate the project or invest in further development.
2. ***Value the options.*** Kellogg and Charnes made a number of assumptions consistent with general industry experience, or specific information about Agouron.

They forecasted the cost, duration, and probability of success at each of the stages. They assigned probabilities and economic outcomes to eventual success of the drug in the marketplace. And they made additional assumptions about the cost of goods sold, marketing costs, general and administrative expenses, tax rates, and working capital. They employed these assumptions in two valuation approaches: decision tree and binomial lattice.

3. ***Interpret the results and develop implications.*** Kellogg and Charnes found that at four out of five points in time, Agouron's share price was materially higher than values estimated by the real options approaches. Exhibit 14.9 gives a summary of the actual and estimated values. These two researchers concluded that real options valued the company reasonably well when all of Agouron's projects were in Phase I or earlier, but that as they approached the successful release, the actual price materially exceeded the estimated value. To explain the difference, the authors backsolved for assumptions that would produce estimated values equal to the actual price: shorter duration of clinical trial phases, higher probabilities of success in clinical phases, and higher revenues for the successful product.

The real options valuation of Agouron reveals the usefulness of this approach in the instance of firms with no revenue, a high proportion of intangible assets, and/or a future that is highly contingent on outcomes of definable processes or events—in such cases, discounted cash flow or multiples-based approaches will poorly capture the economic content of the company.

The case of Agouron also supports the larger truth about valuation: One only *estimates* real option value (that is, with analytical guesses, not facts). But even the mere process of deriving these estimates can yield insights about the drivers of

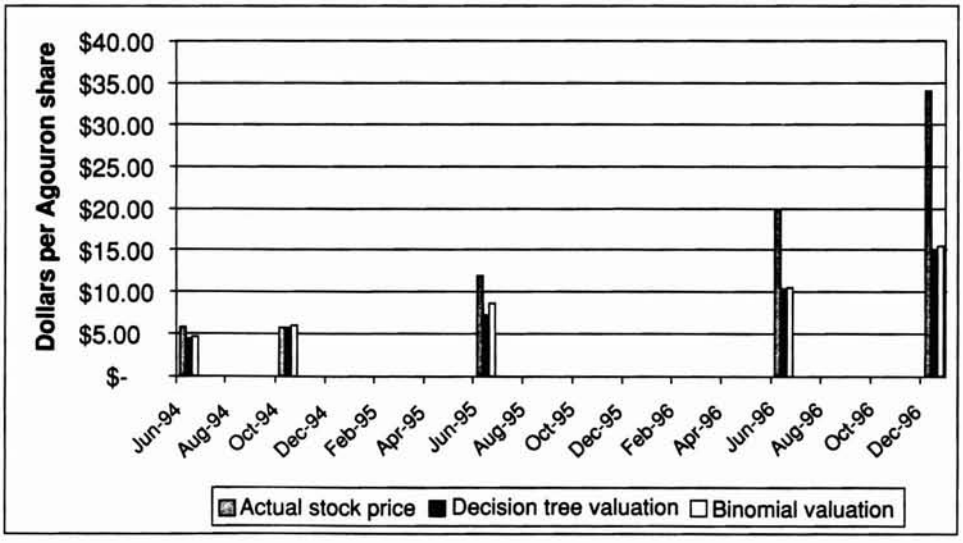


EXHIBIT 14.9 Real Options Values for Agouron Pharmaceuticals (Values in Dollars per Share)

Source of data: Kellogg and Charnes (2000), page 83. Graph prepared by author.

value, which are as important as the insights themselves. Knowledge of these drivers can sharpen one's estimated range of value for a target firm and prepare one for due diligence research and negotiation.

NCNB's Acquisition of First Republic: Valuing the Impact of Staged Investment

In the fall of 1988, North Carolina National Bank (NCNB), an aggressively expanding bank headquartered in Charlotte, announced an agreement to acquire First Republic National Bank of Texas, whose assets had been seized by the Federal Deposit Insurance Corporation (FDIC) following severe loan losses. First Republic had been the victim of an economic "perfect storm" following the collapse of oil prices in 1986 and of Texas real estate values in 1987. The FDIC sought a healthy bank to acquire and operate the branches of First Republic. Three competing buyers surfaced: Citicorp, Wells Fargo, and NCNB. NCNB won the right to acquire First Republic, but sought to hedge the uncertainty about the quality of First Republic's loan portfolio. Accordingly, NCNB negotiated an agreement with the FDIC that had the following features:

- First Republic would be split into a "good bank" (consisting of sound loans and the branch-banking network) and a "bad bank" consisting of a portfolio of defaulted loans. NCNB would acquire the good bank; the FDIC would retain the bad bank.
- At closing, NCNB would acquire 20 percent of the equity of the good bank for $210 million—this would include 100 percent of the voting control of First Republic. The FDIC's economic interest of 80 percent would be in nonvoting stock.
- NCNB held the exclusive option to acquire the remaining 80 percent economic interest within five years of closing. The exercise price would be:
  - Within the first year after closing: 80 percent of the net book value as of closing, plus 115 percent of the increase in net book value.
  - Within the second year after closing: 80 percent of the net book value as of closing plus 120 percent of the increase in net book value.
  - Within the third, fourth, and fifth years after closing: 80 percent of the net book value as of closing plus 125 percent of the increase in net book value.

NCNB purchased an additional 29 percent of the equity in April 1989, and then the remaining 51 percent in July 1989.

As of the closing date, November 22, 1988, what was the value of NCNB's option to acquire the remaining 80 percent of First Republic's "good bank"? Following the real option analysis steps outlined earlier, this question can be approached through the following process:

1. *Specify the option.* NCNB held a five-year American call option on First Republic stock at exercise prices that rise over time. The rate of increase of the exercise price was not very rapid and probably reflected an expectation on the FDIC's part that First Republic would grow over time; plainly, the FDIC

wanted to participate in that growth for as long as it remained an equity holder. At the same time, the rising exercise price probably created an incentive for NCNB to exercise the option before maturity—this, too, might have reflected FDIC policy (i.e., that it is in the business of insuring bank deposits rather than holding an equity portfolio).

2. ***Value the option.*** The valuation analysis was structured as a Monte Carlo simulation. The economic value and net book value (NBV) of First Republic were forecasted over 260 weeks and varied randomly from the economic value and net book value implied in the closing terms of the acquisition (i.e., $1.05 billion each). Different volatility scenarios were assumed for economic value (10 to 30 percent) and net book value (4 to 8 percent). The volatility for economic value was drawn from a range of equity volatilities for peer banks. The volatility for net book value was drawn from volatilities for investment-grade senior corporate debt. NCNB was assumed to exercise the option when economic value exceeded the exercise price (that is, 80 percent of net book value plus change in NBV times the multiple [1.15, 1.2, or 1.25]). Future payoffs were discounted to the present at the five-year Treasury note yield. Exhibit 14.10 presents the frequency distribution for the present value of payoffs under the option in one scenario: Volatility of economic value is 30 percent, and volatility of net book value is 8 percent. The mean of the distribution is $53.2 million. Exhibit 14.11 summarizes the means for nine volatility scenarios.
3. ***Interpret the results.*** The graph and statistical results reveal that:

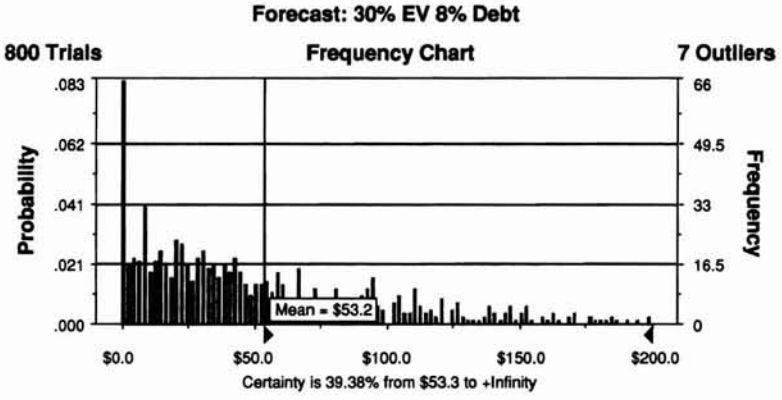
   - The option is valuable: In only 8 percent of the cases does the option never pay off. The graph suggests that the mean is influenced by a few outliers that pull the average upward. Still, the median value ($39.9 million) is not far from the mean ($53.2 million).
   - The option value is material, relative to the value of the asset. The implied value of the remaining 80 percent of First Republic at date of closing is $840 million. At an option value of $53.2 million, the option is 6 percent of the total remaining value.
   - The option value is sensitive to variations in volatility (both for economic value and debt value). A 10 percent increase in volatility is associated with an increase in option value of over $10 million.

There are several possible avenues of improving the analysis. First, the methodology assumes that NCNB *can* exercise the option as soon as possible. In fact, NCNB did not have the financial capacity to buy all of First Republic's shares at the outset. It would take time to raise the cash to complete the acquisition. A more sophisticated assessment of the real options here might account for the uncertainty surrounding NCNB's financial capacity. Second, if anything, the volatility estimates are low. The Texas banking market was in disarray, creating great uncertainty in the minds of businesspeople. NCNB's entry into Texas was fundamentally a bet that the market there would bounce back. Rerunning the Monte Carlo simulation to account for higher volatilities reveals, predictably, higher real option values. Third, the volatilities of net book value and economic value were possibly correlated, since they were driven by the same economic fundamentals in the Texas market. The impact of the correlation would merit further analysis.

EXHIBIT 14.10 Estimated Value of NCNB's Call Option on First Republic for a Single Scenario: Volatility of Economic Value of 30% and Volatility of Net Book Value of 8% (Values Are in Millions of U.S. Dollars)

Summary
Certainty level is 39.38%
Certainty range is from $53.3 to +infinity
Display range is from $0.0 to $200.0
Entire range is from $0.0 to $267.2
After 800 trials, the standard error of the mean is $1.7

Statistics	Value
Trials	800
Mean	$ 53.2
Median	$ 39.9
Mode	$ 0.0
Standard deviation	$ 47.4
Variance	$2,244.1
Skewness	1.18
Kurtosis	4.16
Coefficient of variability	0.89
Range minimum	$ 0.0
Range maximum	$ 267.2
Range width	$ 267.2
Mean standard error	$ 1.67



Source: Author's analysis with the assistance of Crystal Ball add-in software.

NCNB's acquisition of First Republic would rank among the most attractive "deals from heaven" in the annals of M&A history. The optionality in the deal design helped to resolve the uncertainty about NCNB's possible exposure to loan losses—the option amounted to a discount of about 6 percent from the stated acquisition price. But the larger benefit was NCNB's discovery of a provision in the U.S. tax code that would allow it to capture First Republic's tax loss carryforwards—these proved to be so large that in the final analysis, NCNB acquired First Republic virtually for free.

EXHIBIT 14.11 Estimated Values for NCNB's Call Option on First Republic (in Millions of U.S. Dollars)

Volatility of Debt	Volatility of Economic Value		
	10.0%	20.0%	30.0%
4.0%	$22.40	$35.60	$48.70
6.0%	$25.80	$39.30	$50.10
8.0%	$29.80	$40.90	$53.20

Note: The value in each cell is the mean of the simulated distribution of present values of payoffs under NCNB's option to acquire the FDIC's remaining 80 percent interest in First Republic.
Source: Author's analysis.

EM.TV's Partial Acquisition of SLEC: The Long Call and Short Put

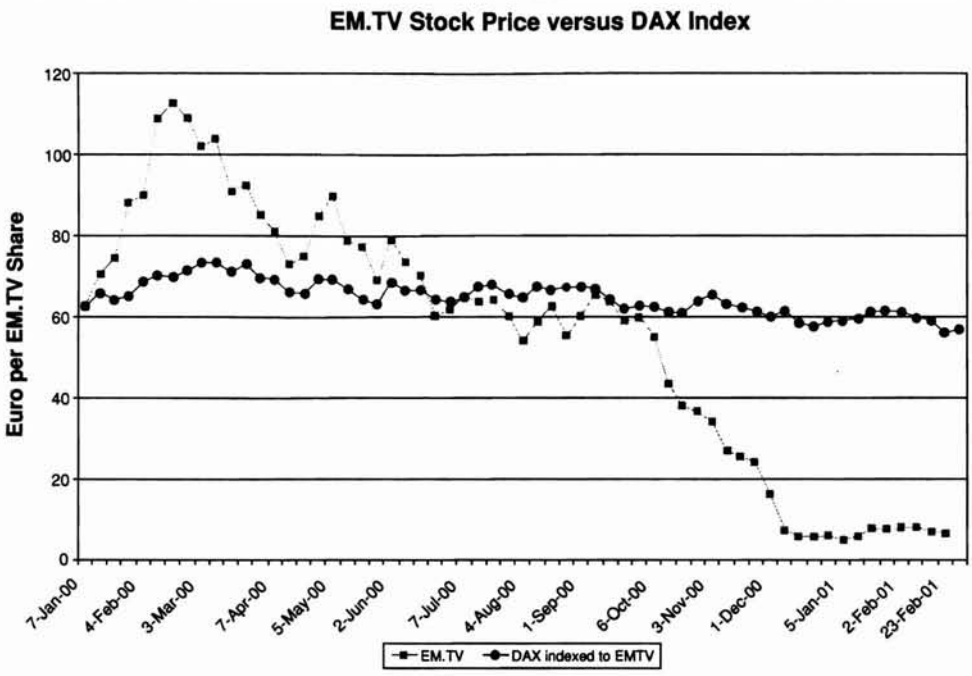
In March 2000, EM.TV, a German media company, bought 50 percent of the equity in SLEC Holdings, the operator of the Formula One racing circuit, for €1.88 billion—this implied that the equity value of SLEC was €3.76 billion. At the time, EM.TV's share price was around €115 per share. As part of the deal, EM.TV announced that it also obtained a call option to buy another 25 percent of SLEC for €1.16 billion by February 28, 2001. Not announced was a second option: EM.TV granted the seller, Bernie Ecclestone, a put option to force EM.TV to buy 25 percent of SLEC for €1.16 billion by May 2001. But in May 2000, EM.TV's fortunes began to wane: Its earnings fell to a quarter of year-earlier figures. Then, in November 2000, word leaked of the hidden put option. As Exhibit 14.12 reveals, this triggered a meltdown in the firm's share price from about €115 to €7, a 94 percent drop in value in eight months.

Two events are associated with the bulk of EM.TV's erosion in value. First, at the announcement of the acquisition in March 2000, EM.TV's share price fell 12 percent (net-of-market) for a loss of about €2 billion. Second, at the revelation of the hidden put option in November 2000, EM.TV's share price fell 43 percent (net-of-market) for a loss of about €2.2 billion. Were the values of EM.TV's long call and short put position in SLEC consistent with the size of value destroyed?

The put and call embedded in the EM.TV/SLEC deal can be valued using the binomial valuation approach:

- Value of the underlying asset today: SLEC's equity was the asset underlying both options. We can assume that SLEC's equity was fairly valued in the transaction, and that the value of the firm was €3.88 billion. But the option entailed a claim on only 25 percent of that amount, €0.97 billion.
- Exercise price: €1.16 billion.

EXHIBIT 14.12 Share Price History of EM.TV Compared to DAX Index, Indexed to Starting Value of EM.TV



Note: EM.TV announced its deal to acquire 50 percent of SLEC in early March 2000. The put option held by SLEC was first reported on November 22, 2000.
Source: Author's analysis with data obtained from Datastream.

- Volatility: 25 percent. Actually, SLEC was a private company, so the volatility of its share price was unobservable. Yet the firm enjoyed monopoly control over Formula One racing events. Suppose that 25 percent was an appropriate annual volatility level, based on peer comparisons. On a quarterly basis, the volatility would equal the annual volatility times the square root of 1 divided by the number of periods in a year, or $0.25 \cdot (0.25)^{0.5} = 0.125$.
- Life: The options expired in February and May 2001, four and five quarters, respectively, from the date of EM.TV's acquisition of half of SLEC.
- The annualized euro risk-free rate for the next five quarters was 4 percent. On a quarterly basis, this equated to 0.00985 (i.e., almost 99 basis points per quarter).

STEP 1: GROW THE TREE The binomial approach assumes that each quarter, the value of SLEC's equity will move up by u ($u = e^{0.125} = 1.133$) or down by d ($d = e^{-0.125} = 1/u = 0.882$). This means that at the end of the first quarter, a quarter of SLEC's equity will be worth either €1.099 ($u \cdot 0.97$) or €0.856 ($d \cdot 0.97$). One can expand outward in similar fashion for the five-quarter period to yield this expansion tree:

Annual Volatility =	0.25
Quarterly Volatility =	0.125
u =	1.133
d =	0.882

Now	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5
					1.812
				1.599	
			1.411		1.411
		1.246		1.246	
	1.099		1.099		1.099
0.970		0.970		0.970	
	0.856		0.856		0.856
		0.755		0.755	
			0.667		0.667
				0.588	
					0.519

STEP 2: ASSESS THE PROBABILITIES OF AN UP OR DOWN MOVEMENT Knowing u, d, and the quarterly risk-free rate, and assuming that we are risk-neutral, the binomial probabilities of an up-movement (p_u) or down-movement (p_d) will be:

$$p_u = \frac{(1+r_f)-d}{u-d} \tag{1}$$

$$p_d = \frac{u-(1+r_f)}{u-d} \tag{2}$$

Under the preceding assumptions, p_u equals 0.508; p_d equals 0.492. These probabilities are constant throughout the tree, and will be used to determine the expected value of the discounted value of future payoffs.

STEP 3: ASSESS THE STATES IN WHICH THE OPTIONS WILL BE EXERCISED One can make a simplifying assumption that neither party will exercise the option early, since this would destroy time value in the option. Therefore, the relevant time for EM.TV is the fourth quarter from now, when it will exercise the call option if the value of one-quarter of SLEC is greater than the exercise price, €1.16 billion. For SLEC, the relevant time is the fifth quarter from now when it will exercise the put option if the value of one-quarter of SLEC is less than the exercise price, €1.16 billion. In the following tree, the boldface numbers indicate where EM.TV will exercise its call; italicized boldface numbers indicate where SLEC will exercise its put.

Now	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5
					1.812
				1.599	
			1.411		1.411
		1.246		**1.246**	
	1.099		1.099		*1.099*
0.970		0.970		0.970	
	0.856		0.856		*0.856*
		0.755		0.755	
			0.667		*0.667*
				0.588	
					0.519

STEP 4: ESTIMATE THE PAYOFFS ASSOCIATED WITH THESE END-STATES This step assesses the consequences for EM.TV. The payoff from a long call option in the end-states will equal *price minus exercise price.* The payoff to EM.TV from a short put option in the end-states will be an outlay equal to *exercise price minus price.* The following tree shows these payoffs:

Now	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5
					NM
				0.439	
			—		NM
		—		**0.086**	
	—		—		*(0.061)*
—		—		0.000	
	—		—		*(0.304)*
		—		0.000	
			—		*(0.493)*
				0.000	
					(0.641)

NM means "not meaningful." If EM.TV has previously exercised its call option, SLEC will not thereafter exercise its put option.

STEP 5: CALCULATE THE PRESENT EXPECTED VALUE OF FUTURE PAYOFFS This final step estimates today's value of the future receipts or payments. For instance, starting with the lower right-hand corner of the table, one would take the expected value of the $p_u(0.493) + p_u(0.641)$ or $(0.508 \cdot 0.493) + (0.492 \cdot 0.641)$ to yield 0.566. Discounting this by one-quarter at the risk-free rate, 0.00985 yields 0.560. This process is

repeated for the other cells, folding back to the present, to find a value of €–0.138 billion. The following tree shows the calculated values at each step:

Now	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Quarter 5
					NM
				0.439	
			0.263		NM
		0.111		**0.086**	
	(0.022)		(0.044)		***(0.061)***
(0.138)		(0.159)		(0.179)	
	(0.261)		(0.281)		***(0.304)***
		(0.371)		(0.393)	
			(0.471)		***(0.493)***
				(0.560)	
					(0.641)

NM means "not meaningful."

STEP 6: INTERPRET THE RESULTS Could the announcement of this hidden put option really have accounted for the meltdown of EM.TV? Hardly. The combination of long call and short put still had a negative value of €138 million—this poorly explains the destruction of over €4 billion surrounding the news about EM.TV's acquisition of SLEC. Separate analysis suggests that the call option alone was worth about €47 million, implying that the short put posed an economic liability to EM.TV of about €185 million. The meltdown was probably due to other factors, such as EM.TV's worsening financial condition and the bursting of the Internet bubble (a name like EM.TV would imply a new economy firm).

SUMMARY AND CONCLUSIONS

This chapter has surveyed the application of real options analysis to M&A. It has discussed four real option valuation methods and offered practical advice for the M&A analyst who must assess the contingencies.

The lessons for the decision maker are perhaps more significant. Chief among these is that the application of options thinking should not be confined to analysts. The first rule, then, should be to *look for real optionality in any business setting.* To look for optionality means to identify the presence of rights and their type of position (put/call, long/short).

The second rule for decision makers should be to *develop a feel for real option value.* At the outset, this means acknowledging that some rights aren't all that interesting or are not easily valued. Recall the distinction between options and opportunities. A feel for option value means understanding the impact of key value drivers.

A third rule is *build or conserve flexibility.* Flexibility appears in large and small ways throughout the design of individual deals and in the management of M&A processes. Real options theory teaches that flexibility is valuable.

NOTES

1. For example, see Hayes and Garvin (1982), Kulatilaka and Marcus (1992), and Nichols (1994).
2. Kester (1984) and Kulatilaka and Perotti (1998) discuss growth options and their valuation.
3. See, for instance, Faulkner (1996) and Grenadier and Weiss (1997) for more discussion of the option valuation of R&D projects.
4. See, for instance, Brennan and Schwartz (1985) for more discussion of the option valuation of natural resources and drilling rights.
5. I studied this situation at AlliedSignal, and found a business unit that had been utterly demoralized—indeed, paralyzed—and was the worst-performing unit in the large conglomerate. In a move to stanch the outflow of cash, AlliedSignal changed managers. The new manager immediately opened negotiations with the environmental authorities, and eventually negotiated a "workout" program in which the refinery would be closed immediately and environmental remediation would be conducted over time, rather than all at once. This was an enormous success for AlliedSignal and the manager, who recognized that not only was the company stuck, but so were the environmental authorities. In this particular case, an exit was in everyone's interest. For more on this, see Bruner, Larson, and Paddack (1996).
6. For a more detailed discussion of the valuation of exit options, see Berger et al. (1996), McDonald and Siegel (1985), Myers and Majd (1990), and Schary (1991).
7. For more discussion of the right to delay, see McDonald and Siegel (1986) and Ross (1995).
8. Margrabe (1978) discusses the right to switch as a call option on the attractive alternative. He argues that in some circumstances switching options can be valued as European calls using the Black-Scholes option pricing model. Moel and Tufano (2002) explored the behavior of mining firms to start and stop production, a decision to switch between operating and mothballed status. They found that option value drivers, such as volatility, had a significant influence on the decisions to open or close mines.
9. For more on the valuation of flexibility, see Brennan and Trigeorgis (1988), Fine and Freund (1990), Kogut and Kulatilaka (1994b), Kulatilaka (1993, 1995), Kulatilaka and Marks (1988), Triantis and Hodder (1990), Trigeorgis (1996), Trigeorgis and Mason (1997), and Upton (1994).
10. For more on the "competencies" perspective on corporate strategy, see Hamel and Prahalad (1994), Hamel (1996), and Kogut and Kulatilaka (1997).
11. For more on buildups as options, see Kogut and Kulatilaka (1994a) and Smit (2001).
12. For detailed discussion of the optionality in M&A agreements, see Chapters 18 ("An Introduction to Deal Design in M&A") and 30 ("Negotiating the Deal").
13. The reasons could include estimation error, synergies, market inefficiencies, and market irrationality.
14. This was estimated using the dividend discount model, where earnings per share were assumed to be $1.60, perpetual growth rate of the business was 5 percent, and the cost of equity was 20 percent. The resulting figure, $11.20,

is probably optimistic owing to the absence of assumed investment to sustain growth.

15. A common approach is to view the equity of the firm as a call option with the principal amount of debt outstanding as the exercise price. Lucent's indebtedness was very low, less than $1.00 per share. Such an approach makes no sense here since we are not valuing the whole firm, just the real options. Also, it ignores the very high rate of investment necessary to exercise options to grow—Lucent's profitability was being used to exercise these options.
16. The first stage is *discovery* in which scientists develop concepts for new compounds. The second is *preclinical tests* of the compound in laboratory tests and on animals. Third, *clinical trials* test the compound on humans—these trials consist of three phases: I (tests on a few healthy volunteers focusing on toxicity and safe dosage); II (tests on a larger number of ill patients focusing on efficacy and safety); and III (large-scale trials focusing on safety). Upon successful completion of the research phases, the company files a New Drug Application with the U.S. Food and Drug Administration, which reviews the findings and approves or denies the application for commercial distribution of the drug. Each phase yields an uncertain outcome. Therefore, the decision to make the investment associated with each phase is the acquisition of a call option on the findings of that phase. Collectively, these options form a stream. As a practical matter in valuing a research firm, one cares about the value of the entire stream.