CREDIT SUISSE FIRST BOSTON

CREDIT SUISSE FIRST BOSTON CORPORATION

Equity Research

Americas | U.S./Value Based Strategy | June 23, 1999

Get Real

Using Real Options in Security Analysis

Michael J. Mauboussin
1 212 325 3108
michael.mauboussin@csfb.com

Volume 10

- **This report introduces real options as a key addition to the valuation toolbox.**
- **Real options offer a great way to wed strategic intuition with analytical rigor—an increasingly important issue given the pace of economic change.**
- **Real options complement the standard discounted cash flow approach and add a meaningful dimension of flexibility.**
- **The real options approach is well suited to mirror the capital- options thinking into useable results. The**

Table of Contents

Executive Summary

The rate of economic change is more rapid than ever. Emerging business models are challenging traditional ways of doing business. Newly unregulated markets are contributing to greater uncertainty. If-it-ain't-broke-don't-fix-it is giving way to break-it-before-someone-else-does.

The breakneck pace of change and elevated uncertainty demand new ways of strategic thinking and new tools for financial analysis. Real options are at the core of such a strategic and financial framework.

We believe that real options will become an increasingly important tool in security analysis. Real options provide the analytical flexibility that standard valuation frameworks lack. The major points of our analysis are as follows:

- *Real options defined.* The real options approach applies financial option theory—the best-known form is the Black-Scholes model—to real investments, such as manufacturing plants, line extensions, and R&D investments. This approach provides important insights about businesses and strategic investments, insights that are more important than ever given the rapid pace of economic change.
- *The marriage of strategic intuition and analytical rigor*. The real options approach is best viewed as a complement to standard DCF analysis. For those comfortable with DCF, real options have substantial intuitive appeal. By adding an important dimension of analytical flexibility, real options allow for a better melding of strategic intuition and analytical rigor.
- *Evolution of strategy and finance.* Most traditional businesses can be valued using DCF, as the general focus is optimization—doing things better today than yesterday. Emerging businesses are best valued using real options, as the focus is on "the next big thing." As the strategic landscape evolves, so too must the tools to evaluate it.
- *Where real options apply.* The real options approach is particularly relevant when three elements are in place. The first is a smart management team, focused on creating, identifying, and exercising real options. Next are market-leading businesses, which tend to get the best look at strategic opportunities and can offer economies of scale and scope. Finally, uncertain markets are where options are most valuable.
- *Improving valuation thinking*. We suggest that stocks of companies that participate in highly uncertain markets are best viewed as a combination of the discounted cash flow value of the current, known businesses plus a portfolio of real options. This real option can be estimated by taking the difference between the current equity value and the DCF value for the established businesses.

Do I dare?
Disturb the Universe?
In a minute there is time
For decisions and revisions
Which a minute can reverse

—T.S. Eliot
"The Love Song of J. Alfred Prufrock"

Introduction

There is a growing gap between how the market is pricing some businesses—especially those fraught with uncertainty—and the values generated by traditional valuation models such as discounted cash flow (DCF). Managers and investors instinctively understand that selected market valuations reflect a combination of known businesses plus a value for *opportunities that are to come*. Real options— a relatively new analytical tool—bridge this gap between hard numbers and intuition.

The real options approach applies financial option theory—the best known form is the Black-Scholes model—to real investments, such as manufacturing plants, line extensions, and R&D investments. This approach provides important insights about businesses and strategic investments. These insights are more vital than ever, given the rapid pace of economic change.

Real options are particularly important for businesses with a few key characteristics. The first is smart and reputable management with access to capital. Managers must understand options, identify and create them, and appropriately exercise them. This contrasts with business leaders focused on maintaining the status quo or maximizing near-term accounting earnings. Businesses that are market leaders are also attractive, as they often have the best information flow and richest opportunities—often linked to economies of scale and scope. Finally, real options are most applicable precisely where change is most evident.

Table 1
Real Options Thinking Is Most Applicable When You Have . . .

- **Smart Managers**
  - Reputable
  - Access to capital
  - Understand options thinking
  - Clearly identify options
  - Ability to exercise options
- **Market-Leading Businesses**
  - First call
  - Economies of scale
  - Economies of scope
- **Uncertain Markets**
  - Source
  - Trend
  - Evolution

Source: CSFB, *Real Options*, Martha Amram and Nalin Kulatilaka, Harvard Business School Press, 1999.

This report is broken into five parts. First, we provide a brief description of real options and the underlying math. Next, we identify common real options and tie the use of real options to strategic thinking. Third, we offer a specific analytical framework. Fourth, we show how real options thinking aids in analyzing market expectations. Finally, we look at a handful of real-world case studies.

Real Options Defined

Real options analysis extends financial option theory to options on real, or nonfinancial, assets. A financial option gives its owner the right—but not the obligation—to purchase or sell a security at a given price. Analogously, a company that has a real option has the right—but not the obligation—to make a potentially value-accretive investment. Investment examples include new plants, line extensions, joint ventures, and licensing agreements.

This approach is best viewed as a complement to standard DCF.[1] For those comfortable with the DCF model, real options have substantial intuitive appeal. By adding an important dimension of analytical flexibility, real options allow for a better melding of strategic intuition and analytical rigor. Further, as real option pricing models rely heavily on financial market data, the framework is closely aligned with the real world.[2]

There are three areas in particular where traditional DCF, most widely articulated as the net present value rule (NPV)[3], comes up short versus options theory:

- *Flexibility.* Flexibility is the ability to defer, abandon, expand, or contract an investment. Because the NPV rule does not factor in the value of uncertainty, it is inherently less robust than an options approach in valuing flexibility. For example, a company may choose to defer an investment for some period of time until it has more information on the market. The NPV rule would value that investment at zero, while the real options approach would correctly allocate some value to that investment's potential.
- *Contingency.* This is a situation when future investments are contingent on the success of today's investment. Managers may make investments today—even those deemed to be NPV negative—to access future investment opportunities. Traditional budgeting models inadequately value these option-creating investments. Pharmaceutical company investments are a good example. Future spending on drug development is often contingent on the product clearing certain efficacy hurdles. This is valuable because investments can be made in stages, rather than all up-front.
- *Volatility.* Somewhat counterintuitively, investments with greater uncertainty have higher option value. In standard finance, higher volatility means higher discount rates and lower net present values. In options theory, higher volatility—because of asymmetric payoff schemes—leads to higher option value.[4] In a sense, real options theory allows us to value the unimaginable. This means that industries with high uncertainty—like the Internet—actually have the most valuable options.

---

[1] In fact, real option value and DCF value are equal when one assumes that there are no changes in managerial decisions across outcome ranges and that cash flow forecasts equal the average of an expected probability range.

[2] Amram, Martha; Kulatilaka, Nalin, "Disciplined Decisions: Aligning Strategy with the Financial Markets," *Harvard Business Review*, January-February 1999.

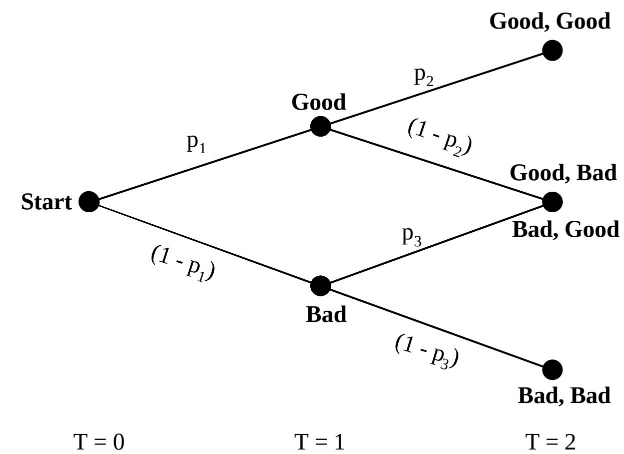
[3] The NPV rule compares current investment outlays to the present value of an investment's future cash flows.

[4] See Appendix A.

The binomial option-pricing model is currently the most widely used real options valuation method. The binomial model describes price movements over time, where the asset value can move to one of two possible prices with associated probabilities. It is not necessary to delve into the math to intuitively understand how the binomial model works.[5]

Figure 1 represents the binomial process through a decision tree. Since an option represents the *right* but *not the obligation* to make an investment, the payoff scheme to the option-holder is asymmetric. In other words, options are only exercised if they have a positive value and are left unexercised if worthless. A brief study of the decision tree shows that time and the range of outcomes are key to option value.

Figure 1
The Binomial Model



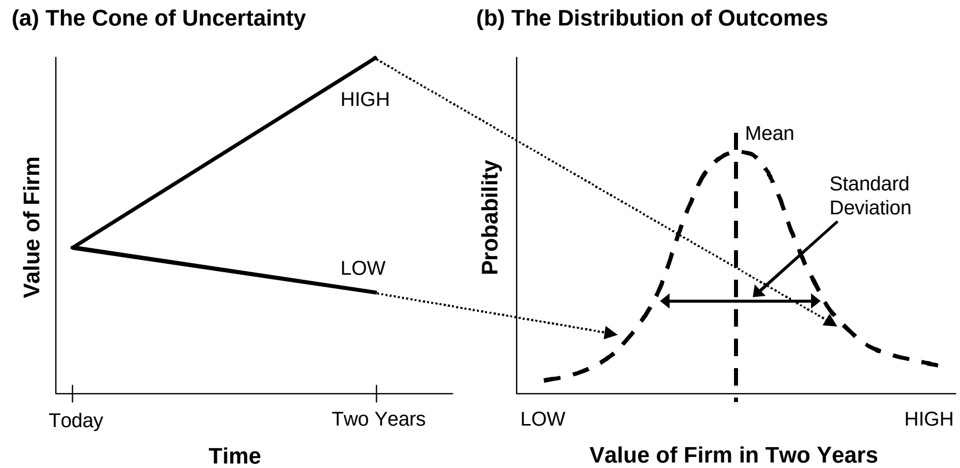
Source: Credit Suisse First Boston Corporation.

The range of potential outcomes is a particularly important dimension in option value. This range has been dubbed the “cone of uncertainty,”[6] and can be recast visually as a more familiar bell-shaped distribution. (See Figure 2.) Wider outcome distributions—higher volatility—lead to higher option value.

[5] The math behind the binomial model is based on the value of a replicating portfolio that combines risk-free borrowing (or lending) with the underlying asset to create the same cash flows as the option. Once the terms of the replicating portfolio are defined, arbitrage principles apply, and the option price has to equal the value of the replicating portfolio. It is in this way that the binomial model relies on financial markets.

[6] *Real Options*, Martha Amram and Nalin Kulatilaka, Harvard Business School Press, 1999.

Figure 2
Views of the Resolution of Uncertainty



Source: *Real Options*, Martha Amram and Nalin Kulatilaka, Harvard Business School Press, 1999.

The widely known Black-Scholes model is a narrow case of the binomial model[7]. The drivers of option value can be condensed into five simple inputs:

1. Current value of the underlying asset (S)
2. Strike price of the option (X)
3. Time to expiration (t)
4. Risk-free interest rate (R_f)
5. Variance in the value of the underlying asset (σ^2)

Conveniently, these variables can be translated directly into "real" investment analogs. (See Figure 3.) Although the complexity of option pricing models can rise significantly as more true-world variables are considered, the key determinants of value are well expressed in these basic drivers.

[7] It applies when the limiting distribution on asset returns is normal distribution (equivalent to the limiting distribution on stock prices is log normal) and assumes a continuous price process.

Figure 3
Real Options: The Link between Investments and Black-Scholes Inputs

Investment Opportunity	*Variable*	*Call Option*
Present value of project's Free Cash Flow	S	**Stock price**
Expenditure required to acquire project assets	X	**Exercise price**
Length of time the decision may be deferred	t	**Time to expiration**
Time value of money	R_f	**Risk-free rate**
Riskiness of project assets	σ^2	**Variance of returns**

Source: Timothy Luehrman, *Investment Opportunities as Real Options, Harvard Business Review*, July-August 1998.

Although real options are analytically robust, we believe they are best understood as a way of thinking. From management's perspective, that means appreciating what types of options exist, how they can be created, how and why option values change, and how to capture their value. Importantly, a real options analysis often provides answers that run counter to the standard, and often limiting, NPV rule.

For investors, real options thinking requires a greater appreciation for business potential and helps explain disparities between DCF values and prevailing stock prices.

Real Options and Strategic Planning

Economist W. Brian Arthur distinguishes between two cultures of competition.[8] Traditional businesses focus on optimizing their operations—hierarchies, planning, and controls are common. Knowledge-based businesses are oriented to find "the next big thing." As a result, hierarchies flatten out, managers have more free rein, and formal planning falls by the wayside. The traditional world is DCF-based; the new economy is options-based.

Strategy guru Henry Mintzberg makes a similar point.[9] He suggests that strategic planning, as historically practiced, is really strategic *programming:* an articulation of strategies that already exist. He advocates strategic *thinking*—really *synthesis*—that incorporates intuition and creativity. Strategic planning is DCF-based; strategic thinking is options-based.

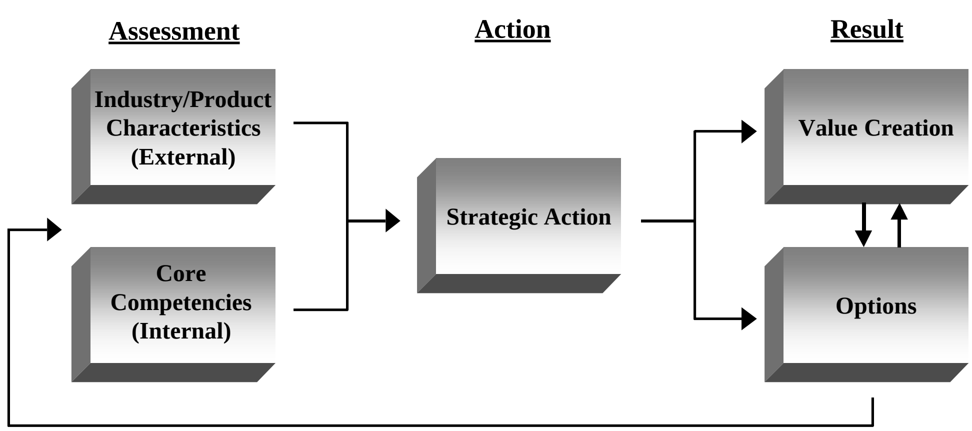
Table 2
Evolving Tools for Evolving Modes

Traditional	New
Old economy	New economy
Strategic planning	Strategic thinking
Optimization	Adaptation
Discounted cash flow	Real options

Source: Credit Suisse First Boston, W. Brian Arthur, Henry Mintzberg.

The strategic decision-making process can be broken down into three steps. (See Figure 4.) A company starts by evaluating industry and product characteristics—external variables—alongside its internal, core competencies. This leads to strategic action. Finally, there is a result—traditionally expressed in terms of shareholder value gains or losses.

Figure 4
Strategy Formulation and Real Options



Source: Credit Suisse First Boston.

[8] "The New World of Business," W. Brian Arthur, *Harvard Business Review*, July-August, 1996.

[9] "The Fall and Rise of Strategic Planning," Henry Mintzberg, *Harvard Business Review*, January-February, 1994.

Real options thinking highlights the point that strategic action often creates valuable options. Once identified, these options can be assessed and exercised (if appropriate), starting the cycle of value creation and new options all over gain. It is the managers and investors who understand the value of these options who will gain the greatest insight into true business potential.

Although real options exist in most businesses, they are not always easy to identify. Real options can be classified into three main groups: Invest/grow options, defer/learn options, and disinvest/shrink options.[10] In turn, real options can be further defined within these broader headings. We list here seven common real options. (See Figure 5.) We define them separately; however, it should be noted that many options are interrelated. What follows is a starting checklist:

Invest/Grow Options

- *Scale up.* This is where initial investments scale up to future value-creating opportunities. Scale-up options require some prerequisite investments. For example, a distribution company may have valuable scale-up options if the served market grows.
- *Switch up.* A switch—or flexibility—option values an opportunity to switch products, process, or plants given a shift in the underlying price or demand of inputs or outputs. One example is a utility company that has the choice between three boilers: natural gas, fuel oil, and dual-fuel. Although the dual-fuel boiler may cost the most, it may be the most valuable, as it allows the company to always use the cheapest fuel.
- *Scope up.* This option values the opportunity to leverage an investment made in one industry into another, related industry. This is also known as link-and-leverage.[11] A company that dominates one sector of e-commerce and leverages that success into a neighboring sector is exercising a scope-up option.

Defer/Learn

- *Study/start.* This is a case where management has an opportunity to invest in a particular project, but can wait some period before investing. The ability to wait allows for a reduction in uncertainty, and can hence be valuable. For example, a real estate investor may acquire an option on a parcel of land and exercise it only if the contiguous area is developed.

Disinvest/Shrink Options

- *Scale down.* Here, a company can shrink or downsize a project in midstream as new information changes the payoff scheme. An example would be an airline's option to abandon a nonprofitable route.
- *Switch down.* This option places value on a company's ability to switch to more cost-effective and flexible assets as it receives new information.
- *Scope down.* A scope-down option is valuable when operations in a related industry can be limited or abandoned based on poor market conditions and some value salvaged. A conglomerate exiting a sector is an example.

---

[10] "How Much Is Flexibility Worth?" Thomas E. Copeland and Philip T. Keenan, *McKinsey Quarterly*, Number 2, 1998.

[11] "The New World of Business," W. Brian Arthur, *Harvard Business Review*, July-August, 1996.

We believe that real options thinking should permeate all corporate strategy decisions. This includes recognizing the options that arise from certain strategic actions as well as identifying and exercising valuable options that exist in the firm.

Investors must be attuned to the fact that stock prices may incorporate real options value. This options value is often not obvious from just looking at current businesses. The goal is to identify those companies that have options and are most likely to exercise them prudently.

Figure 5
Common Real Options

Real Option Category	Real Option Type	Description	Examples
Invest/ grow	***Scale up***	Well positioned businesses can scale up later through cost-effective sequential investments as market grows	• High technology • R&D intensive • Multinational • Strategic acquisition
	Switch up	A flexibility option to switch products, process on plants given a shift in underlying price or demand of inputs or outputs	• Small-batch goods producers • Utilities • Farming
	Scope up	Investments in proprietary assets in one industry enables company to enter another industry cost-effectively. Link and leverage.	• Companies with lock-in • De facto standard bearers
Defer/ learn	***Study/ start***	Delay investment until more information or skill is acquired	• Natural resource companies • Real estate development
Disinvest/ shrink	***Scale down***	Shrink or shut down a project part way through if new information changes the expected payoffs	• Capital-intensive industries • Financial services • New product introduction • Airframe order cancellations
	Switch down	Switch to more cost-effective and flexible assets as new information is obtained	• Small-batch goods producers • Utilities
	Scope down	Limit the scope of (or abandon) operations in a related industry when there is no further potential in a business opportunity	• Conglomerates

Source: "How Much Is Flexibility Worth?" Thomas E. Copeland and Philip T. Keenan, *The McKinsey Quarterly,* 1998, Number 2; *Real Options*, Lenos Trigeorgis, The MIT Press, 1998; *Real Options*, Martha Amram and Nalin Kulatilaka, Harvard Business School Press, 1999.

Analytics

There are three steps in turning real options thinking into useable results. The first is to accurately identify a real option. The second is use of the options model itself. Finally, consideration must be given to the potential differences between option-model-derived value and real-world value.

Defining the application is probably the most important part of a real options analysis. Amram and Kulatilaka break the defining task into four parts: the decision, the uncertainty, the decision rule, and the review. (See Table 3.)

Table 3
Defining the Application

- **The Decision**
  - What are the possible decisions?
  - When might they be made?
  - Who is making them?
- **The Uncertainty**
  - What is the source?
  - What is the trend?
  - How has it evolved?
  - What other market factors are important?
- **The Decision Rule**
  - Create a mathematical expression
- **Look to the Financial Markets**
  - Is uncertainty private or market-priced?
  - Are there better alternate frames?
- **Review for Transparency and Simplicity**
  - Is the application definition clear?
  - Can managers understand the definition?
  - Is the definition clear to investors?

Source: *Real Options*, Martha Amram and Nalin Kulatilaka, Harvard Business School Press, 1999.

Appropriate definition is a difficult balancing act. Managers and investors have to meld some intuition about the business with a model that maintains a degree of rigor. Pinpoint precision is neither an appropriate goal nor a likely outcome of the model: the thought process alone is valuable and leads to potentially important insights and opportunities.

The next step is the actual options pricing model. Although the five Black-Scholes inputs are relatively straightforward in principle—and are largely familiar to DCF users—option-pricing models can get very complex.[12] Further, many real options are intertwined: options on options. Again, while some analytical rigor is required, the power of real options stems more from an appropriate mind-set than from the product of the model. The journey is more important than the destination.

[12] A spreadsheet with various options pricing models is available from the author upon request.

One element that causes a variation between a simple options model value and reality is “leakage.”[13] Leakage is relevant when cash flows move in or out of the underlying asset, affecting the option value.[14]

Sources of leakage in the real world include explicit positive cash flows (dividends, rental, and interest), explicit negative cash flows (storage costs, taxes, and fees), and implicit benefits (convenience yields). The “burn rate,” or rate at which cash flow is consumed, is an important source of leakage that has to be considered in valuing start-up companies.

[13] *Real Options*, Martha Amram and Nalin Kulatilaka, Harvard Business School Press, 1999, pp. 127-140.

[14] For example, consider two stocks that are similar in all ways except that one pays a dividend and one does not. While the shareholders in each case can expect the identical economic returns (capital appreciation plus dividends), there is leakage in the option on the dividend-paying stock. This is because dividend payments result in a lower absolute stock price without an adjustment in the option terms.

Reading the Stock Market

An expectations-based approach to investing starts with a company's stock price and considers what value driver estimates solve for that price. Using this approach, numerous financial analysts and pundits have concluded that many stocks—especially those that compete in rapidly growing, uncertain markets—are substantially overvalued. We believe that such an analysis is incomplete because it ignores the potentially meaningful value of imbedded real options.

We suggest that stocks of companies that participate in highly uncertain markets are best viewed as a combination of the discounted cash flow value of the current, known businesses plus a portfolio of real options. This real option can be estimated by taking the difference between the current equity value and the DCF value for the established businesses. Although reasonable people may disagree about the value of the imbedded real options, we believe that overlooking their existence is a major analytical mistake. Is it valuing the unimaginable? Yes. Is the unimaginable valuable? Yes.

This thinking extends to the issue of volatility. Market watchers assume that real-option-laden businesses are extremely volatile because of the risk in their known operations. As a result, analysts generally assume unduly high costs of capital in their discounted cash flow models.

We believe the reality of the market is a little subtler. There are two factors at play: the risk in the known businesses and the swings in option value. As noted earlier, option values are very sensitive to changes in underlying asset values and time. Table 4 provides numerical support. As an example, an out-of-the-money call is four times more valuable ($28 versus $7) with a five-year life than with a one-year life.[15] So as expectations about current businesses shift—by extension affecting the options they support—the market values of real-option-rich companies swing wildly. The resulting high share price volatility speaks more to changes in option value than to current business value.

Table 4
Sensitivities of Various Option Values
call option with a 5% risk-free rate, $100 strike, and 45% annual volatility

	Net Present Value Ratio		
Time (years)	**0.75**	**1.0**	**1.25**
1	$7.10	$19.90	$37.95
3	19.25	36.65	54.85
5	28.00	46.25	66.45

Note: Net present value ratio = PV of asset FCF/investment.

This means that the discount rates suggested by the capital asset pricing model, which relies heavily on beta, are vastly overstating the risk of the core businesses of real-options-imbued businesses. Using more pedestrian discount rates in valuing the known businesses leads to more reasonable valuations both for the core businesses and the embedded options.

[15] Given the assumptions laid out in Table 4.

Case Studies

Case Study 1: Cable's "Stealth Tier"—A Scale-Up Option[16]

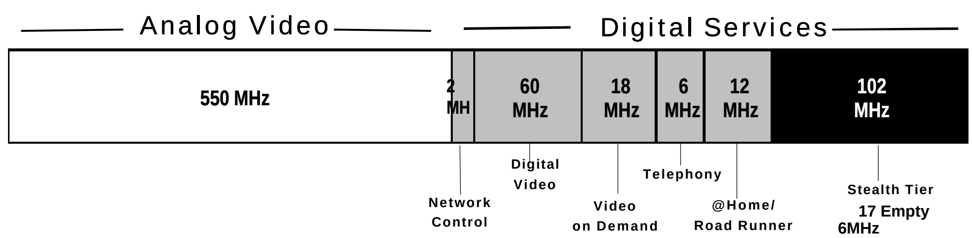
In recent years many cable companies have upgraded their plant. The result is capacity beyond current usage. CSFB cable analyst Laura Martin used real options analysis to value this additional capacity.

Of the 750 MHz available in an upgraded cable system, approximately 648 MHz are being used for four visible revenue streams (analog video, digital video, high-speed data, and telephone). Figure 6 includes a diagram of the typical uses for 750 MHz cable plant.

We refer to the remaining 102 MHz as the "Stealth Tier." It is the tier of future interactive services that do not exist today. However, lack of visibility does not mean a lack of value.

The Stealth Tier could include services such as video telephone, interactive e-commerce, interactive games, and any other application that requires enormous amounts of bandwidth. Entrepreneurs who develop an application requiring broadband delivery must pay the cable operator—the gatekeeper—for access to consumers.

Figure 6
Analysis of 750 MHz Cable Plant Usage



Source: Time Warner.

By our calculations, the present value of the four visible revenue streams equals the current public trading value per home passed by cable wire. Accordingly, investors are attributing no value to the 17 empty 6 MHz channels on the interactive tier.

Embedded in the upgrade of the cable plant is a growth option—or scale-up option—that is being overlooked. We know that the additional 102 MHz will be used, we just do not know when or how. Real options provide a framework for estimating the Stealth Tier's value.

We consider five potential NPV outcomes in our analysis. To minimize analytical complexity, we hold four of the five option inputs constant, making the valuation impact of the various NPV assumptions transparent. We hold volatility (σ^2) constant at 45% per year (the midpoint of the volatility range), time (t) constant at ten years (cable plant's life), the risk-free rate (R_f) constant at 5.2%, and the marginal cost (X) per proposed project at 50% of the project's value.

[16] Adapted from "Portfolio Managers Series: New Valuation Frameworks for Cable Plant," Laura A. Martin, *Credit Suisse First Boston Equity Research*, April 30, 1999.

Table 5
Black-Scholes Call Option Valuation Matrix

PV of Potential Project/Home Passed (S)	$15	$25	$50	$100	$150
Marginal Capital Spending (X)	$7.5	$12.50	$25	$50	$75
Time in Years (t)	10	10	10	10	10
Risk Free Rate (R_f)	5.2%	5.2%	5.2%	5.2%	5.2%
Volatility (σ^2)	45%	45%	45%	45%	45%
Call Option Value/Home Passed	$11.60	$19.40	$38.80	$77.60	$116.40

Source: Black-Scholes model, Credit Suisse First Boston estimates.

Using these variables for each 6 MHz channel in the Stealth Tier, we can determine a range of values. Using just the 17 empty 6 MHz channels available today implies a call option value per home passed of $197-1,979 for the Stealth Tier. (See Table 6.) The midpoint of this range is $1,088, representing approximately 50% of today's trading value per home passed.

Table 6
Value of the Stealth Tier Using Real Options Theory

NPV of Potential Project/Home passed (S)	$15	$25	$50	$100	$150
Call value/home passed, as per Black-Scholes	$11.60	$19.40	$38.80	$77.60	$116.40
Empty 6MHz channels in the Stealth Tier	17	17	17	17	17
Value of the Stealth Tier/home passed	$197	$330	$660	$1,319	$1,979

Source: Credit Suisse First Boston estimates.

Case Study 2: Enron—Flexibility Options

Most utility companies shudder when they consider the price volatility, lack of storage, and transmission constraints in the electricity market. Enron sees opportunity. And management uses real options as a key analytical guide in its turbulent markets. In fact, real options thinking is the only way to fully appreciate Enron's strategy given its markets and management philosophy.

Last year, electricity prices briefly surged from $40 to an unprecedented $7,000 per megawatt hour in parts of the Midwest.[17] Although the magnitude of this jump was unusual, a combination of capital intensity, transmission constraints, a lack of storage capability, deregulation, and always-uncertain weather has led to a secular increase in electricity price volatility. Enron learned from the events of 1998. Management realized that its diverse skills and meaningful resources made it uniquely positioned to capitalize on this volatility and immediately began work on a "peaker" plant strategy. Real options showed the way.

This summer, Enron is slated to open three "peaker" plants—gas-fired electricity-generating facilities that have production costs 50-70% higher than the industry's finest. The plants, situated at strategic intersections between gas pipelines and the electric grid, are licensed to run only 1,200 hours per year but are much cheaper to build than a normal facility. In effect, they serve as the equivalent of underground storage in the gas business: they start up when electricity prices reach peak prices.

Real options analysis demonstrated that the flexibility of the peakers is more valuable than their relative inefficiency, given ENE's wholesale businesses and risk management capabilities. Supporting Enron's efforts to develop its overall energy merchant business, options offer a more robust analytical framework than more traditional tools.

[17] Coy, Peter, "Exploiting Uncertainty," *Business Week*, June 7, 1999.

Case Study 3: Merck and Biogen—Contingent Options

Companies in all industries are increasingly using joint ventures, licenses, and alliances to create shareholder value. These arrangements are particularly prominent in the pharmaceutical industry because of prolonged development phases and the difficulty in predicting future cash flows and market conditions. Given these dynamics, NPV techniques do not capture the strategic value of the research. These deals are best understood and valued as options. Amram and Kulatilaka developed the following case study:[18]

In late 1997, Biogen announced that it had signed an agreement with Merck to help it develop and bring to market an asthma drug. Merck paid Biogen $15 million up front, plus the potential of $130 million of milestone payments over several years.

Before the drug becomes commercially viable, Biogen has to shepherd it through the development process. Along the way, Biogen could face expanded tests, a changing asthma drug market, and the risk of abandonment for safety reasons.

In this case, Merck purchased a stream of options, including scale-up and scale-down (abandonment) options. Drug development represents “options on options,” or a series of contingent options. And Merck’s abandonment option must also be considered. The result is that Merck’s upside is unlimited, while its downside is capped by the payments. Real options analysis revealed that the deal was worth more than the $145 million of up-front and milestone payments that Merck pledged.[19]

From Biogen’s perspective, the value of the joint venture is the up-front payment plus the expected value of the milestone payments. In effect, Biogen transferred options to Merck that cannot be valued using traditional methods.

Case Study 4: Amazon.com—An Options Smorgasbord

Nowhere does a real options approach apply more than at a company like Amazon.com. In fact, options thinking is built into the culture,[20] which stresses flexibility and adaptation. Here is a partial list of the real options at Amazon:

- *Scope-up options.* Amazon has leveraged its position in key markets to launch into similar businesses. For example, it used it market-leading bookselling platform to move into the music business. These can be considered contingency options.
- *Scale-up options.* Flexibility options are part of Amazon’s announced growth in distribution capabilities. The company is adding capacity that will support significantly higher sales volumes in current businesses as well as capacity in potential new ventures. Management believes the cost of this option is attractive when weighed against the potential of disappointing a customer.
- *Learning options.* The company has made a number of acquisitions that may provide the platform for meaningful value creation in the future. The recently acquired business Alexa is an example. Alexa offers Web users a valuable service, suggesting useful alternative Web sites. It also tracks user patterns. Amazon may be able to use this information to better serve its customers in the future.

---

[18] Adapted from *Real Options*, Martha Amram and Nalin Kulatilaka, Harvard Business School Press, 1999, pp. 72-3.

[19] Merck has used this valuation method for some time. See “Scientific Management at Merck: An Interview with CFO Judy Lewent.” *Harvard Business Review*, January-February 1994.

[20] In fact, AMZN’s well-regarded Chief Financial Officer Joy Covey is assuming the role of Chief Strategy Officer.

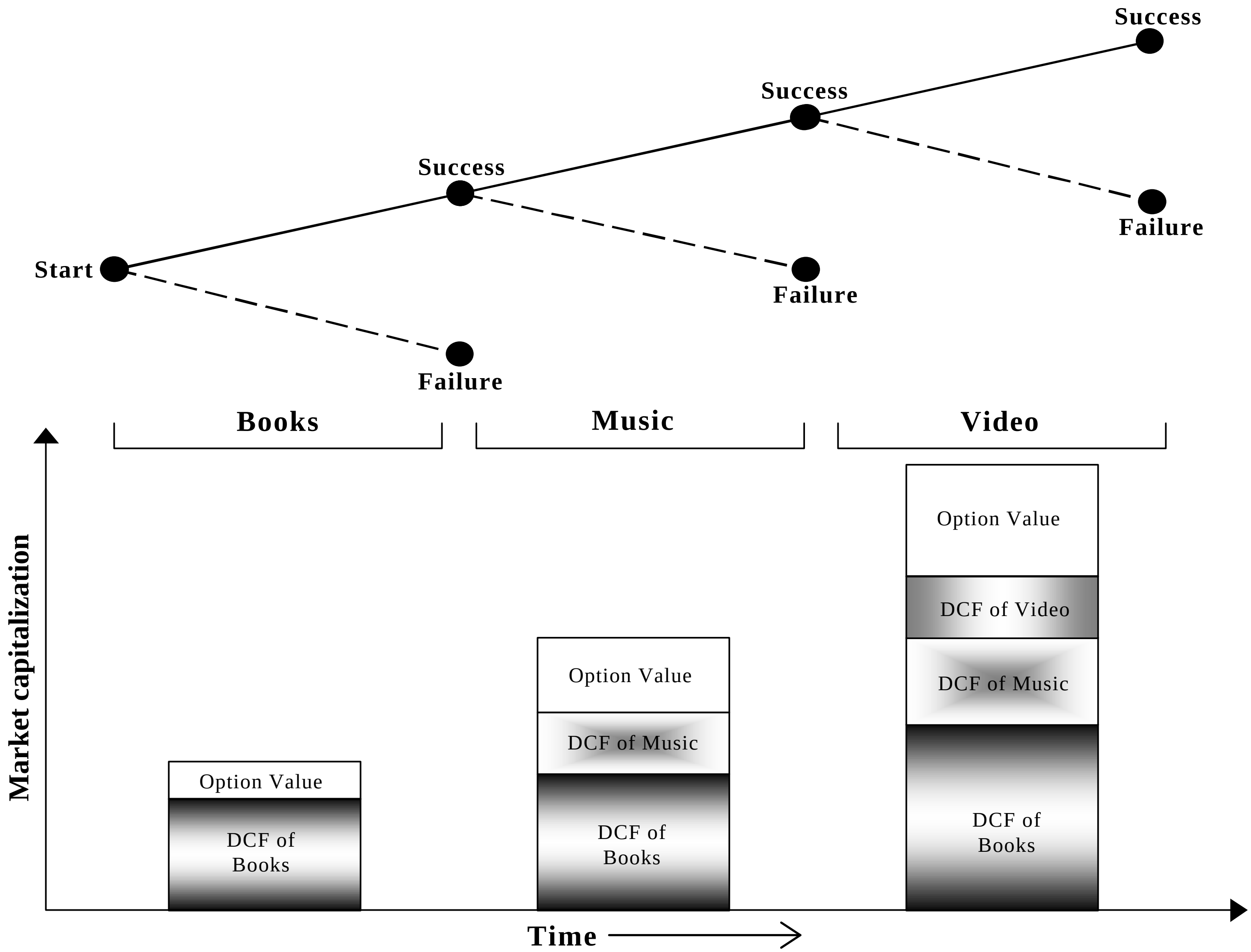
- *Equity stakes.* Amazon has taken equity stakes in a number of promising businesses, including drugstore.com and pets.com. These new ventures are best valued using options models.

Figure 7 shows a conceptual diagram of how value has been created at Amazon. The company started by selling books. So there was a DCF value for the book business plus out-of-the-money contingent options on other offerings. As the book business proved successful, the contingent option on music went from out-of-the-money to in-the-money, spurring the music investment. As the music business thrived, the company exercised an option to get into videos. As time has passed, Amazon's real options portfolio has become more valuable. For example, the recent foray into the auction business, unimaginable one year ago, was contingent on a large base of qualified users.

Many analysts assert that a business like Amazon cannot be realistically valued. We disagree. The key is attributing explicit value to the company's real options. And that value is potentially huge.

Amazon fits the profile of a real options-laden business: smart management, a leading business franchise, and high end-market uncertainty. Real options provide an important dimension in understanding how the market is valuing the company.

Figure 7
Amazon.com
Building Value through Options



Source: CSFB ; *Note:* not to scale.

Conclusion

The standard DCF model is sufficient for valuing most traditional businesses, but it lacks the flexibility to value many new economy companies. Real options theory, a complement to DCF, adds that necessary flexibility. In the process, real options theory addresses important strategic and financial issues.

Although real options analysis has been well understood in the academic community for some time, we believe it will become increasingly important in mainstream security analysis. The primary catalyst is the accelerating rate of change—especially with regard to technology—and the commensurate rise of uncertainty.

The real options approach provides a powerful framework for thinking about corporate value. It not only allows analytical rigor and business intuition to coexist, it also allows them to thrive.

Real Options References

Amram, Martha; Kulatilaka, Nalin, *Real Options*, Cambridge, MA, Harvard Business School Press, 1999.

Amram, Martha; Kulatilaka, Nalin, "Disciplined Decisions: Aligning Strategy with the Financial Markets," *Harvard Business Review*, January-February 1999.

Brealey, Richard A.; Myers, Stewart C., *Principles of Corporate Finance*, New York, McGraw-Hill, 1996.

Copeland, Thomas E.; Keenan, Philip T., "How Much Is Flexibility Worth?" *The McKinsey Quarterly*, Number 2, McKinsey & Company, New York, 1998.

Copeland, Thomas E.; Keenan, Philip T., "Making Real Options Real," *The McKinsey Quarterly*, Number 3, McKinsey & Company, New York, 1998.

Copeland, Tom; Koller, Tim; Murrin, Jack, *Valuation: Measuring and Managing the Value of Companies*, New York, John Wiley & Sons, Inc., 1995.

Coy, Peter, "Exploiting Uncertainty," *BusinessWeek*, June 7, 1999.

Coyne, Kevin P.; Subramaniam, Somu, "Bringing Discipline to Strategy," *The McKinsey Quarterly*, Number 4, McKinsey & Company, New York, 1996.

Damodaran, Aswath, *Investment Valuation*, John Wiley & Sons, New York, 1996.

Dixit, Avinash K.; Pindyck, Robert S., *Investment Under Uncertainty*, Princeton, NJ, Princeton University Press, 1994.

Greene, Jeffrey R., "Is Economic Value Added Stunting Your Growth?" *Perspectives on Business Innovation*, Issue 2, The Ernst & Young Center for Business Innovation.

Grinblatt, Mark; Titman, Sheridan, *Financial Markets and Corporate Strategy*, McGraw-Hill, New York, 1998.

Leslie, Keith J.; Michaels, Max P., "The Real Power of Real Options," *The McKinsey Quarterly*, Number 3, New York, 1993.

Luehrman, Timothy A., "Investment Opportunities as Real Options: Getting Started on the Numbers," *Harvard Business Review*, July-August 1998.

Luehrman, Timothy A., "Strategy as a Portfolio of Real Options," *Harvard Business Review*, September-October 1998.

Nichols, Nancy A., "Scientific Management at Merck: An Interview with CFO Judy Lewent," *Harvard Business Review*, January-February 1994.

Sender, Gary L., "Option Analysis at Merck: The New Pharmaceutical Paradigm," *Harvard Business Review*, January-February 1994.

Trigeorgis, Lenos, *Real Options*, Cambridge, MA, The MIT Press, 1998.

Web Pages

http://www.real-options.com

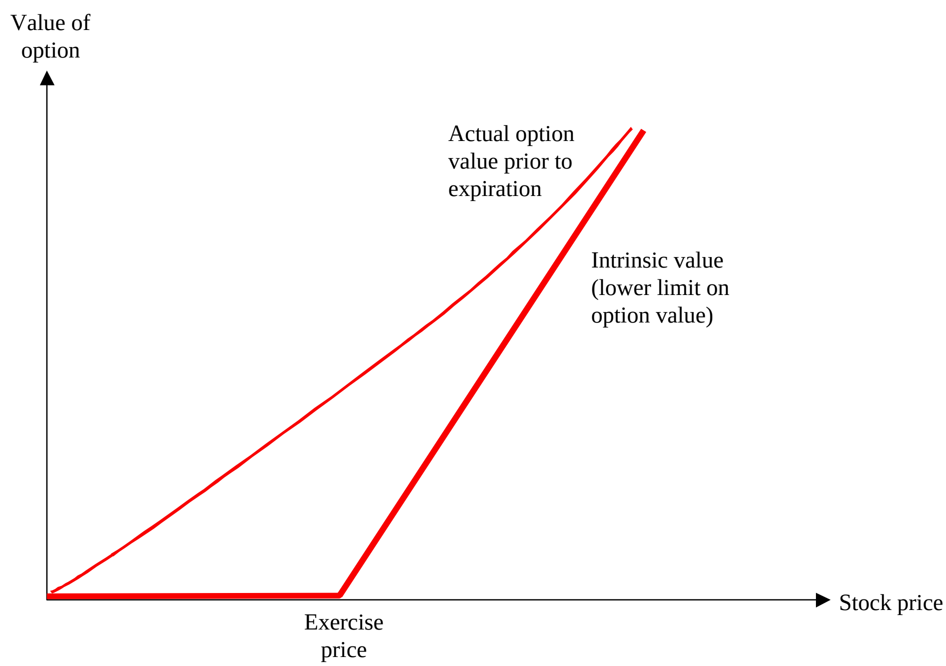
http://www.stern.nyu.edu/~adamodar/

http://www.puc-rio.br/marco.ind/main.html

Appendix A: An Option Primer

An option gives its owner the right—but not the obligation—to buy or sell an asset at a certain prenegotiated price. For example, a call option on a stock gives its owner the right to buy a stock at a fixed price—called an option's exercise or strike price—regardless of the stock's market price. A call option, then, is valuable if the stock's price rises past the exercise price before expiration. However, if the stock price falls below the option's exercise price, the owner will choose not to exercise the option so as not to lose money. Thus, an option offers exposure to a stock's upside potential and limits exposure to possible downside. (See Figure 8.)

Figure 8
A Call Option's Intrinsic Value Increases as the Stock Price Increases, but Never Falls below Zero



Source: *Principles of Corporate Finance*, Richard A. Brealey and Stewart C. Myers.

Although this complicated payoff scheme makes pricing an option a mathematical ordeal, the drivers behind option value can be intuitively understood using simple concepts. This is because Nobel Prize-winning work by Fisher Black[21] and Myron Scholes resolved the precise role of these drivers in options value.[22]

The most obvious determinant of an option's value is its *intrinsic value*, or what it would be worth if it were immediately exercised. This amount, defined as the stock price less the exercise price, ultimately determines how much money the option holder makes.

- *Exercise price*. The less an investor has to pay to convert an option into a more valuable share, the greater the option's worth. Thus, a lower exercise price means a more valuable option.

[21] Unfortunately, Fisher Black died in 1995, so he never received the well-deserved honor.

[22] Black, F.; Scholes, M., "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy*, 81 (1973), pp. 637-654.

- *Stock price*. Because an investor benefits by receiving a more valuable share upon exercising an option, a higher stock price means a more valuable option.

However, an option can still be valuable even if it has no intrinsic value. This is because the possibility exists that the option can be profitably exercised in the future.

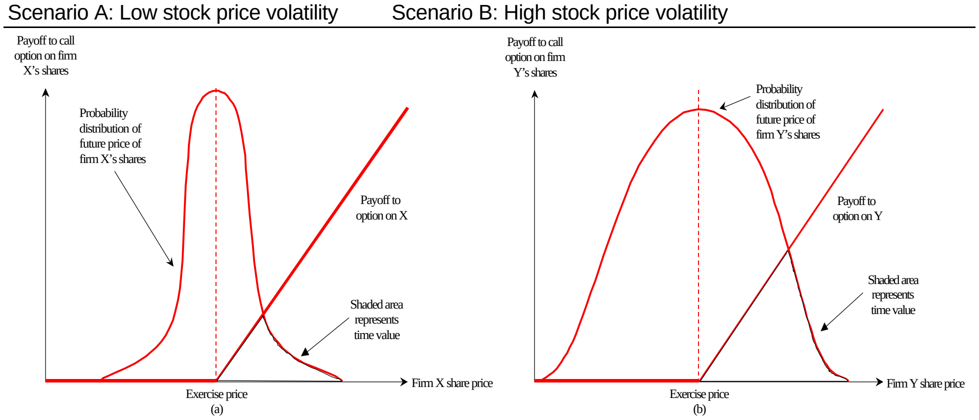
The value of this possibility is an option's *time value* and is determined by three factors:

- *Volatility*. As volatility increases, there is a higher probability that the stock will dramatically increase or decrease in value. Viewed from the perspective of the option owner, if the stock has a huge run-up, the option increases in value from its upside exposure. However, if the stock goes down a lot, the option's downside exposure is limited. This makes option owners prefer high volatility in the price of the underlying stock, as it increases the chance that the option will be very valuable without exposure to large losses.

We can represent this concept graphically as well. Scenario A of Figure 9 shows an option on a low-volatility stock. This option has a narrow price distribution that clusters around the exercise price. In contrast, Scenario B shows a similar option on a high-volatility stock with a wide price distribution. By overlaying these price distributions over a standard option payoff diagram, we can estimate the probability that the underlying stocks will rise above the option's exercise price. The larger shaded area in Scenario B shows that the more volatile the stock, the higher the chance that the option will be profitable. All things equal, then, higher stock price volatility translates into a higher time value.

Figure 9
A Call Option's Time Value Increases as Stock Price Volatility Increases

Scenario A: Low stock price volatility Scenario B: High stock price volatility



Source: *Principles of Corporate Finance*, Richard A. Brealey and Stewart C. Myers.

- *Length of time before an option expires*. The longer an option holder has before expiration, the higher the probability that the stock price will end up above the exercise price. This makes options with long lives more valuable than similar options with short lives.

- *Risk-free rate*. This variable enters the equation in a subtle way. Purchasing an option gives an investor the right to purchase a share at a fixed price in the future. In essence, an option gives its owner an interest-free loan in the amount of the exercise price for the length of the option. The value of this loan increases with the length of the option life and the risk-free rate. Thus, an option's value increases as the risk-free rate increases.

Before we finish our option primer, we can highlight a final practical consideration that will affect our valuation of employee stock options:

- *Dividends*. When a company pays a dividend, the stock's price is lowered precisely by the dividend amount. Thus, while dividends may be an important part of total shareholder returns, they always lower a stock's absolute price level. Accordingly, the value of an option to buy that stock also falls.

When valuing an option with a short life, we should lower the option's underlying share price by the present value of dividends expected to be received over the option's life.[23] Robert Merton's adaptation of the Black-Scholes option pricing formula is preferable for valuing options with a longer life, as it incorporates an estimate of a stock's long-term dividend yield. (See Appendix B for more information on how to adjust the Black-Scholes option pricing model for dividends.)[24]

[23] Espen Gaarder Haug, *The Complete Guide to Option Pricing Formulas*. (New York: McGraw-Hill 1998), p. 3.

[24] Merton, Robert, "Theory of Rational Option Pricing," *Bell Journal of Economics and Management Science* 4 (1973): pp. 141-183.

Appendix B: How to Use the Black-Scholes Option Pricing Model

Before Fisher Black and Myron Scholes came along in 1973, economists had tried for years to develop satisfactory models to price options. In part, these would-be Nobel Prize winners were stymied by the lack of advanced mathematics in classical economics training. Fortunately, we do not need to know how to derive the Black-Scholes model to use it. Indeed, we do not even need to know the Black-Scholes formula to understand what value drivers make options valuable. (See Appendix A.)

In this Appendix, we present the generalized Black-Scholes formula, leaving the derivation of the equation to option textbooks.[25] We do this so readers can enter the formula into a spreadsheet to value options. Following this presentation, we also walk through an example applying the formula to a sample option.

The Black-Scholes Formula

The Black-Scholes formula values a European call or put option as follows:

$$\text{Value of Call} = S\,e^{(b-r)T} N(d_1) - X\,e^{-rT}\;N(d_2)$$

$$\text{Value of Put} = -S\,e^{(b-r)T} N(-d_1) + X\,e^{-rT}\;N(-d_2)$$

where:

- S is the stock price of the underlying stock. If we expect the stock to pay specific dividends before the option expires, we should subtract the present value of those dividends from the stock price and use this "adjusted stock price" as the relevant input for this equation.
- X is the exercise, or strike, price of the option.
- r is the risk-free rate.
- b is the "cost of carry," defined as risk-free rate minus the dividend yield (q).
- T is the expected life of the option in years.
- σ^2 is the variance of the underlying security.
- $d_1 = \dfrac{\ln\left(\frac{S}{X}\right) + \left(b + \frac{s^2}{2}\right) T}{s\,\sqrt{T}}$
- $d_2 = d_1 - s\,\sqrt{T}$

These formulae look intimidating, but can be inputted into a spreadsheet for automatic calculation. Note that the function N (parameter) used in the Black-Scholes formula is mathematical notation for the cumulative normal distribution function. It can be represented in Excel using the following formula: "=NORMDIST(parameter,0,1,TRUE)."

Using the Black-Scholes Formula

To use the Black-Scholes method, we simply enter the properties of an option into the appropriate formula. For example, say a call option has the following properties:

---

[25] For a clear exposition of the derivation of the Black-Scholes formula, see Hull, John, *Options, Futures, and Other Derivatives*, 3rd edition.

- The underlying security is worth \$50 (S = \$50).
- The exercise price is \$40 (X = \$40).
- The risk-free rate is 5% (r = 0.05).
- The dividend yield is 3% (q = 0.03).
- The "cost of carry" is 2% (b = r – q = 0.05 - 0.03 = 0.02).
- The option has a maturity of five years (T = 5).
- The volatility (σ) of the underlying stock is 30% (σ = 0.3).
- e is a constant equal to 2.7183.

We can then calculate the Black-Scholes value of this option:

$$d_1 = \frac{\ln\left(\frac{50}{40}\right) + \left(0.02 + \frac{0.3^2}{2}\right)5}{0.3\sqrt{5}} = \frac{\ln(1.25) + 0.3250}{0.6708} = \frac{0.2231 + 0.3250}{0.6708} = 0.8171$$

$$d_2 = d_1 - s\sqrt{T} = 0.8171 - 0.3\sqrt{5} = 0.8171 - 0.6708 = 0.1463$$

$$N(d_1) = N(0.8171) = 0.7931$$

$$N(d_2) = N(0.1463) = 0.5582$$

$$\text{Value of Call} = 50\,e^{(0.02 - 0.05)5}\,0.7931 - 40\,e^{-0.05\ 5}\ 0.5582 = 34.13 - 17.39 = \$16.74$$

Note that while the option can be immediately exercised for a gain of \$10—by paying \$40 to exercise an option and receiving a share worth \$50—the option will trade in the marketplace at \$16.74. This higher value comes from the "time value" of the option—that is, from the possibility that the stock may be worth even more than \$50 before the option expires in five years.

Spreadsheet

A spreadsheet with the Black-Scholes call and put option pricing models can be obtained from the author upon request.

Appendix C: The Math behind the Binomial Model

In its simplest form, the binomial model describes the process of price movements where the asset value, in any time period, can move to one of two possible prices with associated probabilities. The model is based on a replicating portfolio that combines risk-free borrowing (lending) with the underlying asset to create the same cash flows as the option. As there is rarely a market-priced underlying asset in real options valuation, it is important to be careful to maintain as much of a financial market link as possible.

Here is a simple example. We value a European call option with a strike price of $50, expected to expire in two periods, on an underlying asset of $50, which is expected to follow a binomial process. We assume a 5% risk-free rate.

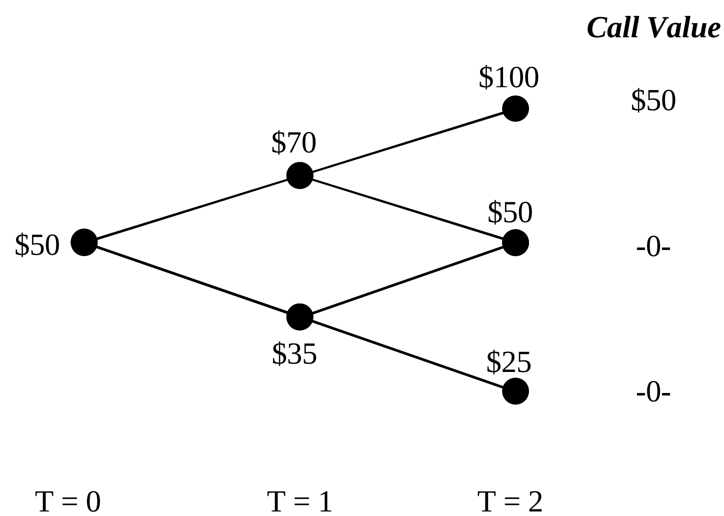
Value of call option = (current value of asset) **x** (option Δ) − (borrowing needed to replicate the option call value)

Where:

Δ = number of shares in replicating portfolio
B = amount of borrowing in replicating portfolio

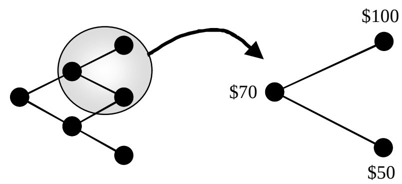
The problem can be diagrammed as follows. (See Figure 10.) The actual valuation can be done in three steps.

Figure 10
Valuing a Call Option with a Binomial Model



Step 1: Start by valuing the end nodes

A.



Call Value

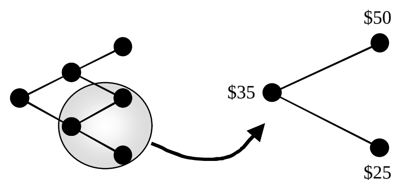
$50 ($100 x Δ) – (1.05 x B) = $50

-0- ($50 x Δ) – (1.05 x B) = $0

B = $47.60
Δ = 1

Call option = ($70 x 1) – $47.60 = **$22.40**

B.



Call Value

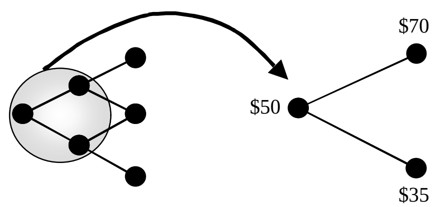
$0 ($50 x Δ) – (1.05 x B) = $0

$0 ($25 x Δ) – (1.05 x B) = $0

B = $0
Δ = 0

Call option = ($35 x 0) – $0 = **$0**

Step 2: Move backward to the previous node and recalculate



Call Value

$25 ($70 x Δ) – (1.05 x B) = $22.40

$0 ($35 x Δ) – (1.05 x B) = $0

B = $21.33
Δ = .64

Step 3: Value the call

Value of the call = ($50 x 0.64) – $21.33 = **$10.67**

Adapted from: *Investment Valuation*, Aswath Damodoran, J. Wiley & Sons, 1996.

CREDIT SUISSE | FIRST BOSTON

Americas

Eleven Madison Avenue
New York, NY 10010, U.S.A.
1 212 325 2000

Atlanta	1 404 656 9500	Pasadena	1 626 395 5100
Boston	1 617 556 5500	Philadelphia	1 215 851 1000
Buenos Aires	1 541 394 3100	Portland, ME	1 207 780 6210
Chicago	1 312 750 3000	San Francisco	1 415 836 7600
Houston	1 713 220 6700	São Paulo	55 11 822 4862
Mexico City	1 525 202 6000	Toronto	1 416 352 4500

Europe

One Cabot Square
London E14 4QJ, England
44 171 888 8888

Amsterdam	31 20 575 4444	Paris	33 1 40 76 8888
Budapest	36 1 202 2188	Prague	42 2 248 10937
Frankfurt	49 69 75380	Vienna	43 1 512 3023
Geneva	41 22 707 0130	Warsaw	48 22 695 0050
Madrid	34 1 532 0303	Zug	41 41 726 1020
Milan	39 2 7702 1	Zurich	41 1 335 7711
Moscow	7 501 967 8200		

Asia Pacific

Three Exchange Square
8 Connaught Place
Central, Hong Kong
852 2101 6000

Auckland	64 9 302 5500	Shanghai	86 21 6219 0808
Beijing	86 10 6410 6611	Singapore	65 538 6322
Melbourne	61 3 9 280 1666	Sydney	61 2 9394 4400
Mumbai	91 22 284 6888	Taipei	8862 2718 5919
Osaka	81 6 243 0789	Tokyo	81 3 5404 9000
Seoul	82 2 3707 3700	Wellington	64 4 474 4400