CHAPTER 4

Real Options and Project Analysis

How many ages hence
Shall this lofty scene be acted over
In states unborn and accents still unknown!
—SHAKESPEARE,
Julius Caesar

The discounted cash flow (DCF) analysis presented so far treats a project's expected cash flows as given at the outset. This approach presupposes a static approach to investment decision making: It assumes that all operating decisions are set in advance. In reality, though, the opportunity to make decisions contingent on information to become available in the future is an essential feature of many investment decisions. Depending on the project's outcome (e.g., the success of a new model in the case of a car factory) and the operating environment at that time (e.g., the level of factor costs and product prices), the rate of output may be speeded up or slowed down, and the facility may be expanded, temporarily closed, or even abandoned. Indeed, in the case of an investment in research and development, a plant may not be built if the outcome is not commercially feasible. In all these cases, the optimal operating policy depends on outcomes that are not known at the project's inception. The ability of companies to change course in response to changing circumstances create what are often termed **real**, or **growth**, **options**.

4.1 Option Valuation and Investment Decisions

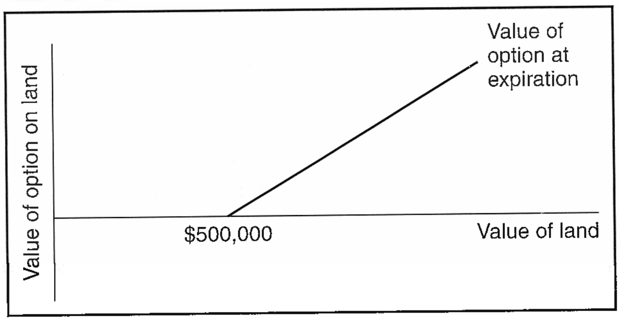
The corporation must value the set of available investment projects in order to decide which are worth undertaking. As we saw in Chapter 2, the standard approach is to estimate the cash flows that a project is expected to generate and to discount them at a risk-adjusted cost of capital. However, many investments have very uncertain payoffs that are best valued with an options approach.

Consider a firm that must decide whether to make a $50,000 down payment on an undeveloped piece of land. The down payment will permit the firm to purchase the property outright by paying an additional $500,000 at any time during the next six months. If the additional payment is not made, the $50,000 will be forfeited. The down payment agreement is a call option, with the $50,000 down payment equivalent to the option price; the extra money needed to complete the deal ($500,000) is the strike price; and the uncertain value of the land after it is developed is the "stock" price. The decision to "exercise the option," that is, to pay the additional $500,000 to own the land, depends on whether the value of the land exceeds $500,000 at the time the agreement is about to expire. Before entering into this agreement and spending the $50,000 option price, the company must determine whether $50,000 is a fair price for the option. Clearly, the Black–Scholes formula could be used for this purpose. Exhibit 4.1 shows how the value of this option varies with the price of the land in six months.

Other explicit and implicit contracts to which a firm is a party and involve investment decision making can be thought of (and valued) as options. A lease with an option to cancel can be viewed as a put option. If the value of leasing the property drops below the value of the lease payments, the lease will be canceled and the property will be "returned" to its owner, just as a stock will be sold to a put writer if its value drops sufficiently low. For example, a federal crop price support program is equivalent to issuing put options to farmers. A farmer would prefer to sell his crop at a higher price in the market but can always sell to the government at the guaranteed price if the market price plummets. The purchase of an insurance policy on property can also be thought of as a put: If the property is not damaged and remains valuable, the insurance contract will not be used; if a fire or earthquake damages the property, it will be forfeited in return for the contracted insurance payoff. It is analogous to exercising a put option when the price of the stock drops below the exercise price.

Any investment that requires an additional infusion of funds for its completion and offers an uncertain payoff can be viewed as an option. Consider the value of a patent on an untested cure for cancer. The price of obtaining the patent is the option price; the cost of developing, producing, and marketing the drug is the striking price; and the market value of profits on sales of the drug is equivalent to the stock price. The extra funds required to start production will be invested only if this cost is less than the payoff in the form of subsequent profits from the sale of the drug.

EXHIBIT 4.1 Value of a Call Option on Land at Expiration



The opportunities that a firm may have to increase the profitability of its existing product lines and benefit from expanding into new products or markets may be thought of as **growth options**.[1] Similarly, a firm's ability to capitalize on its managerial talent, its experience in a particular product line, its brand name, or its other resources, may provide valuable but uncertain future prospects. Growth options are of great importance to new firms. New ventures often have few, if any, tangible assets; their assets consist primarily of the knowledge and skills of an entrepreneur. Yet such firms have value because of the profitable possibilities their intangible assets provide. As we will see in Section 4.4, these growth options may constitute a large fraction of firm value. For example, Genentech, a gene-splicing company, had a stock market value of over $3 billion in late 1986, even though its earnings for the year were only $11 million, giving it a P/E ratio of over 270 to 1. Clearly, the market was valuing Genentech's future ability to capitalize on its research in areas like anticancer therapy and blood clot dissolvers for heart attack victims.

Any firm that faces a continuing series of operating decisions may be thought of as having investment options. The owners of a gold mine, for example, may increase or decrease the mine's gold output depending on the current price of gold and expectations of future gold prices. The mine can be shut down and then reopened when production and market conditions are more favorable, or it can be abandoned permanently. Each decision is an option from the viewpoint of the mine's owners. The value of these options, in turn, affects the value of the mine.

BOX 4.1

APPLICATION: VALUING A GOLD MINE

Consider the decision of whether to reopen a gold mine. The cost of doing so is expected to be $1 million. There are an estimated 40,000 ounces of gold remaining in the mine. If the mine is reopened, the gold can be removed in one year at a variable cost of $390 per ounce. Assuming an expected gold price in one year of $400 per ounce, the expected profit per ounce mined is $10. Clearly, the expected cash inflow (ignoring taxes) of $400,000 next year ($10 × 40,000) is far below that necessary to recoup the $1 million investment in reopening the mine, much less to pay the 15% yield required on such a risky investment. But intuition—which suggests a highly negative project NPV (net present value) of –$652,174 (–$1,000,000 + 400,000/1.15)—is wrong in this case. The reason is that the cash flow projections underlying the classical DCF analysis ignore the option *not* to produce gold if it is unprofitable to do so.

The following is a simple example that demonstrates the fallacy of always using expected cash flows to judge an investment's merits. Suppose there are only two possible gold prices next year: $300 per ounce and $500 per ounce, each with probability 0.5. The expected gold price is $400 per ounce, but this expected price is irrelevant to

[1]Growth options are synonymous with real options.

the optimal mining decision rule: Mine gold if, and only if, the price of gold at year's end is $500 per ounce. Exhibit 4.2 shows the cash flow consequences of that decision rule. Closure costs are assumed to be zero.

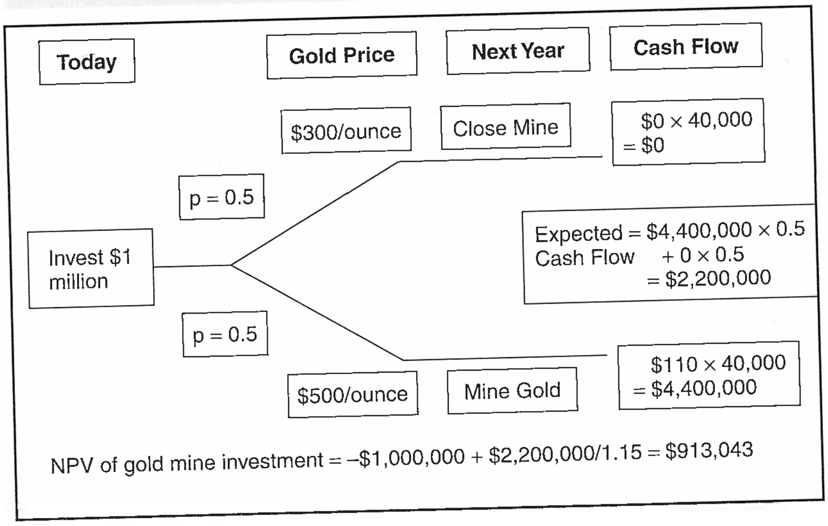
Incorporating the mine owner's option *not* to mine gold when the price falls below the cost of extraction reveals a positive net present value of $913,043 for the decision to reopen the gold mine:

$$\begin{aligned} \textit{NPV} \text{ of gold mine investment} &= -\$1{,}000{,}000 + \frac{\$2{,}200{,}000}{1.15} \\ &= \$913{,}043 \end{aligned}$$

In option pricing terms, the current value of the mine can be thought of as a call option on the value of the gold in the mine: The strike price equals the cost of reopening, and the stock price equals the value of the gold that could subsequently be produced. For valuation purposes, we used the decision rule to reopen the mine only if the value of the gold to be mined exceeds the cost of reopening, just as a call option will be exercised only if the stock price exceeds the exercise price.

With regard to investments already under way, firms have three choices: Continue to invest in the project; abandon the project; or delay it. The flexibility to change course in mid-stream, rather than continue down a losing path, has value. How much value depends on a variety of factors, including the amount of uncertainty surrounding the project's economics, the cost of changing, and payoff associated with the change.

EXHIBIT 4.2 The Gold Mine Operating Decision



BOX 4.2

APPLICATION: MICRON SLOWS THINGS DOWN

In early 1996, Boise, Idaho-based Micron Technology, Inc. faced a glut in the market for computer chips, which caused the prices of Micron's products to slide. In response, the company announced it would postpone completion of a chip plant in Lehi, Utah, after it had already invested $400 million in the project. The partially completed chip plant gave Micron "a leg up on the next 'up' cycle," according to Kipp Bedard, the firm's vice president of corporate affairs.[2] Instead of starting from scratch, Micron could complete its unfinished plant when demand picked up.

4.2 Evaluating R&D Investments Using an Option Valuation Approach

As the case of the gold mine investment demonstrates, the ability to alter decisions in response to new information may contribute significantly to the value of a project. Such investments bear the characteristics of options on securities and should be valued accordingly. Just as a call option gives the holder the right to acquire shares at a fixed exercise price, an investment in research and development gives the investor the right to acquire the outcomes of the R&D at the cost of commercialization. Similarly, the owner of a mine has the right to acquire the mine's output at the variable cost of production ($390 per ounce in the case of the gold mine). In addition, both the investor in R&D and the mine owner have put options; they can abandon their projects at an exercise price equal to the costs of shutdown. By contrast, the traditional approach to investment analysis, which ignores management's ability to respond to future operating conditions, may be likened to valuing a stock option contract while ignoring the holder's right not to exercise when it is unprofitable (e.g., the mine owner's right not to produce when the price of gold falls below $390 per ounce). By failing to take into account the benefits of operating flexibility and potentially valuable add-on projects, the traditional DCF will tend to understate project values.

Consider, for example, an investment in developing a new product and bringing it to market. The product development phase is expected to cost $5 million a year from 2005 through 2007. At that time, the company will build a plant costing $100 million to manufacture the new product. On the basis of the new product's anticipated properties and the projected competition, the annual cash flow from year-end 2008 through 2017 is expected to be $13 million. The terminal value of the project as of year-end 2017 is projected at $105 million. These data are summarized in Exhibit 4.3.

The present values of these cash flow items as of January 1, 2005, and January 1, 2008, if we use an assumed discount rate of 14%, are shown in Exhibit 4.4. They indicate

[2] "Know When To Say No," *Investors Business Daily*, March 28, 1996.

EXHIBIT 4.3 Expected Cash Flows from New Product Development* ($ millions)

R&D Expense		Cost of New Plant		Operating Cash Flows			Terminal Value
2005	2006	2007	2008	2008	2009	...	2017
−5	−5	−5	−100	13	13	...	105

*Costs are assumed to occur at the start of the year and operating cash flows at the end of the year.

EXHIBIT 4.4 Present Values of Cash Flow Items for New Product Development ($ millions)

	Present Value as of January 1	
Cash Flow Item	2005	2008
Research and development expense	−13.2	—
Plant cost (2008, beginning of year)	−67.5	−100.0
Post-2007 operating cash flows (2008–2017)	45.8	67.8
Terminal value (2017)	16.8	28.3
Net present value	−18.2	−3.9

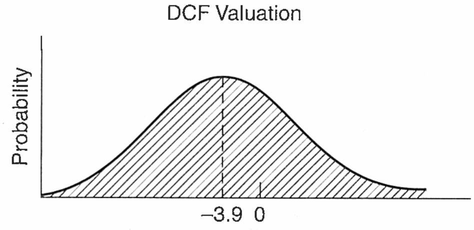
a highly negative project NPV. But as in the case of the gold mine, the numbers are misleading.

The problem with the analysis is that it assumes the plant will be built regardless of the outcome of the product development effort and the market conditions prevailing in 2007. By ignoring the option not to build the plant, standard DCF analysis projects a negative NPV of –$3.9 million as of 2008. Option valuation allows for the decision *not* to build the plant and also values only those outcomes that will follow if the plant is built. Clearly, if the R&D investment does not pan out or if market conditions are unfavorable, the plant will not be built.

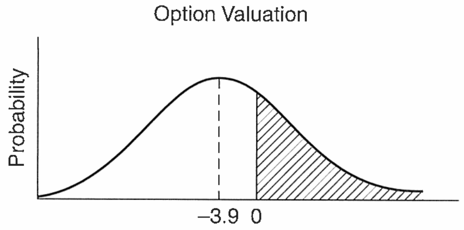
Exhibit 4.5 shows the probability distribution of possible outcomes of the R&D investment as of 2008, according to both the traditional DCF valuation method and the option valuation method, and also illustrates the sharp contrast between these methods. Note that the option valuation approach properly values only *positive* net present value outcomes, whereas the traditional DCF analysis values *all* outcomes, negative as well as positive.

Exhibit 4.6 shows how the different assumptions underlying the two methods affect their estimates of expected cash flows and project NPVs. The analysis considers only four possible scenarios, each with probability 0.25 of occurring (in contrast with the continuous probability distribution shown in Exhibit 4.5). Even though the expected payoff from undertaking the project remains at $96.1 million as of 2008, the figures in Exhibit 4.6 show that the possible payoffs can vary from $223.9 million down to $8.6 million. The variability in possible payoffs means that the plant is worth

EXHIBIT 4.5 Probability Distribution of Outcomes Under DCF Valuation and Option Valuation



DCF valuation assumes the plant will be built and values all positive and negative outcomes.



Option valuation allows for the decision not to build the plant and values only those outcomes that will follow if the plant is built.

EXHIBIT 4.6 DCF Valuation versus Option Valuation ($ millions)

Present Value on January 1		2005 R&D Expense	2008 Plant Cost	2008 Possible Payoff	2005 Project NPV
DCF Analysis		−13.2	−100.0	96.1	−18.2
Assumes one outcome, measured as expected value of all possible outcomes					
Option Analysis	I	−13.2	−100.0	223.9	70.4
Assumes many possible outcomes and measures each one separately	II	−13.2	−100.0	118.1	−1.0
	III	−13.2	—	33.9	−13.2
	IV	−13.2	—	8.6	−13.2

building under some scenarios and not under others. Under scenarios III and IV, the option valuation approach assumes the plant will not be built because the present values of the possible payoffs are negative. In these cases, the project's NPV is just –$13.2 million, the cost of the R&D investment.

Unlike the DCF analysis, in which the net present value is calculated as –$18.2 million, the option valuation approach recognizes that the expected NPV of the new product development project cannot fall below –$13.2 million. The expected project payoff in 2008 of $96.1 million used in the DCF analysis is a weighted average of the four possible outcomes. However, this number is irrelevant to the investment decision because the company will not build the plant unless the future payoff is at least equal to its $100 million cost. Hence, the possible outcomes of $33.9 million and $8.6 million can be disregarded.

EXHIBIT 4.7 Expected NPV of R&D Investment in 2008 ($ millions)

Scenario	Decision	Cost	Payoff	NPV	×	Probability	=	Value
I	Build plant	−100.0	223.9	123.9		0.25		31.0
II	Build plant	−100.0	118.1	18.1		0.25		4.5
III	Don't build	0	0	0		0.25		0
IV	Don't build	0	0	0		0.25		0
								35.5

Note: Because the R&D investment will have already been made by 2008, it is a sunk cost and so does not affect the calculated NPV.

To conclude this example, Exhibit 4.7 shows that the expected project NPV in 2008 valuing only favorable outcomes is $35.5 million. This yields a present value in 2005 of $24.0 million. Subtract the $13.2 million present value of the R&D investment, and the result is a highly acceptable project with a $10.7 million net present value. By contrast, the traditional DCF analysis, which yields an estimated project NPV of −$18.2 million, gives a reject decision. The correct decision is to invest in new product development and exercise the option of proceeding further in 2008 if the outcome looks favorable. Otherwise, the project should be abandoned at that point.

4.3 Strategic Investments and Growth Options

The problem of undervaluing investment projects using the standard DCF analysis is particularly acute for strategic investments. Many strategically important investments, such as investments in R&D, factory automation, a brand name, or a distribution network, provide growth opportunities because they are often but the first link in a chain of subsequent investment decisions. For example, companies that invested in automatic and electronically controlled machine tools in the 1970s were ideally positioned to exploit the microprocessor-based revolution and capabilities (higher performance at a much lower cost) that hit during the 1980s. Since machine operators, maintenance personnel, and process engineers were already comfortable with electronic technology, it was relatively easy to retrofit existing machines with the new technology. Companies that had deferred their investment in the latest technology, fell behind in the 1980s.

The investment in R&D frequently provides growth opportunities since they are the first link in a chain of investments that can create competitive advantage. Such follow-up projects, which create options on investments in other products, markets, or production processes, are sometimes referred to as **growth options** and may be an important component of firm value. Viewing these projects in isolation ignores their ability to create options on future products, markets, and production technologies.

BOX 4.3

APPLICATION: WESTERN FIRMS INVEST IN EASTERN EUROPE

The investments that many Western companies are now considering in Eastern Europe can be thought of as growth options. Some view investments there as a way to gain entry into a potentially large market. Others see Eastern Europe as an underdeveloped area with educated and skilled workers but low wages, and view such investments as a low-cost backdoor to Western European markets. In either case, companies who invest there are buying an option that will pay off in the event that Eastern European markets boom or that Eastern European workers turn out to be much more productive with the right technology and incentives than they have been under communism.

To illustrate the nature of these strategic options, consider the case of Bubbly Beverage, Inc., a soft drink manufacturer thinking about entering the fruit drink segment with its Delightfully Delicious line. The firm is already a world leader in carbonated beverages, and believes that its soft drink marketing expertise, coupled with its global distribution network will provide it with a long-term competitive advantage. Entering the fruited beverage segment will not be costless since Bubbly would face formidable competition from a number of entrenched smaller firms that have been in this market for a number of years. However, not entering the fruited beverage market at this time might preclude entry at a later date if one of the existing fruit beverage firms were acquired by Kampy Kola, Bubbly's major competitor in the carbonated beverage market. This would not only foreclose future product extensions but might make Bubbly vulnerable if soft drink demand shifted dramatically from carbonated to noncarbonated beverages.

Using standard DCF techniques, Bubbly develops its initial cash flow estimates, which are presented in Exhibit 4.8.

EXHIBIT 4.8 Bubbly Beverage Company Summary of Cash flows for Delightfully Delicious Line ($ millions)

Year	1	2	3	4	5
After-tax operating cash flow*	–140	–120	50	100	100
Capital investment	–80	—	—	—	—
Working capital changes	–20	–30	–30	–20	—
Terminal value**	—	—	—	—	500
Net cash flow	–240	–150	20	80	600
Present value @ 20%	–240.0	–125.0	13.9	46.3	289.4
NPV @ 20% = – $15.5 million					

*Equal to net profit after taxes plus depreciation. After-tax operating cash flow is negative in years 1 and 2 because of heavy promotion and advertising expenses.

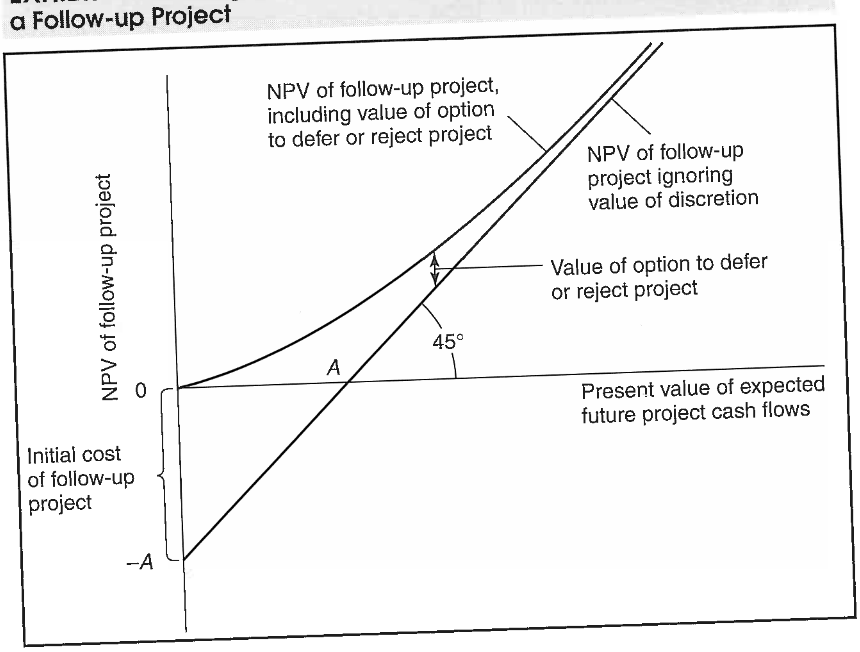
**Cash flows beyond year 5 are assumed to be $100 million per year into the indefinite future. Discounting this cash flow stream by 20% yields the $500 million terminal value.

As Exhibit 4.8 indicates, traditional techniques show that, contrary to management's gut feel, the fruited beverage line should not be introduced because the project does not meet Bubbly's required rate of return of 20%, and has a negative NPV of $15.5 million. However, this analysis does not come close to capturing the project's strategic value. For example, if the Delightfully Delicious line is successful, Bubbly could follow-up with a low calorie version. A product extension such as this would, in all likelihood, require lower market development costs because the brand name is already established. With two lines in place, vertical integration into the fruit juice business and/or related diversification into wine coolers becomes a possibility. While these future investments may be risky, Bubbly does not have to commit additional resources today until it sees how the initial investment turns out. Moreover, since option values increase with risk, the speculative nature of these future ventures enhances the value of the option to invest in these potential new products. For a large firm like Bubbly, the $15.5 million negative NPV associated with the initial offering of Delightfully Delicious may be a small price to pay for a set of options to enter new markets if conditions are favorable.

Valuing investments that embody discretionary follow-up projects requires an expanded net present value rule that considers the attendant options. More specifically, the value of an option to undertake a follow-up project equals the expected project NPV using the conventional DCF analysis plus the value of the discretion associated with undertaking the project. This is shown in Exhibit 4.9. According to option pricing theory, the latter element of value (the discretion to invest or not invest in a project) depends on:

1. *The length of time the project can be deferred.* The ability to defer a project gives the firm more time to examine the course of future events and to avoid costly

EXHIBIT 4.9 Valuing a Growth Option to Undertake a Follow-up Project



errors if unfavorable developments occur. A longer time interval also raises the odds that a positive turn of events will dramatically boost the project's profitability and turn even a negative NPV project into a positive one.

2. *The risk of the project.* Surprisingly, the riskier the investment is, the more valuable an option on it will be. The reason is the asymmetry between gains and losses. A large gain is possible if the project's NPV becomes highly positive, whereas losses are limited by the option not to exercise when the project NPV is negative. The riskier the project is, the greater the odds will be of a large gain without a corresponding increase in the size of the potential loss.
3. *The level of interest rates.* Although a high discount rate lowers the present value of a project's future cash flows, it also reduces the present value of the cash outlay needed to exercise an option. The net effect is that high interest rates generally raise the value of projects that contain growth options.
4. *The proprietary nature of the option.* Consideration of competitive conditions is what separates growth options from stock options. Growth options are valuable because they allow the firm to delay investments to learn more about the value of the underlying growth opportunities. But because these options are (1) often shared with other competitors and (2) cannot generally be traded, competition provides an incentive to exercise the option early and invest in the opportunity before competitors do. This is equivalent to the early exercise of an option on a dividend-paying stock. An exclusively owned option is clearly more valuable than one that is shared with others. The latter might include the chance to enter a new market or to invest in a new production process. Shared options are less valuable because competitors can replicate the investments and drive down returns.

BOX 4.4

APPLICATION: FORD MOTOR CO. GIVES UP ON SMALL-CAR DEVELOPMENT

In late 1986, Ford gave up on small-car development in the United States and handed over the job to Japan's Mazda. Although seemingly cost effective in the short run (Ford should save about $500 million in development costs for one car model alone), such a move—which removed a critical mass from Ford's own engineering efforts—could prove dangerous in the longer term. Overcoming engineering obstacles unique to subcompact cars—for example, the challenges of miniaturization—enhances engineers' skills and allows them to apply innovations to all classes of vehicles. By eroding its technological base, Ford may have yielded the option of generating ideas that can be applied elsewhere in its business. Moreover, the cost of reentering the business of in-house design can be substantial. The abandonment decision is not one to be taken lightly.

Some American consumer electronics companies, for example, are learning the penalties of ceding major technologies and the experiences that come from working with these technologies on a day-to-day basis. Westinghouse Electric, after quitting the development and manufacture of color television tubes in 1976, later decided to get back into the color-video business. But because it had lost touch with the product, Westinghouse was able to reenter only by way of a joint venture with Japan's Toshiba.

The video recorder is a classic example of how production know-how can yield important technical advances. Sony, along with Matsushita Electric and its partner, Japan Victor Corp. (JVC), redesigned a professional-use product from the United States that cost $20,000 or more and turned it into a $1,500 home product with a relatively small market. Japanese designers then worked closely with factory personnel to make every component smaller and less expensive.

Cooperation between Matsushita's design teams and employees on the shop floor eliminated more than three quarters of the product's cost while dramatically improving its quality. In the process, the company turned a niche product into the consumer electronics mass-market success story of the 1980s.

Moreover, in ceding to the Japanese development of videocassette recorders, as well as laser video disk players, RCA and other U.S. manufacturers lost more than these products alone. Each technology has since spawned entirely new, popular product lines—from video cameras to compact disk players—in which U.S. companies are left with nothing to do beyond marketing the Japanese-made goods.

Even those companies that merely turn to outside partners for technical help could nevertheless find their skills atrophying over the years as their partners handle more of the complex designing and manufacturing. Such companies range from Boeing, which has enlisted three Japanese firms to help engineer a new plane, to Honeywell, which is getting big computers from NEC. The corresponding reduction in in-house technological skills decreases the value of the option these firms have to develop and apply new technologies in novel product areas.

Unfortunately, estimating the value of a growth option is an all-but-impossible task since it depends on unknowable future events. A recommended approach is to estimate the NPV ignoring any growth options. If the resulting NPV is positive, then the project is acceptable; consideration of growth options would just increase its value. But if the NPV is negative, say, –$5 million, management must then decide whether it would be willing to spend $5 million (the amount necessary to yield a zero NPV) to acquire the growth options that the project may give rise to. Such a question is easier to answer than the one that asks "How much are these growth options worth?

4.4 Investment Decisions and Real Options

The preceding suggests that the existence of strategic options increases the value of a project. In general, the value of a project (*VPROJ*) can be viewed as follows:

$$VPROJ = VDCF + VSTRAT \tag{4.1}$$

where *VDCF* is the project's value using traditional DCF techniques, and *VSTRAT* is the value of the strategic options. While the value of the strategic options may be difficult (if not impossible) to assess, their presence can be treated as qualitative factors in making decisions. Further, the value of an option increases with uncertainty. Since an option represents a right, but not the obligation, to buy or sell an asset, there is no commitment to future investments unless conditions are favorable. In this way, a company can exploit a project's upside potential without incurring significant downside risks.

There are many classes of investment decisions containing embedded options. The potential for product line extensions for Bubbly Beverage's Deliciously Delightful fruit drink is an example of a growth option, which is essentially an option to change output in response to changes in product demand. A variation on this theme is the decision to build a pilot plant to manufacture a new product. While pilot plant operations, in general, do not exploit economies of scale, they do mitigate losses if sales are disappointing. On the other hand, if sales take off, the firm can invest in a higher capacity plant that would be more efficient.

In some cases, the firm may also have the option to abandon a project after it is undertaken. This may consist of simply selling the assets for cash or redeploying the assets in some other area of the business thereby eliminating the requirements for additional cash outlays. Effectively, the ability to abandon a project represents a put option for the firm. Whether we are dealing with a single piece of equipment, or whether the firm is considering a divestiture of an entire product line or division, the decision rule is the same: A project should be abandoned if the abandonment value exceeds the present value of subsequent cash flows.

Although we do not usually think about it this way, the flexibility of a project represents a set of options made available to management if the project is accepted. Baldwin, Mason, and Ruback refer to such options as "operating options," which may be inherent in some large-scale production projects.[3] For example, the management of an electric utility may face the choice of building a power plant that burns only oil or one that is capable of burning both oil and coal. While the latter facility would cost more to build, it also provides greater flexibility because management now has the option to switch back and forth between fuel sources based on prices in the energy markets. Operating options also exist in production facilities like oil refineries and chemical plants where the firm can use different raw material mixes to produce the same final product, or the same inputs (e.g., crude oil) to produce a variety of outputs (e.g., gasoline, heating oil). In an environment characterized by highly variable commodity prices, such operating options can be extremely valuable.

Other operating options include the following:

- Reducing or increasing output in response to changing demand.
- Changing marketing (pricing/promotion) strategies.
- Redesigning a product in response to changing demand or input costs.
- Changing the mix of products made at a plant (see the refinery example above).
- Temporarily closing a plant in response to a decline in demand.

The examples presented above represent a "short list" of situations where there are options imbedded in an investment project. As a practical matter, valuing these

[3]Operating options are also called **managerial options**. See Baldwin, C.Y., Mason, S.P., and Ruback, R.S. *Evaluation of Government Subsidies to Large Scale Energy Projects: A Contingent Claims Approach.* Harvard Business School Working Paper, 1983.

options may be extremely difficult; however, ignoring their existence can lead to the rejection of strategically valuable—and value-adding—projects. Thus, while DCF analysis represents a useful starting point for determining a project's value, its results should be tempered by the existence of real options.

One approach to incorporating options in a capital-budgeting analysis would be to first estimate the value of a project using DCF. If the project has a positive net present value ignoring the value of its strategic options, there is no need to engage in costly and uncertain estimates of their value; the project is acceptable regardless of the value of the strategic options imbedded in it. On the other hand, if the project's NPV is negative, then management would have to decide whether they would be prepared to pay X dollars to acquire the strategic options associated with it, where $NPV(project) + X = 0$; that is, X is the added value that would just yield a zero NPV for the project. This type of break-even analysis avoids forcing managers to determine the actual value of the options. Instead, they can focus on whether the options are likely to be worth more or less than X, an easier decision.

The use of real options evaluation techniques appears to be more widespread by corporate America than one might think given the complexity of the methodology. In their previously referenced survey of capital-budgeting techniques, Graham and Harvey report that more than one-fourth of the companies claimed to be using real options evaluation techniques.[4] However, they state that the dominant corporate use of real options probably remains as a qualitative strategic planning tool rather than a valuation technique.

4.5 Summary and Conclusions

The standard approach to investment decision making involves forecasting future project cash flows and then discounting them back to their present value. The underlying assumption is that all decisions are made at the outset, with no subsequent changes. Such an approach, however, fails to account for the flexibility that companies often have to change their decisions in response to new information and changing circumstances. This flexibility gives companies what have come to be termed real, or growth, options.

Options are valuable because they allow the holder to defer a decision until a later date, by which time more information will have been acquired about what is best to do. The more uncertain the future, the more valuable the ability to delay decisions will be. What this means is that the cash flows associated with growth options are contingent on how the world evolves and whether it makes sense to exploit the growth opportunities that may appear.

Failure to account for the options available to managers to adjust the scope or scale of a project will lead to a downward bias in estimating project cash flows. These options include the possibility of expanding or contracting the project, speeding it up or slowing it down, or abandoning it altogether, the chance to employ radical new process technologies by utilizing skills developed from implementing the project, and the possibility of entering the new lines of business to which a project may lead. Except

[4]Graham, J., and Harvey, C. "How Do CFOs Make Capital Budgeting and Capital Structure Decisions?" *Journal of Applied Corporate Finance*, Spring 2002, pp. 8–23.

in very special circumstances, valuing these real options precisely is a task beyond our current capabilities. However, ignoring them altogether will result in a downwards biased estimate of a project's value.

References

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Questions

1. Imagine that the price of copper rises to the point that the copper value of a penny is worth more than $0.01. As a result, pennies disappear from circulation. Your firm uses copper in its production process, and you can melt pennies down and retrieve their copper content at zero cost. At present, you have a six-month supply of copper reserves and you have also managed to collect 1 million pennies. Should you melt the pennies down and add the copper to your stockpile? Why or why not?
2. Will a gold mine ever be shut permanently? Why or why not?
3. Some economists have stated that too many companies are not calculating the cost of *not* investing in new technology, world-class manufacturing facilities, or market position overseas. What are some of these costs? How do these costs relate to the notion of growth options discussed in the chapter?
4. In December 1989, General Electric spent $150 million to buy a controlling interest in Tungsram, the Hungarian state-owned light bulb maker. Even in its best year, Tungsram earned less than a 4% return on equity (based on the price GE paid). What might account for GE's decision to spend so much money to acquire such a dilapidated, inefficient manufacturer?

Problems

1. A biotech firm must decide whether to purchase the patent to a new food additive, a low-cal starch substitute. It is estimated that the funds required to bring the additive to the market can be as high as $50 million or as low as $25 million. The payoff is uncertain as well: The present value of profits could be as high as $500 million or as low as $30 million. The risk-free rate is 10%, and the standard deviation of rate of return on biotech products is 35%. The patent's life is estimated at one year.
   a. In a worst-case scenario, how much is the patent worth?
   b. In a best-case scenario, how much is the patent worth?
2. The managers of a firm are asked to consider two possible new product lines for the firm. Project 1 is quite risky and may result in a market value for the firm of $50 million in two years, or nothing. Project 2 is much more certain in outcome and may result in a firm market value as high as $25 million or as low as $15 million.

   The face value of the company's debt, payable in two years, is $20 million.
   a. What are the possible payoffs to the bondholders under projects 1 and 2?
   b. What are the possible payoffs to the shareholders under projects 1 and 2?
   c. Which will the shareholders favor? The bondholders?
3. Eastern Shallow, Ltd., is a gold mining company operating a single mine. The present price of gold is $300 an ounce and it costs the company $250 an ounce to produce the gold. Last

year, 50,000 ounces were produced and engineers estimate that at this rate of production the mine will be exhausted in seven years. The required rate of return on gold mines is 10%.

a. What is the value of the mine?
b. Suppose inflation is expected to increase the cost of producing gold by 10% a year but the price of gold does not change because of large sales of stockpiled gold by foreign governments. Furthermore, imagine that the inflation raises the required rate of return to 21%. Now, what is the value of the mine?
c. Suppose the company may shut, reopen, or abandon the mine in response to fluctuations in the price of gold. Can the NPV method be used to value the mine under these conditions?

4. G.D. Sorrell is developing an anticancer drug. The project is in its preliminary stage. G.D.S. must decide whether to initiate a large-scale drug test costing $1.5 million a year for two years. If the test results are positive, a $17.5 million plant to produce the drug for commercial trials will be built at the end of the testing period. If commercial sales of the drug meet the company's forecast for the next two years, a second, larger plant costing $50 million will be built to produce the drug in quantity. The cash flows resulting from this larger plant are expected to be $76 million for eight years after it is built. The following are the relevant cash flows associated with the three possible scenarios.

	Year 0	1	2	3	4	5–12
Scenario 1	($1,500)	($1,500)	Unsuccessful			
Scenario 2	(1,500)	(1,500)	(17,500)	$3,000	$2,000	Unsuccessful
Scenario 3	(1,500)	(1,500)	(17,500)	5,000	7,500 (50,000)	9,500

a. With a cost of capital of 10%, value the research project using DCF analysis. Is the project acceptable? (Assume the two plants are built.)
b. Assuming that the three possible scenarios have equal probability, is the project acceptable? (*Hint*: Value this project as a growth option.)

5. An oil company has paid $100,000 for the right to pump oil on a plot of land during the next three years. A well has already been sunk and all other necessary facilities are in place. The land has known reserves of 60,000 barrels. The company wishes to know the market value of this operation. The interest rate is 8% and the marginal cost of pumping is $8 per barrel. Both these costs are expected to remain unchanged over the three-year period. The current price of oil is $10 per barrel. Company economists have estimated the following:

(i) Oil will increase in price by 10% with a probability of 40%, or decrease in price by 12% with a probability of 60% during each of the next three years.
(ii) The cost of storing oil in above-ground tanks is $0.50 per year.
(iii) The company can pump a maximum of 20,000 barrels per year at the site.
(iv) The site may be shut down for a year and then reopened at a cost of $2,000.

Determine the market value of the operation ignoring taxes. Assume that all cash flows occur at the end of each year. (*Hint*: Chart all possible sequences of oil prices, and calculate the optimal production decisions and payoffs associated with each sequence.)