chapter 13

Real Options

When Hewlett-Packard sells a printer internationally, it customizes the printer for the particular country. This customization can be done either at the factory that produces the printers or in the field immediately prior to the sale. At one time HP customized almost all printers at the factory because it was much cheaper to do so. Now, however, HP ships unfinished printers to its warehouses and customizes them at locations nearer the point of sale. Why would HP choose the high-cost production method? Because it gives the company an option to match supply and demand. For example, if HP customizes at its factory and then ships printers to a French warehouse, it might be stuck with too many printers customized for French customers but not enough for Germans. However, if it ships unfinished printers to a warehouse close to the border, it can quickly customize them for French, German, or Swiss customers and thus meet unexpected shifts in demand. This flexibility is called a "real option," because it gives the company a better option for dealing with market conditions that differ from the original forecast.

Cadence Design Systems, which develops electronic products and services, provides another illustration of a real option. Rather than create all the necessary software itself, Cadence often contracts with specialized software developers. As a part of the license, Cadence must make a royalty payment to the software developer each time it sells a product that contains the software. Many of the software contracts include a floor that requires Cadence to make a specified minimum number of royalty payments, even if actual sales are lower than the floor. Because the demand for Cadence's products is uncertain, sales may be less than the floor, causing the company to make large payments without revenue to cover it. Of course, if sales are higher than expected, Cadence must make more royalty payments than expected, but it would then also have high revenues and thus could afford the payments.

In negotiating with its software suppliers, Cadence proposed an arrangement that had a relatively low floor but a higher per-unit royalty. Using a standard NPV analysis, Cadence's proposal produced a negative NPV. However, option pricing techniques showed that Cadence's proposed royalty arrangement would actually add value.

As you read this chapter and learn more about options, think about how option pricing techniques can lead to better capital budgeting decisions.

Sources: Peter Coy, "Exploiting Uncertainty: The 'Real-Option' Revolution in Decision-Making," *BusinessWeek*, June 7, 1999, p. 118; and S. L. Mintz, "Getting Real," *CFO*, November 1999, pp. 52–60.

e-resource

The textbook's Web site contains an *Excel* file that will guide you through the chapter's calculations. The file for this chapter is ***FM12 Ch 13 Tool Kit.xls***, and we encourage you to open the file and follow along as you read the chapter.

Traditional discounted cash flow (DCF) analysis—where an asset's cash flows are estimated and then discounted to obtain the asset's NPV—has been the cornerstone for valuing all types of assets since the 1950s. Accordingly, most of our discussion of capital budgeting has focused on DCF valuation techniques. However, in recent years academics and practitioners have demonstrated that DCF valuation techniques do not always tell the complete story about a project's value, and that rote use of DCF can, at times, lead to incorrect capital budgeting decisions.[1]

DCF techniques were originally developed to value securities such as stocks and bonds. Securities are passive investments—once they have been purchased, most investors have no influence over the cash flows the assets produce. However, real assets are not passive investments—managerial actions after an investment has been made can influence its results. Furthermore, investing in a new project often brings with it the potential for increasing the firm's future investment opportunities. Such opportunities are, in effect, options—the right but not the obligation to take some action in the future. As we demonstrate in the next section, options are valuable, so projects that expand the firm's set of opportunities have positive **option values.** Similarly, any project that reduces the set of future opportunities destroys option value. Since a project's impact on the firm's opportunities, or its option value, may not be captured by conventional NPV analysis, this option value should be considered separately, as we do in this chapter.

13.1 Valuing Real Options

Recall from Chapter 12 that real options are opportunities for management to change the timing, scale, or other aspects of an investment in response to changes in market conditions. These opportunities are options in the sense that management can, if it is in the company's best interest, undertake some action; management is not required to undertake the action. These opportunities are real, as opposed to financial, because they involve decisions regarding real assets, such as plants, equipment, and land, rather than financial assets like stocks or bonds. Four examples of real options are investment timing options, growth options, abandonment options, and flexibility options. We give an example of how to value an investment timing option and a growth option. ***Web Extension 13A,*** available at the textbook's Web site, shows how to value an abandonment option.

Valuing a real option requires judgment, both to formulate the model and to estimate the inputs. Does this mean the answer won't be useful? Definitely not. For example, the models used by NASA only approximate the centers of gravity for the moon, the earth, and other heavenly bodies, yet even with these "errors" in their models, NASA has been able to put astronauts on the moon. As one professor said, "All models are wrong, but some are still quite useful." This is especially true for real options. We might not be able to find the exact value of a real option, but the value we find can be helpful in deciding whether or not to accept the project. Equally important, the process of looking for and then valuing real options often identifies critical issues that might otherwise go unnoticed.

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[1] For an excellent general discussion of the problems inherent in discounted cash flow valuation techniques as applied to capital budgeting, see Avinash K. Dixit and Robert S. Pindyck, "The Options Approach to Capital Investment," *Harvard Business Review*, May–June 1995, pp. 105–115.

Five possible procedures can be used to deal with real options. Starting with the simplest, they are as follows:

1. Use discounted cash flow (DCF) valuation and ignore any real options by assuming their values are zero.
2. Use DCF valuation and include a qualitative recognition of any real option's value.
3. Use decision tree analysis.
4. Use a standard model for a financial option.
5. Develop a unique, project-specific model using financial engineering techniques.

The following sections illustrate these procedures.

SELF-TEST

List the five possible procedures for dealing with real options.

13.2 The Investment Timing Option: An Illustration

FM e-resource

All calculations for the analysis of the investment timing option are shown in ***FM12 Ch 13 Tool Kit.xls*** at the textbook's Web site.

When we discussed capital budgeting in Chapters 11 and 12 we implicitly assumed that the projects we analyzed were "take it or leave it" endeavors. In reality, there is frequently an alternative to investing immediately—the decision to invest or not can be postponed until more information becomes available. By waiting, a better-informed decision can be made, and this investment timing option adds value to the project and reduces its risk.

Murphy Systems is considering a project for a new type of handheld device that provides wireless Internet connections. The cost of the project is $50 million, but the future cash flows depend on the demand for wireless Internet connections, which is uncertain. Murphy believes there is a 25% chance that demand for the new device will be very high, in which case the project will generate cash flows of $33 million each year for 3 years. There is a 50% chance of average demand, with cash flows of $25 million per year, and a 25% chance that demand will be low and annual cash flows will be only $5 million. A preliminary analysis indicates that the project is somewhat riskier than average, so it has been assigned a cost of capital of 14% versus 12% for an average project at Murphy Systems. Here is a summary of the project's data:

Demand	Probability	Annual Cash Flow
High	0.25	$33 million
Average	0.50	25 million
Low	0.25	5 million
Expected annual cash flow		$22 million
Project's cost of capital		14%
Life of project		3 years
Required investment, or cost of project		$50 million

Murphy can accept the project and implement it immediately, but since the company has a patent on the device's core modules, it can also choose to delay the decision until next year, when more information about demand will be available. The cost will still be \$50 million if Murphy waits, and the project will still be expected to generate the indicated cash flows, but each flow will be pushed back 1 year. However, if Murphy waits, it will know which of the demand conditions, hence which set of cash flows, will exist. If it waits, Murphy will of course make the investment only if demand is sufficient to provide a positive NPV.

Note that this real timing option resembles a call option on a stock. A call gives its owner the right to purchase a stock at a fixed strike price, but only if the stock's price is higher than the strike price will the owner exercise the option and buy the stock. Similarly, if Murphy defers implementation, then it will have the right to "purchase" the project by making the \$50 million investment if the NPV as calculated next year, when new information is available, is positive.

Approach 1. DCF Analysis Ignoring the Timing Option

Based on probabilities for the different levels of demand, the expected annual cash flows are \$22 million per year:

$$\begin{aligned}\text{Expected cash flow per year} &= 0.25(\$33) + 0.50(\$25) + 0.25(\$5)\\ &= \$22 \text{ million.}\end{aligned}$$

Ignoring the investment timing option, the traditional NPV is \$1.08 million, found as follows:

$$\text{NPV} = -\$50 + \frac{\$22}{(1+0.14)^1} + \frac{\$22}{(1+0.14)^2} + \frac{\$22}{(1+0.14)^3} = \$1.08.$$

The present value of the cash inflows is \$51.08 million while the cost is \$50 million, leaving an NPV of \$1.08 million.

Based just on this DCF analysis, Murphy should accept the project. Note, though, that if the expected cash flows had been slightly lower, say, \$21.5 million per year, the NPV would have been negative and the project would have been rejected. Also, note that the project is risky—there is a 25% probability that demand will be weak, in which case the NPV will turn out to be a negative \$38.4 million.

Approach 2. DCF Analysis with a Qualitative Consideration of the Timing Option

The discounted cash flow analysis suggests that the project should be accepted, but just barely, and it ignores the existence of a possibly valuable real option. If Murphy implements the project now, it gains an expected (but risky) NPV of \$1.08 million. However, accepting now means that it is also giving up the option to wait and learn more about market demand before making the commitment. Thus, the decision is this: Is the option Murphy would be giving up worth more or less than \$1.08 million? If the option is worth more than \$1.08 million, then Murphy should not give up the option, which means deferring the decision, and vice versa if the option is worth less than \$1.08 million.

Based on the discussion of financial options in Chapter 9, what qualitative assessment can we make regarding the option's value? Put another way, without doing any additional calculations, does it appear that Murphy should go forward now or wait? In thinking about this decision, first note that the value of an option is higher if the current value of the underlying asset is high relative to its strike price, other things held constant. For example, a call option with a strike price of $50 on a stock with a current price of $50 is worth more than if the current price were $20. The strike price of the project is $50 million, while our first guess at the value of its cash flows is $51.08 million. We will calculate the exact value of Murphy's underlying asset later, but the DCF analysis does suggest that the underlying asset's value will be close to the strike price, so the option should be valuable. We also know that an option's value is higher the longer its time to expiration. Here the option has a 1-year life, which is fairly long for an option, and this too suggests that the option is probably valuable. Finally, we know that the value of an option increases with the risk of the underlying asset. The data used in the DCF analysis indicate that the project is quite risky, which again suggests that the option is valuable.

Thus, our qualitative assessment indicates that the option to delay might well be more valuable than the expected NPV of $1.08 if we undertake the project immediately. This is quite subjective, but the qualitative assessment should make Murphy's management pause, and then go on to make a quantitative assessment of the situation.

Approach 3. Scenario Analysis and Decision Trees

Part 1 of Figure 13-1 presents a scenario analysis similar to the ones in Chapter 12 except now the cash flows are shown as a decision tree diagram. Each possible outcome is shown as a "branch" on the tree. Each branch shows the cash flows and probability of a scenario, laid out as a time line. Thus, the top line, which gives the payoffs of the high-demand scenario, has positive cash flows of $33 million for the next 3 years, and its NPV is $26.61 million. The average-demand branch in the middle has an NPV of $8.04 million, while the NPV of the low-demand branch is a negative $38.39 million. Since Murphy will suffer a $38.39 million loss if demand is weak, and since there is a 25% probability of weak demand, the project is clearly risky.

The expected NPV is the weighted average of the three possible outcomes, with the weight for each outcome being its probability. The sum in the last column in Part 1 shows that the expected NPV is $1.08 million, the same as in the original DCF analysis. Part 1 also shows a standard deviation of $24.02 million for the NPV, and a coefficient of variation, defined as the ratio of standard deviation to the expected NPV, of 22.32, which is quite large. Clearly, the project is quite risky under the analysis thus far.

Part 2 is set up similarly to Part 1 except that it shows what happens if Murphy delays the decision and then implements the project only if demand turns out to be high or average. No cost is incurred now at Year 0—here the only action is to wait. Then, if demand is average or high, Murphy will spend $50 million at Year 1 and receive either $33 million or $25 million per year for the following 3 years. If demand is low, as shown on the bottom branch, Murphy will spend nothing at Year 1 and will receive no cash flows in subsequent years. The NPV of the high-demand branch is $23.35 million and that of the average-demand branch is $7.05 million. Because all cash flows under the low-demand scenario are zero, the NPV in this case will also be zero. The expected NPV if Murphy delays the decision is $9.36 million.

Figure 13-1

DCF and Decision Tree Analysis for the Investment Timing Option (Millions of Dollars)

PART 1. SCENARIO ANALYSIS: PROCEED WITH PROJECT TODAY

			FUTURE CASH FLOWS					
Now: Year 0			Year 1	Year 2	Year 3	NPV of This Scenario[a]	Probability	Probability × NPV
−$50	High	0.25	$33	$33	$33	$26.61	0.25	$6.65
	Average	0.50	$25	$25	$25	$8.04	0.50	$4.02
	Low	0.25	$5	$5	$5	−$38.39	0.25	−$9.60
							1.00	

Expected value of NPVs = $1.08

Standard deviation[b] = $24.02

Coefficient of variation[c] = 22.32

PART 2. DECISION TREE ANALYSIS: IMPLEMENT NEXT YEAR ONLY IF OPTIMAL

			FUTURE CASH FLOWS						
Now: Year 0			Year 1	Year 2	Year 3	Year 4	NPV of This Scenario[d]	Probability	Probability × NPV
Wait	High	0.25	–$50	$33	$33	$33	$23.35	0.25	$5.84
	Average	0.50	–$50	$25	$25	$25	$7.05	0.50	$3.53
	Low	0.25	$0	$0	$0	$0	$0.00	0.25	$0.00
								1.00	

Expected value of NPVs = $9.36

Standard deviation[b] = $8.57

Coefficient of variation[c] = 0.92

Notes:

[a] The WACC is 14%.

[b] The standard deviation is calculated as explained in Chapter 6.

[c] The coefficient of variation is the standard deviation divided by the expected value.

[d] The NPV in Part 2 is as of Year 0. Therefore, each of the project cash flows is discounted back one more year than in Part 1.

This analysis shows that the project's expected NPV will be much higher if Murphy delays than if it invests immediately. Also, since there is no possibility of losing money under the delay option, this decision also lowers the project's risk. This clearly indicates that the option to wait is valuable, hence that Murphy should wait until Year 1 before deciding whether to proceed with the investment.

Before we conclude the discussion of decision trees, note that we used the same cost of capital, 14%, to discount cash flows in the "proceed immediately" scenario analysis in Part 1 and under the "delay 1 year" scenario in Part 2. However, for three reasons this is not appropriate. First, since there is no possibility of losing money if Murphy delays, the investment under that plan is clearly less risky than if Murphy charges ahead today. Second, the 14% cost of capital might be appropriate for risky cash flows, yet the investment in the project at Year 1 in Part 2 is known with certainty. Perhaps, then, we should discount it at the risk-free rate.[2] Third, the project's cash inflows (excluding the initial investment) are different in Part 2 than in Part 1 because the low-demand cash flows are eliminated. This suggests that if 14% is the appropriate cost of capital in the "proceed immediately" case, some lower rate would be appropriate in the "delay decision" case.

In Figure 13-2, Part 1, we repeat the "delay decision" analysis, with one exception. We continue to discount the operating cash flows in Year 2 through Year 4 at the 14% WACC, but now we discount the project's cost back at Year 1 with the risk-free rate, 6%. This increases the PV of the cost, which lowers the NPV from $9.36 million to $6.88 million. Note, though, that we really don't know precisely the appropriate WACC for the project—the 14% we used might be too high or too low for the operating cash flows in Year 2 through Year 4.[3] Therefore, in Part 2 of Figure 13-2 we show a sensitivity analysis of the NPV where the discount rates used for both the operating cash flows and for the project's cost vary. This sensitivity analysis shows that under all reasonable WACCs, the NPV of delaying is greater than $1.08 million, the NPV of immediate implementation. This means that the option to wait is more valuable than the $1.08 million resulting from immediate implementation. Therefore, Murphy should wait rather than implement the project immediately.

Approach 4. Valuing the Timing Option with the Black-Scholes Option Pricing Model

The decision tree approach, coupled with a sensitivity analysis, may provide enough information for a good decision. However, it is often useful to obtain additional insights into the real option's value, which means using the fourth procedure, an option pricing model. To do this, the analyst must find a standard financial option that resembles the project's real option.[4] As noted earlier, Murphy's option to delay the project is similar to a call option on a stock; hence the Black-Scholes Option Pricing Model can be used. This model requires five

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[2] See Timothy A. Luehrman, "Investment Opportunities as Real Options: Getting Started on the Numbers," *Harvard Business Review*, July–August 1998, pp. 51–67, for a more detailed explanation of the rationale for using the risk-free rate to discount the project cost. This paper also provides a discussion of real option valuation. Professor Luehrman also has a follow-up paper that provides an excellent discussion of the ways real options affect strategy. See Timothy A. Luehrman, "Strategy as a Portfolio of Real Options," *Harvard Business Review*, September–October 1998, pp. 89–99.

[3] If we delay, the cash inflows might be considered more risky if there is a chance that the delay might cause those flows to decline due to the loss of Murphy's "first mover advantage." Put another way, we might gain information by waiting, and that could lower risk, but if a delay would enable others to enter and perhaps preempt the market, this could increase risk. In our example, we assumed that Murphy has a patent on critical components of the device, hence that no one could come in and preempt its position in the market.

[4] In theory, financial option pricing models apply only to assets that are continuously traded in a market. Even though real options usually don't meet this criterion, financial option models often provide a reasonably accurate approximation of the real option's value.

Figure 13-2

Decision Tree and Sensitivity Analysis for the Investment Timing Option (Millions of Dollars)

PART 1. DECISION TREE ANALYSIS: IMPLEMENT IN ONE YEAR ONLY IF OPTIMAL (DISCOUNT COST AT THE RISK-FREE RATE AND OPERATING CASH FLOWS AT THE WACC)

			FUTURE CASH FLOWS					
Now: Year 0		Year 1	Year 2	Year 3	Year 4	NPV of This Scenario[a]	Probability	Probability × NPV
Wait	High 0.25	−$50	$33	$33	$33	$20.04	0.25	$5.01
	Average 0.50	−$50	$25	$25	$25	$3.74	0.50	$1.87
	Low 0.25	$0	$0	$0	$0	$0.00	0.25	$0.00
							1.00	

Expected value of NPVs = $6.88

Standard deviation[b] = $7.75

Coefficient of variation[c] = 1.13

PART 2. SENSITIVITY ANALYSIS OF NPV TO CHANGES IN THE COST OF CAPITAL USED TO DISCOUNT COST AND CASH FLOWS

	Cost of Capital Used to Discount the Year 1 Cost						
Cost of Capital Used to Discount the Year 2 through Year 4 Operating Cash Flows	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%
8.0%	$13.11	$13.46	$13.80	$14.14	$14.47	$14.79	$15.11
9.0%	11.78	12.13	12.47	12.81	13.14	13.47	13.78
10.0%	10.50	10.85	11.20	11.53	11.86	12.19	12.51
11.0%	9.27	9.62	9.97	10.30	10.64	10.96	11.28
12.0%	8.09	8.44	8.78	9.12	9.45	9.78	10.09
13.0%	6.95	7.30	7.64	7.98	8.31	8.64	8.95
14.0%	5.85	6.20	6.54	6.88	7.21	7.54	7.85
15.0%	4.79	5.14	5.48	5.82	6.15	6.48	6.79
16.0%	3.77	4.12	4.46	4.80	5.13	5.45	5.77
17.0%	2.78	3.13	3.47	3.81	4.14	4.46	4.78
18.0%	1.83	2.18	2.52	2.86	3.19	3.51	3.83

Notes:

[a] The operating cash flows in Year 2 through Year 4 are discounted at the WACC of 14%. The cost in Year 1 is discounted at the risk-free rate of 6%.

[b] The standard deviation is calculated as explained in Chapter 6.

[c] The coefficient of variation is the standard deviation divided by the expected value.

inputs: (1) the risk-free rate, (2) the time until the option expires, (3) the strike price, (4) the current price of the stock, and (5) the variance of the stock's rate of return. Therefore, we need to estimate values for those five inputs.

First, assuming that the rate on a 52-week Treasury bill is 6%, this rate can be used as the risk-free rate. Second, Murphy must decide within a year whether or not to implement the project, so there is 1 year until the option expires. Third, it will cost $50 million to implement the project, so $50 million can be used for the strike price. Fourth, we need a proxy for the value of the underlying asset, which in Black-Scholes is the current price of the stock. Note that a stock's current price is the present value of its expected future cash flows. For Murphy's real option, the underlying asset is the project itself, and its current "price" is the present value of its expected future cash flows. Therefore, as a proxy for the stock price we can use the present value of the project's future cash flows. And fifth, the variance of the project's expected return can be used to represent the variance of the stock's return in the Black-Scholes model.

Figure 13-3 shows how one can estimate the present value of the project's cash inflows. We need to find the current value of the underlying asset, that is, the project. For a stock, the current price is the present value of all expected future cash flows, including those that are expected even if we do not exercise the call option. Note also that the strike price for a call option has no effect on the stock's current price.[5] For our

Figure 13-3

Estimating the Input for Stock Price in the Option Analysis of the Investment Timing Option (Millions of Dollars)

		FUTURE CASH FLOWS						
Now: Year 0		Year 1	Year 2	Year 3	Year 4	PV of This Scenario[a]	Probability	Probability PV
Wait	High	0.25 →	$33	$33	$33	$67.21	0.25	$16.80
	Average	0.50 →	$25	$25	$25	$50.91	0.50	$25.46
	Low	0.25 →	$5	$5	$5	$10.18	0.25	$2.55
							1.00	

Expected value of PVs[b] = $44.80

Standard deviation[c] = $21.07

Coefficient of variation[d] = 0.47

Notes:

[a] The WACC is 14%. All cash flows in this scenario are discounted back to Year 0.

[b] Here we find the PV, not the NPV, as the project's cost is ignored.

[c] The standard deviation is calculated as explained in Chapter 6.

[d] The coefficient of variation is the standard deviation divided by the expected value.

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[5] The company itself is not involved with traded stock options. However, if the option were a warrant issued by the company, then the strike price would affect the company's cash flows, hence its stock price.

real option, the underlying asset is the delayed project, and its current "price" is the present value of all its future expected cash flows. Just as the price of a stock includes all of its future cash flows, the present value of the project should include all of its possible future cash flows. Moreover, since the price of a stock is not affected by the strike price of a call option, we ignore the project's "strike price," or cost, when we find its present value. Figure 13-3 shows the expected cash flows if the project is delayed. The PV of these cash flows as of now (Year 0) is \$44.80 million, and this is the input we should use for the current price in the Black-Scholes model.

The last required input is the variance of the project's return. Three different approaches could be used to estimate this input. First, we could use judgment—an educated guess. Here we would begin by recalling that a company is a portfolio of projects (or assets), with each project having its own risk. Since returns on the company's stock reflect the diversification gained by combining many projects, we might expect the variance of the stock's returns to be lower than the variance of one of its average projects. The variance of an average company's stock return is about 12%, so we might expect the variance for a typical project to be somewhat higher, say, 15% to 25%. Companies in the Internet infrastructure industry are riskier than average, so we might subjectively estimate the variance of Murphy's project to be in the range of 18% to 30%.

The second approach, called the direct method, is to estimate the rate of return for each possible outcome and then calculate the variance of those returns. First, Part 1 in Figure 13-4 shows the PV for each possible outcome as of Year 1, the time when the option expires. Here we simply find the present value of all future operating cash flows discounted back to Year 1, using the WACC of 14%. The Year 1 present value is \$76.61 million for high demand, \$58.04 million for average demand, and \$11.61 million for low demand. Then, in Part 2, we show the percentage return from the current time until the option expires for each scenario, based on the \$44.80 million starting "price" of the project at Year 0 as calculated in Figure 13-3. If demand is high, we will obtain a return of 71.0%: (\$76.61 − \$44.80)/\$44.80 = 0.710 = 71.0%. Similar calculations show returns of 29.5% for average demand and −74.1% for low demand. The expected percentage return is 14%, the standard deviation is 53.6%, and the variance is 28.7%.[6]

The third approach for estimating the variance is also based on the scenario data, but the data are used in a different manner. First, we know that demand is not really limited to three scenarios—rather, a wide range of outcomes is possible. Similarly, the stock price at the time a call option expires could take on one of many values. It is reasonable to assume that the value of the project at the time when we must decide on undertaking it behaves similarly to the price of a stock at the time a call option expires. Under this assumption, we can use the expected value and standard deviation of the project's value to calculate the variance of its rate of return, σ^2, with this formula:[7]

$$\sigma^2 = \frac{\ln(CV^2 + 1)}{t}. \tag{13-1}$$

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[6] Two points should be made about the percentage return. First, for use in the Black-Scholes model, we need a percentage return calculated as shown, not an IRR return. The IRR is not used in the option pricing approach. Second, the expected return turns out to be 14%, the same as the WACC. This is because the Year 0 price and the Year 1 PVs were all calculated using the 14% WACC, and because we are measuring return over only 1 year. If we measure the compound return over more than 1 year, then the average return generally will not equal 14%.

[7] See David C. Shimko, *Finance in Continuous Time* (Miami, FL: Kolb Publishing Company, 1992), for a more detailed explanation.

Figure 13-4

Estimating the Input for Variance in the Option Analysis of the Investment Timing Option (Millions of Dollars)

PART 1. FIND THE VALUE AND RISK OF FUTURE CASH FLOWS AT THE TIME THE OPTION EXPIRES

Now: Year 0		Year 1	Year 2	Year 3	Year 4	PV in Year 1 for This Scenario[a]	Probability	Probability × $\text{PV}_{\text{Year 1}}$
			FUTURE CASH FLOWS					
	High	0.25	$33	$33	$33	$76.61	0.25	$19.15
Wait	Average	0.50	$25	$25	$25	$58.04	0.50	$29.02
	Low	0.25	$5	$5	$5	$11.61	0.25	$2.90
							1.00	

Expected value of $\text{PV}_{\text{Year 1}}$ = $51.08

Standard deviation of $\text{PV}_{\text{Year 1}}$[b] = $24.02

Coefficient of variation of $\text{PV}_{\text{Year 1}}$[c] = 0.47

PART 2. DIRECT METHOD: USE THE SCENARIOS TO DIRECTLY ESTIMATE THE VARIANCE OF THE PROJECT' S RETURN

$\text{Price}_{\text{Year 1}}$[d]			$\text{PV}_{\text{Year 1}}$[e]	$\text{Return}_{\text{Year 1}}$[f]	Probability	Probability × $\text{Return}_{\text{Year 1}}$
	High	0.25	$76.61	71.0%	0.25	17.8%
$44.80	Average	0.50	$58.04	29.5%	0.50	14.8%
	Low	0.25	$11.61	−74.1%	0.25	−18.5%
					1.00	

Expected return = 14.0%

Standard deviation of return[b] = 53.6%

Variance of return[g] = 28.7%

PART 3. INDIRECT METHOD: USE THE SCENARIOS TO INDIRECTLY ESTIMATE THE VARIANCE OF THE PROJECT'S RETURN

Expected "price" at the time the option expires[h] = $51.08

Standard deviation of expected "price" at the time the option expires[i] = $24.02

Coefficient of variation (CV) = 0.47

Time (in years) until the option expires (t) = 1

Variance of the project's expected return = $\ln(CV^2 + 1)/t$ = 20.0%

(continued)

Figure 13-4

Estimating the Input for Variance in the Option Analysis of the Investment Timing Option (Millions of Dollars) (*continued*)

Notes:

[a] The WACC is 14%. The Year 2 through Year 4 cash flows are discounted back to Year 1.

[b] The standard deviation is calculated as explained in Chapter 6.

[c] The coefficient of variation is the standard deviation divided by the expected value.

[d] The Year 0 price is the expected PV from Figure 13-3.

[e] The Year 1 PVs are from Part 1.

[f] The returns for each scenario are calculated as $(\text{PV}_{\text{Year 1}} - \text{Price}_{\text{Year 0}})/\text{Price}_{\text{Year 0}}$.

[g] The variance of return is the standard deviation squared.

[h] The expected "price" at the time the option expires is taken from Part 1.

[i] The standard deviation of expected "price" at the time the option expires is taken from Part 1.

Here CV is the coefficient of variation of the underlying asset's price at the time the option expires and t is the time until the option expires. Thus, while the three scenarios are simplifications of the true condition, where there are an infinite number of possible outcomes, we can still use the scenario data to estimate the variance of the project's rate of return if it has an infinite number of possible outcomes.

For Murphy's project, this indirect method produces the following estimate of the variance of the project's return:

$$\sigma^2 = \frac{\ln(0.47^2 + 1)}{1} = 0.20 = 20\%. \tag{13-1a}$$

Which of the three approaches is best? Obviously, they all involve judgment, so an analyst might want to consider all three. In our example, all three methods produce similar estimates, but for illustrative purposes we will simply use 20% as our initial estimate for the variance of the project's rate of return.

In Part 1 of Figure 13-5 we calculate the value of the option to defer investment in the project based on the Black-Scholes model, and the result is $7.04 million. Since this is significantly higher than the $1.08 million NPV under immediate implementation, and since the option would be forfeited if Murphy goes ahead right now, we conclude that the company should defer the final decision until more information is available.

Note, though, that judgmental estimates were made at many points in the analysis, and it is useful to see how sensitive the final outcome is to certain of the key inputs. Thus, in Part 2 of Figure 13-5 we show the sensitivity of the option's value to different estimates of the variance. It is comforting to see that for all reasonable estimates of variance, the option to delay remains more valuable than immediate implementation.

Approach 5. Financial Engineering

Sometimes an analyst might not be satisfied with the results of a decision tree analysis and cannot find a standard financial option that corresponds to the real option. In such a situation the only alternative is to develop a unique model for the specific real option being analyzed, a process called **financial engineering.** When financial engineering is applied on Wall Street, where it

Figure 13-5

Estimating the Value of the Investment Timing Option Using a Standard Financial Option (Millions of Dollars)

PART 1. FIND THE VALUE OF A CALL OPTION USING THE BLACK-SCHOLES MODEL

Real Option

r_{RF} =	Risk-free interest rate	=	6%
t =	Time in years until the option expires	=	1
X =	Cost to implement the project	=	$50.00
P =	Current value of the project	=	$44.80[a]
σ^2 =	Variance of the project's rate of return	=	20.0%[b]
d_1 =	$\{\ln(P/X) + [r_{RF} + (\sigma^2/2)]t\}/(\sigma t^{1/2})$	=	0.112
d_2 =	$d_1 - \sigma(t^{1/2})$	=	−0.33
$N(d_1)$ =		=	0.54
$N(d_2)$ =		=	0.37
V =	$P[N(d_1)] - Xe^{-r_{RF}t}[N(d_2)]$	=	$\boxed{\$7.04}$

PART 2. SENSITIVITY ANALYSIS OF OPTION VALUE TO CHANGES IN VARIANCE

Variance	Option Value
12.0%	$5.24
14.0	5.74
16.0	6.20
18.0	6.63
20.0	$\boxed{7.04}$
22.0	7.42
24.0	7.79
26.0	8.15
28.0	8.49
30.0	8.81
32.0	9.13

Notes:

[a] The current value of the project is taken from Figure 13-3.

[b] The variance of the project's rate of return is taken from Part 3 of Figure 13-4.

was developed, the result is a newly designed financial product.[8] When it is applied to real options, the result is the value of a project that contains embedded options.

Although financial engineering was originally developed on Wall Street, many financial engineering techniques have been applied to real options during the last 10 years. We expect this trend to continue, especially in light of the rapid improvements in computer processing speed and spreadsheet software capabilities. One financial engineering technique is called **risk-neutral valuation**. This technique uses simulation, and we discuss it in ***Web Extension 13B***. Most other

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[8] Financial engineering techniques are widely used for the creation and valuation of derivative securities.

financial engineering techniques are too complicated for a course in financial management, and so we leave a detailed discussion of them to a specialized course.

For an illustrative valuation of an abandonment option, see ***Web Extension 13A***. The calculations are also shown in ***FM12 Ch 13 Tool Kit.xls*** available at the textbook's Web site.

SELF-TEST

What is a decision tree?
In a qualitative analysis, what factors affect the value of a real option?

13.3 The Growth Option: An Illustration

As we saw with the investment timing option, there is frequently an alternative to merely accepting or rejecting a static project. Many investment opportunities, if successful, lead to other investment opportunities. The production capacity of a successful product line can later be expanded to satisfy increased demand, or distribution can be extended to new geographic markets. A company with a successful name brand can capitalize on its success by adding complimentary or new products under the same brand. These growth options add value to a project and explain, for example, why companies are flocking to make inroads into the very difficult business environment in China.

Kidco Corporation designs and produces products aimed at the pre-teen market. Most of its products have a very short life, given the rapidly changing tastes of pre-teens. Kidco is now considering a project that will cost $30 million. Management believes there is a 25% chance that the project will "take off" and generate operating cash flows of $34 million in each of the next 2 years, after which pre-teen tastes will change and the project will be terminated. There is a 50% chance of average demand, in which case cash flows will be $20 million annually for 2 years. Finally, there is a 25% chance that the pre-teens won't like the product at all, and it will generate cash flows of only $2 million per year. The estimated cost of capital for the project is 14%.

Based on its experience with other projects, Kidco believes it will be able to launch a second-generation product if demand for the original product is average or above. This second-generation product will cost the same as the first product, $30 million, and the cost will be incurred at Year 2. However, given the success of the first-generation product, Kidco believes the second-generation product will be just as successful as the first-generation product.

This growth option resembles a call option on a stock, since it gives Kidco the opportunity to "purchase" a successful follow-on project at a fixed cost if the value of the project is greater than the cost. Otherwise, Kidco will let the option expire by not implementing the second-generation product.

The following sections apply the first four valuation approaches: (1) DCF, (2) DCF and qualitative assessment, (3) decision tree analysis, and (4) analysis with a standard financial option.

Approach 1. DCF Analysis Ignoring the Growth Option

Based on probabilities for the different levels of demand, the expected annual operating cash flows for the project are $19 million per year:

$$0.25(\$34) + 0.50(\$20) + 0.25(\$2) = \$19.00.$$

Ignoring the investment timing option, the traditional NPV is $1.29 million:

$$\text{NPV} = -\$30 + \frac{\$19}{(1 + 0.14)^1} + \frac{\$19}{(1 + 0.14)^2} = \$1.29.$$

Based on this DCF analysis, Kidco should accept the project.

Approach 2. DCF Analysis with a Qualitative Consideration of the Growth Option

Although the DCF analysis indicates that the project should be accepted, it ignores a potentially valuable real option. The option's time to maturity and the volatility of the underlying project provide qualitative insights into the option's value. Kidco's growth option has 2 years until maturity, which is a relatively long time, and the cash flows of the project are volatile. Taken together, this qualitative assessment indicates that the growth option should be quite valuable.

Approach 3. Decision Tree Analysis of the Growth Option

Part 1 of Figure 13-6 shows a scenario analysis for Kidco's project. The top line, which describes the payoffs for the high-demand scenario, has operating cash flows of $34 million for the next 2 years. The NPV of this branch is $25.99 million. The NPV of the average-demand branch in the middle is $2.93 million, and it is −$26.71 million for the low-demand scenario. The sum in the last column of Part 1 shows the expected NPV of $1.29 million. The coefficient of variation is 14.54, indicating that the project is very risky.

Part 2 of Figure 13-6 shows a decision tree analysis in which Kidco undertakes the second-generation product only if demand is average or high. In these scenarios, shown on the top two branches of the decision tree, Kidco will incur a cost of $30 million at Year 2 and receive operating cash flows of either $34 million or $20 million for the next 2 years, depending on the level of demand. If the demand is low, shown on the bottom branch, Kidco has no cost at Year 2 and receives no additional cash flows in subsequent years. All operating cash flows, which do not include the cost of implementing the second-generation project at Year 2, are discounted at the WACC of 14%. Because the $30 million implementation cost is known, it is discounted at the risk-free rate of 6%. As shown in Part 2 of Figure 13-6, the expected NPV is $4.70 million, indicating that the growth option is quite valuable.

The option itself alters the risk of the project, which means that 14% is probably not the appropriate cost of capital. Table 13-1 presents the results of a sensitivity analysis in which the cost of capital for the operating cash flows varies from 8% to 18%. The sensitivity analysis also allows the rate used to discount the implementation cost at Year 2 to vary from 3% to 9%. The NPV is positive for all reasonable combinations of discount rates.

Approach 4. Valuing the Growth Option with the Black-Scholes Option Pricing Model

The fourth approach is to use a standard model for a corresponding financial option. As we noted earlier, Kidco's growth option is similar to a call option on a

Figure 13-6

Scenario Analysis and Decision Tree Analysis for the Kidco Project (Millions of Dollars)

PART 1. SCENARIO ANALYSIS OF KIDCO'S FIRST-GENERATION PROJECT

			FUTURE CASH FLOWS				
Now: Year 0			Year 1	Year 2	NPV of This Scenario[a]	Probability	Probability × NPV
	High	0.25	$34	$34	$25.99	0.25	$6.50
−$30	Average	0.50	$20	$20	$2.93	0.50	$1.47
	Low	0.25	$2	$2	−$26.71	0.25	$6.68
						1.00	

Expected value of NPVs = $1.29

Standard deviation[b] = $18.70

Coefficient of variation[c] = 14.54

PART 2. DECISION TREE ANALYSIS OF THE GROWTH OPTION

			FUTURE CASH FLOWS						
Now: Year 0			Year 1	Year 2[d]	Year 3	Year 4	NPV of This Scenario[e]	Probability	Probability × NPV
	High	0.25	$34	$34 −$30	$34	$34	$42.37	0.25	$10.59
−$30	Average	0.50	$20	$20 −$30	$20	$20	$1.57	0.50	$0.79
	Low	0.25	$2	$2	$0	$0	−$26.71	0.25	$6.68
								1.00	

Expected value of NPVs = $4.70

Standard deviation[b] = $24.62

Coefficient of variation[c] = 5.24

Notes:

[a] The operating cash flows are discounted by the WACC of 14%.

[b] The standard deviation is calculated as in Chapter 6.

[c] The coefficient of variation is the standard deviation divided by the expected value.

[d] The total cash flows at Year 2 are equal to the operating cash flows for the first-generation product minus the $30 million cost to implement the second-generation product, if it is optimal to do so. For example, the Year 2 cash flow in the high-demand scenario is $34 − $30 = $4 million. Based on Part 1, it is optional to implement the second-generation product only if demand is high or average.

[e] The operating cash flows in Year 1 through Year 2, which do not include the $30 million cost of implementing the second-generation project at Year 2 for the high-demand and average-demand scenarios, are discounted at the WACC of 14%. The $30 million implementation cost at Year 2 for the high-demand and average-demand scenarios is discounted at the risk-free rate of 6%.

Table 13-1

Sensitivity Analysis of the Kidco Decision Tree Analysis in Figure 13-6 (Millions of Dollars)

Cost of Capital Used to Discount the Year 1 through Year 4 Operating Cash Flows (These do not include the $30 million implementation cost of the second-generation project at Year 2.)	Cost of Capital Used to Discount the $30 Million Implementation Cost at Year 2 of the Second-Generation Project						
	3.0%	4.0%	5.0%	6.0%	7.0%	8.0%	9.0%
8.0%	$10.96	$11.36	$11.76	$12.14	$12.51	$12.88	$13.23
9.0	9.61	10.01	10.41	10.79	11.16	11.52	11.88
10.0	8.30	8.71	9.10	9.49	9.86	10.22	10.57
11.0	7.04	7.45	7.84	8.23	8.60	8.96	9.31
12.0	5.83	6.23	6.63	7.01	7.38	7.75	8.10
13.0	4.65	5.06	5.45	5.84	6.21	6.57	6.92
14.0	3.52	3.92	4.32	4.70	5.07	5.44	5.79
15.0	2.42	2.83	3.22	3.61	3.98	4.34	4.69
16.0	1.36	1.77	2.16	2.54	2.92	3.28	3.63
17.0	0.33	0.74	1.13	1.52	1.89	2.25	2.60
18.0	−0.66	−0.25	0.14	0.52	0.90	1.26	1.61

stock, and so we will use the Black-Scholes model to find the value of the growth option. The time until the growth option expires is 2 years. The rate on a 2-year Treasury security is 6%, and this provides a good estimate of the risk-free rate. It will cost $30 million to implement the project, which is the strike price.

The input for stock price in the Black-Scholes model is the current value of the underlying asset. For the growth option, the underlying asset is the second-generation project, and its current value is the present value of its cash flows. The calculations in Figure 13-7 show that this is $24.07 million. Because the strike price of $30 million is greater than the current "price" of $24.07 million, the growth option is presently out of the money.

Figure 13-8 shows the estimates for the variance of the project's rate of return using the two methods described earlier in the chapter for the analysis of the investment timing option. The direct method, shown in Part 2, produces an estimate of 17.9% for the variance of return. The indirect method, in Part 3, estimates the variance as 15.3%. Both estimates are somewhat higher than the 12% variance of a typical company's stock return, which is consistent with the idea that a stock's variance is lower than a project's due to diversification effects. Thus, an estimated variance of 15% to 20% seems reasonable. We use an initial estimate of 15.3% in our initial application of the Black-Scholes model, shown in Part 1 of Figure 13-9.

Using the Black-Scholes model for a call option, Figure 13-9 shows a $4.34 million value for the growth option. The total NPV is the sum of the first-generation project's NPV and the value of the growth option: Total NPV = $1.29 + $4.34 = $5.63 million, which is much higher than the NPV of only the first-generation

Figure 13-7

Estimating the Input for Stock Price in the Growth Option Analysis of the Investment Timing Option (Millions of Dollars)

	FUTURE CASH FLOWS						
Now: Year 0	Year 1	Year 2	Year 3	Year 4	PV of This Scenario[a]	Probability	Probability PV
High 0.25			$34	$34	$43.08	0.25	$10.77
Average 0.50			$20	$20	$25.34	0.50	$12.67
Low 0.25			$2	$2	$2.53	0.25	$0.63
						1.00	

Expected value of PVs = $24.07

Standard deviation[b] = $14.39

Coefficient of variation[c] = 0.60

Notes:

[a] The WACC is 14%. All cash flows in this scenario are discounted back to Year 0.

[b] The standard deviation is calculated as in Chapter 6.

[c] The coefficient of variation is the standard deviation divided by the expected value.

Figure 13-8

Estimating the Input for Stock Return Variance in the Growth Option Analysis (Millions of Dollars)

PART 1. FIND THE VALUE AND RISK OF FUTURE CASH FLOWS AT THE TIME THE OPTION EXPIRES

	FUTURE CASH FLOWS						
Now: Year 0	Year 1	Year 2	Year 3	Year 4	PV of This Scenario[a]	Probability	Probability × PV
High 0.25			$34	$34	$55.99	0.25	$14.00
Average 0.50			$20	$20	$32.93	0.50	$16.47
Low 0.25			$2	$2	$3.29	0.25	$0.82
						1.00	

Expected value of $\text{PV}_{\text{Year 2}}$ = $31.29

$\text{Standard deviation}_{\text{Year 2}}{}^{b}$ = $18.70

$\text{Coefficient of variation}_{\text{Year 2}}{}^{c}$ = 0.60

(continued)

Figure 13-8

Estimating the Input for Stock Return Variance in the Growth Option Analysis (Millions of Dollars) (*continued*)

Price$_{\text{Year 0}}$[d]			PV$_{\text{Year 2}}$[e]	Return$_{\text{Year 2}}$[f]	Probability	Probability × Return$_{\text{Year 2}}$
	High	0.25	$55.99	52.5%	0.25	13.1%
$24.07	Average	0.50	$32.93	17.0%	0.50	8.5%
	Low	0.25	$3.29	–63.0%	0.25	–15.8%
					1.00	

Expected return[g] = 5.9%

Standard deviation of return[b] = 43.2%

Varienc of return[h] = 17.9%

PART 3. INDIRECT METHOD: USE THE SCENARIOS TO INDIRECTLY ESTIMATE THE VARIANCE OF THE PROJECT'S RETURN

Expected "price" at the time the option expires[i] = $31.29

Standard deviation of expected "price" at the time the option expires[j] = $18.70

Coefficient of variation (CV) = 0.60

Time (in years) until the option expires (t) = 2

Variance of the project's expected return = $\ln(CV^2 + 1)/t$ = 15.3%

Notes:

[a] WACC of 14%. The Year 3 through Year 4 cash flows are discounted back to Year 2.

[b] The standard deviation is calculated as in Chapter 6.

[c] The coefficient of variation is the standard deviation divided by the expected value.

[d] The Year 2 price is the expected PV from Figure 13-7.

[e] The Year 2 PVs are from Part 1.

[f] The returns for each scenario are calculated as $(PV_{\text{Year 2}}/Price_{\text{Year 0}})0.5 - 1$.

[g] The expected 1-year return is not equal to the cost of capital, 14%. However, if you do the calculations, you'll see the expected 2-year return is 14% compounded twice, or $(1.14)^2 - 1 = 29.26\%$.

[h] The variance of return is the standard deviation squared.

[i] The expected "price" at the time the option expires is taken from Part 1.

[j] The standard deviation of the expected "price" at the time the option expires is taken from Part 1.

project. As this analysis shows, the growth option adds considerable value to the original project. In addition, sensitivity analysis in Part 2 of Figure 13-9 shows that the growth option's value is large for all reasonable values of variance. Thus, Kidco should accept the project.

SELF-TEST

Explain how growth options are like call options.

Figure 13-9

Estimating the Value of the Growth Option Using a Standard Financial Option (Millions of Dollars)

PART 1. FIND THE VALUE OF A CALL OPTION USING THE BLACK-SCHOLES MODEL

Real Option

r_{RF} =	Risk-free interest rate	=	6%
t =	Time (in years) until the option expires	=	2
X =	Cost to implement the project	=	$30.00
P =	Current value of the project	=	$24.07[a]
σ^2 =	Variance of project's rate of return	=	15.3%[b]
d_1 =	$\{\ln(P/X) + [r_{RF} + (\sigma^2/2)]t\}/(\sigma t^{1/2})$	=	0.096
d_2 =	$d_1 - \sigma(t^{1/2})$	=	−0.46
$N(d_1)$ =		=	0.54
$N(d_2)$ =		=	−0.32
V =	$P[N(d_1)] - Xe^{-r_{RF}t}[N(d_2)]$	=	$4.34

PART 2. SENSITIVITY ANALYSIS OF PUT OPTION VALUE TO CHANGES IN VARIANCE

Variance	Option Value
11.3%	$2.29
13.3	3.98
15.3	4.34
17.3	4.68
19.3	4.99
21.3	5.29
23.3	5.57
25.3	5.84
27.3	6.10
39.3	6.35
31.3	6.59

Notes:

[a] The current value of the project is taken from Figure 13-7.

[b] The variance of the project's rate of return is taken from Part 3 of Figure 13-8.

13.4 Concluding Thoughts on Real Options

We don't deny that real options can be pretty complicated. Keep in mind, however, that 50 years ago very few companies used NPV because it seemed too complicated. Now NPV is a basic tool used by virtually all companies and taught in all business schools. A similar, but more rapid, pattern of adoption is occurring with real options. Ten years ago very few companies used real options, but a recent survey

Growth Options at Dot-Com Companies

In September 2000, several dot-com companies had recently failed, including DEN (Digital Entertainment Network) and Boo.com, an e-tailer of clothing. Other dot-coms had incredible market valuations, such as Yahoo! ($58.2 billion), Amazon.com ($15.5 billion), and America Online ($126.9 billion).

What explained these wide variations in values? It was certainly not the physical assets the companies owned, since Yahoo! had enormous value but virtually no physical assets. We might be tempted to say the differences were explained by free cash flows. Perhaps dot-coms such as Amazon and Yahoo! had large expected future free cash flows, and their high values reflected this, but we certainly can't base that conclusion on their past results.

This is where real options come into play. Given its name recognition, infrastructure, and customer base, Amazon was in a position to grow into a variety of businesses, some of which might have been very profitable. The same was true for Yahoo!. In other words, it had many growth options with very low exercise prices. We know from our discussion of real options that an option is more valuable if the underlying source of risk is very volatile, and it's hard to imagine anything more volatile than the prospects of profitability in e-commerce. The field of e-commerce may end up being so competitive that there is little profit for the participating companies, or it may replace most existing forms of commerce, with the first movers having an enormous advantage. This uncertainty means that a growth option in e-commerce is very valuable. Therefore, companies with many growth options should have had high valuations.

Interestingly, it now (2006) looks as though Yahoo!'s and Amazon's options are in-the-money, while AOL's are out-of-the-money.

Source: Geoffrey Colvin, "You're Only as Good as Your Choices," *Fortune*, June 12, 2000, p. 75.

of CFOs reported that more than 26% of companies now use real option techniques when evaluating projects.[9] Just as with NPV, it's only a matter of time before virtually all companies use real option techniques.

We have provided you with some basic tools necessary for evaluating real options, starting with the ability to identify real options and make qualitative assessments regarding a real option's value. Decision trees are another important tool, since they facilitate an explicit identification of the embedded options, which is very important in the decision-making process. However, keep in mind that the decision tree should not use the original project's cost of capital. Although finance theory has not yet provided a way to estimate the appropriate cost of capital for a decision tree, sensitivity analysis can identify the effect that different costs of capital have on the project's value.

Many real options can be analyzed using a standard model for an existing financial option, such as the Black-Scholes model for calls and puts. There are also other financial models for a variety of options. These include the option to exchange one asset for another, the option to purchase the minimum or the maximum of two or more assets, the option on an average of several assets, and even an option on an option.[10] In fact, there are entire textbooks that describe even more options.[11]

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[9] See John R. Graham and Campbell R. Harvey, "The Theory and Practice of Corporate Finance: Evidence from the Field," *Journal of Financial Economics*, 2001, pp. 187–243.

[10] See W. Margrabe, "The Value of an Option to Exchange One Asset for Another," *Journal of Finance*, March 1978, pp. 177–186; R. Stulz, "Options on the Minimum or Maximum of Two Risky Assets: Analysis and Applications," *Journal of Financial Economics*, 1982, pp. 161–185; H. Johnson, "Options on the Maximum or Minimum of Several Assets," *Journal of Financial and Quantitative Analysis*, September 1987, pp. 277–283; P. Ritchken, L. Sankarasubramanian, and A. M. Vijh, "Averaging Options for Capping Total Costs," *Financial Management*, Autumn 1990, pp. 35–41; and R. Geske, "The Valuation of Compound Options," *Journal of Financial Economics*, March 1979, pp. 63–81.

[11] See John C. Hull, *Options, Futures, and Other Derivatives*, 6th ed. (Upper Saddle River, NJ: Prentice-Hall, 2006).

Given the large number of standard models for existing financial options, it is often possible to find a financial option that resembles the real option being analyzed.

Sometimes there are some real options that don't resemble any financial options. But the good news is that many of these options can be valued using techniques from financial engineering. This is frequently the case if there is a traded financial asset that matches the risk of the real option. For example, many oil companies use oil futures contracts to price the real options that are embedded in various exploration and leasing strategies. With the explosion in the markets for derivatives, there are now financial contracts that span an incredible variety of risks. This means that an ever-increasing number of real options can be valued using these financial instruments. Most financial engineering techniques are beyond the scope of this book, but ***Web Extension 13B,*** available at the textbook's Web site, describes one particularly useful financial engineering technique called risk-neutral valuation.[12]

SELF-TEST

How widely used is real option analysis?
What techniques can be used to analyze real options?

Summary

In this chapter we discussed some topics that go beyond the simple capital budgeting framework, including the following:

- Investing in a new project often brings with it a potential increase in the firm's future opportunities. Opportunities are, in effect, options—the right but not the obligation to take some future action.
- A project may have an **option value** that is not accounted for in a conventional NPV analysis. Any project that expands the firm's set of opportunities has positive option value.
- **Real options** are opportunities for management to respond to changes in market conditions and involve "real" rather than "financial" assets. There are five possible procedures for valuing real options: (1) **DCF analysis only, and ignore the real option,** (2) **DCF analysis and a qualitative assessment of the real option's value,** (3) **decision tree analysis,** (4) **analysis with a standard model for an existing financial option,** and (5) **financial engineering techniques.**

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[12] For more on real options, see Martha Amram, *Value Sweep: Mapping Corporate Growth Opportunities* (Boston: Harvard Business School Press, 2002); Martha Amram and Nalin Kulatilaka, *Real Options: Managing Strategic Investment in an Uncertain World* (Boston: Harvard Business School Press, 1999); Michael Brennan and Lenos Trigeorgis, *Project Flexibility, Agency, and Competition: New Developments in the Theory and Application of Real Options* (New York: Oxford University Press, 2000); Eduardo Schwartz and Lenos Trigeorgis, *Real Options and Investment Under Uncertainty* (Cambridge, MA: The MIT Press, 2001); Han T. J. Smit and Lenos Trigeorgis, *Strategic Investment: Real Options and Games* (Princeton, NJ: Princeton University Press, 2004); Lenos Trigeorgis, *Real Options in Capital Investment: Models, Strategies, and Applications* (Westport, CT: Praeger, 1995); and Lenos Trigeorgis, *Real Options: Managerial Flexibility and Strategy in Resource Allocation* (Cambridge, MA: The MIT Press, 1996).

Questions

(13-1) Define each of the following terms:

a. Real options; managerial options; strategic options; embedded option

b. Investment timing option; growth option; abandonment option; flexibility option

c. Decision trees

(13-2) What factors should a company consider when it decides whether to invest in a project today or to wait until more information becomes available?

(13-3) In general, do timing options make it more or less likely that a project will be accepted today?

(13-4) If a company has an option to abandon a project, would this tend to make the company more or less likely to accept the project today?

Self-Test Problem

Solution Appears in Appendix A

(ST-1) Real Options

Katie Watkins, an entrepreneur, believes consolidation is the key to profit in the fragmented recreational equine industry. In particular, she is considering starting a business that will develop and sell franchises to other owner-operators, who will then board and train hunter-jumper horses. The initial cost to develop and implement the franchise concept is $8 million. She estimates a 25% probability of high demand for the concept, in which case she will receive cash flows of $13 million at the end of each year for the next 2 years. She estimates a 50% probability of medium demand, in which case the annual cash flows will be $7 million for 2 years, and a 25% probability of low demand with annual cash flow of $1 million for 2 years. She estimates the appropriate cost of capital is 15%. The risk-free rate is 6%.

a. Find the NPV of each scenario, and then find the expected NPV.

b. Now assume that the expertise gained by taking on the project will lead to an opportunity at the end of Year 2 to undertake a similar venture that will have the same cost as the original project. The new project's cash flows would follow whichever branch resulted for the original project. In other words, there would be an $8 million cost at the end of Year 2 and then cash flows of $13 million, $7 million, or $1 million for Years 3 and 4. Use decision tree analysis to estimate the combined value of the original project and the additional project (but implement the additional project only if it is optimal to do so). Assume the $8 million cost at Year 2 is known with certainty and should be discounted at the risk-free rate of 6%. [Hint: Do one decision tree that discounts the operating cash flows at the 15% cost of capital and another decision tree that discounts the costs of the projects (that is, the costs at Year 0 and Year 2) at the risk-free rate of 6%. Then sum the two decision trees to find the total NPV.]

c. Instead of using decision tree analysis, use the Black-Scholes model to estimate the value of the growth option. Assume the variance of the project's rate of return is 15%. Find the total value of the project with the option to expand (that is, the sum of the original expected value and the growth option). (Hint: You will need to find the expected present value of the additional project's operating cash flows to estimate the current price of the option's underlying asset.)

Problems

Answers Appear in Appendix B

Intermediate Problems 1–5

(13-1) Investment Timing Option: Decision Tree Analysis

Kim Hotels is interested in developing a new hotel in Seoul. The company estimates that the hotel would require an initial investment of $20 million. Kim expects that the hotel will produce positive cash flows of $3 million a year at the end of each of the next 20 years. The project's cost of capital is 13%.

a. What is the project's net present value?

b. While Kim expects the cash flows to be $3 million a year, it recognizes that the cash flows could, in fact, be much higher or lower, depending on whether the Korean government imposes a large hotel tax. One year from now, Kim will know whether the tax will be imposed. There is a 50% chance that the tax will be imposed, in which case the yearly cash flows will be only $2.2 million. At the same time, there is a 50% chance that the tax will not be imposed, in which case the yearly cash flows will be $3.8 million. Kim is deciding whether to proceed with the hotel today or to wait 1 year to find out whether the tax will be imposed. If Kim waits a year, the initial investment will remain at $20 million. Assume that all cash flows are discounted at 13%. Using decision tree analysis, should Kim proceed with the project today or should it wait a year before deciding?

(13-2) Investment Timing Option: Decision Tree Analysis

The Karns Oil Company is deciding whether to drill for oil on a tract of land that the company owns. The company estimates that the project would cost $8 million today. Karns estimates that once drilled, the oil will generate positive net cash flows of $4 million a year at the end of each of the next 4 years. While the company is fairly confident about its cash flow forecast, it recognizes that if it waits 2 years, it would have more information about the local geology as well as the price of oil. Karns estimates that if it waits 2 years, the project would cost $9 million. Moreover, if it waits 2 years, there is a 90% chance that the net cash flows would be $4.2 million a year for 4 years, and there is a 10% chance that the cash flows will be $2.2 million a year for 4 years. Assume that all cash flows are discounted at 10%.

a. If the company chooses to drill today, what is the project's net present value?

b. Using decision tree analysis, does it make sense to wait 2 years before deciding whether to drill?

(13-3) Investment Timing Option: Decision Tree Analysis

Hart Lumber is considering the purchase of a paper company. Purchasing the company would require an initial investment of $300 million. Hart estimates that the paper company would provide net cash flows of $40 million at the end of each of the next 20 years. The cost of capital for the paper company is 13%.

a. Should Hart purchase the paper company?

b. While Hart's best guess is that cash flows will be $40 million a year, it recognizes that there is a 50% chance the cash flows will be $50 million a year, and a 50% chance that the cash flows will be $30 million a year. One year from now, it will find out whether the cash flows will be $30 million or $50 million. In addition, Hart also recognizes that if it wanted, it could sell the company at Year 3 for $280 million. Given this additional information, does using decision tree analysis indicate that it makes sense to purchase the paper company? Again, assume that all cash flows are discounted at 13%.

(13-4)
Real Options: Decision Tree Analysis

Utah Enterprises is considering buying a vacant lot that sells for $1.2 million. If the property is purchased, the company's plan is to spend another $5 million today ($t = 0$) to build a hotel on the property. The after-tax cash flows from the hotel will depend critically on whether the state imposes a tourism tax in this year's legislative session. If the tax is imposed, the hotel is expected to produce after-tax cash inflows of $600,000 at the end of each of the next 15 years. If the tax is not imposed, the hotel is expected to produce after-tax cash inflows of $1,200,000 at the end of each of the next 15 years. The project has a 12% cost of capital. Assume at the outset that the company does not have the option to delay the project. Use decision tree analysis to answer the following questions.

a. What is the project's expected NPV if the tax is imposed?

b. What is the project's expected NPV if the tax is not imposed?

c. Given that there is a 50% chance that the tax will be imposed, what is the project's expected NPV if they proceed with it today?

d. While the company does not have an option to delay construction, it does have the option to abandon the project 1 year from now if the tax is imposed. If it abandons the project, it would sell the complete property 1 year from now at an expected price of $6 million. Once the project is abandoned the company would no longer receive any cash inflows from it. Assuming that all cash flows are discounted at 12%, would the existence of this abandonment option affect the company's decision to proceed with the project today?

e. Finally, assume that there is no option to abandon or delay the project, but that the company has an option to purchase an adjacent property in 1 year at a price of $1.5 million. If the tourism tax is imposed, the net present value of developing this property (as of $t = 1$) is only $300,000 (so it wouldn't make sense to purchase the property for $1.5 million). However, if the tax is not imposed, the net present value of the future opportunities from developing the property would be $4 million (as of $t = 1$). Thus, under this scenario it would make sense to purchase the property for $1.5 million. Assume that these cash flows are discounted at 12%, and the probability that the tax will be imposed is still 50%. How much would the company pay today for the option to purchase this property 1 year from now for $1.5 million?

(13-5)
Growth Option: Decision Tree Analysis

Fethe's Funny Hats is considering selling trademarked curly orange-haired wigs for University of Tennessee football games. The purchase cost for a 2-year franchise to sell the wigs is $20,000. If demand is good (40% probability), then the net cash flows will be $25,000 per year for 2 years. If demand is bad (60% probability), then the net cash flows will be $5,000 per year for 2 years. Fethe's cost of capital is 10%.

a. What is the expected NPV of the project?

b. If Fethe makes the investment today, then it will have the option to renew the franchise fee for 2 more years at the end of Year 2 for an additional payment of $20,000. In this case, the cash flows that occurred in Years 1 and 2 will be repeated (so if demand was good in Years 1 and 2, then it will continue to be good in Years 3 and 4). Write out the decision tree and use decision tree analysis to calculate the expected NPV of this project including the option to continue on for an additional 2 years. Note: The franchise fee payment at the end of Year 2 is known, so it should be discounted at the risk-free rate, which is 6%.

Challenging Problems 6–8

(13-6) Investment Timing Option: Option Analysis

Rework Problem 13-1 using the Black-Scholes model to estimate the value of the option. (Hint: Assume the variance of the project's rate of return is 6.87% and the risk-free rate is 8%.)

(13-7) Investment Timing Option: Option Analysis

Rework Problem 13-2 using the Black-Scholes model to estimate the value of the option: The risk-free rate is 6%. (Hint: Assume the variance of the project's rate of return is 1.11%.)

(13-8) Growth Option: Option Analysis

Rework Problem 13-5 using the Black-Scholes model to estimate the value of the option. The risk-free rate is 6%. (Hint: Assume the variance of the project's rate of return is 20.25%.)

Spreadsheet Problem

(13-9) Build a Model: Real Options

FM e-resource

Start with the partial model in the file ***FM12 Ch 13 P09 Build a Model.xls*** from the textbook's Web site. Bradford Services Inc. (BSI) is considering a project that has a cost of $10 million and an expected life of 3 years. There is a 30% probability of good conditions, in which case the project will provide a cash flow of $9 million at the end of each year for 3 years. There is a 40% probability of medium conditions, in which case the annual cash flows will be $4 million, and there is a 30% probability of bad conditions and a cash flow of −$1 million per year. BSI uses a 12% cost of capital to evaluate projects like this.

a. Find the project's expected present value, NPV, and the coefficient of variation of the present value.

b. Now suppose that BSI can abandon the project at the end of the first year by selling it for $6 million. BSI will still receive the Year 1 cash flows, but will receive no cash flows in subsequent years.

c. Now assume that the project cannot be shut down. However, expertise gained by taking it on would lead to an opportunity at the end of Year 3 to undertake a venture that would have the same cost as the original project, and the new project's cash flows would follow whichever branch resulted for the original project. In other words, there would be a second $10 million cost at the end of Year 3, and then cash flows of either $9 million, $4 million, or –$1 million for the following 3 years. Use decision tree analysis to estimate the value of the project, including the opportunity to implement the new project at Year 3. Assume the $10 million cost at Year 3 is known with certainty and should be discounted at the risk-free rate of 6%.

d. Now suppose the original (no abandonment and no additional growth) project could be delayed a year. All the cash flows would remain unchanged, but information obtained during that year would tell the company exactly which set of demand conditions existed. Use decision tree analysis to estimate the value of the project if it is delayed by 1 year. (Hint: Discount the $10 million cost at the risk-free rate of 6% since it is known with certainty.)

e. Go back to part c. Instead of using decision tree analysis, use the Black-Scholes model to estimate the value of the growth option. The risk-free rate is 6%, and the variance of the project's rate of return is 22%.

Cyberproblems

FM e-resource

Please go to the textbook's Web site to access any Cyberproblems.

Mini Case

Assume that you have just been hired as a financial analyst by Tropical Sweets Inc., a mid-sized California company that specializes in creating exotic candies from tropical fruits such as mangoes, papayas, and dates. The firm's CEO, George Yamaguchi, recently returned from an industry corporate executive conference in San Francisco, and one of the sessions he attended was on real options. Because no one at Tropical Sweets is familiar with the basics of real options, Yamaguchi has asked you to prepare a brief report that the firm's executives can use to gain at least a cursory understanding of the topic.

To begin, you gathered some outside materials on the subject and used these materials to draft a list of pertinent questions that need to be answered. In fact, one possible approach to the paper is to use a question-and-answer format. Now that the questions have been drafted, you have to develop the answers.

a. What are some types of real options?

b. What are five possible procedures for analyzing a real option?

c. Tropical Sweets is considering a project that will cost $70 million and will generate expected cash flows of $30 million per year for 3 years. The cost of capital for this type of project is 10% and the risk-free rate is 6%. After discussions with the marketing department, you learn that there is a 30% chance of high demand, with future cash flows of $45 million per year. There is a 40% chance of average demand, with cash flows of $30 million per year. If demand is low (a 30% chance), cash flows will be only $15 million per year. What is the expected NPV?

d. Now suppose this project has an investment timing option, since it can be delayed for a year. The cost will still be $70 million at the end of the year, and the cash flows for the scenarios will still last 3 years. However, Tropical Sweets will know the level of demand and will implement the project only if it adds value to the company. Perform a qualitative assessment of the investment timing option's value.

e. Use decision tree analysis to calculate the NPV of the project with the investment timing option.

f. Use a financial option pricing model to estimate the value of the investment timing option.

g. Now suppose the cost of the project is $75 million and the project cannot be delayed. But if Tropical Sweets implements the project, then Tropical Sweets will have a growth option. It will have the opportunity to replicate the original project at the end of its life. What is the total expected NPV of the two projects if both are implemented?

h. Tropical Sweets will replicate the original project only if demand is high. Using decision tree analysis, estimate the value of the project with the growth option.

i. Use a financial option model to estimate the value of the project with the growth option.

j. What happens to the value of the growth option if the variance of the project's return is 14.2%? What if it is 50%? How might this explain the high valuations of many dot-com companies?