Chapter **Eleven**

Application of Real-Option Techniques to Capital Budgeting and Capital Structure

The main objective of this chapter is for students to demonstrate that they can identify the manner in which psychological phenomena affect managers' use of real-option techniques.

After completing this chapter students will be able to:

1. Explain why opaque framing causes managers to refrain from using real-option techniques.
2. Explain how excessive optimism affects the investment policies of managers who use real-option techniques.
3. Explain how overconfidence affects the investment policies of managers who use real-option techniques.
4. Explain why excessive optimism and overconfidence mitigate the impact of agency conflicts associated with debt overhang and asset substitution.
5. Describe how real-option techniques can mitigate managers' tendencies to throw good money after bad.

11.1 TRADITIONAL APPROACH TO OPTION THEORY

Option theory is tailor-made for capital budgeting in a volatile environment. The optimal exercise policy for the option effectively provides the firm with its investment policy in respect to a project.

The traditional way to teach option theory is by demonstrating how an option on an asset can be dynamically replicated as a combination of the risk-free security and

the underlying asset. This demonstration involves either the binomial framework or the Black–Scholes framework. Both frameworks make use of a concept known as risk-neutral probabilities to assess both value and exercise policy. In both frameworks, options are valued by computing the expected value of cash flows using the risk-neutral probabilities and then discounting at the risk-free rate of interest.

In the binomial framework, the formula for the risk-neutral probability associated with the "up" return is

$$\frac{\text{Risk-free rate of interest} - \text{Down return}}{\text{Up return} - \text{Down return}}$$

while the probability associated with the "down" return is 1 minus the probability associated with the up return. In this chapter, it is possible to use the binomial framework to explain how psychological phenomena affect managers' use of real-option techniques. Therefore, no discussion of the Black–Scholes framework appears in the following.

11.2 DO MANAGERS USE REAL-OPTION TECHNIQUES?

The idea underlying real options was first proposed in the mid-1970s. Although real-option techniques are taught regularly in corporate finance classes, the use of real-option techniques in corporate decision processes occurs, but it is not commonplace.

The pharmaceuticals firm Merck & Company regularly employs real options to analyze a variety of different issues. Indeed, its chief financial officer, Judy Lewent, was quoted in a 1994 *Harvard Business Review* article as saying: "To me all kinds of business decisions are options."[1] Other firms that have used real-option techniques include Hoffman-La Roche, Texaco, BP Amoco, Anadarko Petroleum, New England Electric,[2] Intel, and Toshiba.[3]

At the same time, the proverbial glass is less than half full. Survey evidence from the year 2000 indicated that among 25 management techniques, real options ranked twenty-fourth. This particular survey was completed by 451 senior executives and covered more than 30 industries. Moreover, the survey showed that during 2000, 32 percent of real-option users abandoned the technique. Survey evidence from the year 2002 found that real options even ranked low among supplementary capital budgeting tools. This study surveyed the chief financial officers of 205 Fortune 1000 companies.[4]

opaque framing
Describing a decision task in a manner that renders the consequences of the decision difficult to discern.

transparent framing
Describing a decision task in a manner that renders the consequences of the decision easy to discern.

Opaque Framing?

Why are real options more popular with finance professors than corporate executives?[5] Is it because real-option framing is natural for finance professors but unnatural for executives? Do executives find that real-option framing is **opaque framing** or **transparent framing?**

In order to explore this question, consider some of the comments made at roundtables held to discuss the application of real-option techniques.

Behavioral Pitfalls Sun Microsystems

Sun Microsystems had been a successful high-technology firm, known for its workstations and for having invented the programming language Java that is widely used in Internet applications. Sun had an ongoing interest in the development of new technologies, an interest that it expressed either in-house or through acquisition. Did the managers at Sun use real-option techniques to help them evaluate potential acquisitions?

Michael Lehman, CFO of Sun Microsystems, stated:

> The real options approach may have something to offer us here, since many of our technology deals can be seen as providing options on the future technological development. But up to this point, we haven't explored this possibility enough to get comfortable with this method—but, as I said, I'm here to learn.

In April 2001, one year after the roundtable, Sun's treasurer was asked to give a talk about financial decision making at Sun, including any use of real-option techniques. The treasurer responded by saying that he was unfamiliar with real options but would investigate the issue.

Several weeks later, the treasurer presented an overview of financial decision making at Sun. As to real options, he indicated that he had read the proceedings of the April 2000 roundtable and that he and Mike Lehman had discussed the relative merits of using real options. In the end they had concluded that real options were really nothing more than an attempt to rationalize the exorbitant market valuations that were assigned to technology stocks during the irrationally exuberant period that ended in March 2000 when the technology bubble burst. That is to say, Sun had not adopted real-option techniques as part of its business practices.

Source: "Bank of America Roundtable on: The Real Options Approach to Creating Value in the New Economy," *Journal of Applied Corporate Finance*, vol. 13, no. 2, 2000, pp. 45–63.

Real-options Roundtable 2000

On May 25, 2000, the Bank of America hosted a roundtable on the use of real options, which took place in Pebble Beach, California. The purpose of the roundtable was to discuss the application of real-option techniques.[6] Among the roundtable participants were Martha Amram, co-author of the book *Real Options: Managing Strategic Investment in an Uncertain World*, and Michael Lehman, CFO of Sun Microsystems.[7]

Martha Amram described why real-option techniques are valuable, especially for understanding the valuation of technology companies. She emphasized that because new technologies are highly uncertain, their value is embedded within the opportunity to move forward if they turn out to be successful. In this respect, much of the value in a technology firm may derive from an embedded option, the option to move forward if the technology proves to be successful.

Martha Amram cautioned that valuations based on traditional discounted cash flow (DCF) analysis, applied to expected cash flow streams, might not provide an appropriate measure of value. Why? Because focusing exclusively on the expected cash flow stream typically masks the embedded option.[8]

Sun CFO Lehman appeared to have grasped Martha Amram's point, at least intellectually. However, Sun decided against the adoption of real-option techniques. See the Behavioral Pitfalls box above.[9]

Real-options Roundtable 2002[10]

In April 2002, the University of Maryland hosted another roundtable on real options and corporate practice. A panel of consultants described their experiences using real options.

The panelists made three key points about the use of real options in practice. First, good managers have always understood the importance of waiting to gather information before committing resources and will readily grasp the general idea behind real options. Second, real options provide a systematic approach for what had formerly been a highly intuitive approach. In other words, what had formerly been pure art now had some science.

Third, some of the experts in real options are strong in science but severely lacking in art. Gill Eapen, founder and principal of the firm Decision Options LLC, described his experience working for the pharmaceutical firm Pfizer. MIT professor Stewart Myers had presented the concept of real options to Pfizer's management, in order to help them assess how much they should pay for acquiring early-stage technologies. Although the group had found the general concept of real options attractive, they became resistant when the discussion shifted to partial differential equations and finite difference solutions. For most business people, even those well trained in finance, partial differential equations and finite difference equations comprise a very opaque frame.

As Gill Eapen indicated, executives might ask about the assumptions in the real-options model, and they might ask about the mathematics that lies inside of the option model black box. However, he argued that it is neither necessary nor productive for executives to become involved in long discussions about the assumptions underlying the model. After all, most senior executives neither know nor care about the assumptions that underlie the capital asset pricing model. What is more important is that the real-options approach capture executives' intuitive sense of the major risks and opportunities.

Valuation Heuristics and Efficient Prices John McCormack, a senior vice president at the consulting firm Stern Stewart, was one of the panelists. He made the following interesting comment.

> If you really believe that EPS is what determines your stock price, then you have no business using DCF analysis for valuing investments. And you won't have much use for real options either. Because the intellectual foundation for using all of these methods, whether it is DCF or real options, is that today's value is mainly a function of size, timing and riskiness of future cash flows. Now, this may not be a controversial point in this audience, but I will say that the economic model of valuation that we all subscribe to is far from accepted in the corporate world.

This comment is worth thinking about in light of the discussion in Chapter 2 on valuation, in Chapter 5 on inefficient prices, and in Chapter 6 on the choice of capital structure when prices are inefficient.

Decision Analysis Several panelists mentioned the use of decision (tree) analysis (DA) in place of real-option analysis. Decision analysis shares much in common with real-option analysis. However, DA has a longer history and is simpler to use than real options. Unlike real-option techniques, DA makes no use of risk-neutral probabilities and does not emphasize valuation. Panelists mentioned that firms that already made use of DA saw little incremental value in shifting to real-option techniques.

Interestingly, since the April 2000 roundtable, Martha Amram rethought her position about the use of real-option techniques.[11] She suggested that although it is

important for managers to engage in DA, they might do themselves a disservice by using real-option techniques. Her reasons are intriguing.

Martha Amram asked whether the risk that firms bear is mostly systematic risk, essentially market risk, or whether it is risk that is specific to the company or project. She indicated that most of the risk firms bear is specific to the company and that most of the risk that project managers bear is specific to their projects. However, the valuations implicit in real options treat risk as systematic: Real-option analysis assumes that firm-specific risk can be diversified away. Moreover, this assumption is buried deep within the risk-neutral probabilities.

Martha Amram concluded that most firms would be fine simply doing DA well. After all, DA essentially uses the same decision trees as real options and therefore identifies the same contingent decisions. Although DA erroneously applies a constant discount rate, when in theory the discount rate should vary as risk changes through the decision tree, this error is minor compared to other possible errors. In reality, many companies do not even match discount rates to cash flow riskiness, let alone vary the discount rate over time for the cash flows from a single project.[12]

Opaque Probabilities?

In option theory, discounting for risk is accomplished by means of risk-neutral probabilities. Think about the term *risk-neutral probability.* Is it transparent and intuitively appealing?

In most presentations of traditional option theory, risk-neutral probabilities are invariant to the actual probabilities. Is it intuitive or counterintuitive that valuation should appear not to depend on the true probabilities but on artificial (risk neutral) probabilities instead? As it happens, only in special cases are risk-neutral probabilities independent of the true underlying probabilities. In the general case, and certainly the case that applies to investment projects, risk-neutral probabilities depend on the true underlying probabilities. This dependence is illustrated in one of the examples later in the chapter.

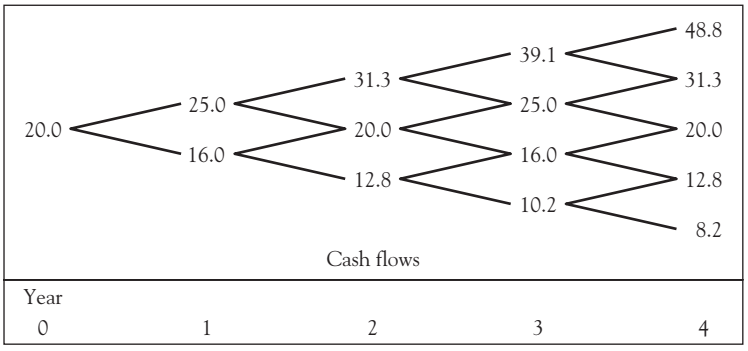
Most people find the concept of risk-neutral probabilities opaque and unintuitive. In traditional textbooks, risk-neutral probabilities are derived by solving equations that show how an option can be synthesized using the underlying stock and risk-free asset. Is this derivation likely to provide managers with the intuition they require to use option valuation techniques with confidence, especially in deliberations with managers working in functional areas other than finance? It appears not.

Traditional textbooks frame option techniques opaquely. However, managers are likely to favor techniques that make intuitive sense to them. Therefore, as powerful as risk-neutral probability techniques are, they will continue to be underutilized until they can be framed more transparently.

11.3 VALUING LEVERED EQUITY

Real options are now a fixture in traditional courses in corporate finance, applied to investment timing issues and to elucidating agency conflicts involving debt holders and shareholders. Yet, managers routinely exhibit excessive optimism and overconfidence. How will these psychological features impact the manner in which real-option

EXHIBIT 11.1



techniques are applied? In order to answer this question, the present section develops an example involving rational managers who act in the interests of equity holders. Later sections then modify the example to illustrate the impact of excessive optimism and overconfidence.

Example

Consider a firm that is all-equity financed and whose earnings are $20 million during Year 0, the end of which is denoted time t_0. For the sake of simplicity, imagine that the firm pays out all its earnings as dividends. Suppose that the firm's growth rate from year to year is uncertain. Specifically, earnings will grow by 25 percent with probability 44.45 percent and will decline by 20 percent with probability 55.55 percent. With these values, the firm's expected growth rate will be zero ($= 0.4445 \times 0.25 - 0.5555 \times 0.2$). Exhibit 11.1 displays the possible earnings (cash flow) scenarios for years 0 through 4.

Value of Firm

Suppose that the firm's cost of capital is 20 percent. In this case, the predividend value of the firm is $120 million and the ex-dividend value of the firm is $100 million. The ex-dividend value is computed by dividing the expected future dividend of $20 million at t_1 by the cost of capital ($100 = $20/0.2).

Imagine that at t_0 the owners of the firm decide to cash out their stakes. In this regard they retain the $20 million in cash flow they received at t_0 and sell the assets of the firm for a price of $100 million. What return will the new owners receive at the end of t_1? The answer depends on whether Year 1 turns out to be an up-year or a down-year.

Returns

Total return is the sum of the cash flow yield and the capital gains rate. If Year 1 is an up-year, then the new owners receive a cash flow of $25 million, giving them a cash flow yield of 25 percent ($25/$100). The corresponding capital gains rate would also be 25 percent, as the asset has increased in value from $100 million to $125 million. Therefore, the total return associated with an up-year is 50 percent.

On the other hand, if Year 1 is a down-year, then the new owners receive a cash flow yield of 16 percent ($16/$100), along with a 20 percent capital loss (because

the asset has declined in value from \$100 million to \$80 million). Therefore, the total return associated with a down-year is −4 percent.

Expected Return

What about the expected return? Recall that the actual probability of an up-year is 44.45 percent and the return in an up-year is 50 percent. Therefore the expected return is just the difference $0.4445 \times 0.5 - 0.5555 \times 0.04$, which comes to 20 percent, the same as the required return. Of course that should come as no surprise: 20 percent was the rate used to arrive at the fair value of the firm, and the returns are based on fair value.

Risk-Neutral Probabilities

Designate the return in an up-year by the symbol u, the return in a down-year by the symbol d, and the risk-free rate by r. In this example, u is 50 percent and d is −4 percent. The traditional textbook formula for the risk-neutral probability attached to the up-return is $(r - d)/(u - d)$. Therefore, the risk-neutral probability attached to the up-return (growth of 25 percent) is 16.67 percent $\{= [0.05 - (-0.04)]/[0.5 - (-0.04)]\}$, and the risk-neutral probability attached to the down-return (growth of –20 percent) is 83.33 percent.

Levered Equity and Implicit Put Option

Next, imagine that at t_0 the firm takes out a loan and engages in a share repurchase. The loan repayments are \$3.25 million before t_4, with a final loan payment of \$68.25 million due at t_4. Suppose further that after paying off the debt, the managers plan to sell the firm at the end of t_4, at fair value.

Risk-free debt bears interest at the rate of 5 percent, and payment of the full principal is due at t_4. Therefore, if the firm took out a \$65 million risk-free loan, then the interest would be \$3.25 per year, with repayment of interest and principal being \$68.25. In this case, the future value of the debt would be \$68.25 million at t_4. In fact, the future value of the debt would be \$68.25 million at the end of every year from t_1 on. The first interest payment is due at t_1. Of course, the (present) value of the debt at t_0 would just be \$65 million.

Notably, the firm's debt is not risk-free. The managers have the option to default and, on behalf of shareholders, to effectively sell the firm to the debt holders for the face value of the debt plus any current interest that is due. In other words, the debt holders effectively provide the shareholders with a put option.

Value of Levered Equity

How much is the firm's levered equity worth? If the debt were risk-free, then the value of the equity at any date would just be the difference between the value of the firm at that date minus the \$65 million of debt. Because the debt is not risk-free, valuing the firm's equity requires identifying the circumstances in which the firm's managers would choose to default on their debt obligations. Therefore, consider the tree in Exhibit 11.2 depicting the predividend value of the firm at each date.

Notice that at the bottom left node in Exhibit 11.2, the value of the firm is \$49.16 million, less than the \$68.25 million that the debt is worth at that node.

EXHIBIT 11.2

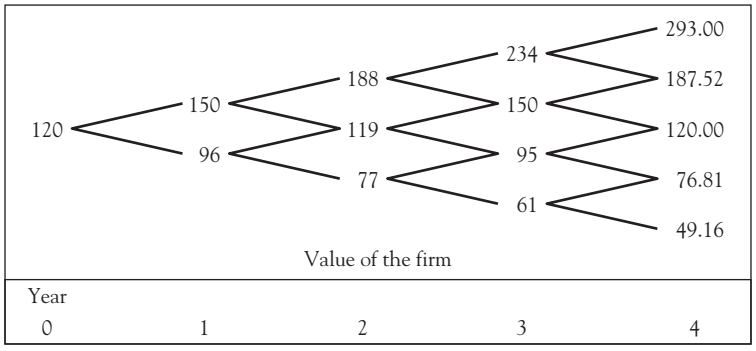
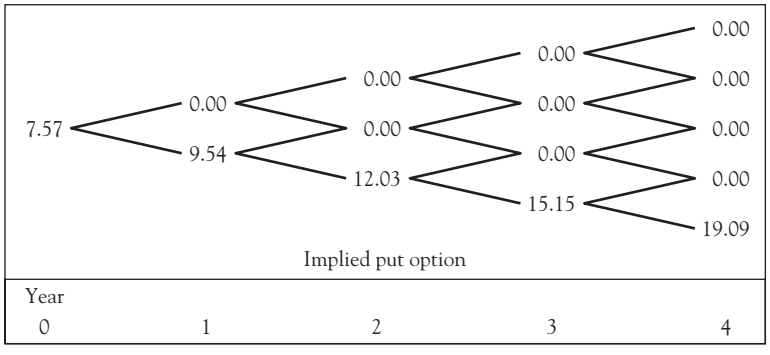


EXHIBIT 11.3



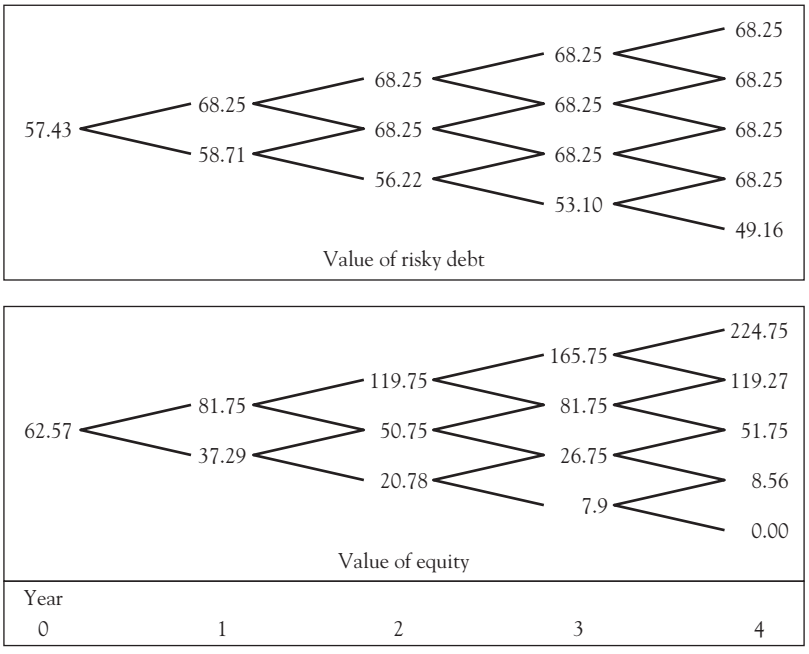
Therefore, in the event that this node occurs, the managers of the firm would declare bankruptcy. The ownership of the firm would pass from the equity holders to the debt holders. However, the equity holders would not be liable for the difference of $19.09 million between the $68.25 million due the debt holders and the $49.16 million of value in the firm.

In effect, because of limited liability the debt holders have conferred a put option on the equity holders that enables them to sell the firm to debt holders at a price of $68.25 million, even though the market value of the firm is only $49.16 million.

Value of Put Option The put option can be valued using the traditional risk-neutral pricing methodology. As was mentioned earlier, the risk-neutral probability attached to the up-return (growth of 25 percent) is 16.67 percent, and the risk-neutral probability attached to the down-return (growth of −20 percent) is 83.33 percent.

Exhibit 11.3 depicts the valuation tree. At t_4 the put option only has value at the bottom node, and its value is the difference between $68.25 and $49.16 (in millions). At t_3, the option has positive value only at the bottom node. The $15.15 million is obtained by taking the expected value of the put option at t_4 using the risk-neutral probabilities and discounting at the risk-free rate of 5 percent. Recursive computation back through the tree implies that the value of the put option at t_0 is $7.57 million.

EXHIBIT 11.4



Because the debt holders confer a put option worth $7.57 million on the equity holders at t_0, the value of the debt at t_0 is not $65 million, but $57.43 million, the difference being $7.57 million. In effect, the debt holders would not loan the firm $65 million in exchange for interest of $3.25 million per year. They would only loan the firm $57.43 million. Therefore, the interest rate associated with the risky debt would be 8.6 percent, the internal rate of return of the loan amount and subsequent loan payments if paid, rather than the risk-free 5 percent.

Exhibit 11.4 shows how the value of the firm's risky debt and equity co-evolve over time, depending on the rate at which the firm's cash flows change from year to year. Notice that the firm's equity is worth zero in the bottom-most node of t_4. At t_0 the combined value of the firm's risky debt and its equity are $120 million, the value of the firm.

11.4 CONFLICTS OF INTEREST

This section focuses on agency conflicts involving debt holders and equity holders. At issue is how excessive optimism and overconfidence on the part of managers affects the nature of this conflict. One of the interesting conclusions is that mild optimism and overconfidence can ameliorate the conflict.

Example: Small-Scale Project

Suppose that the firm discussed in Section 11.3 experiences two down-years and one up-year. As a result, the value of the firm at the end of Year 3, predividend,

is \$95 million. Imagine that the managers find that they have the opportunity to undertake a project that would increase the value of the firm at t_4 by an additional \$20 million if the value of the firm goes up, but decrease the value of the firm at t_4 by an additional \$1.8 million if the value of the firm goes down. Moreover, suppose that the project requires an investment at t_3 in the amount \$1.75 million, and suppose that the appropriate discount rate for a project this risky is 352 percent. As a result, the NPV of the project is slightly negative, but very close to zero.

A manager with the goal of maximizing the value of the firm should reject this project because it has a negative net present value. At the same time, the managers have a fiduciary responsibility to equity holders, not to all investors. Therefore, they will be carrying out their fiduciary duty only if the equity holders' interests are served by rejecting the project.

Because the firm is a corporation, equity holders possess a put option, conferred on them by debt holders. In order to make sure that equity holders are well served if they reject the project, managers need to understand how adopting the project affects the value of the option. In the worst case, the project would reduce the value of the firm at t_4 from \$76.8 million to \$75 million, well above the \$68.25 million value that would trigger default. Therefore, the value of the option is zero regardless of whether or not the project is adopted. Hence, a manager whose goal was to maximize the value of equity should reject the project in these circumstances.

Asset Substitution

Consider next whether it is possible for a different project to increase the value of the implied option, and hence the value of equity. In this regard, think about what happens when the project cash flows are magnified tenfold.

Example: Large-Scale Project

The net present value of the project is still negative. At the same time, this project is large enough to have an impact on the value of the put option. The reason is that if the fourth year is a down-year, the value of the firm will fall to \$58.8 million, \$9.45 million below the \$68.25 million value that triggers default. Therefore the value of the option will be \$7.5 million ($= 0.833 \times 9.45/1.05$). As a result, the interest of equity holders would be well served if the managers decided to adopt the project. They benefit by an amount equal to the increased option value plus the project NPV. On the other hand, debt holders lose. The value of their position declines by \$7.5 million, the increase in the value of the put option that debt holders have conferred on equity holders.

These kinds of projects serve to increase the riskiness of the firm's cash flows. The key question is: Who bears the risk of these projects? For the small-scale project, equity holders alone bear the risk. However, the large-scale project leads the risk to be shifted from the equity holders to the debt holders, so much so that equity holders would prefer that the project be undertaken. Effectively the project serves to substitute a riskier asset for a safer asset. Therefore, the project generates an effect known as *asset substitution*.

Debt Overhang

Suppose that the firm has experienced three down-years in a row. At the end of Year 3, the predividend value of the firm has fallen from $120 million to $61 million. Notice that the value of the firm is now below $68.25 million, the amount that would trigger default in Year 4. Nevertheless, the firm does have the cash flows to enable it to meet its interest obligations in year t_3, because the repayment of principal is not yet due.

At the end of t_3 the managers learn of the small-scale project described earlier, whereby they can invest in a project that will either increase Year 4 cash flows by $20 million or reduce Year 4 cash flows by $1.8 million. As before, this project destroys value.

However, the project also serves to increase the value of the put option by $1.43 million, from $15.15 million to $16.58 million. How do we know? The option only features a positive payoff when the new project fails, meaning after a down-move. Because of the project, the firm is worth $1.8 million less in this situation. To value this reduction from the perspective of t_3, multiply the $1.8 million by the risk-neutral probability 83.33 percent, and discount at the risk-free rate to obtain $1.43 million ($1.43 = 1.8 \times 0.8333/1.05$).

Therefore, just as in the case of asset substitution, adopting the project would generate a benefit to equity holders, a cost to debt holders, and a reduction in the overall value of the firm.

Forgoing Projects That Create Value In the preceding example, rational managers chose to adopt a negative net-present-value (NPV) project. The flip side is that in certain circumstances, the conflict between bondholders and equity holders might induce rational managers to forgo choosing a positive NPV project.

Here is an example. Suppose that the firm's cash flows are as in Exhibit 11.1 and that the firm has experienced three consecutive down-years. At the end of Year 3, the firm's managers learn of a new project. The effect of the project is to reduce the value of the firm by $20 million at t_4 in the event of an up-move, but increase the value of the firm by $9 million in the event of a down-move. Undertaking this project would require the firm to spend $3.95 million at t_3. The risk-neutral probabilities and risk-free interest rate are the same as in the previous examples. Applying them to the new project results in the NPV of the project being $17,135.

The new project does not alter whether or not bankruptcy occurs at the two t_4-events. After a down-move, the firm will still have to declare bankruptcy, although the value of the firm will be higher because of the new project, in the amount of $9 million. After an up-move, the firm will not have to declare bankruptcy, but will be worth $20 million less because of the project.

Notice that at t_4 the put option will only be valuable in the event of bankruptcy. Moreover, at t_3 the new project will reduce the value of the put option by $7.14 million ($7.14 = 0.833 \times 9/1.05$). The combination of the change in value to the option plus the new project NPV is approximately −$7.12 million. That is, adopting the new project leads the wealth of equity holders to decline by $7.12 million. Therefore debt overhang can induce managers to reject positive NPV projects, as the costs are borne by equity holders but the benefits mostly accrue to debt holders.

Capital Structure

Sophisticated debt holders understand that their interests can be compromised by asset substitution and debt overhang. What alternatives are available to them? Here are four. The first alternative is to use debt covenants in an effort to constrain managers. The second alternative is to demand a higher rate of interest to compensate for the attendant risk. The third alternative is for debt holders to refuse to loan the firm money; that is, they might ration credit. The fourth alternative is for debt holders to ask equity holders to renegotiate the terms of the debt obligation.

Covenant constraints, the first alternative, are often imperfect. Therefore, debt holders may need to rely on higher interest rates (the second alternative) or credit rationing (the third alternative) in order to protect their interests. A higher interest rate lowers the share of earnings before interest and taxes (EBIT) that flows to equity holders. Equity-maximizing managers will respond to a higher interest rate by lowering the amount of debt. Therefore, both a higher interest rate and credit rationing typically lead the firm to hold less debt than is consistent with tradeoff theory, meaning that managers leave tax shield benefits on the table.

11.5 OVERCONFIDENCE AND EXCESSIVE OPTIMISM

Consider now how overconfidence and excessive optimism would impact the behavior of managers who have the sophistication to use risk-neutral probability techniques correctly but are excessively optimistic and overconfident in their beliefs. We begin with overconfidence.[13]

Overconfidence

Suppose that the managers underestimate the riskiness of a project. For example, suppose that managers perceive that the incremental flows of a project are \$20 million and −\$1.8 million, when the true amounts are \$63 million and −\$12.6 million respectively. The initial investment is \$1.75 million.

How would this misperception impact the analysis? Consider the case when the firm has experienced two down-years and one up-year. Recall that the previous discussion of this situation actually examined this case for the small scale project. In the small-scale project, when the incremental cash flows are \$20 million and −\$1.8 million, the project does not impact the value of the put option. As a result, the managers see no reason to adopt the project, since the project creates no value for equity holders. However, when the incremental cash flows are larger, the managers do indeed adopt the project, not because the NPV of the project has changed, but because the value of the implied option has increased from \$0 to \$3.21 ($= 0.8333 \times (68.25 - 64.21)/1.05$).

What are we to conclude in this situation? We conclude that managerial overconfidence can actually help debt holders. Remember that the project is actually riskier than managers believe. Therefore, managers fail to compute the correct value of the put option as a result of the project being undertaken. As a result, they reject the project, even though it would benefit equity holders. In this case, overconfidence causes

managers to abstain from taking actions that reduce the value of the firm and from shifting wealth from debt holders to equity holders. At time t_0, debt holders with rational expectations will foresee how overconfident managers will behave and will therefore be willing to pay a higher price for the firm's debt.

Although overconfidence serves to alleviate debt holder–shareholder conflicts, overconfidence can also induce managers to choose negative net-present-value projects. Some projects are sufficiently risky that the expected cash flows feature negative net present value. Think about an overconfident manager who holds unbiased beliefs about expected cash flows. By virtue of underestimating the risk of these cash flows, this manager might use a discount rate that is too low. Therefore, managers might conclude that the project cash flows have positive NPV, whereas had they used the correct higher discount rate they would have concluded that the project had negative NPV.

Excessive Optimism

In order to understand the impact of excessive optimism, suppose that the firm is evaluating a possible project at t_0. To set the stage for the discussion of optimism, assume that the project cash flows and probabilities are objectively the same as those depicted in Exhibit 11.1. However, let the appropriate discount rate now be 10 percent, not the 20 percent discussed earlier. In addition, assume that undertaking the project requires an investment of $180 million. Suppose that the managers have some flexibility and can invest the $180 million at any time over the next two years. That is, the managers could choose to wait for either one more year or two more years before committing resources to the project.

Consider the case when the managers hold objectively correct beliefs. If the managers had to make up their minds at t_0 about whether to adopt or reject the project, then they should adopt the project. After all, the present value of the future expected cash flow stream is $200 million, more than the $180 million of required investment. However, if managers are able to wait a bit longer before committing themselves, then they would be able to ascertain whether market conditions change unfavorably (down-moves), in which case they might wish to forgo the project. At the same time, waiting means forgoing cash flows that would otherwise arrive. How should managers decide on the correct combination of timing and conditions for investing the $180 million and adopting the project?

A Real Option

The answer to this last question is to use real-option analysis. Being able to invest in the project at any time over the next two years is tantamount to having a call option on the project with an exercise price of $180 million. Exhibit 11.5 depicts the key option trees for this problem. Keep in mind that the underlying cash flows and interest rate are the same as in the previous examples, but the risk-neutral probabilities are a bit different because of the change in discount rate. (The new risk-neutral probabilities are 34.35 percent and 65.65 percent.)

At each node in the decision tree, managers face a challenge. They have to decide whether exercising the option at that node is more valuable than keeping the option open and waiting to see if they would like to exercise the option at a later date.

EXHIBIT 11.5

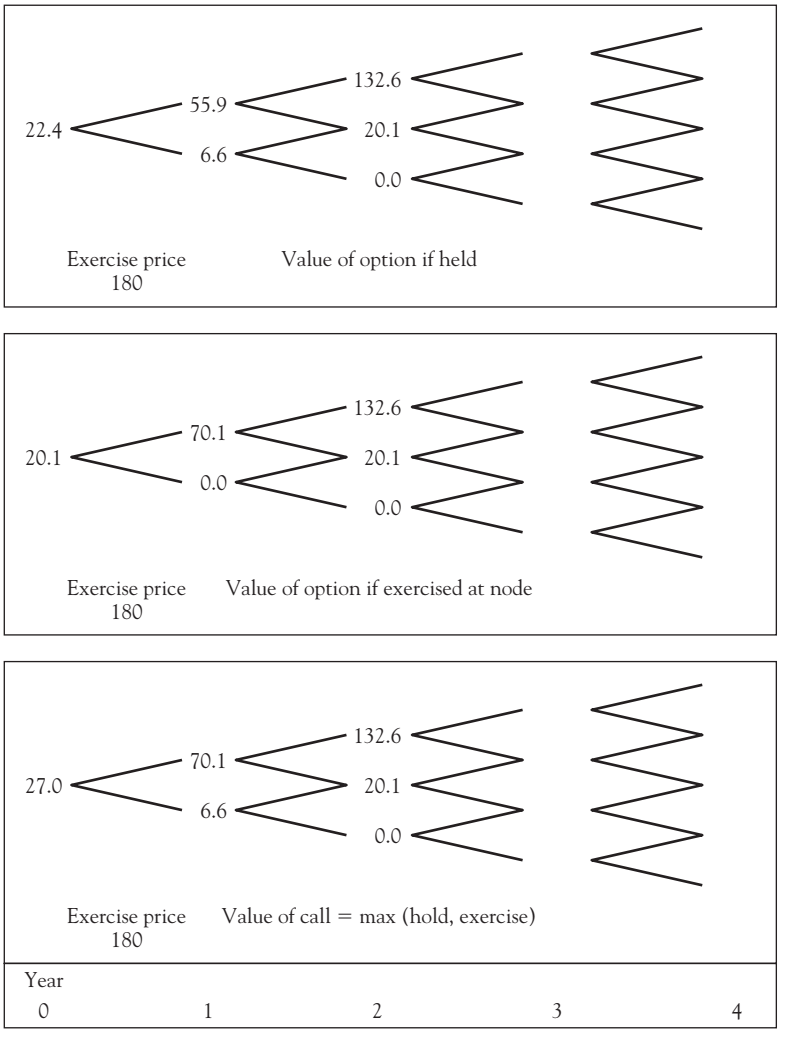


Exhibit 11.5 has three panels. The top panel depicts the value of the option at each node if managers wait until the option expiration date before deciding whether or not to exercise the option. The middle panel depicts the value of the option if it is exercised at each node. The bottom panel assumes that at each node, managers choose between immediate exercise and waiting, based on whether the option is more valuable if kept open or exercised immediately.

Notice that as long as there has been at least one up-move, Exhibit 11.5 indicates that managers should exercise the option and invest in the project. Otherwise, managers should not invest and should either hold the option open or abandon the project at t_2. In this respect, Exhibit 11.5 also indicates that the value of the option at t_0 is \$27 million.

Optimism

Suppose that in the preceding situation, managers are excessively optimistic, believing the probability of an up-move to be 50 percent instead of 45 percent. How does this optimism impact the decisions of managers who follow an optimal exercise policy?

In the traditional introduction to option theory, the risk-neutral probabilities are independent of the actual probabilities. Therefore, if optimism manifests itself in actual probabilities, then we should infer that optimism would have no impact on valuation and exercise policy. In this example, such a conclusion is a bit hasty. Once account is taken of the impact of probabilities on the value of the underlying asset, returns are impacted and with them risk-neutral probabilities.

The channel through which managers' beliefs affect the real-option framework is indeed through the risk-neutral probabilities. Keep in mind that the market does not provide managers with explicit risk-neutral probabilities. Instead managers would infer risk-neutral probabilities using formulas based on returns and the risk-free interest rate. Recall that if u and d are, respectively, the returns attached to up- and down-movements and r is the risk-free interest rate, then the risk-neutral probability attached to the up-return is $(r - d)/(u - d)$.

Returns

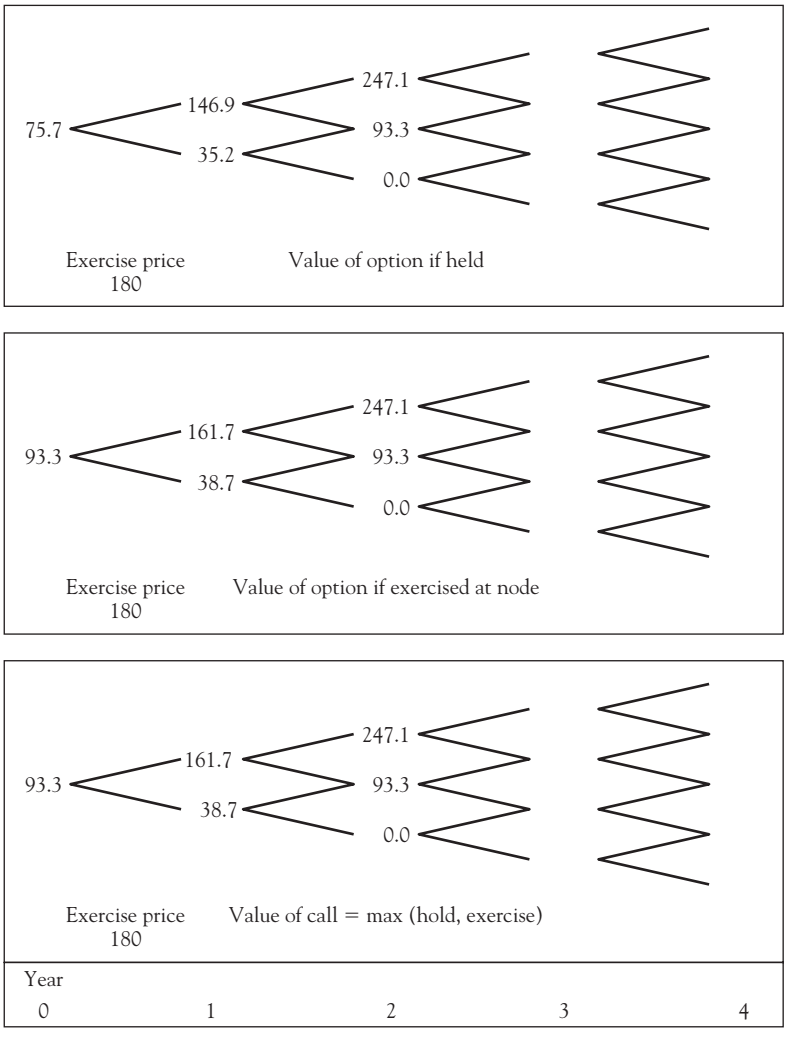
Returns are based on the present value of expected future cash flows. Objectively, the expected future cash flows at t_1 are \$20 million. Therefore the present value of the future cash flows at t_0 is \$200 million ($= 20/0.1$). After an up-move, the expected future cash flow per year either grows to \$25 million or falls to \$16 million. The present value of the future cash flows either grows to \$250 million or falls to \$160 million. Taking account of both the cash flow and capital gain, the return after an up-move is therefore 37.5 percent: $0.375 = (250 + 25 - 200)/200$. Likewise the return after a down-move is –12 percent.

Under the original probabilities, the average return is 10 percent, the same as the discount rate. However, excessively optimistic managers believe that the probability of an up-move is 50 percent, not 44.45 percent. Therefore, the excessively optimistic manager expects a growth rate of 2.5 percent, not 0.

An excessively optimistic manager expects the returns to be either 34.1 percent or -14 percent. To see why this is the case, notice that at t_0, the managers' expected t_1 cash flow is \$20.5 million, not \$20 million. Why? Because the optimistic manager expects the \$20 million (at t_0) to grow by 2.5 percent. Recall that the present value of the cash flows at t_0 will be given by the constant-growth perpetuity formula: $\$273 = \$20.5/(0.1 - 0.025)$. In analogous fashion, the present value of the cash flows at t_1 will be either \$342 million after an up-move or \$219 million after a down-move. Therefore, the return after an up-move will be 34.1 percent, $0.341 = (342 + 25 - 273)/273$. Likewise the return after a down-move will be -14 percent, $-0.14 = (219 + 16 - 273)/273$.

Exhibit 11.6 displays the panel associated with the option valuation. Notice that with the change in probability, during the first two years immediate exercise is now more valuable than waiting. In particular, the optimal exercise policy now requires

EXHIBIT 11.6



immediate exercise at t_0. That is, excessive optimism leads managers to adopt the project under less favorable conditions than they would if they were rational.

In general, excessive optimism leads managers to undervalue the benefits of waiting to exercise the real option. In some circumstances, excessive optimism will actually cause managers to exercise the option when the project features negative NPV.

Conflicts between Debt Holders and Equity Holders

Excessive optimism also holds implications for conflicts between debt holders and shareholders. In the absence of debt, equity holders capture the entire net present value of new projects. However, as we saw earlier, a positive net-present-value project can reduce the value of the put option that debt holders have conferred on equity holders. In this respect, debt-holders are like free riders, deriving a side benefit from the selection of a positive net-present-value project.

As a result, debt overhang will incline rational equity-maximizing managers to reject a zero net-present-value project, in that such a project features negative net present value for equity holders. In real-option terms, rational equity-maximizing managers will be inclined to wait for a somewhat more favorable outcome before exercising the real option and undertaking the project. Rational debt holders will respond by downgrading the quality of that debt and imposing the cost on equity holders.

However, excessive optimism induces managers to underweight the benefit of waiting. Therefore, mild optimism can serve to ameliorate the conflict between debt holders and equity holders, by counteracting the cost of delay. At the same time, be aware that extremely optimistic managers will be inclined to adopt projects whose net present values are objectively negative.

Capital Structure

Keep in mind that sophisticated equity-maximizing managers take debt and bankruptcy into account when determining their investment timing decisions. Therefore, they effectively choose their leverage decisions and investment decisions together, rather than separately.

Debt holders worry that managers may delay choosing positive net-present-value projects, in order to increase the value of the put option conferred by debt holders on equity holders. Debt holders also worry that managers will seek to avoid or postpone bankruptcy for failing firms, and instead adopt high-risk, negative net-present-value projects.

Suppose that managers choose the firm's leverage in accordance with tradeoff theory. That is, managers seek to balance expected tax shield benefits against the expected costs of bankruptcy. Typically, concerns about asset substitution and debt overhang will lead firms to be underleveraged relative to tradeoff theory. How will excessive optimism and overconfidence affect the firm's capital structure, as well as its investment policy?

Excessively optimistic, overconfident managers underestimate the probability of failing. Therefore they overestimate the expected tax shield benefits and underestimate the expected costs of bankruptcy. Hence excessive optimism and overconfidence mitigates the tendency for firms to be underleveraged.

Recall from the preceding discussion that excessive optimism and overconfidence also mitigate the tendency for managers to delay investing in positive net-present-value projects. What does this mean for sophisticated debt holders who perceive managers to be excessively optimistic and overconfident? These debt holders will be less concerned about conflicts of interest associated with asset substitution and debt overhang than they would be if the managers were unbiased. As a result, debt holders will view themselves as facing less risk and will price the debt accordingly. Managers will respond by choosing a higher degree of leverage for the firm. Of course, this will alter the threshold cash flow level that will trigger bankruptcy.

As residual claimants, equity holders pay the price when bondholders perceive conflicts of interest. However, equity holders also benefit when bondholders perceive a reduction in those conflicts, which tends to be the case for mildly optimistic and/or overconfident managers.

Debiasing for Better Decisions

Errors or biases: Reliance on heuristics instead of real-option techniques, excessive optimism, and overconfidence.
Why does it happen? Most managers rely on heuristics that conform to their intuitive judgment instead of a technique that they find opaque. The minority of managers who do use real-option techniques are prone to using assumptions that reflect excessive optimism and overconfidence.
How does it happen? Most managers engage in a series of short-term planning exercises, with the attitude of "we'll cross that road when we come to it," rather than a clearly defined contingency plan. The minority of managers who use real-option techniques assign probabilities to favorable outcomes that are too high and underweight the magnitudes associated with cash flow changes.
What can be done about it? Managers can develop processes that identify possible future events, both favorable and unfavorable, along with valuation techniques to help identify the appropriate courses of action for various contingencies. Those that do use real-option techniques can apply some of the debiasing techniques described in Chapter 3 but should also be aware of the beneficial side effects these biases generate in respect to asset substitution and debt overhang.

Summary

A key premise in the discussion is that managers are sufficiently sophisticated so as to use real-option techniques. However, in practice, the application of real-option techniques is spotty. Many managers find real-option techniques to be framed opaquely, and their resulting discomfort leads them to rely on simpler heuristics.

Mild excessive optimism and overconfidence can be desirable traits for managers to possess when there are conflicts of interest between bondholders and equity holders. Ultimately, equity holders bear the cost of conflicts that lead managers to favor the interests of equity holders over debt holders. However, excessive optimism and overconfidence tend to introduce countervailing forces that mitigate the behavior that concerns bondholders.

Additional Behavioral Readings

Amram, M. and N. Kulatilaka, 1998. *Real Options: Managing Strategic Investment in an Uncertain World,* Boston: Harvard Business School Press.

Copeland, T. and V. Antikarov, 2003. *Real Options, Revised Edition: A Practitioner's Guide,* Texere.

"Scientific Management at Merck: An Interview with CFO Judy Lewent," *Harvard Business Review,* Jan–Feb, 1994.

Key Terms

opaque framing, *A11-2*

transparent framing, *A11-2*

Explore the Web

www.real-options.com
The Web site that supports the book *Real Options,* by Martha Amram and Nalin Kulatilaka.

www.cfo.com/article.cfm/3009782?f=insidecfo
An insightful article about the use of real options in practice that appeared in *CFO Magazine*.

www.puc-rio.br/marco.ind/main.html
Web site dedicated to the use of real options in the petroleum industry.

Chapter Questions

1. Discuss whether the comments of John McCormack that were quoted in Section 11.2 involve any behavioral issues.
2. Imagine that the current date is t_1. A year ago (t_0), the firm invested $125 million in the project depicted in the illustrative example in Section 11.5, at a time when expected cash flows were $25 million. At that time, the firm's managers thought that the project had a zero NPV. Assume that the firm's cost of capital is 20 percent. Suppose that last year turned out to have been unfavorable for the firm, in that actual cash flows were $20 million, less than the expected $25 million. In addition, the firm's managers have learned that if they wish the project to continue (into perpetuity), then they will have to spend an additional $75 million sometime in the next two years. If they do not spend the additional amount, then the project will terminate at the end of two years (t_3). If the project terminates at t_3, then the cash flows will terminate at t_3 and will be zero for $t > t_3$. Moreover, the assets associated with the project will have zero disposal (scrap) value at t_3. Adapt the illustrative example provided in Section 11.5 to show how real-option theory can be used to help the firm's managers decide whether, and under what circumstances, to invest an additional $75 million, as opposed to abandoning the project. How would your analysis have changed if the discount rate were 15 percent? How would the optimal investment policy change when the discount rate was 20 percent, but the additional amount to be invested varied from $50 million to $200 million in increments of $25 million? Begin your analysis by identifying the incremental cash flows associated with the asset that underlies the option. (See the Excel file *Chapter 11 answer template.xls* located on the book Web site at **www.mhhe.com/shefrin.**)
3. Suppose that the firm just had the one project (see Question 2) and you were thinking about acquiring the firm. What would the fair value of the acquisition be today, under the assumption that the firm would have to invest $75 million in the next two years in order to keep the project alive into perpetuity? (See the Excel file *Chapter 11 answer template.xls* at **www.mhhe.com/shefrin.**)
4. Section 11.5 contains a real-option example involving a discount rate of 10 percent. Analyze how the real-option exercise policy is affected if the required return on the project is 15 percent instead of 10 percent. (See the Excel file *Chapter 11 answer template.xls* at **www.mhhe.com/shefrin.**)
5. Make three modifications to the example in Question 4 and then reanalyze the problem. The three changes are: **(1)** Change the up-move to 15 percent from 25 percent and the down-move to –13 percent from –20 percent. **(2)** Change the probability of an up-move to 46.51 percent from 44.45 percent. **(3)** Change the required rate of return to 10 percent from 20 percent. (See the Excel file *Chapter 11 answer template.xls* at **www.mhhe.com/shefrin.**)
6. An overconfident manager misjudges the risk associated with a project and uses a discount rate that is too low. Suppose that the true situation is described by the situation in Question 4, but the manager believes the true situation to be the one described in Question 5. With this interpretation, contrast your analyses of these two problems. (See the Excel file *Chapter 11 answer template.xls* at **www.mhhe.com/shefrin.**)

MiniCase

The Savings and Loan Crisis of the 1980s

In essence, a savings and loan (S&L) is a firm whose projects are long-term mortgages, whose customers are homeowners that mortgage their homes, and whose debt holders are depositors. In a typical project, an S&L will invest in a 30-year mortgage, where the cash flows from the project are mortgage payments.

In the 1970s, market traditions and pressures led S&Ls to finance their projects by relying heavily on short-term debt, borrowing from depositors. Nominal capital requirements were that an S&L's equity be no less than 6 percent of its liabilities, leading S&Ls to have debt-to-capital ratios of approximately 95 percent. Not surprisingly, the S&L industry was among the most highly leveraged in the United States.[14]

S&Ls borrow short-term, but invest long-term. Notably, the prices of long-term bonds are more sensitive to interest rate changes than are short-term bonds. Therefore the assets of S&Ls are riskier than their liabilities.

When the interest rate is i, the present value of a one-year zero-coupon bond that pays \$1 is $1/(1 + i)$. In contrast, the present value of a consol bond that pays \$1 every year into perpetuity is $1/i$. By comparing the two present-value formulas, it is easy to see that when the interest rate rises, the percentage decline in price is greater for the long-term bond than for the short-term bond.

In the 1970s, S&Ls with short-term liabilities and long-term assets exposed themselves to risks associated with increases in interest rates. The gap between long-term mortgage rates and short-term CD rates declined precipitously. As the difference between mortgage rates and short-term rates closed in the mid-to-late 1970s, the market value of S&L liabilities grew relative to the market value of S&L assets, to the point where the industry became insolvent. However, accounting rules did not require the recognition of market value losses in mortgages caused by interest rate increases.

S&Ls could have ended their (losing) bets on interest rate risk by selling their mortgages and reinvesting in short-term assets or by hedging. However, either action would have required S&Ls to recognize, for accounting purposes, that they were insolvent. Instead, they gambled by continuing their overall exposure to interest rate risk and by investing in assets that featured high credit risk.

Interest rates dropped sharply after 1982. The high-risk gamble did pay off for many S&Ls. Yet in 1983, thirty-five percent of institutions still sustained losses. By generally accepted accounting principles (GAAP) 9 percent of all S&Ls (representing 10 percent of industry assets) remained insolvent, meaning that the market value of their liabilities exceeded the market value of their assets.

In most corporations, it is debt holders who confer a put option on equity holders. However, in the case of S&Ls, the debt holders are ordinary depositors. S&L debt comprises the deposits of ordinary people. If an S&L were an ordinary corporation, then bankruptcy would mean that some depositors lost some or all of their savings. In order to prevent such a situation from coming about, S&L deposits were government insured, up to \$100,000, with the Federal Savings and Loan Insurance Corporation (FSLIC). In essence the FSLIC, rather than depositors and debt holders, conferred a put option on the equity holders of S&Ls.

In mid-1982, virtually every S&L was insolvent, except for those that had just received charters. The industry, with roughly \$750 billion in liabilities was insolvent: The market value of its liabilities exceeded the market value of its assets by roughly \$150 billion. Moreover, the FSLIC that insured deposits had only \$6 billion in assets.

Clearly, the insurance guarantee represented an enormous contingent liability that was off the books of the U.S. Treasury. Therefore the \$144 billion (= \$150 − 6) was not reflected in the federal budget deficit. Having conferred a put option on the equity holders of S&Ls, the U.S. government was in the same position as a debt holder in the theoretical framework described in the chapter.

Managers representing the interests of equity holders have an incentive to maximize the value of the put option, thereby transferring wealth to equity holders. Managers can increase the value of the put option by adopting risky projects. S&Ls make loans for acquisition, development, and construction (ADC). Many insolvent S&Ls did indeed make ADC loans to high-risk developers with poor reputations.[15] That is, the S&Ls behaved as if they were averse to a sure loss and "gambled for resurrection." On average, such gambles failed. Ultimately, many of these investments did indeed fail, giving rise to a major financial crisis that in 1989 required government intervention.

Interestingly, during the S&L crisis of the 1980s, the majority of insolvent S&Ls actually appear to have refrained from maximizing the value of the implicit put option and did not choose to invest in extremely risky projects. Fewer than 100 (of roughly 4000) CEOs of S&Ls engaged in seriously abusive behavior in response to unfavorable business conditions and the potential for moral hazard.

Case Analysis Question

1. Discuss any psychological phenomena that you perceive to have been at work in the S&L crisis, emphasizing the implicit option features described in the case. Relate these phenomena to the issues described in the chapter text.

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[1] See "Scientific Management at Merck: An Interview with CFO Judy Lewent," *Harvard Business Review,* January–February 1994.

[2] See Robert Pindyck and Avinash Dixit, "The Options Approach to Capital Investment," *Harvard Business Review*, May–June 1995.

[3] See Martha Amram and Nalin Kulatilaka, *Real Options: Managing Strategic Investment in an Uncertain World*, Boston: Harvard Business School Press, 1998. See also Luke T. Miller and Chan S. Park, "Decision Making under Uncertainty—Real Options to the Rescue?" *Engineering Economist*, 2002.

[4] The first survey was conducted by Bain & Co., and the second survey was conducted by Patricia A. Ryan at Colorado State University. See Edward Teach, "Will Real Options Take Root? Why Companies Have Been Slow to Adopt the Valuation Technique," *CFO Magazine*, July 1, 2003.

[5] In "Core Finance Course Trends in the Top MBA Programs in 2005," Kent Womack and Ying Zhang from the Tuck School of Business at Dartmouth University report that in top programs, corporate finance courses devote than 10 percent of class time on real options.

[6] See "Bank of America Roundtable on: The Real Options Approach to Creating Value in the New Economy," *Journal of Applied Corporate Finance*, vol. 13, no. 2, 2000, pp. 45–63.

[7] Lehman subsequently retired as CFO, but was invited to join Sun's board. Other participants included Mark McCollum, CFO of Tenneco Automotive; David Glassman from the consulting firm Stern Stewart & Co.; and Carliss Baldwin, professor at the Harvard Business School.

[8] Lehman's remarks appear on p. 50 of the previously mentioned article.

[9] The treasurer at the time was George Reyes. The comments attributed to him were ones he made in a lecture delivered at Santa Clara University on April 6, 2001.

[10] See "University of Maryland Roundtable on Real Options and Corporate Finance," *Journal of Applied Corporate Finance*, vol. 15, no. 2, 2003, pp. 8–23.

[11] The comments attributed to Martha Amram were ones she made in a lecture she delivered at Santa Clara University on December 14, 2001.

[12] See Chapter 8.

[13] The basis for the discussion of how excessive optimism and overconfidence affect the firm's borrowing and investment policies is Dirk Hackbarth, "Determinants of Corporate Borrowing: A Behavioral Perspective," Working Paper, Indiana University, 2003.

[14] $D/(D + E) = (1 + D/E) - 1$ and $E/D = 0.06$.

[15] See W. Black, K. Calavita, and H. Pontell, "The Savings and Loan Debacle of the 1980s: White Collar Crime or Risky Business?" *Law and Policy*, vol. 17, no. 1, 1995, pp. 23–55.