At the dawn of the new millennium, stock market speculators scrambled to bet their hard-
earned money on Amazon.com, Cisco Systems, Yahoo!, and others poised to take advantage
of the Internet. Speculators piled into a handful of stock market favorites at unheard of val-
uations, only to see a significant chunk of their portfolios vanish as the Internet bubble burst.
Within 18 months, the S&P 500 crumbled by more than 30 percent and Nasdaq crashed by
more than 70 percent. Many dot.com investors lost everything as The Wall Street Journal
mused about “the madness of crowds.”

Then, to make a bad situation worse, the terrorist attacks of September 11, 2001, on New
York City and Washington, DC, sent a shiver through global financial markets that caused a
plunge in both consumer confidence and retail sales. Add in a currency crisis emanating from
Argentina and other emerging markets, and the essential elements fell into place for a sharp
and lasting economic downturn in the United States, Europe, and Asia. It never happened.
Rather than allowing the world economy to stumble along at less than full capacity, savvy
risk management by public officials and business leaders helped bring quick economic
recovery. Growing business activity, rising employment, and surging business profits all
gave mid-decade testimony to the importance of skillful risk management in both the pub-
lic and private sectors.¹

This chapter introduces certainty equivalents, risk-adjusted discount rates, decision trees,
simulation, and game-theory techniques as practical means for dealing with risk and uncer-
tainty. These are vital weapons in the arsenal used to fight economic stagnation, sluggish
employment, and sub-par profit performance.

¹ See Greg Ip, “Fed Member Cites Risks to Economy,” The Wall Street Journal Online, January 14, 2005
(http://online.wsj.com).
CONCEPTS OF RISK AND UNCERTAINTY

"Risk" is a four-letter word. When it comes to investing, investment managers and other investors often prefer not to hear much about the chance of loss. However, to make effective investment decisions, one must understand the many faces of risk.

Economic Risk and Uncertainty

Investors sometimes know with certainty the outcomes that each possible course of action will produce. A firm with $100,000 in cash that can be invested in a 30-day Treasury bill yielding 6 percent ($493 interest income for 30 days) or used to prepay a 10 percent bank loan ($822 interest expense for 30 days) can determine with certainty that prepayment of the bank loan provides a $329 higher 1-month return. A retailer can just as easily predict the cost savings earned by placing a given order directly with the manufacturer versus through an independent wholesaler; manufacturers can often forecast the precise cost effect of meeting a rush order when overtime wages rather than standard labor rates are required. Order backlogs give a wide variety of consumer and producer goods manufacturers a clear indication of product demand conditions. Similarly, book, magazine, and trade journal publishers accurately judge product demand conditions on the basis of subscription revenues. Resort hotels can often foretell with a high degree of accuracy the amount of food, beverages, and linen service required to meet the daily needs of a 1,500-person convention, especially when such conventions are booked on a regular basis. Even when events cannot be predicted exactly, only a modest level of decision uncertainty is present in such situations.

Many other important managerial decisions are made under conditions of risk or uncertainty. Economic risk is the chance of loss because all possible outcomes and their probability of happening are unknown. Actions taken in such a decision environment are purely speculative, such as the buy and sell decisions made by traders and other speculators in commodity, futures, and option markets. All decision makers in such environments are equally likely to profit as well as to lose; luck is the sole determinant of success or failure. Uncertainty exists when the outcomes of managerial decisions cannot be predicted with absolute accuracy but all possibilities and their associated probabilities are known. Under conditions of uncertainty, informed managerial decisions are possible. Experience, insight, and prudence allow investment managers to devise strategies for minimizing the chance of failing to meet business objectives. Although luck still plays a role in determining ultimate success, managers can deal effectively with an uncertain decision environment by limiting the scope of individual projects and developing contingency plans for dealing with failure.

When the level of risk and the attitudes toward risk taking are known, the effects of uncertainty can be directly reflected in the basic valuation model of the firm. The certainty equivalent method converts expected risky profit streams to their certain sum equivalents to eliminate value differences that result from different risk levels. For risk-averse decision makers, the value of a risky stream of payments is less than the value of a certain stream, and the application of certainty equivalent adjustment factors results in a downward adjustment in the value of expected returns. For risk-seeking decision makers, the value of a risky stream of payments is greater than that of a certain stream, and application of certainty equivalent adjustment factors results in an upward adjustment in the value of expected returns. In both cases, risky dollars are converted into certain-sum equivalents. Another method used to reflect uncertainty in the basic valuation model is the risk-adjusted discount rate approach. In this technique, the interest rate used in the denominator of the basic valuation model depends on the level of risk. For highly risk-averse decision makers, economic risk
Chance of loss due to the fact that all possible outcomes and their probability of occurrence are unknown
uncertainty
When the outcomes of managerial decisions cannot be predicted with absolute accuracy but all possibilities and their associated probabilities of occurrence are known
business risk
Chance of loss associated with a given managerial decision.

market risk
Chance that a portfolio of investments can lose money because of swings in the financial markets as a whole.

inflation risk
Danger that a general increase in the price level will undermine the real economic value of any legal agreement that involves a fixed promise to pay over an extended period.

interest-rate risk
Market risk that stems from the fact that changing interest rates affect the value of any agreement that involves a fixed promise to pay over a specified period.

credit risk
Chance that another party will fail to abide by its contractual obligations.

liquidity risk
Difficulty of selling corporate assets or investments that have otherwise not been transferable at favorable prices under typical market conditions.

derivative risk
Chance that volatile financial derivatives such as commodities futures and index options could create losses in underlying investments by increasing rather than decreasing price volatility.

higher discount rates are implemented; for less risk-averse decision makers, lower discount rates are employed. Using this technique, discounted expected profit streams reflect risk differences and become directly comparable.

General Risk Categories

Business risk is the chance of loss associated with a given managerial decision. Such losses are a normal by-product of the unpredictable variation in product demand and cost conditions. Business risk must be dealt with effectively; it seldom can be eliminated.

In a globally competitive environment with instant communication, businesspeople face a wide variety of risks. For managers, a main worry is something called market risk, or the chance that a portfolio of investments can lose money because of overall swings in the financial markets. Managers must be concerned about market risk because it influences the cost and timing of selling new debt and equity securities to investors. When a bear market ensues, investors are not the only ones to lose. Companies unable to raise funds for new plant and equipment must forego profitable investment opportunities when the cost of financing escalates. Inflation risk is the danger that a general increase in the price level will undermine the real economic value of corporate agreements that involve a fixed promise to pay a specified amount over an extended period. Leases, rental agreements, and corporate bonds are all examples of business contracts that can be susceptible to inflation risk. Interest-rate risk is another type of market risk that can severely affect the value of corporate investments and obligations. This stems from the fact that a fall in interest rates will increase the value of any contract that involves a fixed promise to pay over an extended time frame. Conversely, a rise in interest rates will decrease the value of any agreement that involves fixed interest and principal payments.

Credit risk is the chance that another party will fail to abide by its contractual obligations. A number of companies have lost substantial sums because other parties were either unable or unwilling to provide raw commodities, rental space, or financing at agreed-upon prices. Like other investors, corporations must also consider the problem of liquidity risk, or the difficulty of selling corporate assets or investments that are not easily transferable at favorable prices under typical market conditions. Another type of risk is related to the rapidly expanding financial derivatives market. A financial derivative is a security that derives value from price movements in some other security. Derivative risk is the chance that volatile financial derivatives such as commodities futures and index options could create losses in underlying investments by increasing price volatility.

Special Risks of Global Operations

Cultural risk is borne by companies that pursue a global investment strategy. Product market differences due to distinctive social customs make it difficult to predict which products might do well in foreign markets. For example, breakfast cereal is extremely popular and one of the most profitable industries in the United States, Canada, and the United Kingdom. However, in France, Germany, Italy, and many other foreign countries, breakfast cereal is less popular and less profitable. In business terms, breakfast cereal doesn’t “travel” as well as U.S.-made entertainment like movies and television programming.

Currency risk is another important danger facing global businesses because most companies wish to eventually repatriate foreign earnings back to the domestic parent. When the U.S. dollar rises in value against foreign currencies such as the Canadian dollar, foreign profits translate into fewer U.S. dollars. Conversely, when the U.S. dollar falls in value against the Canadian dollar, profits earned in Canada translate into more U.S. dollars. Because price
Internet Fraud

The Internet allows individuals or companies to communicate with a large audience without spending a lot of time, effort, or money. Anyone can reach tens of thousands of people by building an Internet Web site, posting a message on an online bulletin board, entering a discussion in a live "chat" room, or sending e-mail. It is easy for fraud perpetrators to make their messages look credible, it is nearly impossible for investors to tell the difference between fact and fiction.

Investment frauds come online under many names, including:

- **The "pump and dump" scam.** Paid promoters sometimes accumulate stock and then look for any favorable information to pump up the stock price. After the stock price rises, unscrupulous promoters dump their shares on an unsuspecting public.
- **The pyramid.** Many Internet frauds are merely electronic versions of the classic "pyramid" scheme in which participants attempt to make money solely by recruiting new participants.
- **The "risk-free" fraud.** By way of opportunity that promises spectacular profits or "guaranteed" returns, if the deal sounds too good to be true, then it probably is.
- **Off-shore schemes.** Watch out for off-shore scams and investment "opportunities" in other countries. When you send your money abroad and something goes wrong, it is more difficult to find out what happened and to locate your money.

The Securities and Exchange Commission (SEC) is effectively tracking Internet investment fraud and has taken quick action to stop scams. With the cooperation of federal and state criminal authorities, the SEC has also helped put Internet fraudsters in jail. If you believe any person or entity may have violated the federal securities laws, submit a complaint of http://www.sec.gov.

Fad stock stories, "Miracle Pay, "New Deals with SEC Fraud Charges."

- **government policy risk**
  - Chance of loss because government grants of monopoly franchises, tax abatements, and favored trade status can be tenuous. In the "global friendly" 1990s, many corporate investors seem to have forgotten the widespread confiscation of private property owned by U.S. corporations in Mexico, Cuba, Libya, the former Soviet Union, and in a host of other countries. **Expropriation risk,** or the risk that business property located abroad might be seized by host governments, is a risk that global investors must not forget. During every decade of the twentieth century, U.S. and other multinational corporations have suffered from expropriation and probably will in the years ahead.

**PROBABILITY CONCEPTS**

A clear understanding of probability concepts provides a background for discussing various methods of effective risk analysis. Managers cannot make insightful investment decisions without reliable information about risk.

**Probability Distribution**

The probability of an event is the chance, or odds, that the incident will occur. If all possible events or outcomes are listed, and if a probability is assigned to each event, the listing is called a **probability distribution.** For example, suppose a sales manager observes that there is a 70 percent chance that a given customer will place a specific order versus a 30 percent...
chance that the customer will not. This situation is described by the probability distribution shown in Table 17.1.

Both possible outcomes are listed in column 1, and the probabilities of each outcome, expressed as decimals and percentages, appear in column 2. Notice that the probabilities sum to 1.0, or 100 percent, as they must if the probability distribution is complete. In this simple example, risk can be read from the probability distribution as the 30 percent chance of the firm not receiving the order. For most managerial decisions, the relative desirability of alternative events or outcomes is not absolute. A more general measure of the relation between risk and the probability distribution is typically required to adequately incorporate risk considerations into the decision-making process.

Suppose a firm is able to choose only one of two investment projects, each calling for an outlay of $10,000. Assume also that profits earned from the two projects are related to the general level of economic activity during the coming year, as shown in Table 17.2. This table is known as a payoff matrix because it illustrates the dollar outcome associated with each possible state of nature. Both projects provide a $5,000 profit in a normal economy, higher profits in an economic boom, and lower profits if a recession occurs. However, project B profits vary far more according to the state of the economy than do profits from project A. In a normal economy, both projects return $5,000 in profit. Should the economy be in a recession next year, project B will produce nothing, whereas project A will still provide a $4,000 profit. If the economy is booming next year, project B's profit will increase to $12,000, but profit for project A will increase only moderately, to $6,000.

Project A is clearly more desirable if the economy is in recession, whereas project B is superior in a boom. In a normal economy, the projects offer the same profit potential, and both are equally desirable. To choose the best project, one needs to know the likelihood of a boom, a recession, or normal economic conditions. If such probabilities can be estimated, the expected profits and variability of profits for each project can be determined. These measures make it possible to evaluate each project in terms of expected return and risk, where risk is measured by the deviation of profits from expected values.

<table>
<thead>
<tr>
<th>Table 17.1 Simple Probability Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event (1)</td>
</tr>
<tr>
<td>Receive order</td>
</tr>
<tr>
<td>Do not receive order</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 17.2 Payoff Matrix for Projects A and B</th>
</tr>
</thead>
<tbody>
<tr>
<td>State of the Economy</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Recession</td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>Boom</td>
</tr>
</tbody>
</table>
Expected Value

The expected value is the anticipated realization from a given payoff matrix and probability distribution. It is the weighted-average payoff, where the weights are defined by the probability distribution.

To continue with the previous example, assume that forecasts based on the current trend of economic indicators suggest a 2 in 10 chance of recession, a 6 in 10 chance of a normal economy, and a 2 in 10 chance of a boom. As probabilities, the probability of recession is 0.2, or 20 percent; the probability of normal economic activity is 0.6, or 60 percent; and the probability of a boom is 0.2, or 20 percent. These probabilities add up to 1.0 (0.2 + 0.6 + 0.2 = 1.0), or 100 percent, and thereby form a complete probability distribution, as shown in Table 17.3.

If each possible outcome is multiplied by its probability and then summed, the weighted average outcome is determined. In this calculation, the weights are the probabilities of occurrence, and the weighted average is called the expected outcome. Column 4 of Table 17.3 illustrates the calculation of expected profits for projects A and B. Each possible profit level in column 3 is multiplied by its probability of occurrence from column 2 to obtain weighted values of the possible profits. Summing column 4 of the table for each project gives the weighted average of profits under various states of the economy. This weighted average is the expected profit from the project.

The expected-profit calculation is expressed by the equation

\[ E(\pi) = \sum_{i=1}^{N} \pi_i \times p_i \]

where \( \pi_i \) is the profit level associated with the \( i \)th outcome, \( p_i \) is the probability that outcome will occur, and \( N \) is the number of possible outcomes or states of nature. Thus, \( E(\pi) \) is a weighted average of possible outcomes (the \( \pi \) values), with each outcome’s weight equal to its probability of occurrence.

The expected profit for project A is obtained as follows:

\[
E(\pi_A) = \pi_1 \times p_1 + \pi_2 \times p_2 + \pi_3 \times p_3 \\
= \$4,000(0.2) + $5,000(0.6) + $6,000(0.2) \\
= $5,000
\]

Table 17.3 Calculation of Expected Values

<table>
<thead>
<tr>
<th>State of the Economy</th>
<th>Probability of This State Occurring</th>
<th>Profit Outcome if This State Occurs</th>
<th>Expected Profit Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recession</td>
<td>0.2</td>
<td>$4,000</td>
<td>$800</td>
</tr>
<tr>
<td>Normal</td>
<td>0.6</td>
<td>5,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Boom</td>
<td>0.2</td>
<td>6,000</td>
<td>1,200</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recession</td>
<td>0.2</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Normal</td>
<td>0.6</td>
<td>5,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Boom</td>
<td>0.2</td>
<td>12,000</td>
<td>2,400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Expected Profit A $5,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$5,400</td>
</tr>
</tbody>
</table>
The results in Table 17.3 are shown as a bar chart in Figure 17.1. The height of each bar signifies the probability that a given outcome will occur. The probable outcomes for project A range from $4,000 to $6,000, with an average, or expected, value of $5,000. For project B, the expected value is $5,400, and the range of possible outcomes is from $0 to $12,000.

For simplicity, this example assumes that only three states of nature can exist in the economy: recession, normal, and boom. Actual states of the economy range from deep depression, as in the early 1930s, to tremendous booms, such as in the mid- to late 1990s, with an unlimited number of possibilities in between. Suppose sufficient information exists to assign a probability to each possible state of the economy and a monetary outcome in each circumstance for every project. A table similar to Table 17.3 could then be compiled that would include many more entries for columns 1, 2, and 3. This table could be used to calculate expected values as shown, and the probabilities and outcomes could be approximated by the continuous curves in Figure 17.2.

Figure 17.2 is a graph of the probability distribution of returns for projects A and B. In general, the tighter the probability distribution, the more likely it is that actual outcomes will be close to expected values. The more loose the probability distribution, the less likely it is that actual outcomes will be close to expected values. Because project A has a relatively tight probability distribution, its actual profit is more likely to be close to its expected value than is that of project B.
Absolute Risk Measurement

Risk is a complex concept, and some controversy surrounds attempts to define and measure it. Common risk measures that are satisfactory for most purposes are based on the observation that tight probability distributions imply low risk because of the correspondingly small chance that actual outcomes will differ greatly from expected values. From this perspective, project A is less risky than project B.

Standard deviation, shown as σ (sigma), is a popular and useful measure of absolute risk. Absolute risk is the overall dispersion of possible payoffs. The smaller the standard deviation, the tighter the probability distribution and the lower the risk in absolute terms. To calculate standard deviation using probability information, the expected value or mean of the return distribution must first be calculated as

$$E(\pi) = \sum_{i=1}^{n} (\pi_i p_i)$$  \hspace{1cm} (17.2)

In this calculation, πᵢ is the profit or return associated with the i-th outcome; pᵢ is the probability that the i-th outcome will occur; and E(π), the expected value, is a weighted average of the various possible outcomes, each weighted by the probability of its occurrence.

The deviation of possible outcomes from the expected value must then be derived:

$$\text{Deviation}_i = \pi_i - E(\pi)$$

The squared value of each deviation is then multiplied by the relevant probability and summed. This arithmetic mean of the squared deviations is the variance of the probability distribution:

$$\text{Variance} = \sigma^2 = \sum_{i=1}^{n} [\pi_i - E(\pi)]^2 p_i$$  \hspace{1cm} (17.3)
The standard deviation is found by obtaining the square root of the variance:

\[
\text{Standard Deviation} = \sigma = \sqrt{\sum_{i=1}^{n} (\pi_i - E(\pi))^2 p_i}
\]

The standard deviation of profit for project A can be calculated to illustrate this procedure:

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Deviation²</th>
<th>Deviation² × Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>[\pi_i - E(\pi)]</td>
<td>[\pi_i - E(\pi)]²</td>
<td>[\pi_i - E(\pi)]² × p_i</td>
</tr>
<tr>
<td>$4,000 - $5,000 = -$1,000</td>
<td>$1,000,000</td>
<td>$1,000,000(0.2) = $200,000</td>
</tr>
<tr>
<td>$5,000 - $5,000 = 0</td>
<td>0</td>
<td>$0(0.6) = $0</td>
</tr>
<tr>
<td>$6,000 - $5,000 = $1,000</td>
<td>$1,000,000</td>
<td>$1,000,000(0.2) = $200,000</td>
</tr>
</tbody>
</table>

Variance = \sigma^2 = $400,000

Standard deviation = \sigma = \sqrt{\sigma^2} = \sqrt{$400,000} = $632.46

Using the same procedure, the standard deviation of project B's profit is $3,826.23. Because project B has a larger standard deviation of profit, it is the riskier project.

Relative Risk Measurement

Problems sometimes arise when standard deviation is used to measure risk. If an investment project is relatively expensive and has large expected cash flows, it will have a large standard deviation of returns without being truly riskier than a smaller project. Suppose a project has an expected return of $1 million and a standard deviation of only $1,000. Some might reasonably argue that it is less risky than an alternative investment project with expected returns of $1,000 and a standard deviation of $900. The absolute risk of the first project is greater; the risk of the second project is much larger relative to the expected payoff. Relative risk is the variation in possible returns compared with the expected payoff amount.

A popular method for determining relative risk is to calculate the coefficient of variation. Using probability concepts, the coefficient of variation is

\[
\text{Coefficient of Variation} = v = \frac{\sigma}{E(\pi)}
\]

In general, when comparing decision alternatives with costs and benefits that are not of approximately equal size, the coefficient of variation measures relative risk better than does the standard deviation.

Other Risk Measures

The standard deviation and coefficient of variation risk measures are based on the total variability of returns. In some situations, however, a project's total variability overstates its risk. This is because projects with returns that are less than perfectly correlated can be combined, and the variability of the resulting portfolio of investment projects is less than the sum of individual project risks. Much recent work in finance is based on the idea that project risk should be measured in terms of its contribution to total return variability for the firm's asset portfolio. The contribution of a single investment project to the overall variation of the firm's asset portfolio is measured by a concept known as beta. Beta is a measure of the systematic variability or covariance of one asset's returns with returns on other assets.
The concept of beta should be employed when the returns from potential investment projects are likely to greatly affect or be greatly affected by current projects. However, in most circumstances the standard deviation and coefficient of variation measures provide adequate assessments of risk.

STANDARD NORMAL CONCEPT

The standard normal concept is an intuitive and practical means for assessing the dispersion of possible outcomes in terms of expected value and standard deviation measures.

Normal Distribution

The relation among risk, standard deviation, and the coefficient of variation can be clarified by examining the characteristics of a normal distribution, as shown in Figure 17.3. A normal distribution has a symmetrical dispersion about the mean or expected value. If a probability distribution is normal, the actual outcome will lie within ±1 standard deviation of the mean roughly 68 percent of the time; the probability that the actual outcome will be within ±2 standard deviations of the expected outcome is approximately 95 percent; and there is a greater than 99 percent probability that the actual outcome will occur within ±3 standard deviations of the mean. The smaller the standard deviation, the tighter the distribution about the expected value and the smaller the probability of an outcome that is very different from the expected value.

Probability distributions can be viewed as a series of discrete values represented by a bar chart, such as in Figure 17.1, or as a continuous function represented by a smooth curve, such as in Figure 17.2. Probabilities associated with the outcomes in Figure 17.1 are given by the heights of the bars, whereas in Figure 17.2, the probabilities must be found by calculating the area under the curve between points of interest.

**Figure 17.3** Probability Ranges for a Normal Distribution

When returns display a normal distribution, actual outcomes will lie within ±1 standard deviation of the mean 68.26 percent of the time, within ±2 standard deviations 95.46 percent of the time, and within ±3 standard deviations 99.74 percent of the time.
Standardized Variables

Distribution of costs or revenues can be transformed or standardized. A standardized variable has a mean of 0 and a standard deviation equal to 1. Any distribution of revenue, cost, or profit data can be standardized with the following formula:

\[ z = \frac{x - \mu}{\sigma} \]

where \( z \) is the standardized variable, \( x \) is the outcome of interest, and \( \mu \) and \( \sigma \) are the mean and standard deviation of the distribution, respectively. If the point of interest is \( 1 \sigma \) away from the mean, then \( x - \mu = \sigma \), so \( z = \sigma / \sigma = 1.0 \). When \( z = 1.0 \), the point of interest is \( 1 \sigma \) away from the mean; when \( z = 2.0 \), the value is \( 2 \sigma \) away from the mean; and so on. Although the standard normal distribution theoretically runs from minus infinity to plus infinity, the probability of occurrences beyond 3 standard deviations is very near zero.

Use of the Standard Normal Concept: An Example

Suppose that Martha Stewart Realty is considering a boost in advertising to reduce a large inventory of unsold homes. Management plans to make its media decision using the data shown in Table 17.4 on the expected success of television versus newspaper promotions. For simplicity, assume that the returns from each promotion are normally distributed. If the television promotion costs $2,295 and the newspaper promotion costs $4,013, what is the probability that each will generate a profit?

To calculate the probability that each promotion will generate a profit, it is necessary to calculate the portion of the total area under the normal curve that is to the right of (greater than) each breakeven point (see Figure 17.3). Here, the breakeven point is where the profit contribution before advertising costs just equals the required advertising expenditure. Using methods described earlier, relevant expected values and standard deviations are \( E(R_{TV}) = \$2,500 \), \( \sigma_{TV} = \$250 \), \( E(R_N) = \$5,000 \), and \( \sigma_N = \$600 \). For the television promotion, the breakeven revenue level of $2,295 is 0.82 standard deviations less than (to the left of) the expected return level of $2,500 because

\[ z = \frac{x_{TV} - E(R_{TV})}{\sigma_{TV}} = \frac{\$2,295 - \$2,500}{\$250} = -0.82 \]

Table 17.4 Return Distributions for Television and Newspaper Promotions

<table>
<thead>
<tr>
<th>Market Response</th>
<th>Probability of Occurring (( P ))</th>
<th>Return (( R )) (profit contribution before ad costs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Television</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>0.125</td>
<td>$2,000</td>
</tr>
<tr>
<td>Good</td>
<td>0.750</td>
<td>$2,500</td>
</tr>
<tr>
<td>Very good</td>
<td>0.125</td>
<td>$3,000</td>
</tr>
<tr>
<td><strong>Newspaper</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>0.125</td>
<td>$3,800</td>
</tr>
<tr>
<td>Good</td>
<td>0.750</td>
<td>$5,000</td>
</tr>
<tr>
<td>Very good</td>
<td>0.125</td>
<td>$6,200</td>
</tr>
</tbody>
</table>
Utility Theory and Risk Analysis

The assumption of risk aversion is basic to many decision models in managerial economics. Because this assumption is so crucial, it is appropriate to examine attitudes toward risk and discuss why risk aversion holds in general.

Why Lotteries Are Popular

The success of state-run lotteries is convincing evidence that many in our society display risk-seeking behavior, especially when small sums of money are involved. The popularity of lotteries stems from the fact that ticket buyers are willing to pay a price for the privilege of buying a lottery ticket that may combine into the millions of dollars promised from the fact that such opportunities are rare and lottery-ticket buyers value them highly. Many of the poor, inexperienced, or elderly have no opportunity for hitting the jackpot in their lifetimes. The lottery is their only choice, however remote, of a substantial sum of money. It should therefore come as no surprise that lottery-ticket buyers tend to be poor, uneducated, and elderly.

The success of state-run lotteries is noteworthy because it reflects risk attitudes that are fairly unusual. Typically, consumers and investors display risk-averse behavior, especially when substantial sums of money are involved. Still, the eagerness of consumers to take on enormous risks when small sums of money are involved has made gambling one of America's great growth industries.

If legislative agendas are any indication, Americans can expect to see even more Internet gambling, card clubs, off-track betting parlors, and casinos in their own backyards. Native American-run casinos are also becoming increasingly popular. Americans are so eager to gamble that they are shifting long-established leisure-time expenditures. Today, U.S. consumers spend more on legal games of chance than on movie theaters, books, amusement attractions, and recorded music combined.

In theory, three possible attitudes toward risk are present: aversion to risk, indifference to risk, and preference for risk. Risk aversion characterizes individuals who seek to avoid or minimize risk. Risk neutrality characterizes decision makers who focus on expected returns and disregard the dispersion of returns (risk). Risk seeking characterizes decision makers who prefer risk. Given a choice between more risky and less risky investments with identical expected monetary returns, a risk averter selects the less risky investment and a risk seeker selects the riskier investment. Faced with the same choice, the risk-neutral investor is indifferent between the two investment projects. Some individuals prefer high-risk projects and the corresponding potential for substantial returns, especially when relatively small sums of money are involved. Entrepreneurs, innovators, inventors, speculators, and lottery-ticket buyers are all examples of individuals who sometimes display risk-seeking behavior. Risk-neutral behavior is exhibited in some business decision making. However, most managers and investors are predominantly risk averters, especially when substantial dollar amounts are involved.

At the heart of risk aversion is the notion of diminishing marginal utility for money. If someone with no money receives $5,000, it can satisfy his or her most immediate needs. If such a person then receives a second $5,000, it will obviously be useful, but the second $5,000 is not quite so necessary as the first $5,000. Thus, the value, or utility, of the second, or marginal, $5,000 is less than the utility of the first $5,000, and so on. Diminishing marginal utility of money implies that the marginal utility of money diminishes for additional increments of money. Figure 17.4 graphs the relation between money and its utility, or value. In the figure, utility is measured in units of value or satisfaction, an index that is unique to each individual.

For risk averters, money has diminishing marginal utility. If such an individual's wealth were to double suddenly, he or she would experience an increase in happiness or satisfaction, but the new level of well-being would not be twice the previous level. In cases of diminishing marginal utility, a less than proportional relation holds between total utility and money.

Figure 17.4 Example of a Money/Utility Relation
A risk seeker's marginal utility of money increases. A risk-indifferent individual has a constant marginal utility of money. A risk averter displays a diminishing marginal utility of money.
Accordingly, the utility of a doubled quantity of money is less than twice the utility of the original level. In contrast, those who are indifferent to risk perceive a strictly proportional relationship between total utility and money. Such a relation implies a constant marginal utility of money, and the utility of a doubled quantity of money is exactly twice the utility of the original level. Risk seekers perceive a more than proportional relation between total utility and money. In this case, the marginal utility of money increases. With increasing marginal utility of money, the utility of doubled wealth is more than twice the utility of the original amount. These relations are illustrated in Figure 17.4.

Even though total utility increases with increased money for risk averters, risk seekers, and those who are indifferent to risk, the relation between total utility and money is quite different for each group. These differences lead to dissimilar risk attitudes. Because individuals with a diminishing marginal utility for money suffer more pain from a dollar lost than the pleasure derived from a dollar gained, they seek to avoid risk. Risk averters require a very high return on any investment that is subject to much risk.

In Figure 17.4, for example, a gain of $5,000 from a base of $10,000 brings 2 units of additional satisfaction, but a $5,000 loss causes a 4-unit loss in satisfaction. A person with this utility function and $10,000 would be unwilling to make an investment with a 50/50 chance of gaining or losing $5,000. The 9-unit expected utility of such a gamble \( E(u) = 0.5 \times 5 + 0.5 \times 12 = 9 \) is less than the 10 units of utility obtained by forgoing the gamble and keeping $10,000 in certain wealth.

Because an individual with a constant marginal utility for money values a dollar gained as highly as a dollar lost, the expected utility from a fair gamble always exactly equals the utility of the expected outcome. An individual indifferent to risk makes decisions on the basis of expected monetary outcomes and is not concerned with possible variation in the distribution of outcomes.

### Employee Stock Options

In a conventional employee stock-option plan, key employees are granted the right to buy a fixed number of shares for a predetermined price. The number of shares granted depends on the employee’s level of responsibility. Usually, the number of shares granted under an employee stock-option plan is commensurate with total compensation. According to current tax law, the exercise period for employee stock options cannot exceed 10 years. It may be less. Because stock prices usually rise from 10 to 12 percent per year on average, from the employees’ perspective, the longer the exercise period, the better.

An employee can exercise the right to buy stock covered by a stock-option plan once the vesting period has been completed. The vesting period is an employment time frame after which vested options can be exercised. The length of the vesting period is designed by the employer to keep valued employees motivated. It is also designed to keep employees from betting on the company. Structured properly, an employee stock-option plan with appropriate vesting requirements can create “golden handcuffs” that benefit both valued employees and their employers.

Once exercised, employee stock options create a taxable event for the employees. The difference between the current market price and the original exercise price, multiplied by the number of shares covered, is used to calculate the amount of employee compensation derived from the option exercise. By granting employee stock options, employers replace cash compensation that reduces operating income with contingent-based pay that never appears on the income statement. Income statements issued by companies with extensive stock-option plans can dramatically understate the total amount of employee compensation. This can result in earnings statements that present too rosy a picture of corporate performance. Such problems become evident when the company’s stock price falls, and employees demand more cash compensation.

In the long run, investors lose out unless they consider the economic cost of employee stock options.

ADJUSTING THE VALUATION MODEL FOR RISK

Diminishing marginal utility leads directly to risk aversion, and risk aversion is reflected in the basic valuation model used to determine the worth of a firm. Two primary methods are used to adjust the basic valuation model to account for decision making under conditions of uncertainty.

Basic Valuation Model

The basic valuation model developed in Chapter 1 is

\[ V = \sum_{i=1}^{n} \frac{\pi_i}{(1 + \bar{r})^i} \]  \hspace{1cm} (17.7)

This model states that the value of the firm is equal to the discounted present worth of future profits. Under conditions of certainty, the numerator is profit, and the denominator is a time-value adjustment using the risk-free rate of return \( \bar{r} \). After time-value adjustment, the profits to be earned from various projects are strictly and completely comparable.

Under conditions of uncertainty, the profits shown in the numerator of the valuation model as \( \pi \) equal the expected value of profits during each future period. This expected value is the best available estimate of the amount to be earned during any given period. However, because profits cannot be predicted with absolute precision, some variability is to be anticipated. If the firm must choose between two alternative methods of operation, one with high expected profits and high risk and another with smaller expected profits and lower risks, some technique must be available for making the alternative investments comparable. An appropriate ranking and selection of projects is possible only if each respective investment project can be adjusted for considerations of both time value of money and risk. At least two popular methods are employed to make such adjustments. In the first, expected profits are adjusted to account for risk. In the second, the interest rate used in the denominator of the valuation model is increased to reflect risk considerations. Either method can be used to ensure that value-maximizing decisions are made.

Certainty Equivalent Adjustments

The certainty equivalent method is an adjustment to the numerator of the basic valuation model to account for risk. Under the certainty equivalent approach, decision makers specify the certain sum that they regard comparable to the expected value of a risky investment alternative. The certainty equivalent of an expected risk amount typically differs in dollar terms but not in terms of the amount of utility provided. To illustrate, suppose that you face the following choices:

- Invest $100,000. From a successful project, you receive $1,000,000; if it fails, you receive nothing. If the probability of success is 0.5, or 50 percent, the investment's expected payoff is $500,000 (0.5 × $1,000,000 + 0.5 × $0).
- You do not make the investment; you keep the $100,000.

If you find yourself indifferent between the two alternatives, $100,000 is your certainty equivalent for the risky expected return of $500,000. In other words, a certain or riskless amount of $100,000 provides exactly the same utility as the 50/50 chance to earn $1,000,000 or $0. You are indifferent between these two alternatives.
In this example, any certainty equivalent of less than $500,000 indicates risk aversion. If the maximum amount that you are willing to invest in the project is only $100,000, you are exhibiting very risk-averse behavior. Each certain dollar is "worth" five times as much as each risky dollar of expected return. Alternatively, each risky dollar of expected return is worth only 20¢ in terms of certain dollars. In general, any risky investment with a certainty equivalent less than the expected dollar value indicates risk aversion. A certainty equivalent greater than the expected value of a risky investment indicates risk preference.

Any expected risky amount can be converted to an equivalent certain sum using the certainty equivalent adjustment factor, \( \alpha \), calculated as the ratio of a certain sum divided by an expected risky amount, where both dollar values provide the same level of utility:

\[
\text{Certainty Equivalent Adjustment Factor} = \alpha = \frac{\text{Equivalent Certain Sum}}{\text{Expected Risky Sum}}
\]

The certain-sum numerator and expected-return denominator may vary in dollar terms, but they provide the exact same reward in terms of utility. In the previous investment problem, in which a certain sum of $100,000 provides the same utility as an expected risky return of $500,000, the certainty equivalent adjustment factor \( \alpha = 0.2 = \frac{100,000}{500,000} \). This means that the "price" of one dollar in risky expected return is 20¢ in certain dollar terms.

The following general relations enable decision makers to use the certainty equivalent adjustment factor to analyze risk attitudes:

<table>
<thead>
<tr>
<th>If</th>
<th>Then</th>
<th>Implies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent certain sum &lt; Expected risky sum</td>
<td>( \alpha &lt; 1 )</td>
<td>Risk aversion</td>
</tr>
<tr>
<td>Equivalent certain sum = Expected risky sum</td>
<td>( \alpha = 1 )</td>
<td>Risk indifference</td>
</tr>
<tr>
<td>Equivalent certain sum &gt; Expected risky sum</td>
<td>( \alpha &gt; 1 )</td>
<td>Risk preference</td>
</tr>
</tbody>
</table>

The appropriate \( \alpha \) value for a given managerial decision varies according to the level of risk and degree of the decision maker's risk aversion.

The basic valuation model (Equation 17.7) can be converted into a risk-adjusted valuation model, one that explicitly accounts for risk:

\[
V = \sum_{i=1}^{n} \frac{\alpha E(\pi_i)}{(1+i)^t}
\]

In this risk-adjusted valuation model, expected future profits, \( E(\pi_i) \), are converted to their certainty equivalents, \( \alpha E(\pi_i) \), and are discounted at a risk-free rate, \( i \), to obtain the risk-adjusted present value of a firm or project. With the valuation model in this form, one can appraise the effects of different courses of action with different risks and expected returns.

To use Equation 17.9 for real-world decision making, managers must estimate appropriate \( \alpha \) for various investment opportunities. Deriving such estimates can prove difficult, because \( \alpha \) varies according to the size and riskiness of investment projects as well as according to the risk attitudes of investors. In many instances, however, the record of past investment decisions offers a guide that can be used to determine appropriate certainty equivalent adjustment factors. The following example illustrates how one might use certainty equivalent adjustment factors in practical decision making.

**Certainty Equivalent Adjustment Example**

Assume that operations at Burns & Allen Industries have been seriously disrupted by problems with a faulty boiler at its main fabrication facility. In fact, state fire marshals shut the
facility down for an extended period recently following repeated overheating and minor explosions. The boiler problem was solved when it was discovered that a design flaw had made the pilot light safety switch inoperable.

Burns & Allen retained the Denver law firm of Dewey, Cheetham & Howe to recover economic damages from the boiler manufacturer. The company has filed suit in state court for $250,000 in damages. Prior to filing suit, the attorney estimated legal, expert witness, and other litigation costs to be $10,000 for a fully litigated case, for which Burns & Allen had a 10 percent chance of receiving a favorable judgment. For simplicity, assume that a favorable judgment will award Burns & Allen 100 percent of the damages sought, whereas an unfavorable judgment will result in the firm receiving zero damages. Also assume that $10,000 is the most Burns & Allen would be willing to pay to sue the boiler manufacturer.

In filing suit against the boiler manufacturer, Burns & Allen has made a risky investment decision. By its willingness to bear litigation costs of $10,000, the company has implicitly stated that it regards these out-of-pocket costs to be at least equivalent to the value of the risky expectation of receiving a favorable judgment against the boiler manufacturer. In other words, Burns & Allen is willing to exchange $10,000 in certain litigation costs for the possibility of receiving a $250,000 judgment against the boiler manufacturer.

Burns & Allen’s investment decision can be characterized using the certainty equivalent adjustment method. To do this, it is important to realize that the $10,000 in litigation costs is incurred irrespective of the outcome of a fully litigated case. This $10,000 represents a certain sum that the company must value as highly as the expected risky outcome to be willing to file suit. The expected risky outcome, or expected return from filing suit, is

\[
\text{Expected Return} = \text{Favorable Judgment Payoff} \times \text{Probability} + \text{Unfavorable Judgment Payoff} \times \text{Probability} \\
= 250,000(0.1) + 0(0.9) \\
= 25,000
\]

To justify filing suit, Burns & Allen’s certainty equivalent adjustment factor for investment projects of this risk class must be

\[
\alpha = \frac{\text{Certain Sum}}{\text{Expected Risky Sum}} = \frac{\text{Litigation Costs}}{\text{Expected Return}} = \frac{10,000}{25,000} = 0.4
\]

Therefore, each risky dollar of expected return from the litigation effort is worth, in terms of utility, at least 40¢ in certain dollars. Alternatively, $10,000 is the certain sum equivalent of the risky expected return of $25,000.

Now assume that after Burns & Allen goes to court, incurring $5,000 in litigation costs, especially damaging testimony by an expert witness dramatically changes the outlook of the case in Burns & Allen’s favor. In response, the boiler manufacturer’s attorney offers an out-of-court settlement in the amount of $30,000. However, Burns & Allen’s attorney recommends that the company reject this offer, estimating that it now has a 50/50 chance of obtaining a favorable judgment in the case. Should Burns & Allen follow the attorney’s advice and reject the settlement offer?

In answering this question, one must keep in mind that having already spent (“sunk”) $5,000 in litigation costs, Burns & Allen must consider as relevant litigation costs only the addi-
tional $5,000 necessary to complete litigation. These $5,000 litigation costs, plus the $30,000 out-of-court settlement offer, represent the relevant certain sum, because proceeding with the suit will require an "investment" of these additional litigation plus opportunity costs. Given the revised outlook for a favorable judgment, the expected return to full litigation is

$$\text{Expected Return} = (250,000)(0.5) + (0)(0.5)$$

$$= 125,000$$

In light of Burns & Allen's earlier decision to file suit on the basis that each dollar of expected risky return was "worth" 40% in certain dollars, this expected return would have a $50,000 (= $125,000 \times 0.4) certainty equivalent value. Because this amount exceeds the settlement offer plus remaining litigation costs, the settlement offer seems deficient and should be rejected. On the basis of Burns & Allen's revealed risk attitude, an out-of-court settlement offer has to be at least $45,000 to receive favorable consideration. At that point, the settlement plus saved litigation costs of $5,000 would equal the certainty equivalent value of the expected return from continuing litigation.

This simple example illustrates that historical investment decisions offer a useful guide to current decisions. If a potential project's required investment and risk levels are known, the $\alpha$ implied by a decision to accept the investment project can be calculated. This project-specific $\alpha$ can then be compared with $\alpha$s for prior projects with similar risks. Risk-averse individuals should invest in projects if calculated $\alpha$s are less than or equal to those for accepted historical projects in the same risk class. Furthermore, given an estimate of expected return and risk, the maximum amount that the firm should be willing to invest in a given project can also be determined from the certainty equivalent adjustment factor. Risk-averse management will accept new projects if the level of required investment per dollar of expected return is less than or equal to that for historical projects of similar risk.

### Risk-Adjusted Discount Rates

Another way to incorporate risk in managerial decision making is to adjust the discount rate or denominator of the basic valuation model (Equation 17.7). Like certainty equivalent factors, risk-adjusted discount rates are based on the trade-off between risk and return for individual investors. Suppose an investor is indifferent to a riskless asset with a sure 5 percent rate of return, a moderately risky asset with a 10 percent expected return, and a very risky asset with a 15 percent expected return. As risk increases, higher expected returns on investment are required to compensate for additional risk. Observe also that the required risk premium is directly related to the level of risk associated with a particular investment. This is a common situation.

The basic valuation model shown in Equation 17.7 can be adapted to account for risk through adjustment of the discount rate, $i$, where

$$V = \sum_{t=1}^{n} \frac{E(\pi_t)}{(1 + k)^t} \quad 17.10$$

The risk-adjusted discount rate $k$ is the sum of the risk-free rate of return, $R_F$, plus the required risk premium, $R_p$:

$$k = R_F + R_p$$

In Equation 17.10, value is measured by the present worth of expected future income or profits, $E(\pi_t)$, discounted at a risk-adjusted rate.
Risk-Adjusted Discount Rate Example

Suppose the Property & Casualty Insurance Company (P&C) is contemplating the purchase of one of the two database and file management software systems offered by Rockford Files. System A is specifically designed for P&C's current computer software system and cannot be used with those of other providers; system B is compatible with a broad variety of computer software systems, including P&C's and those of other software providers. The expected investment outlay is $500,000 for each alternative. Expected annual cost savings (cash inflows) over 5 years are $175,000 per year for system A and $185,000 per year for system B. The standard deviation of expected annual returns from system A is $10,000, whereas that of system B is $15,000. In view of this risk differential, P&C management has decided to evaluate system A with a 10 percent cost of capital and system B with a 15 percent cost of capital.

The risk-adjusted value for each system is as follows:  

\[
Value_A = \sum_{t=1}^{5} \frac{$175,000}{(1.10)^t} - $500,000
\]

\[
= $175,000 \times \left(\frac{1}{\sum_{t=1}^{5} (1.10)^t}\right) - $500,000
\]

\[
= $175,000 \times 3.7908 - $500,000
\]

\[
= $163,390
\]

\[
Value_B = \sum_{t=1}^{5} \frac{$185,000}{(1.15)^t} - $500,000
\]

\[
= $185,000 \times \left(\frac{1}{\sum_{t=1}^{5} (1.15)^t}\right) - $500,000
\]

\[
= $185,000 \times 3.3522 - $500,000
\]

\[
= $120,157
\]

Because the risk-adjusted value of system A is larger than that for system B, P&C should choose system A. This choice maximizes the value of the firm.

DECISION TREES AND COMPUTER SIMULATION

Decision trees that follow the sequential nature of the decision-making process provide a logical framework for decision analysis under conditions of uncertainty. When a high degree of uncertainty exists and data are not readily available, computer simulation often provides the basis for reasonable conjecture.  

2 The terms  

\[
\sum_{t=1}^{5} \frac{1}{(1.10)^t} = 3.7908
\]

and  

\[
\sum_{t=1}^{5} \frac{1}{(1.15)^t} = 3.3522
\]

are present-value-of-an-annuity interest factors. Tables of interest factors for various interest rates and years appear in Appendix A.4.
Decision Trees

A decision tree is a sequential decision-making process. Decision trees are designed for analyzing decision problems that involve a series of choice alternatives that are constrained by previous decisions. They illustrate the complete range of future possibilities and their associated probabilities in terms of a logical progression from an initial decision point, through each subsequent constrained decision alternative, to an ultimate outcome. Decision points are instances where management must select among several choice alternatives. Chance events are possible outcomes following each decision point.

Decision trees are widely employed because many important decisions are made in stages. For example, a pharmaceutical company considering expansion into the generic prescription drug market might take the following steps:

- Spend $100,000 to survey supply and demand conditions in the generic drug industry.
- If survey results are favorable, spend $2 million on a pilot plant to investigate production methods.
- Depending on cost estimates and potential demand, either abandon the project, build a large plant, or build a small one.

These decisions are made in stages; subsequent determinations depend on prior judgments. The sequence of events can be mapped out to visually resemble the branches of a tree—hence, the term decision tree.

Figure 17.5 illustrates the decision-tree method for the pharmaceutical company decision problem. Assume that the company has completed its industry supply and demand analysis and determined that it should develop a full-scale production facility. Either a large plant or a small plant can be built. The probability is 50 percent for high demand, 30 percent for

decision tree
Map of a sequential decision-making process
decision points
Instances where management must select among choice alternatives
chance events
Possible outcomes following each decision point

**Figure 17.5 Illustrative Decision Tree**

The expected net present value of each investment alternative (column 5) is determined by linking possible outcomes (column 2), probabilities (column 3), and monetary values (column 4):

<table>
<thead>
<tr>
<th>Action (1)</th>
<th>Demand conditions (2)</th>
<th>Probability (3)</th>
<th>Present value of cash flows (4)</th>
<th>(5) = (3) × (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>0.5</td>
<td>$8,600,000</td>
<td>$4,400,000</td>
</tr>
<tr>
<td>Build big plant: invest $5 million</td>
<td>Medium</td>
<td>0.3</td>
<td>$3,500,000</td>
<td>1,050,000</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0.2</td>
<td>$1,400,000</td>
<td>280,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Revenue = $5,730,000</td>
<td></td>
</tr>
<tr>
<td>Expected value of cash flows</td>
<td></td>
<td></td>
<td>$5,730,000</td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>5,000,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected net present value</td>
<td></td>
<td></td>
<td>$ 730,000</td>
<td></td>
</tr>
</tbody>
</table>

| Build small plant: invest $2 million | High | 0.5            | $2,600,000                | $1,300,000     |
|                                      | Medium | 0.3            | $2,400,000                | 720,000        |
|                                      | Low    | 0.2            | $1,400,000                | 280,000        |
| Expected value of cash flows       |        |                | $2,300,000                |                |
| Cost                               | 2,000,000 |                |                            |                |
| Expected net present value         |        |                | $ 300,000                  |                |
medium demand, and 20 percent for low demand. Depending on actual demand, the present value of net cash flows, defined as sales revenue minus operating costs, ranges from $8.8 million to $1.4 million for a large plant and from $2.6 million to $1.4 million for a small plant.

Because demand probabilities are known, the expected value of cash flow can be determined, as in column 5 of Figure 17.5. Investment outlays are deducted from expected net cash flow to obtain the expected net present value for each decision. The expected net present value is $730,000 for the large plant and $300,000 for the small one. Notice the wide range of possible outcomes for the large plant. Actual net present values for the large plant investment equal the present value of cash flows (column 4) minus the large plant investment cost of $5 million. These values vary from $3.8 million to $3.6 million. Actual net present values for the small plant investment range only from $600,000 to $600,000. Clearly, the smaller plant appears less risky based on the width of the range of possible net present value outcomes. Because the investment requirement differs for each plant, the coefficient of variation for each plant's net present value can be examined to provide an alternate measure of relative risk. The coefficient of variation for the large plant's present value is 4.3, whereas that for the small plant is only 1.5. Again, risk appears greater for the large plant alternative.

These risk and expected return differentials can be incorporated into the decision-making process in a variety of ways. Assigning utility values to the cash flows given in column 4 of Figure 17.5 would state column 5 in terms of expected utility. The company could then choose the plant size that provided the greatest expected utility. Alternatively, present values given in column 4 could be adjusted using the certainty equivalent or risk-adjusted discount rate method. The plant that offers the largest risk-adjusted net present value is the optimal choice.

**Computer Simulation**

Another technique designed to assist business decision makers in making decisions under uncertainty is computer simulation. Computer simulation involves the use of computer software and sophisticated desktop computers to create a wide variety of decision outcome scenarios. These simulations illustrate a broad range of possible outcomes to help managers assess the possible and probable consequences of decision alternatives. Using the computer simulation technique, a variety of hypothetical "What if?" questions can be asked and answered on the basis of measurable differences in underlying assumptions. More than just informed conjecture, computer simulation allows managers to make precise judgments concerning the desirability of various choices on the basis of highly detailed probability information.

Computer simulations require probability distribution estimates for a number of variables, such as investment outlays, unit sales, product prices, input prices, and asset lives. In some instances, full-scale simulations are expensive and time-consuming and therefore restricted to projects such as major plant expansions or new-product decisions. When a firm is deciding whether to accept a major undertaking involving an outlay of millions of dollars, full-scale computer simulations provide valuable insights that are well worth their cost. Somewhat less expensive, limited-scale simulations are used to project outcomes for projects or strategies. Instead of using complete probability distributions for each variable included in the problem, results are simulated based on best-guess estimates for each variable. Changes in the values of each variable are then considered to see the effects of such changes on project returns. Typically, returns are highly sensitive to some variables, less so to others. Attention is then

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3 Using Equation 17.6 and data on possible returns in Figure 17.5, the standard deviation for the big plant is $3.135 million and for the small plant it is $458,260. Dividing these standard deviations by the appropriate expected return for each respective plant size, as in Equation 17.5, gives the coefficient of variation.
Computer Simulation Example

To illustrate the computer simulation technique, consider the evaluation of a new minimill investment project by Remington Steel, Inc. The exact cost of the plant is not known, but it is expected to be about $150 million. If no difficulties arise in construction, this cost can be reduced to as low as $125 million. An unfortunate series of events such as strikes, greater than projected increases in material costs, and/or technical problems could drive the required investment outlay as high as $225 million. Revenues from the new facility depend on the growth in regional income and construction, competition, developments in the field of metallurgy, steel import quotas and tariffs, and so on. Operating costs depend on production efficiency, cost of raw materials, and the trend in wage rates. Because sales revenues and operating costs are uncertain, annual profits are unpredictable.

Assuming that probability distributions can be developed for each major cost and revenue category, a computer program can be constructed to simulate the pattern of future events. Computer simulation randomly selects revenue and cost levels from each relevant distribution and uses this information to estimate future profits, net present values, or the rate of return on investment. This process is repeated a large number of times to identify the central tendency of projected returns and their expected values. When the computer simulation

MANAGEMENT APPLICATION

Game Theory at the FCC

In 1997 Congress passed the Omnibus Budget Reconciliation Act and gave the Federal Communications Commission (FCC) authority to use competitive bidding to allocate electromagnetic spectrum among multiple applicants. The electromagnetic spectrum covers a wide range of wavelengths used to transmit information by radio, telephone, and other means. Prior to this legislation, the FCC relied upon competitive bidding and auctions to select a single licensee from a panel of applicants. The auction approach is intended to award the licenses to the highest bidder and to assure that the licensees will use their best efforts to enhance the average time that the FCC can use the auction to license grants, and get the general public a better financial benefit from the award of licenses.

Since 1994, the FCC has conducted a host of auctions of licenses for electromagnetic spectrum. One of the most successful game theory applications has been in the design of the FCC auctions. In the design of the auction process, the FCC has relied on advice from top game theorists at Stanford, Caltech, and other leading universities. The agency has generally adopted a standard English auction in which the winner pays what it bids, and everyone can see all bids as they are made. Game theory research shows that open auctions stimulate bidding, whereas sealed auctions foster collusive bid rigging, whereas sealed auctions foster collusive bid rigging.

Although the FCC initially favored auctioning off vital spectrum licenses all at once to make it easier for bidders to assemble blocks of adjoining areas, this approach also posed a problem of complexity. Conquering the problem is the fact that bidders must be allowed some flexibility to withdraw bids when adjoining areas are sold to others. All offers could be withdrawn only in an orderly and efficient manner. However, the integrity of the process would suffer. A sequential auction, where areas are put up for bid one at a time, also involves problems because it denies participants the opportunity to bid more for economically efficient blocks of service areas. Winning bidders in a sequential auction have the potential for a snowballing effect where one success leads to another, and another, and another. After considering a wide variety of options, the FCC adopted a modified sequential bidding approach.

The FCC has found that spectrum auctions more effectively assign licenses than either competitive hearings or lotteries.
is completed, the frequency pattern and range of future returns can be plotted and analyzed. Although the expected value of future profits is of obvious interest, the range of possible outcomes is similarly important as a useful indicator of risk.

The computer simulation technique is illustrated in Figures 17.6 and 17.7. Figure 17.6 is a flowchart that shows the information flow pattern for the simulation procedure just described. The computer generated outcomes are then evaluated for their range, taking into account factors such as profit margins, revenue, and investment risks. The simulation results provide insights into the performance of alternative investments, helping decision-makers make informed choices.

**Figure 17.6** Simulation for Investment Planning

Computer simulation allows detailed analysis of business problems involving complex cost and revenue relations.
Figure 17.7  Expected Rates of Return on Investments X and Y
Investments X and Y both have continuous distributions of returns around their expected values.

<table>
<thead>
<tr>
<th>Probability of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment X</td>
</tr>
<tr>
<td>Investment Y</td>
</tr>
<tr>
<td>Rate of return</td>
</tr>
</tbody>
</table>

-10 -5 0 5 10 15 20 25 30 35 40 45

described. Figure 17.7 illustrates the frequency distribution of rates of return generated by such a simulation for two alternative projects, X and Y, each with an expected cost of $20 million. The expected rate of return on investment X is 15 percent, and 20 percent on investment Y. However, these are only average rates of return derived by the computer simulation. The range of simulated returns is from -10 percent to 45 percent for investment Y, and from 5 percent to 25 percent for investment X. The standard deviation for X is only 4 percent; that for Y is 12 percent. Based on this information, the coefficient of variation is 0.267 for investment X and 0.60 for investment Y. Investment Y is clearly riskier than investment X. A decision about which alternative to choose can be made on the basis of expected utility, or on the basis of a present value determination that incorporates either certainty equivalents or risk-adjusted discount rates.

USES OF GAME THEORY IN RISK ANALYSIS

In an uncertain economic environment, value maximization is often achieved using the risk-adjusted valuation models described in this chapter. However, when the decision environment is hostile rather than neutral, other game-theory decision criteria may be appropriate.

Game Theory and Auction Strategy

Game theory dates from the 1940s, when mathematician John von Neumann and economist Oskar Morgenstern decided to turn their card-playing ability into a more general theory of decision making under uncertainty. They discovered that deciding when to bluff, fold, stand pat, or raise is not only relevant when playing cards, but also when opposed by aggressive competitors in the marketplace. Rules they developed are increasingly regarded as relevant for analyzing competitive behavior in a wide variety of settings. One of the most interesting uses of game theory is to analyze bidder strategy in auctions.

The most familiar type of auction is an English auction, where an auctioneer keeps raising the price until a single highest bidder remains. The advantage of an English auction is that it is widely regarded as a fair and open process. It is an effective approach for obtaining high winning bid prices. Because participants can see and hear what rivals are doing, bidders often
act aggressively. In fact, winners sometimes overpay for their winning bids. The so-called *winner's curse* results when overly aggressive bidders pay more than the economic value of auctioned-off items. For example, participants in the bidding process for offshore oil properties in the Gulf of Mexico routinely seemed to overestimate the amount of oil to be found.

Another commonly employed auction method is a *sealed-bid auction*, where all bids are secret and the highest bid wins. Local and state governments, for example, employ the sealed-bid approach to build roads, buy fuel for schools and government offices, and to procure equipment and general supplies. A compelling advantage of the sealed-bid approach is that it is relatively free from the threat of collusion because, at least ostensibly, no one knows what anyone else is doing. The downside to the approach is that it could yield less to the government when airwave space is auctioned off because the approach often encourages bidders to act cautiously.

A relatively rare sealed-bid auction method is a *Vickrey auction*, where the highest sealed bid wins, but the winner pays the price of the second-highest bid. The reason for this design is that the technique tends to produce high bids because participants know beforehand that they will not be forced to pay the full amount of their winning bid. A disadvantage of the technique is that it creates the perception that the buyer is taking advantage of the seller by paying only the second highest price.

Another uncommon auctioning method is the so-called reverse or *Dutch auction*. In a Dutch auction, the auctioneer keeps lowering a very high price until a winning bidder emerges. The winning bidder is the first participant willing to pay the auctioneer's price. A disadvantage of this approach is that bidders tend to act cautiously out of fear of overpaying for auctioned items. In terms of the FCC's sale of airwave space, a Dutch auction might yield less to the government than an English auction. Offsetting this disadvantage is the fact that winning bidders would then be left with greater resources to quickly build a viable service network.

In auctions of airwave space for new communications services, the FCC uses a number of auction strategies to achieve a variety of sometimes conflicting goals. To raise the most money while creating efficient service areas and encouraging competitive bidding, the FCC uses all four basic auction strategies. To better understand the motives behind these auction strategies, it is necessary to examine game-theory rules for decision making under uncertainty.

**Maximin Decision Rule**

One decision standard that is sometimes applicable for decision making under uncertainty is the *maximin criterion*. This criterion states that the decision maker should select the alternative that provides the best of the worst possible outcomes. This is done by finding the worst possible (minimum) outcome for each decision alternative and then choosing the option whose worst outcome provides the highest (maximum) payoff. This criterion instructs one to maximize the minimum possible outcome.

To illustrate, consider Table 17.5, which shows the weekly profit contribution payoffs from alternative gasoline-pricing strategies by the self-service U-Pump gas station in Jackson, Wyoming. Assume that U-Pump has just been notified of a $3 price reduction in the wholesale price of gas. If U-Pump reduces its current self-service price by $3 per gallon, its weekly profit contribution will depend on the reaction, if any, of its nearest competitor. If U-Pump’s competitor matches the price reduction, a $2,500 profit contribution will result. Without any competitor reaction, U-Pump would earn $3,000. If U-Pump and its competitor both maintain current prices, U-Pump will earn $5,000, whereas if U-Pump did not match the competitor’s price cut, U-Pump would earn only $1,000. The worst possible outcome following a price reduction by U-Pump is $2,500, but a $1,000 outcome is possible if U-Pump...
called "blue of red."

and, by the approach is shown to the

sealed design that of the filler by

n. In a bidder. A chance might be fact the serv-

umber of money n, all strategy.

The maximin criterion requires U-Pump to reduce its price, because the minimum possible outcome from this decision is greater than the minimum $1,000 payoff possible by maintaining the current price.

Although the maximin criterion suffers from the obvious shortcoming of focusing on the most pessimistic outcome for each decision alternative, it should not be dismissed as naive and unsophisticated. The maximin criterion implicitly assumes a very strong aversion to risk and is appropriate for decisions involving the possibility of catastrophic outcomes. When decision alternatives involve outcomes that endanger worker lives or the survival of the organization, for example, the maximin criterion can be an appropriate technique. Similarly, if the state of nature that prevails depends on the course of action taken by the decision maker, the maximin criterion might be appropriate. In the preceding example, one might expect that a decision by U-Pump to reduce prices would cause the competitor to follow suit, resulting in the worst possible outcome for that decision alternative.

Minimax Regret Decision Rule

A second useful decision criterion focuses on the opportunity loss associated with a decision rather than on its worst possible outcome. This decision rule, known as the minimax regret criterion, states that the decision maker should minimize the maximum possible regret (opportunity loss) associated with a wrong decision after the fact. This criterion instructs one to minimize the difference between possible outcomes and the best outcome for each state of nature.

To illustrate this decision technique, the concept of opportunity loss, or regret, must be examined in greater detail. In game theory, opportunity loss is defined as the difference between a given payoff and the highest possible payoff for the resulting state of nature. Opportunity losses result because returns actually received under conditions of uncertainty are frequently lower than the maximum return that would have been possible had perfect knowledge been available beforehand.

Table 17.5 shows the opportunity loss or regret matrix associated with U-Pump's gasoline pricing problem. It was constructed by finding the maximum payoff for a given state of nature and then subtracting from this amount the payoffs that would result from various
decision alternatives. Opportunity loss is always a positive figure or zero, because each alternative payoff is subtracted from the largest payoff possible in a given state of nature. For example, if U-Pump's competitor reduced its price, the best possible decision for that state of nature would be for U-Pump to have also reduced prices. After the fact, U-Pump would have no regrets had it done so. Should U-Pump maintain its current price, the firm would experience a $1,500 opportunity loss, or regret. To calculate this amount, subtract the $1,000 payoff associated with U-Pump's maintaining its current price despite a competitor price reduction from the $2,500 payoff that it would have received from matching the competitor's price reduction. Similarly, if U-Pump would reduce its price while its competitor maintains the current price, U-Pump would experience a $2,000 opportunity loss or regret after the fact.

The minimax regret criterion would cause U-Pump to maintain the current retail price of gasoline because this decision alternative minimizes the maximum regret, or opportunity loss. The maximum regret in this case is limited to the $1,500 loss that would result if the competitor reduced its current price. If U-Pump were to reduce its price while the competitor maintained its current price, U-Pump's opportunity loss would be $2,000 per week, $500 more than the maximum regret from U-Pump maintaining its current price.

Cost of Uncertainty

An unavoidable opportunity loss is the cost associated with uncertainty. Therefore, the expected opportunity loss associated with a decision provides a measure of the expected monetary gain from the removal of all uncertainty about future events. From the opportunity loss or regret matrix, the cost of uncertainty is measured by the minimum expected opportunity loss. From the payoff matrix, the cost of uncertainty is measured by the difference between the expected payoff associated with choosing the correct alternative under each state of nature (which will be known only after the fact) and the highest expected payoff available from among the decision alternatives. The cost of uncertainty is the unavoidable economic loss that is due to chance. Using this concept, it becomes possible to judge the value of gaining additional information before choosing among decision alternatives.

The previous gasoline pricing problem can illustrate this use of opportunity loss. On the basis of the data in Table 17.5, the expected opportunity loss of each decision alternative can be calculated as shown in Table 17.6. Here it is assumed that U-Pump projects a 50/50, or 50 percent, chance of a competitor price reduction. The minimum expected opportunity cost in this case is $750 and represents U-Pump's loss from not knowing its competitor's pricing reaction with certainty. This cost of uncertainty represents the $750 value to U-Pump of resolving doubt about its competitor's pricing policy. U-Pump would be better off if it could eliminate this uncertainty by making an expenditure of less than $750 on information gathering.

Firms often engage in activities aimed at reducing the uncertainty of various alternatives before making an irrevocable decision. For example, a food-manufacturing company will employ extensive marketing tests in selected areas to gain better estimates of sales potential before going ahead with the large-scale introduction of a new product. Manufacturers of consumer goods frequently install new equipment in a limited number of models to judge reliability and customer reaction before including the equipment in all models. Similarly, competitors often announce price changes well in advance of their effective date to elicit the reaction of rivals.
Table 17.6 U-Pump's Calculation of Expected Opportunity Loss

<table>
<thead>
<tr>
<th>State of Nature</th>
<th>Probability of This State of Nature (1)</th>
<th>Reduce Price Opportunity Loss of This Outcome (2)</th>
<th>Expected Opportunity Loss (3) = (1) × (2)</th>
<th>Maintain Current Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competitor reduces price</td>
<td>0.5</td>
<td>$0</td>
<td>$0</td>
<td>0.5</td>
</tr>
<tr>
<td>Competitor maintains current price</td>
<td>0.5</td>
<td>$2,000</td>
<td>$1,000</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Cost of uncertainty = Minimum expected opportunity loss = $750.

<table>
<thead>
<tr>
<th>State of Nature</th>
<th>Probability of This State of Nature (1)</th>
<th>Reduce Price Outcome (2) (3) = (1) × (2)</th>
<th>Maintain Current Price Outcome (2) (3) = (1) × (2)</th>
<th>Loss (3) = (1) × (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competitor reduces price</td>
<td>0.5</td>
<td>$2,500</td>
<td>$1,250</td>
<td>$500</td>
</tr>
<tr>
<td>Competitor maintains current price</td>
<td>0.5</td>
<td>$3,000</td>
<td>$1,500</td>
<td>$2,500</td>
</tr>
</tbody>
</table>

Expected value of a correct decision after the fact = $2,500(0.5) + $5,000(0.5) = $3,750.
Cost of uncertainty = Expected value of a correct decision – Expected value of best alternative = $3,750 – $3,000 = $750.

SUMMARY

Risk analysis plays an integral role in the decision process for most business problems. This chapter defines the concept of economic risk and illustrates how the concept can be dealt with in the managerial decision making process.

- **Economic risk** is the chance of loss due to the fact that all possible outcomes and their probability of occurrence are unknown. **Uncertainty** exists when the outcomes of managerial decisions cannot be predicted with absolute accuracy but all possibilities and their associated probabilities of occurrence are known.

- **Business risk** is the chance of loss associated with a given managerial decision. Many different types of business risk are apparent in the globally competitive 1990s. **Market risk** is the chance that a portfolio of investments can lose money because of swings in the stock market as a whole. **Inflation risk** is the danger that a general increase in the price level will undermine real economic values. **Interest-rate risk** stems from the fact that a fall in interest rates will increase the value of any agreement that involves a fixed promise to pay interest and principal over a specified period. **Credit risk** is the chance that another party will fail to abide by its contractual obligations. Corporations must also consider the problem of **liquidity risk**, or the difficulty of selling corporate assets or investments that have only a few willing buyers or that are otherwise not easily transferable at favorable prices under typical market conditions. **Derivative risk** is the chance that volatile financial derivatives could create losses in underlying investments by increasing rather than decreasing price volatility.
• Cultural risk is borne by companies that pursue a
global rather than a solely domestic investment
strategy. Product market differences due to dis-
tinctive social customs make it difficult to predict
which products might do well in foreign markets.
Currency risk is another important danger facing
global businesses because most companies wish
to eventually repatriate foreign earnings back to
the domestic parent. Finally, global investors also
experience government policy risk because for-
government grants of monopoly franchises,
tax abatements, and favored trade status can be
tenuous. Expropriation risk, or the risk that busi-
ness property located abroad might be seized by
host governments, is another type of risk that
global investors must not forget.

• The probability of an event is the chance, or odds,
that the incident will occur. If all possible events or
outcomes are listed, and if a probability of occur-
rence is assigned to each event, the listing is called
a probability distribution. A payoff matrix illus-
trates the outcome associated with each possible
state of nature. The expected value is the antici-
pated realization from a given payoff matrix.

• Absolute risk is the overall dispersion of possible
payoffs. The smaller the standard deviation, the
tighter the probability distribution and the lower
the risk in absolute terms. Relative risk is the
variation in possible returns compared with the
expected payoff amount. Beta is a measure of the
systematic variability or covariance of one asset’s
returns with returns on other assets.

• A normal distribution has a symmetrical dis-
tribution about the mean or expected value. If a
probability distribution is normal, the actual out-
come will lie within ±1 standard deviation of the
mean roughly 68 percent of the time. The proba-
bility that the actual outcome will be within ±2
standard deviations of the expected outcome is
approximately 95 percent; and there is a greater
than 99 percent probability that the actual out-
come will occur within ±3 standard deviations
of the mean. A standardized variable has a mean of
0 and a standard deviation equal to 1.

• Risk aversion characterizes individuals who seek
to avoid or minimize risk. Risk neutrality char-
acterizes decision makers who focus on expected
returns and disregard the dispersion of returns
(risk). Risk seeking characterizes decision makers
who prefer risk. At the heart of risk aversion is
the notion of diminishing marginal utility,
where additional increments of money bring ever
smaller increments of marginal utility.

• Under the certainty equivalent approach, decision
makers specify the certain sum that they regard
comparable to the expected value of a risky invest-
ment alternative. Any expected risky amount can
be converted to an equivalent certain sum using
the certainty equivalent adjustment factor, \( \alpha \), cal-
culated as the ratio of a certain sum divided by an
expected risky amount, where both dollar values
provide the same level of utility. The risk-adjusted
valuation model reflects both time value and risk
considerations.

• The risk-adjusted discount rate, \( \bar{r} \), is the sum of
the risk-free rate of return, \( R_f \), plus the required
risk premium, \( R_p \). The difference between the
expected rate of return on a risky asset and the rate
of return on a riskless asset is the risk premium on
the risky asset.

• A decision tree is a map of a sequential decision-
making process. Decision trees are designed for
analyzing decision problems that involve a series
of choice alternatives that are constrained by pre-
vious decisions. Decision points represent
instances when management must select among
several choice alternatives. Chance events are
possible outcomes following each decision point.

• Computer simulation involves the use of com-
puter software and workstations or sophisticated
desktop computers to create a wide variety of
decision outcome scenarios. Sensitivity analysis
focuses on those variables that most directly affect
decision outcomes, and it is less expensive and
less time-consuming than full-scale computer
simulation.

• Game theory is a useful decision framework
employed to make choices in hostile environments
and under extreme uncertainty. A variety of auc-
tion strategies are based on game-theory principles.

• The most familiar type of auction is an English
auction, where an auctioneer keeps raising the
price until a single highest bidder remains. A win-
nor’s curse results when overly aggressive bidders
pay more than the economic value of auctioned
items. In a sealed-bid auction, all bids are secret
and the highest bid wins. A relatively rare sealed-
bid auction method is a Vickrey auction, where
the highest sealed bid wins, but the winner pays
the price of the second-highest bid. Another auc-
tioning method is the so-called reverse or Dutch auction. In a Dutch auction, the auctioneer keeps lowering a very high price until a winning bidder emerges. The winning bidder is the first participant willing to pay the auctioneer’s price.

- A game-theory decision standard that is sometimes applicable for decision making under uncertainty is the maximin criterion, which states that the decision maker should select the alternative that provides the best of the worst possible outcomes. The minimax regret criterion states that the decision maker should minimize the maximum possible regret (opportunity loss) associated with a wrong decision after the fact. In game theory, opportunity loss is defined as the difference between a given payoff and the highest possible payoff for the resulting state of nature. From the opportunity loss or regret matrix, the cost of uncertainty is measured by the minimum expected opportunity loss.

Decision making under conditions of uncertainty is greatly facilitated by use of the tools and techniques discussed in this chapter. Although uncertainty can never be eliminated, its harmful consequences can be minimized.

**QUESTIONS**

Q17.1 In economic terms, what is the difference between risk and uncertainty?

Q17.2 Domestic investors sometimes miss out on better investment opportunities available to global investors. At the same time, global investors face special risks. Discuss some of the special risks faced by global investors.

Q17.3 The standard deviation measure of risk implicitly gives equal weight to variations on both sides of the expected value. Can you see any potential limitations of this treatment?

Q17.4 State-run lotteries commonly pay out 50 percent of total lottery ticket sales in the form of jackpots and prizes. Use the certainty equivalent concept to quantify the minimum value placed on each risky dollar of expected return by lottery ticket buyers. Why are such lotteries so popular?

Q17.5 Graph the relation between money and its utility for an individual who buys both household fire insurance and state lottery tickets.

Q17.6 When the basic valuation model is adjusted using the risk-free rate, i, what economic factor is being explicitly accounted for?

Q17.7 If the expected net present value of returns from an investment project is $50,000, what is the maximum price that a risk-neutral investor would pay for it? Explain.

Q17.8 “Market estimates of investors’ reactions to risk cannot be measured precisely, so it is impossible to set risk-adjusted discount rates for various classes of investment with a high degree of precision.” Discuss this statement.

Q17.9 What is the value of decision trees in managerial decision making?

Q17.10 When is it most useful to use game theory in decision analysis?

**SELF-TEST PROBLEMS**

S17.1 Certainty Equivalent Method. Courteney-Cox, Inc., is a Texas-based manufacturer and distributor of components and replacement parts for the auto, machinery, farm, and construction equipment industries. The company is currently funding a program of capital investment that is necessary to reduce production costs and thereby meet an onslaught of competition from low-cost suppliers located in Mexico and throughout Latin America. Courteney-Cox has a limited amount of capital available and must carefully weigh both the risks and potential rewards associated with alternative investments. In particular, the company seeks to weigh the advantages and disadvantages of a new investment project, project X, in light of two other recently adopted investment projects, project Y and project Z:
### Expected Cash Flows After Tax (CFAT) per Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Project X</th>
<th>Project Y</th>
<th>Project Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>$10,000</td>
<td>$20,000</td>
<td>$  0</td>
</tr>
<tr>
<td>2002</td>
<td>10,000</td>
<td>18,000</td>
<td>2,500</td>
</tr>
<tr>
<td>2003</td>
<td>10,000</td>
<td>16,000</td>
<td>5,000</td>
</tr>
<tr>
<td>2004</td>
<td>10,000</td>
<td>14,000</td>
<td>7,500</td>
</tr>
<tr>
<td>2005</td>
<td>10,000</td>
<td>12,000</td>
<td>10,000</td>
</tr>
<tr>
<td>2006</td>
<td>10,000</td>
<td>10,000</td>
<td>12,500</td>
</tr>
<tr>
<td>2007</td>
<td>10,000</td>
<td>8,000</td>
<td>15,000</td>
</tr>
<tr>
<td>2008</td>
<td>10,000</td>
<td>6,000</td>
<td>17,500</td>
</tr>
<tr>
<td>2009</td>
<td>10,000</td>
<td>4,000</td>
<td>20,000</td>
</tr>
<tr>
<td>2010</td>
<td>10,000</td>
<td>2,000</td>
<td>22,500</td>
</tr>
</tbody>
</table>

PV of Cash Flow @ 5% $91,131 $79,130
Investment Outlay in 2000: $60,000 $60,000 $50,000

A. Using a 5 percent risk-free rate, calculate the present value of expected cash flows after tax (CFAT) for the 10-year life of project X.

B. Calculate the minimum certainty equivalent adjustment factor for each project's CFAT that would justify investment in each project.

C. Assume that the management of Courteney-Cox is risk averse and uses the certainty equivalent method in decision making. Is project X as attractive or more attractive than projects Y and Z?

D. If the company would not have been willing to invest more than $60,000 in project Y nor more than $50,000 in project Z, should project X be undertaken?

### ST17.2 Project Valuation

The Central Perk Coffee House, Inc., is engaged in an aggressive store refurbishing program and is contemplating expansion of its in-store baking facilities. This investment project is to be evaluated using the certainty equivalent adjustment factor method and the risk-adjusted discount rate method. If the project has a positive value when both methods are employed, the project will be undertaken. The project will not be undertaken if either evaluation method suggests that the investment will fail to increase the value of the firm. Expected cash flow after tax (CFAT) values over the 5-year life of the investment project and relevant certainty equivalent adjustment factor information are as follows:

<table>
<thead>
<tr>
<th>Time Period (years)</th>
<th>Alpha</th>
<th>Project E(CFAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td>($75,000)</td>
</tr>
<tr>
<td>1</td>
<td>0.95</td>
<td>22,500</td>
</tr>
<tr>
<td>2</td>
<td>0.90</td>
<td>25,000</td>
</tr>
<tr>
<td>3</td>
<td>0.85</td>
<td>27,500</td>
</tr>
<tr>
<td>4</td>
<td>0.75</td>
<td>30,000</td>
</tr>
<tr>
<td>5</td>
<td>0.70</td>
<td>32,500</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>$62,500</td>
</tr>
</tbody>
</table>

At the present time, an 8 percent annual rate of return can be obtained on short-term U.S. government securities; the company uses this rate as an estimate of the risk-free rate of return.

A. Use the 8 percent risk-free rate to calculate the present value of the investment project.

B. Using this present value as a basis, utilize the certainty equivalent adjustment factor information given previously to determine the risk-adjusted present value of the project.
C. Use an alternative risk-adjusted discount rate method of project valuation on the assumption that a 15 percent rate of return is appropriate in light of the level of risk undertaken. D. Compare and contrast your answers to parts B and C. Should the investment be made?

**PROBLEMS**

**P17.1 Risk Preferences.** Identify each of the following as being consistent with risk-averse, risk-neutral, or risk-seeking behavior in investment project selection. Explain your answers.

A. Larger risk premiums for riskier projects  
B. Preference for smaller, as opposed to larger, coefficients of variation  
C. Valuing certain sums and expected risky sums of equal dollar amounts equally  
D. Having an increasing marginal utility of money  
E. Ignoring the risk levels of investment alternatives

**P17.2 Certainty Equivalents.** The certainty equivalent concept can be widely employed in the analysis of personal and business decision making. Indicate whether each of the following statements is true or false and explain why:

A. The appropriate certainty equivalent adjustment factor, \( \alpha \), indicates the minimum price in certain dollars that an individual should be willing to pay per risky dollar of expected return.
B. \( \alpha \neq 1 \) implies that a certain sum and a risky expected return of different dollar amounts provide equivalent utility to a given decision maker.
C. If previously accepted projects with similar risk have \( \alpha \) in a range from \( \alpha = 0.4 \) to \( \alpha = 0.5 \), an investment with an expected return of \( \$150,000 \) is acceptable at a cost of \( \$50,000 \).
D. A project for which \( NPV > 0 \) using an appropriate risk-adjusted discount rate has an implied \( \alpha \) factor that is too large to allow project acceptance.
E. State lotteries that pay out 50 percent of the revenues that they generate require players who place at least a certain \$2 value on each \$1 of expected risky return.

**P17.3 Expected Value.** Perry Chandler, a broker with Caveat Emptor, Ltd., offers free investment seminars to local PTA groups. On average, Chandler expects 1 percent of seminar participants to purchase \$25,000 in tax-sheltered investments and 5 percent to purchase \$5,000 in stocks and bonds. Chandler earns a 4 percent net commission on tax shelters and a 1 percent commission on stocks and bonds. Calculate Chandler’s expected net commissions per seminar if attendance averages 10 persons.

**P17.4 Probability Concepts.** Aquarius Products, Inc., has just completed development of a new line of skin-care products. Preliminary market research indicates two feasible marketing strategies: (1) creating general consumer acceptance through media advertising or (2) creating distributor acceptance through intensive personal selling. Sales estimates for each marketing alternative are:

<table>
<thead>
<tr>
<th>Media Advertising Strategy</th>
<th>Personal Selling Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>Sales</td>
</tr>
<tr>
<td>0.1</td>
<td>$500,000</td>
</tr>
<tr>
<td>0.4</td>
<td>1,500,000</td>
</tr>
<tr>
<td>0.4</td>
<td>2,500,000</td>
</tr>
<tr>
<td>0.1</td>
<td>3,500,000</td>
</tr>
</tbody>
</table>
A. Assume that the company has a 50 percent profit margin on sales (that is, profits equal one-half of sales revenue). Calculate expected profits for each plan.

B. Construct a simple bar graph of the possible profit outcomes for each plan. Which plan appears to be riskier?

C. Assume that management’s utility function resembles the one illustrated in the following figure. Calculate expected utility for each strategy. Which strategy should the marketing manager recommend?

### The Relation Between Total Profit and Utility for Aquarius Products, Inc.

<table>
<thead>
<tr>
<th>Profit ($000)</th>
<th>Utility of profit (utils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>25</td>
</tr>
<tr>
<td>500</td>
<td>50</td>
</tr>
<tr>
<td>750</td>
<td>70</td>
</tr>
<tr>
<td>1,000</td>
<td>82.5</td>
</tr>
<tr>
<td>1,250</td>
<td>90</td>
</tr>
<tr>
<td>1,500</td>
<td>95</td>
</tr>
<tr>
<td>1,750</td>
<td>97.5</td>
</tr>
<tr>
<td>2,000</td>
<td>100</td>
</tr>
</tbody>
</table>

P17.5 Probability Concepts. Phoebe Buffay, marketing director for Narcissism Records, Inc., has just completed an agreement to re-release a recording of “The Boss’s Greatest Hits.” (The Boss had a number of hits on the rock and roll charts during the early 1980s.) Preliminary market research indicates two feasible marketing strategies: (1) concentration on developing general consumer acceptance by advertising on late-night television or (2) concentration on developing distributor acceptance through intensive sales calls by company representatives. Buffay developed estimates for sales under each alternative plan and has constructed payoff matrices according to his assessment of the likelihood of product acceptance under each plan. These data are as follows:
### Strategy 1

<table>
<thead>
<tr>
<th>Probability</th>
<th>Outcome (Sales)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.32</td>
<td>$250,000</td>
</tr>
<tr>
<td>0.36</td>
<td>1,000,000</td>
</tr>
<tr>
<td>0.32</td>
<td>1,750,000</td>
</tr>
</tbody>
</table>

### Strategy 2

<table>
<thead>
<tr>
<th>Probability</th>
<th>Outcome (Sales)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.125</td>
<td>$250,000</td>
</tr>
<tr>
<td>0.750</td>
<td>750,000</td>
</tr>
<tr>
<td>0.125</td>
<td>1,250,000</td>
</tr>
</tbody>
</table>

A. Assuming that the company has a 50 percent profit margin on sales, calculate the expected profits for each plan.

B. Construct a simple bar graph of the possible profit outcomes for each plan. Which plan appears to be riskier?

C. Calculate the standard deviation of the profit distribution associated with each plan.

D. Assume that the management of Narcissism has a utility function like the one illustrated in the following graph. Calculate expected utility for each strategy. Which marketing strategy should Buffay recommend?

---

The Relation Between Total Utility and Profit for Narcissism Records, Inc.
P17.6 Risk-Adjusted Discount Rates. One-Hour Dryclean, Inc., is contemplating replacing an obsolete dry-cleaning machine with one of two innovative pieces of equipment. Alternative 1 requires a current investment outlay of $25,373, whereas alternative 2 requires an outlay of $24,199. The following cash flows (cost savings) will be generated each year over the new machines’ 4-year lives:

<table>
<thead>
<tr>
<th>Probability</th>
<th>Cash Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative 1</td>
<td></td>
</tr>
<tr>
<td>0.18</td>
<td>$5,000</td>
</tr>
<tr>
<td>0.64</td>
<td>10,000</td>
</tr>
<tr>
<td>0.18</td>
<td>15,000</td>
</tr>
<tr>
<td>Alternative 2</td>
<td></td>
</tr>
<tr>
<td>0.125</td>
<td>$8,000</td>
</tr>
<tr>
<td>0.75</td>
<td>10,000</td>
</tr>
<tr>
<td>0.125</td>
<td>12,000</td>
</tr>
</tbody>
</table>

A. Calculate the expected cash flow for each investment alternative.
B. Calculate the standard deviation of cash flows (risk) for each investment alternative.
C. The firm will use a discount rate of 12 percent for the cash flows with a higher degree of dispersion and a 10 percent rate for the less risky cash flows. Calculate the expected net present value for each investment. Which alternative should be chosen?

P17.7 Certainty Equivalent Method. Tex-Mex, Inc., is a rapidly growing chain of Mexican food restaurants. The company has a limited amount of capital for expansion and must carefully weigh available alternatives. Currently, the company is considering opening restaurants in Santa Fe or Albuquerque, New Mexico. Projections for the two potential outlets are as follows:

<table>
<thead>
<tr>
<th>City</th>
<th>Outcome</th>
<th>Contribution</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albuquerque</td>
<td>Failure</td>
<td>$100,000</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Success</td>
<td>200,000</td>
<td>0.5</td>
</tr>
<tr>
<td>Santa Fe</td>
<td>Failure</td>
<td>$60,000</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Success</td>
<td>340,000</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Each restaurant would require a capital expenditure of $700,000, plus land acquisition costs of $500,000 for Albuquerque and $1 million for Santa Fe. The company uses the 10 percent yield on riskless U.S. Treasury bills to calculate the risk-free annual opportunity cost of investment capital.
A. Calculate the expected value, standard deviation, and coefficient of variation for each outlet’s profit contribution.
B. Calculate the minimum certainty equivalent adjustment factor for each restaurant’s cash flows that would justify investment in each outlet.
C. Assuming that the management of Tex-Mex is risk averse and uses the certainty equivalent method in decision making, which is the more attractive outlet? Why?

P17.8 Decision Trees. Keystone Manufacturing, Inc., is analyzing a new bid to supply the company with electronic control systems. Alpha Corporation has been supplying the systems and Keystone is satisfied with its performance. However, a bid has just been received from Beta Controls, Ltd., a firm that is aggressively marketing its products. Beta has offered to supply systems for a price of $120,000. The price for the Alpha system is $160,000. In addition to an attractive price, Beta offers a money-back guarantee. That is, if Beta’s sys-
tems do not match Alpha’s quality, Keystone can reject and return them for a full refund. However, if it must reject the machines and return them to Beta, Keystone will suffer a delay costing the firm $60,000.

A. Construct a decision tree for this problem and determine the maximum probability that Keystone could assign to rejection of the Beta system before it would reject that firm’s offer, assuming that it decides on the basis of minimizing expected costs.

B. Assume that Keystone assigns a 50 percent probability of rejection to Beta Controls. Would Keystone be willing to pay $15,000 for an assurance bond that would pay $60,000 in the event that Beta Controls fails the quality check? (Use the same objective as in part A.) Explain.

P17.9 Standard Normal Concept. Speedy Business Cards, Inc., supplies customized business cards to commercial and individual customers. The company is preparing a bid to supply cards to the Nationwide Realty Company, a large association of independent real estate agents. Because paper, ink, and other costs cannot be determined precisely, Speedy anticipates that costs will be normally distributed around a mean of $20 per unit (on each 500-card order) with a standard deviation of $2 per unit.

A. What is the probability that Speedy will make a profit at a price of $20 per unit?

B. Calculate the unit price necessary to give Speedy a 95 percent chance of making a profit on the order.

C. If Speedy submits a successful bid of $23 per unit, what is the probability that it will make a profit?

P17.10 Game Theory. Sierra Mountain Bike, Inc., is a producer and wholesaler of rugged bicycles designed for mountain touring. The company is considering an upgrade to its current line by making high-grade chrome alloy frames standard. Of course, the market response to this upgrade in product quality depends on the competitor’s reaction, if any. The company’s comptroller projects the following annual profits (payoffs) following resolution of the upgrade decision:

<table>
<thead>
<tr>
<th>Sierra’s Decision Alternatives</th>
<th>Competitor Upgrade</th>
<th>No Competitor Upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upgrade</td>
<td>$1,000,000</td>
<td>$1,500,000</td>
</tr>
<tr>
<td>Do not upgrade</td>
<td>800,000</td>
<td>2,000,000</td>
</tr>
</tbody>
</table>

A. Which decision alternative would Sierra choose given a maximin criterion? Explain.

B. Calculate the opportunity loss or regret matrix.

C. Which decision alternative would Sierra choose given a minimax regret criterion? Explain.

CASE STUDY

Stock-Price Beta Estimation for the Royal Dutch Petroleum Company

Statisticians use the Greek letter beta to signify the slope coefficient in a linear relation. Financial economists use this same Greek letter \( \beta \) to signify stock-price risk because betas are the slope coefficients in a simple linear relation that links the return on an individual stock to the return on the overall market in the capital asset pricing model (CAPM). In the CAPM, the security characteristic line shows the simple linear relation between the return on individual securities and the overall market at every point in time:

\[
R_p = \alpha_i + \beta_i R_m + \epsilon_i
\]
where $R_{it}$ is the rate of return on an individual security $i$ during period $t$, the intercept term is described by the Greek letter $\alpha$ (alpha), the slope coefficient is the Greek letter $\beta$ (beta) and signifies systematic risk (as before), and the random disturbance or error term is depicted by the Greek letter $\epsilon$ (epsilon). At any point in time, the random disturbance term $\epsilon$ has an expected value of zero. This means that the expected return on an individual stock is determined by $\alpha$ and $\beta$.

The slope coefficient $\beta$ shows the anticipated effect on an individual security's rate of return following a 1 percent change in the market index. If $\beta = 1.5$, then a 1 percent rise in the market would lead to a 1.5 percent hike in the stock price, a 2 percent boost in the market would lead to a 3 percent jump in the stock price, and so on. If $\beta = 0$, then the rate of return on an individual stock is totally unrelated to the overall market. The intercept term $\alpha$ shows the anticipated rate of return when either $\beta = 0$ or $R_{M} = 0$. When $\alpha > 0$, investors enjoy positive abnormal returns. When $\alpha < 0$, investors suffer negative abnormal returns. Investors would celebrate a mutual fund manager whose portfolio consistently generated positive abnormal returns $(\alpha > 0)$. They would fire portfolio managers that consistently suffered negative abnormal returns $(\alpha < 0)$. In a perfectly efficient capital market, the CAPM asserts that investor rates of return would be solely determined by systematic risk and both alpha and epsilon would equal zero, $\alpha = \epsilon = 0$.

As shown in Figure 17.8, managers and investors can estimate beta for individual stocks by using a simple ordinary least-squares regression model. In this simple regression model, the dependent $Y$ variable is the rate of return on an individual stock, and the independent $X$ variable is the rate of return on an appropriate market index. Within this context, changes in the stock market rate of return are said to cause changes in the rate of return on an individual stock. In this example, beta is estimated for the Royal

![Figure 17.8 Stock-Price Beta Estimation for Royal Dutch Petroleum Company (RD)](image-url)
Dutch Petroleum Company (ticker symbol: RD), the holding company for the Royal Dutch/Shell Group of Companies. Present in more than 145 countries and territories worldwide, the Royal Dutch/Shell Group of Companies are engaged in the business of exploration and production of natural gas, electric power, oil products, chemicals, and related products. The price data used to estimate beta for RD were downloaded for free from the Internet at the Yahoo! Finance Web site (Monthly returns for RD and for the Standard & Poor's 500 were analyzed over a 5-year period (60 observations), as shown in Table 17.7. In this case, as predicted by the CAPM, α = 0.0021 = 0. During a typical month when the overall market

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
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<tbody>
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<td>5.36%</td>
<td>1.20%</td>
<td>Nov-01</td>
<td>4.39%</td>
<td>1.20%</td>
</tr>
<tr>
<td>May-04</td>
<td>5.09%</td>
<td>1.21%</td>
<td>Oct-01</td>
<td>4.29%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Apr-04</td>
<td>4.66%</td>
<td>1.21%</td>
<td>Sep-01</td>
<td>4.29%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Mar-04</td>
<td>4.68%</td>
<td>1.21%</td>
<td>Aug-01</td>
<td>4.29%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Feb-04</td>
<td>4.69%</td>
<td>1.21%</td>
<td>Jul-01</td>
<td>4.29%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Jan-04</td>
<td>4.70%</td>
<td>1.21%</td>
<td>Jun-01</td>
<td>4.29%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Dec-03</td>
<td>1.60%</td>
<td>1.21%</td>
<td>May-01</td>
<td>4.83%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Nov-03</td>
<td>1.24%</td>
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<td>Apr-01</td>
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</tr>
<tr>
<td>Oct-03</td>
<td>1.72%</td>
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</tr>
<tr>
<td>Sep-03</td>
<td>1.49%</td>
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</tr>
<tr>
<td>Aug-03</td>
<td>2.09%</td>
<td>1.21%</td>
<td>Jan-01</td>
<td>5.39%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Jul-03</td>
<td>2.27%</td>
<td>1.21%</td>
<td>Dec-00</td>
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</tr>
<tr>
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<td>Nov-00</td>
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</tr>
<tr>
<td>May-03</td>
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<td>Oct-00</td>
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<tr>
<td>Apr-03</td>
<td>1.89%</td>
<td>1.21%</td>
<td>Sep-00</td>
<td>5.01%</td>
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<td>2.73%</td>
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<td>Aug-00</td>
<td>6.17%</td>
<td>1.20%</td>
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<tr>
<td>Feb-03</td>
<td>5.31%</td>
<td>1.21%</td>
<td>Jul-00</td>
<td>5.07%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Jan-03</td>
<td>4.82%</td>
<td>1.21%</td>
<td>Jun-00</td>
<td>5.07%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Dec-02</td>
<td>1.63%</td>
<td>1.21%</td>
<td>May-00</td>
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<td>1.20%</td>
</tr>
<tr>
<td>Nov-02</td>
<td>1.82%</td>
<td>1.21%</td>
<td>Apr-00</td>
<td>5.18%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Oct-02</td>
<td>6.48%</td>
<td>1.21%</td>
<td>Mar-00</td>
<td>5.07%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Sep-02</td>
<td>11.12%</td>
<td>1.21%</td>
<td>Feb-00</td>
<td>4.39%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Aug-02</td>
<td>0.58%</td>
<td>1.21%</td>
<td>Jan-00</td>
<td>5.97%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Jul-02</td>
<td>17.32%</td>
<td>1.21%</td>
<td>Dec-99</td>
<td>5.08%</td>
<td>1.20%</td>
</tr>
<tr>
<td>Jun-02</td>
<td>0.50%</td>
<td>1.21%</td>
<td>Nov-99</td>
<td>5.72%</td>
<td>1.20%</td>
</tr>
<tr>
<td>May-02</td>
<td>5.28%</td>
<td>1.21%</td>
<td>Oct-99</td>
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<td>1.20%</td>
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<tr>
<td>Apr-02</td>
<td>28.98%</td>
<td>1.21%</td>
<td>Sep-99</td>
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<tr>
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<td>Aug-99</td>
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<td>1.20%</td>
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<tr>
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<td>1.21%</td>
<td>Jul-99</td>
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<td>1.20%</td>
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<td>Jan-02</td>
<td>1.94%</td>
<td>1.21%</td>
<td>Jun-99</td>
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<td>1.20%</td>
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<tr>
<td>Dec-01</td>
<td>1.39%</td>
<td>1.21%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CASE STUDY (continued)

return is zero (essentially flat), the return for RD common stockholders is expected to be zero as well. The slope coefficient $\beta = 0.6892$ is statistically significant ($t = 5.47$). There is a meaningful empirical relationship between movement in the overall market and RD stock, at least on a statistical basis. Because $\beta < 1$, RD is less volatile than the overall market. During a month when the overall market rises by 1 percent, RD can be expected to rise by 0.69 percent; during a month when the market falls by 1 percent, RD can be expected to fall by 0.69 percent.

The usefulness of betas as risk measures can be undermined by the fact that the simple linear model used to estimate stock-price beta fails to include other important systematic influences on stock market volatility. In the case of RD, for example, $R^2$ information shown in Figure 17.8 indicates that only 34.03 percent of the total variation in RD returns can be explained by variation in the overall market. This means that 65.97 percent of the variation in weekly returns for RD stock is unexplained by such a simple regression model. Although the amount of explained variation is statistically significant, it may not be economically meaningful in the sense of providing investors with consistently useful risk information.

A. Describe some of the attributes of an ideal risk indicator for stock market investors.

B. On the Internet, go to Yahoo! Finance (or MSN/Money) and download weekly price information over the past year (52 observations) for RD and the S&P 500. Then, enter this information in a spreadsheet like Table 17.7 and use these data to estimate RD’s beta. Describe any similarities or dissimilarities between your estimation results and the results depicted in Figure 17.8.

C. Estimates of stock-price beta are known to vary according to the time frame analyzed; length of the daily, weekly, monthly, or annual return period; choice of market index; bull or bear market environment; and other nonmarket risk factors. Explain how such influence can undermine the usefulness of beta as a risk indicator. Suggest practical solutions.