INSTRUCTOR SOLUTIONS MANUAL

An Introduction to Derivative Securities, Financial Markets, and Risk Management

Robert A. Jarrow
CORNELL UNIVERSITY

Arkadev Chatterjea
THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL

W • W • NORTON & COMPANY • NEW YORK • LONDON

W. W. Norton & Company has been independent since its founding in 1923, when William Warder Norton and Mary D. Herter Norton first published lectures delivered at the People's Institute, the adult education division of New York City's Cooper Union. The firm soon expanded its program beyond the Institute, publishing books by celebrated academics from America and abroad. By midcentury, the two major pillars of Norton's publishing program—trade books and college texts—were firmly established. In the 1950s, the Norton family transferred control of the company to its employees, and today—with a staff of four hundred and a comparable number of trade, college, and professional titles published each year—W. W. Norton & Company stands as the largest and oldest publishing house owned wholly by its employees.

Printed in the United States of America.

Associate media editors: Nicole Sawa and Carson Russell
Production manager: Vanessa Nuttry
Composition by Westchester Publishing Services

W. W. Norton & Company, Inc.
500 Fifth Avenue, New York, N.Y. 10110-0017

wwnorton.com

W. W. Norton & Company Ltd.
Castle House, 75/76 Wells Street, London W1T 3QT

1 2 3 4 5 6 7 8 9 0

TABLE OF CONTENTS

Part IV: Interest Rates Derivatives

CHAPTER 1 Derivatives and Risk Management

1.1. What is a derivative security? Give an example of a derivative and explain why it is a derivative.

ANSWER

A derivative security is a financial contract that derives its value from the price of an underlying asset such as a stock or a commodity, or from the value of an underlying notional variable such as a stock index or an interest rate (see Section 1.1).

Consider a forward contract to trade 50 ounces of gold three months from today at a forward price of $F = \$1{,}500$ per ounce. The spot price of the underlying commodity gold determines this derivative's payoff. For example, if the spot price of gold is $S(T) = \$1{,}510$ per ounce at time $T = 3$ months, then the buyer of this forward contract buys gold worth \$1,510 for \$1,500. Her profit is $[S(T) - F] \times \text{Number of units} = (1{,}510 - 1{,}500) \times 50 = \$500$. This is the seller's loss because derivative trading is a zero-sum game; that is, for each buyer there is a seller.

1.2. List some major applications of derivatives.

ANSWER

Some applications of derivatives:

- They help generate a variety of future payoffs, which makes the market more "complete."
- They enable trades at lower transactions costs.
- Hedgers can use them to cheaply reduce preexisting risk in their economic activities. Speculators can take leveraged positions without tying up too much capital.
- They help traders overcome market restrictions. For example, an exchange may restrict traders from short-selling a stock in a falling market, but a trader can adopt a similar position by buying a put option.
- They promote a more efficient allocation of risk by allowing the risk of economic transactions to be shifted to dealers who can better manage these risks.

- They facilitate the process of price discovery. For example, futures traders, by placing bids and offers to trade various quantities of the underlying commodity at different prices, reveal some of their information, which gets built into the market price of the underlying commodity. Many people watch the futures price to get a sense of the demand and supply situation in the months and years ahead.

1.3. Evaluate the following statement: "Hedging and speculation go hand in hand in the derivatives market."

ANSWER

This statement provides a good description of derivatives market activity. Many traders buy or sell derivatives to hedge some preexisting risk in a portfolio or business. It is often very hard to find counterparties with exactly opposite hedging needs. For this reason, a speculator usually takes the other side of the hedger's trade. Since derivatives trade in zero-supply markets, for each buyer there must be a seller. Speculators make the market more liquid.

Consider an example: A gold mining firm sells 100,000 ounces of gold through a forward contract. The gold mining firm may not find a jewelry manufacturer who wants to simultaneously buy the same quantity of gold on the same future date. So a speculator (who is often a dealer) steps in and becomes the counterparty to the trade providing liquidity to the forward market.

1.4. What risks does a business face?

ANSWER

A business may face a variety of risks such as credit risk, legal risk, operational risk, and regulatory risk. However, there are three major kinds of market risk that affect most businesses: currency risk, interest rate risk, and (in case of nonfinancial companies) commodity price risk (see Section 1.7).

1.5. Explain why financial futures have replaced agricultural futures as the most actively traded contracts.

ANSWER

Before the 1970s, governments succeeded in keeping many macroeconomic variables like exchange rates and interest rates relatively stable. Traders were mostly concerned about commodity price risk and they used agricultural futures to manage this risk.

During the 1970s, many of these macroeconomic variables became volatile. Dismantling of the Bretton Woods system (1971) made exchange rates more volatile. Oil shocks and other supply-side disturbances led to double-digit inflation. Inflation premiums soon got built into interest rates, which increased to double-digit levels and became more volatile.

Exchanges responded to this increased volatility by creating financial futures for hedging these risks. Many of these products became very popular and eventually replaced agricultural futures as the most actively traded contracts. Because the demand for hedging financial risks in larger than the demand for hedging price risks for agricultural commodities, financial futures have become the more actively traded contracts.

1.6. Explain why derivatives are zero-sum games.

ANSWER

A derivative obtains its value from something else: a stock price, an exchange rate, an interest rate, or even an index. Unlike a stock or a bond, a derivative does not have a preexisting supply. Hence, it is described as a "zero-supply" contract. It gets created the moment a trader decides to trade a derivative and another trader accepts the opposite side of the transaction. These traders are called counterparties. Consequently, one counterparty's gain creates a loss of equal magnitude for the other counterparty. Their payoffs, being of equal magnitude, add up to zero. Hence, trading derivatives is a zero-sum game (see Example 1.1).

1.7. Explain why all risks cannot be hedged. Give an example of a risk that cannot be hedged.

ANSWER

Not all risks can be hedged because of moral hazard. For example, a trader would not like to be in a situation where a counterparty's actions affect the outcome. Thus, it is very hard to hedge operational risk, which is the risk of a loss due to events like human error, faulty management, and fraud. Because of moral hazard, no trader (visualize, as an example, an insurance company insuring a bank against operational risk) would trade a "derivative" that pays the counterparty for mistakes like pressing the wrong computer button and entering the wrong trade (see Section 1.7).

1.8. What is a notional variable, and how does it differ from an asset's price?

ANSWER

Notional variables are notions (computed variables) based on asset prices and other quantities. Examples include interest rates, inflation rates, stock indexes, and weather indices. A traded asset, such as a stock, has a price at which it trades in the market. By contrast, a computed stock index, which is an average of stock prices, does not directly trade and does not have its own market price.

1.9. Explain how derivatives give traders high leverage.

ANSWER

A derivative's payoff is determined by the evolution of some commodity's price over a predetermined future time period. One can collect these payoffs by paying a premium in case of options or by posting collaterals or margin deposits in case of forwards and futures. The premium is usually a small fraction of the commodity's price. Collaterals and margins are also a small fraction of the commodity's price because they depend on the past price volatility—an exchange may set the margin for a future contract at less than 5 percent of the commodity price. For these reasons, derivatives provide leverage because these transactions are significantly cheaper or require far less capital commitment than an outright purchase or short sale of the commodity. Leverage is the amount of borrowing implicit in a derivative position. This leverage implies that for small changes in the underlying security's price, large changes in the derivative security's price results.

1.10. Explain the essence of Merton Miller's argument explaining what spurs financial innovation.

ANSWER

Merton Miller argued in a 1986 article that *regulations and taxes cause financial innovation*. The reason is that derivative securities are often created to circumvent government regulations that prohibit otherwise lucrative transactions. And because most countries tax income from different sources (and uses) at different rates, financial innovations are often designed to save tax dollars as well. He cites examples like Eurodollars, Eurobonds, and Swaps that were initiated to circumvent restrictive regulations and taxes (see Section 1.2 and Extension 1.1).

1.11. Explain the essence of Ronald Coase's argument explaining what spurs financial innovation.

ANSWER

Ronald Coase argued in the article, "The Nature of the Firm" (1937), that transactions incur costs, which come from "negotiations to be undertaken, contracts . . . to be drawn up, inspections . . . to be made, arrangements . . . to be made to settle disputes, and so on," and firms often appear to lower these transactions costs. With respect to financial markets, market participants often trade where they can achieve their objectives at minimum costs. Financial derivatives are often created so that these costs are minimized as well.

An example is the migration of traders during the 1990s from Treasury securities and their associated derivatives to Eurodollars and their related derivatives that are free from Fed regulations, are unaffected by peculiarities of the Treasury security auction cycle, and have lower liquidity costs.

Another example would be exchange-traded funds (ETFs), which are securities giving the holder fractional ownership rights over a basket of securities. An ETF's structure allows it to lower many kinds of transactions costs vis-à-vis a mutual fund with a similar investment objective. Unlike a mutual fund, which has daily or (at the most) hourly pricing, an ETF behaves much like a common stock—it trades continuously during trading hours, it can be shorted, it may be traded on margin, and it can even have derivatives (such as calls and puts) written on them.

1.12. Does more volatility in a market lead to more use of financial derivatives? Explain your answer.

ANSWER

Yes, increased volatility leads to more use of financial derivatives. More volatility increases the risk of a trader's portfolio or a firm's balance sheet. This risk is often unwanted, and it can be hedged with derivatives. This hedging motive in the presence of volatile prices generates the demand for the trading of derivatives. Examples of this include options trading on stock market indexes, foreign currencies, interest rates, and commodities. Without price volatility, the vast derivatives market would disappear leaving behind just credit derivatives for managing credit risk. Note, however, that although volatility is the lifeblood of derivatives trading, extreme volatility sometimes destroys markets (as it happens during times of market crashes).

1.13. When the international banking regulators defined risk in their 1994 report, what definition of risk did they have in mind? How does this compare with the definition of risk from modern portfolio theory?

ANSWER

The international regulators wanted to cover all aspects of risk associated with security trading: market risk, credit risk (including settlement risk), liquidity risk, operational risk, and legal risk. The last four definitions of risk deal with the nitty-gritty real-world problems of implementing a derivatives trade.

The definition of risk given in connection with the capital asset pricing model and modern portfolio theory looks at portfolio risk, both diversifiable and nondiversifiable, caused by the randomness in asset prices. The randomness in asset prices usually considered is that due to market risk, which is essential for understanding an investor's risk-return trade-off. This definition is more restrictive than the regulators' definition.

1.14. What's the difference between real and financial assets?

ANSWER

Real assets include land, buildings, machines, and commodities. Financial assets include stocks, bonds, currencies, which are claims on real assets. Both real and financial assets have tangible values. Both real and financial assets have derivatives traded on them.

1.15. Explain the differences between market risk, credit risk, liquidity risk, and operational risk.

ANSWER

See the Basel Committee's *Risk Management Guidelines for Derivatives* (July 1994) for definitions of these risks:

- *Market risk* is the risk to an institution's financial condition resulting from adverse movements in the level or volatility of market prices.
- *Credit risk* (including settlement risk) is the risk that a counterparty will fail to perform on an obligation.
- *Liquidity risk* can be of two types: one related to specific assets and the other related to the general funding of the institution's activities. The former is the risk that an institution may not be able to easily unwind a particular asset position near the previous market price because of market disruptions. Funding liquidity risk is the risk that the institution will be unable to meet its payment obligations in the event of margin calls.
- *Operational risk* (also known as operations risk) is the risk that deficiencies in information systems or internal controls will result in unexpected loss. This risk is associated with human error, system failures, and inadequate procedures and controls. (*Legal risk* is the risk that contracts are not legally enforceable or documented correctly. We include this as part of operational risk.)

1.16. Briefly present Warren Buffett's and Alan Greenspan's views on derivatives.

ANSWER

Although supportive of plain vanilla derivatives that are used by farmers and other economic agents to hedge input and output price risks, Warren Buffett expressed a strong dislike for complex over-the-counter derivatives. In 2002, he even characterized them as "time bombs, both for the parties that deal in them and the economic system." This prophecy proved to be correct in light of large derivatives-related losses suffered by financial institutions during 2007 and 2008, which contributed to the severe economic downturn. Interestingly, in 2008 Buffett's company sold 251 long dated European put options in the over-the-counter market because they were attractively priced.

By contrast, former Fed chairman Alan Greenspan (served 1987–2006) opined in a 1999 speech that derivatives "unbundle" risks by carefully measuring and allocating them "to those investors most able and willing to take it," a phenomenon that has contributed to a more efficient allocation of capital. Greenspan reversed his position somewhat before Congress in 2008 when he testified that he "had put too much faith in the self-correcting power of free markets and had failed to anticipate the self-destructive power of wanton mortgage lending."

1.17. Consider the situation in sunny Southern California in 2005, where house prices have skyrocketed over the last few years and are at an all-time high. Nathan, a software engineer, buys a second home for $1.5 million. Five years back, he bought his first home in the same region for $350,000 and financed it with a thirty-year mortgage. He has paid off $150,000 of the first loan. His first home is currently worth $900,000. Nathan plans to rent out his first home and move into the second. Is Nathan speculating or hedging?

ANSWER

Nathan is speculating. He has assumed the price risk on two properties whose total value is $1.5 million plus $0.9 million, or $2.4 million.

1.18. During the early years of the new millennium, many economists described the past few decades as the period of the Great Moderation. For example,

- an empirical study by economists Olivier Blanchard and John Simon found that "the variability of quarterly growth in real output (as measured by its standard deviation) had declined by half since the mid-1980s, while the variability of quarterly inflation had declined by about two thirds."
- an article titled "Upheavals Show End of Volatility Is Just a Myth" in the *Wall Street Journal*, dated March 19, 2008, observed that an important measure of stock market volatility, "the Chicago Board Options Exchange's volatility index, had plunged about 75% since October 2002, the end of the latest bear market, through early 2007"; the article also noted that "in the past 25 years, the economy has spent only 16 months in recession, compared with more than 60 months for the previous quarter century."

a. What were the explanations given for the Great Moderation?
b. Does the experience of the US economy during January 2007 to December 2010 still justify characterizing this as a period of Great Moderation?

Report (1) quarterly values for changes in the gross domestic product, (2) quarterly values for changes in the inflation rate, and (3) the volatility VIX Index value during this period to support your answer.

ANSWER

a. The chairman of the Federal Reserve System, Ben Bernanke, in a 2004 speech provided three explanations for the Great Moderation: structural change (changes in economic institutions, technology, or other features of the economy), improved macroeconomic policies, and good luck ("the shocks hitting the economy became smaller and more infrequent").

b. Data presented in the following table suggests that January 2007 to December 2010 cannot be considered a period of "Great Moderation"; rather, this period is considered to belong to the "Great Recession." The table reports:

1. Quarterly values for changes in the gross domestic product.
2. Quarterly values for changes in the inflation rate (which we have calculated from the CPI values, assuming 1982–84 = 100).
3. Volatility index VIX's value at the end of each quarter during January 2007 to December 2010.

Quarters	GDP Percent Change (based on current dollars)	GDP Percent Change (based on chained 2005 dollars)	Consumer Price Index	Annual Inflation Rate (measured over each quarter)	Date	VIX at Close on the Last Trading Day of the Quarter
			201.8			
2007q1	5.2	0.5	205.352	7.0406	3/30/2007	14.64
2007q2	6.5	3.6	208.352	5.8436	6/29/2007	16.23
2007q3	4.3	3.0	208.49	0.2649	9/28/2007	18
2007q4	3.6	1.7	210.036	2.9661	12/31/2007	22.5
2008q1	0.6	–1.8	213.528	6.6503	3/31/2008	25.61
2008q2	4.0	1.3	218.815	9.9041	6/30/2008	23.95
2008q3	–0.6	–3.7	218.783	–0.0585	9/30/2008	39.39
2008q4	–8.4	–8.9	210.228	–15.6411	12/31/2008	40
2009q1	–5.2	–6.7	212.709	4.7206	3/31/2009	44.14
2009q2	–1.1	–0.7	215.693	5.6114	6/30/2009	26.35
2009q3	1.9	1.7	215.969	0.5118	9/30/2009	25.61
2009q4	4.9	3.8	215.949	–0.0370	12/31/2009	21.68
2010q1	5.5	3.9	217.631	3.1156	3/31/2010	17.59

Quarters	GDP Percent Change (based on current dollars)	GDP Percent Change (based on chained 2005 dollars)	Consumer Price Index	Annual Inflation Rate (measured over each quarter)	Date	VIX at Close on the Last Trading Day of the Quarter
2010q2	5.4	3.8	217.965	0.6139	6/30/2010	34.54
2010q3	3.9	2.5	218.439	0.8699	9/30/2010	23.7
2010q4	4.2	2.3	219.179	1.3551	12/31/2010	17.75

The data was retrieved on March 8, 2012, from the following sources:

1. Gross Domestic Product: percent change from preceding period, from www.bea.gov/national /index.htm#gdp. (*Chain-weighted indexes* use "up-to-date weights in order to provide a more accurate picture of the economy, to better capture changes in spending patterns and in prices, and to eliminate the bias present in fixed-weighted indexes," from "Chained-Dollar Indexes: Issues, Tips on Their Use, and Upcoming Changes," by J. Steven Landefeld, Brent R. Moulton, and Cindy M. Vojtech in *Survey of Current Business* [Nov 2003].)
2. Consumer Price Index History Table: table containing history of CPI-U in the United States, retrieved from www.bls.gov/cpi/tables.htm; All Urban Consumers (CPI-U) US city average (1982–84 = 100).
3. VIX Historical Price Data from New Methodology: VIX data for 2004 to present (updated daily); retrieved from www.cboe.com/micro/vix/historical.aspx.

1.19. Drawing on your experience, give examples of two risks that one can easily hedge and two risks that one cannot hedge.

ANSWER

A gold mining company can easily hedge the output price risk of its gold by selling gold futures. A manufacturer of silver jewelries can hedge input price risk by buying silver futures.

A cell phone manufacturer cannot hedge the risk that a new model of mobile phones that it developed will sell well. A firm cannot hedge operational risks like the risk of a loss due to human error, faulty management, and fraud.

1.20. Download Form 10-K filed by P&G from the company's website or the US Securities and Exchange Commission's website. Answer the following questions based on a study of this report:

a. What are the different kinds of risks to which P&G is exposed?
b. How does P&G manage its risks? Identify and state the use of some derivatives in this regard.
c. Name some techniques that P&G employs for risk management.
d. Does P&G grant employee stock options? If so, briefly discuss this program. What valuation model does the company use for valuing employee stock options?

ANSWER

The 2011 Annual Report was retrieved on March 11, 2012, from the Procter & Gamble (P&G) website: www.pg.com/en_US/investors/index.shtml. Information provided on page 50 under section "Other Information," subsection "Hedging and Derivative Financial Instruments" and on page 60, "Note 5: Risk Management Activities and Fair Value Measurements," helps answers these questions.

a. Being a "multinational company with diverse product offerings," P&G is exposed to "market risks, such as changes in interest rates, currency exchange rates and commodity prices." And it is exposed to risks that hinder smooth completion of a transaction like credit risk. As with all firms, it is also exposed to operational risk.

b. P&G manages its risks by:

- Evaluating exposures on a "centralized basis to take advantage of natural exposure correlation and netting."
- Except within financing operations, leveraging its "broadly diversified portfolio of exposures as a natural hedge" and prioritizing "operational hedging activities over financial market instruments."
- Entering into different financial transactions (read: derivatives) in case it decides to "further manage volatility associated with the net exposures." It accounts for these transactions by "using the applicable accounting guidance for derivative instruments and hedging activities."
- Monitoring interest rate, currency rate, and commodity derivatives positions using CorporateManager™ value-at-risk model using a one-year horizon and a 95 percent confidence level.
- Controlling credit risk by following its "counterparty credit guidelines" and trying to trade only with "investment grade financial institutions"; it monitors counterparty exposures daily and reviews "downgrades in counterparty credit ratings" on a timely basis.

Some of the derivatives used by P&G for risk management purposes are:

- Interest rate risk management. P&G manages interest cost by using a combination of fixed-rate and variable-rate debt. It uses interest rate swaps to hedge risks on these debt obligations.
- Foreign currency risk management. Because P&G has operations in many nations, its revenue and expenses are impacted by currency exchange rates. The primary objective of the company's currency hedging activities is "to manage the volatility associated with short-term changes in exchange rates." P&G primarily uses forward contracts with maturities of less than eighteen months. It also uses some currency options and currency swaps with maturities of up to five years for managing foreign exchange risk.
- Commodity risk management. P&G spends significant amounts on raw materials whose prices can become volatile due to "weather, supply conditions, political and economic variables and other unpredictable factors." It manages volatility by using fixed price contracts and also by trading futures, options, and swap contracts.

c. P&G uses market valuation, sensitivity analysis, and value-at-risk modeling for risk management.

d. P&G grants stock options and restricted stock awards to key managers and directors and to a small number of employees.

Some key features of the employee stock options program are:

- Option's exercise price is set at the market price of the underlying shares on the date of the grant.
- Key manager stock option awards: Such awards granted since September 2002 are vested after three years and have a ten-year life.
- Company director stock option awards. Such awards are in the form of restricted stock and restricted stock units.
- Employee stock option awards. P&G also gives some employees minor stock option grants and RSU grants with substantially similar terms.

To calculate the compensation expense for stock options granted, P&G utilizes a binomial lattice-based valuation model. (These models are discussed in chapters 17 and 18.)

CHAPTER 2 Interest Rates

2.1. The interest rate is 5 percent per year. Compute the six-month zero-coupon bond price using a simple interest rate.

ANSWER

The simple interest rate is $i = 0.05$ per year. The time to maturity is $T = 0.5$ year. Using expression (2.4c) of Result 2.3 of chapter 2, the six-month dollar return is

$$1 + R(0.5) = (1 + i \times T) = (1 + 0.05 \times 0.5) = \$1.0250.$$

The six-month zero-coupon bond price is

$$B(0.5) = 1/[1 + R(0.5)] = 1/1.025 = \$0.9756.$$

2.2. The interest rate is 5 percent per year. Compute the six-month zero-coupon bond price using a compound interest rate with monthly compounding.

ANSWER

The compound interest rate is $i = 0.05$ per year. The time to maturity is $T = 0.5$ year. The number of times interest is compounded every year is $m = 12$. Using expression (2.3b) of Result 2.2 of chapter 2, the six-month dollar return is

$$1 + R(0.5) = [1 + (i/m)]^{mT} = [1 + (0.05/12)]^{12 \times 0.5} = \$1.0253.$$

Six-month zero-coupon bond price is

$$B(0.5) = 1/[1 + R(0.5)] = \$0.9754.$$

2.3. The interest rate is 5 percent per year. Compute the six-month zero-coupon bond price using a continuously compounded interest rate.

ANSWER

The continuously compounded interest rate is $r = 0.05$ per year. The time to maturity is $T = 0.5$ year. Using expression (2.4d) of Result 2.3 of chapter 2, the six-month dollar return is

$$1 + R(0.5) = e^{rT} = e^{0.05 \times 0.5} = 1.025315.$$

The six-month zero-coupon bond price is

$$B(0.5) = 1/[1 + R(0.5)] = \$0.9753099.$$

2.4. The interest rate is 5 percent per year. Compute the six-month zero-coupon bond price using a banker's discount yield (the zero-coupon bond is a US T-bill with 180 days to maturity).

ANSWER

Expression (2.7b) of chapter 2 gives the T-bill price as

$$\begin{aligned} B(0.5) &= [1 - (\text{Banker's discount yield}) \times T/360] \\ &= 1 - 0.05 \times (180/360) \\ &= \$0.9750. \end{aligned}$$

2.5. What is a fixed-income security?

ANSWER

Bonds or loans are called fixed-income securities because they make interest and principal repayments according to a fixed schedule.

The next three questions are based on the following table, where the interest rate is 4 percent per year, compounded once a year.

Time (in years)	Cash Flows (in dollars)
0 (today)	–105
1	7
2	9
3	108

2.6. Compute the present value of the preceding cash flows.

ANSWER

Let us write the cash flow at time T as $C(T)$, today's zero-coupon bond price for a bond maturing at time T as $B(T)$, and the dollar return over time T for \$1 invested today as

$1 + R(T)$, where time T stand for times 0 (today), 1, 2, and 3 years.

As the interest rate is 4 percent per year, compounded once a year, dollar return and zero-coupon bond prices are computed as follows:

$1 + R(1) = 1 + 0.04 = 1.04,$
$1 + R(2) = [1 + R(1)]^2 = 1.0816,$
$B(1) = 1 / [1 + R(1)] = 0.961538,$
$B(2) = 1 / [1 + R(2)] = 0.924556,$
and so on.

These values are reported in the following table:

Time	Dollar Return (notation)	Dollar Return (values)	Zero-Coupon Bond (notation)	Zero-Coupon Bond (values)	Cash Flow (notation)	Cash Flow (values)
0	$1 + R(0)$	1	$B(0)$	1	$C(0)$	–105
1	$1 + R(1)$	1.04	$B(1)$	0.961538462	$C(1)$	7
2	$1 + R(2)$	1.0816	$B(2)$	0.924556213	$C(2)$	9
3	$1 + R(3)$	1.124864	$B(3)$	0.888996359	$C(3)$	108

The present value of the above cash flows is given by

$$\sum_{T=0}^{3} B(T)C(T) = B(0)C(0) + B(1)C(1) + B(2)C(2) + B(3)C(3)$$
$$= 1 \times (-105) + 0.9615 \times 7 + 0.9246 \times 9 + 0.8890 \times 108$$
$$= 6.0634 \text{ or } \$6.06.$$

2.7. Compute the future value of the preceding cash flows after three years.

ANSWER

The future value of the cash flows (given in the table) in three years is obtained by multiplying the present value determined in 2.6 by the three-period dollar return (which is the value of \$1 invested today for three years):

$6.0634 \times [1 + R(3)] = 6.0634 \times 1.1249 = 6.8205$ or \$6.82.

2.8. What would be the fair value of the preceding cash flows after two years?

ANSWER

The future value of the cash flows (given in the table) in two years is obtained by multiplying the present value determined in 2.6 by the two-period dollar return:

$$6.0634 \times [1 + R(2)] = 6.0634 \times 1.0816 = 6.5582 \text{ or } \$6.56.$$

Alternatively this is obtained by discounting the cash flow value determined in 2.7 by the one-period dollar return:

$$6.8205 / 1.04 = \$6.56.$$

2.9. If the price of a zero-coupon bond maturing in three years is \$0.88, what is the continuous compounded rate of return?

ANSWER

Result 2.4 of chapter 2 gives the continuously compounded rate of return as

$$r = (1/T)log(1/B) = (1/3)log(1/0.88) = 0.0426 \text{ or } 4.26 \text{ percent.}$$

2.10. What are the roles of the primary dealers in the US Treasury market?

ANSWER

The primary dealers (like BNP Paribas, Barclays, Cantor Fitzgerald, and Citigroup) are large financial firms with whom the New York Fed buys and sells Treasuries to conduct open market operations that fine-tune the US money supply. These firms regularly participate in Treasury securities auctions and provide information to the Fed's open-market trading desk (see Section 2.6).

2.11. What is the when-issued market with respect to US Treasuries? What role does this market play in helping the US Treasury auction securities?

ANSWER

A week or so before a Treasury securities auction, the Treasury announces the size of the offering, the maturities, and the denominations of the auctioned Treasuries. The Treasury permits forward trading of Treasury securities between the announcement and the auction, and the to-be-auctioned issue trades "when, as, and if issued." Traders take positions in this when-issued market and a consensus price emerges. The traders in the when-issued market fulfill their commitments after the Treasuries become available through the auction. Thus, the when-issued market helps in price discovery and spreads the demand over seven to ten days, which leads to a smooth absorption of the securities by the market (see Section 2.7).

2.12. What is the difference between on-the-run and off-the-run Treasuries?

ANSWER

Newly auctioned Treasuries are called on-the-run Treasuries. Off-the-run Treasuries are those issued in prior auctions. On-the-run Treasuries tend to be more liquid market with a lower spread than off-the-run issues.

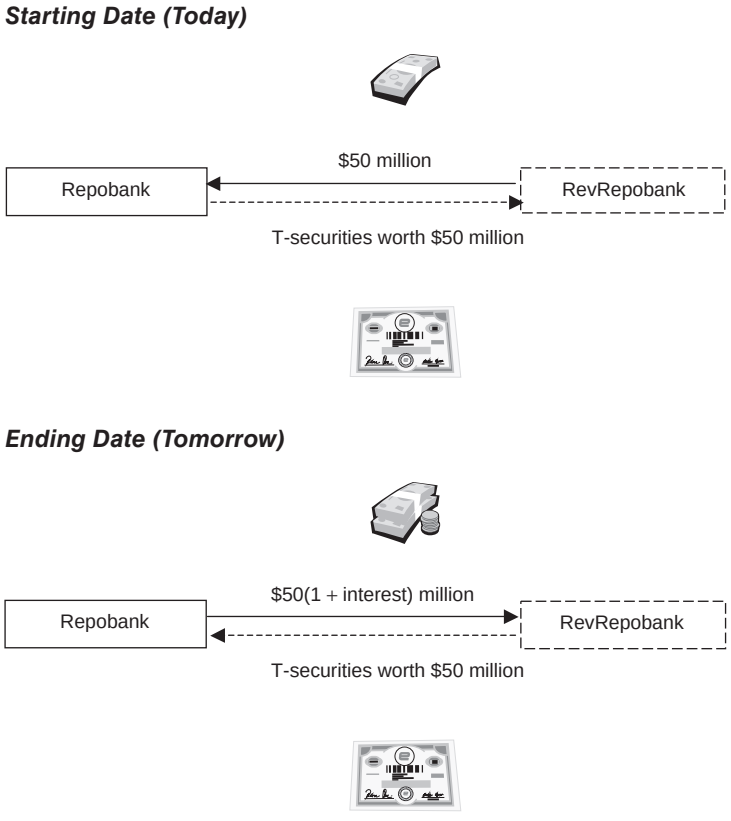
2.13. What is a repurchase agreement? Explain your answer with a diagram of the transaction.

ANSWER

A repurchase agreement (also known as a repo, RP, or sale and repurchase agreement) involves the sale of securities together with an agreement that the seller buys back (repurchases) the securities at a later date at a predetermined price.

Consider an example: suppose Repobank takes $50 million from RevRepobank and sells RevRepobank Treasury securities worth a little more. The next day Repobank repurchases those securities at a slightly higher price. The extra amount determines an annual interest rate known as the repo rate. Thus a repurchase agreement is a short-term loan that is backed by high quality collateral (see the next figure). If Repobank defaults, then RevRepobank keeps the securities. If RevRepobank fails to deliver the securities instead, then Repobank keeps the cash longer; the repo is extended by a day, but the terms remain the same (see Extension 2.4 for further examples and discussion).

An Overnight Repo and a Reverse Repo Transaction



2.14. What is a Treasury STRIPS? What benefits do the trading of Treasury STRIPS provide?

ANSWER

US Treasury STRIPS (Separate Trading of Registered Interests and Principal of Securities) are artificially created zero-coupon bonds. They are created by selling the principal or the interest payments on a Treasury security (an eligible T-note, or a T-bond, or a Treasury inflation-protected security) separately. The claims on these cash flows are individual zero-coupon bonds. The Treasury does not create these securities by itself. It allows certain eligible traders (financial instutions, brokers, and dealers of government securities) to create them, and it also allows traders to reconstruct the original Treasury security by collecting and combining the relevant individual STRIPS.

STRIPS have several benefits. They make Treasuries more attractive to investors leading to greater demand, higher prices, lower yields, and cheaper financing of the national debt. For example, compared to the demand for purchasing a thirty-year bond with sixty cash flows, there is greater demand for the same bond with the added flexibility that these cash flows can be sold as STRIPS. This is because different investors need zeros of different maturities and this increases the demand for the original security.

Moreover, STRIPS help to identify the term structure of interest rates—a graph that plots the interest rate on bonds (yield) against the time to maturity. These graphs are useful for managing interest rate risk (see Section 2.8 and discussions in part IV of the book).

2.15. Explain how bbalibor is computed by the BBA.

ANSWER

The major London banks handle deficit or surplus funds by borrowing or lending deposits of different maturities in this market. A bank with surplus funds lends to another bank for a fixed time period at the London Interbank Offered Rate (libor). These rates may change minute by minute, and they may vary from bank to bank, but competition ensures that they are almost nearly the same at any given point in time.

The British Bankers' Association (BBA) collects libor quotes from sixteen major banks for Eurodollar deposit maturities ranging from overnight to a year. The BBA computes a trimmed average of these libor quotes to compute an index known as bbalibor. The contributing banks are selected on the basis of: (1) the scale of their market activity, (2) their credit rating, and (3) their perceived expertise in the currency concerned. Soon after 11 am London time on every trading day, banks submit confidential annualized interest rate quotes for various currencies and maturities to BBA's agent, Thomson Reuters. Thomson Reuters: (1) checks the data, (2) discards the highest and lowest 25 percent of submissions, and (3) uses the middle two quartiles to calculate a trimmed arithmetic mean. It publishes and widely distributes the bbalibor indexes along with the individual banks' quotes by 12 noon (see chapter 2, Extension 25.2: "Alleged Manipulation of Bbalibor during 2007–9" for recent non-competitive behavior in the submission of libor quotes).

2.16. What is a Eurodollar deposit, and what is a TED spread?

ANSWER

Eurodollars are US dollar deposits held outside the United States in a foreign bank or a subsidiary of a US bank. Eurodollar deposits are highly popular in the global markets due to two benefits: they are dollar deposits and they are free from US jurisdiction.

The BBA collects libor quotes and computes trimmed averages known as bbalibor. Due to credit risk, the bbalibor for Eurodollars has a higher value than a similar maturity Treasury security. Their difference goes by the name of TED (Treasury-Eurodollar) spread.

2.17. What is the difference between Treasury bills, notes, and bonds? What are TIPS, and how do they differ from Treasury bills, notes, and bonds?

ANSWER

The US Treasury issues debt securities with maturities of one year or less in the form of zero-coupon bonds that do not pay any interest but pay back the principal at maturity. It calls these securities Treasury bills. It also sells coupon bonds that pay fixed interest (coupons) every six months and a principal amount (par or face value) at maturity. Coupon bonds with original maturity of two to ten years are called Treasury notes while those with original maturity of more than ten years up to a maximum of thirty years are called Treasury bonds.

Investors in Treasury bills, notes, and bonds receive cash flows that remain fixed over the security's life. The Treasury also sells inflation-indexed bonds called TIPS (Treasury Inflation Protected Securities), which are coupon bonds with maturities of five, ten, and thirty years. TIPS guarantee a fixed real rate of return (which is the nominal rate of return in dollar terms minus the inflation rate as measured by the consumer price index [CPI] over their life). This is done by adjusting the principal of the bond each year by changes in the US CPI. Each year the coupon payment is determined by multiplying the adjusted (and increasing) principal by the real rate of return. Ordinary Treasury notes and bonds do not have this CPI adjustment (see Section 2.8).

2.18. You bought a stock for \$40, received a dividend of \$1, and sold it for \$41 after five months. What is your annualized arithmetic rate of return?

ANSWER

Assuming five months has $T = 5 \times 30 = 150$ days, Result 2.1 of chapter 2 gives

$$\begin{aligned}
&\textit{Annualized rate of return} \\
&= \left(\frac{365}{T}\right) \times \left(\frac{\textit{Selling price} + \textit{Income} - \textit{Expenses} - \textit{Buying price}}{\textit{Buying price}}\right) \\
&= \left(\frac{365}{150}\right) \times \left(\frac{41 + 1 - 40}{40}\right) \\
&= 0.1217 \text{ or } 12.17 \text{ percent.}
\end{aligned}$$

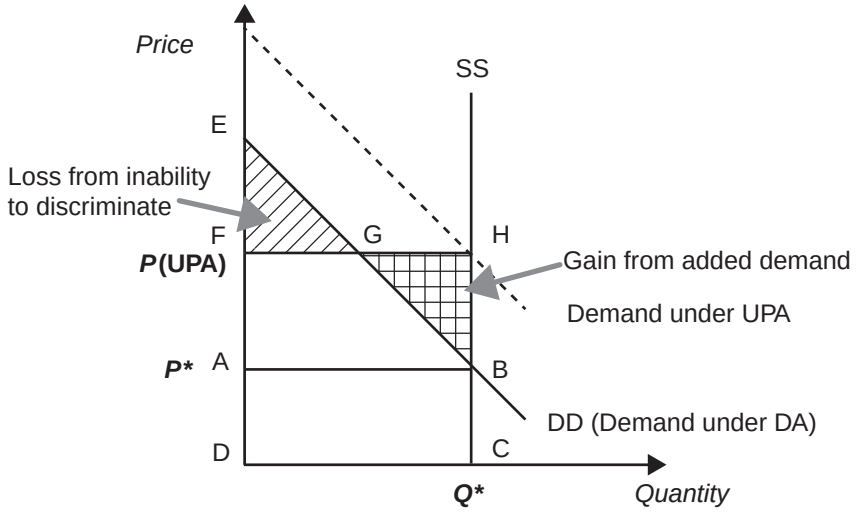
2.19. Using the standard demand–supply analysis of microeconomics, explain how a uniform price auction can generate more or less revenue than a discriminatory auction.

ANSWER

Suppose that a fixed quantity Q^* units of a good is offered for sale. Its supply curve is depicted in the diagram by the vertical line SS. The demand is shown by a downward sloping demand curve DD, which cuts the supply curve at P^*. In the demand-supply analysis, buyers pay the equilibrium price P^* and an equilibrium quantity Q^* gets sold.

Ideally, the seller would like to make each buyer pay the maximum amount he is willing to pay (called a buyer's "reservation price"). To do this the seller can set up a "discriminatory auction" (DA) where successful bidders pay the amount they have bid. Assume that this demand curve is depicted by DD. In a DA, the buyer with the highest reservation price gets the first unit (which would be approximately equal to the intercept of the DD curve on the vertical axis [point E]), the next person pays a slightly lower price and acquires the second unit, and so on. Thus the seller captures the "consumer surplus" (given by the triangle ABE), which is the extra amount that the consumers are willing to pay over and above the revenue $P^* \times Q^*$ given by the rectangle ABCD.

Discriminatory and Uniform Price Auctions (UPA) in a Demand-Supply Framework



However, a discriminatory auction has a "winner's curse" problem. If a bidder wants to make sure that she "wins" the auctioned item, then she is likely to overbid and overpay. This leads to more cautious bid submissions by the auction participants. It also creates an environment conducive to collusion and information sharing among the bidders.

A uniform price auction is an alternate format where all successful bidders pay the highest losing bid (or the lowest winning bid). Wouldn't a UPA lower revenue because the seller now gets just the rectangle ABCD? Not necessarily. A change in the rules of the auction game can cause a change in behavior. A UPA is likely to lead to more aggressive bidding due to elimination of the winner's curse. For example, even if you overbid at $100, if all successful bidders are paying $50 then you also pay $50. Assume that the DD curve in a UPA shifts

outward and is given by the dashed line in the figure (Demand under UPA). *P*(UPA) is the price paid by all successful bidders. The total revenue is given by the rectangle FHCD.

Which auction format raises more revenue? The seller in a DA gets revenue that equals the quadrilateral EBCD while the seller in a UPA gets the rectangle FHCD. By moving from a DA to a UPA, the auctioneer gives up the triangle with stripes inside (EGF) but gains the triangle that is cross-hatched inside (GHB). The area EGF is the loss from the inability to discriminate across bidders while the area GHB is the gain added from the shift in demand due to the changed auction mechanism. The revenue implication is unclear. It depends on which triangle is bigger. The key insight of this analysis is that the bidders' actions are influenced by the rules of the game.

2.20. Suppose that you are planning to enroll in a master's degree program two years in the future. Its cost will be the equivalent of $160,000 to enroll. You expect to have the following funds:

- From your current job, you can save $5,000 after one year and $7,000 after two years.
- You expect a year-end bonus of $10,000 after one year and $12,000 after two years.
- Your grandparents have saved money for your education in a tax-favored savings account, which will give you $18,000 after one year.
- Your parents offer you the choice of taking $50,000 at any time, but you will get that amount deducted from your inheritance. They are risk-averse investors and put money in ultrasafe government bonds that give 2 percent per year.

The borrowing and the lending rate at the bank is 4 percent per year, daily compounded. Approximating this by continuous compounding, how much money will you need to borrow when you start your master's degree education two years from today?

ANSWER

At time $t = 1$ year, you expect to have $C_1(1) = \$5{,}000$ (savings) + $10,000 (bonus) + $18,000 (grandparents) = $33,000. Invested at 4 percent, this becomes after another year

$$C_1(2) = C_1(1) \times \textit{One-year dollar return} = 33{,}000\, e^{rT} = 33{,}000 \times e^{0.04 \times 1} = \$34{,}346.76.$$

At time $t = 2$ years, you will have

$$C_2(2) = \$7{,}000 \text{ (savings)} + \$12{,}000 \text{ (bonus)} = \$19{,}000.$$

As your parents' investment earns just 2 percent, take $50,000 now and invest this at 4 percent for two years. This becomes after two years

$$C_3(2) = C_3(0) \times \textit{Two-year dollar return} = 50{,}000\, e^{rT} = 50{,}000 \times e^{0.04 \times 2} = \$54{,}164.35.$$

Thus you expect to have after two years

$$C(2) = C_1(2) + C_2(2) + C_3(2) = \$107{,}511.11.$$

As you need $160,000 in two years, you need to borrow 160,000 – 107,511.11 = $52,488.89 at the time.