Chapter 8 Options

Chapter Overview

The CitiGroup in Australia launched warrants for its shares in late 2012, to join a growing list of companies that have been increasing their capital raisings with option-based products. The particular details of the CitiFirst warrants listed in the extract generally encourage investors to consider them for their portfolios, but the extract does conclude with some warnings about limits on the entitlements of warrant-holders. So, how was the value of the investments in the financial institution determined using the Black and Scholes model? This chapter will introduce the concept of options and the many ways they are used in today's financial world.

***What Companies Do* Discussion Questions:**

1. Why are the potential benefits of the warrants attractive to investors?
2. What precautions should the investors take to avoid capital losses?

This chapter covers:

8-1. Options Vocabulary
8-2. Option Payoff Diagrams
8-3. Qualitative Analysis of Option Prices
8-4. Option Pricing Models
8-5. Options in Corporate Finance

Technology

1. **Smart Video.** Myron Scholes of Stanford University and chairman of Oak Hill Platinum Partners (and also half of the Black-Scholes option pricing model) talks about the extensive growth in the options market over the past 30 years.

2. **Smart Concepts.** A step-by-step explanation of the use of the put-call parity equations.

3. **Smart Concepts.** A step-by-step explanation of the binomial option pricing model.

4. **Smart Concepts.** A step-by-step illustration of the Black Scholes option pricing model.

5. **Smart Solutions.** Step-by-step solutions to problems P8-6 and P8-10

After reading this chapter you should be able to:

- describe the basic features of call and put options
- construct payoff diagrams for individual options as well as portfolios of options and other securities
- explain qualitatively what factors are important in determining option prices
- calculate the price of an option, using the binomial model
- list several corporate finance applications of option pricing theory.

Lecture Guide

While options can be viewed as betting on a desired outcome – price up, price down, price stable, price moving within a certain range, etc. – options also can be used as insurance. Using options can in fact decrease, not increase, risk. The market for derivative securities, which includes options, has grown exponentially in recent decades. Options and other derivative securities help complete the markets, by providing securities to meet investors' needs for particular payoffs. In fact, in some markets options trading is greater than trading in the underlying assets.

While options are perhaps more extensively studied in an investments class, they are also an appropriate study topic for a corporate finance course. Risk management is becoming increasing important to corporations. One of the fastest growing upper level management positions is Chief Risk Officer. Options are also used extensively for employee compensation. Companies also issue securities with option characteristics, such as rights offerings, convertible bonds and warrants.

8-1 Options Vocabulary

There are no easy shortcuts to learning and memorising basic options terminology. Showing a clip from the movie 'Trading Places' can lighten the understanding of these concepts and terms. This movie shows clips from the futures market, illustrating the chaotic, loud atmosphere of the trading floor. This section also illustrates the potential high profits from options if the underlying asset moves in the correct direction.

8-1a Option Trading

This section breaks down a simple example of the trading of an option on BHP Billiton shares between two individuals. It explains that not all options are issued by the corporation on its own shares.

- *Student Involvement*: Have the student think of a company where an option would be a good choice for making money or as insurance.

Table 8.1 Option Price Quotes for St Kilda Optics

8-1b Option Prices

This section introduces more terminology, explaining when options are *in, out of, and at the money*. The instructor may wish to use a numerical example, for example, a call option with a strike price of $50 and a current share price of $75 is in the money, while a put option with the same strike price and share price would be out of the money.

This section also details the way options prices are quoted in the financial press. The instructor may want to bring in an *Australian Financial Review* or look at quotes of option prices on the internet, as well. Most financial websites including Yahoo!, Reuters and Bloomberg have options sections.

The *intrinsic value* of an option is its value if exercised immediately. Its additional time value represents the fact that time is valuable – the more time left, the greater the chance that the underlying asset will move in the desired direction, down for put options and up for call options.

8-2 Option Payoff Diagrams

8-2a Call Option Payoffs

Figure 8-1 Payoff of a Call Option with X = $75

The value of options at expiration is best illustrated with 'hockey stick' diagrams which show the payoff at expiration at various levels of underlying asset prices. Students often have trouble reading the payoff diagrams. The instructor may consider creating an option payout scenario and having students create a payoff diagram and then explain it to classmates.

8-2b Put Option Payoffs

Figure 8-2 Payoff of Put Option with X = $75

This section diagrams buying (going long) and selling (going short) with put options and their payoffs. Note that the payoff line is not exactly the same as the line that represents the value of the option at expiration. This is because there is a cost to buying options. The purchaser must pay a premium to purchase the option, which reduces the final payoff.

This section also discusses a *naked option* position. This is a risky but common choice to purchase/sell an option without purchasing a position in the underlying asset.

8-2c Payoffs for Portfolios of Options and Other Securities
Note that put and call options can be combined to create literally any payout pattern desired. For example, Figure 8-3 illustrates a combination of buying a call and buying a put option with the same exercise. This combination pays off when the share price moves either up or down. The option does not pay off when the share price remains stable, it pays off if the asset either has large increases or decreases in value. The investor loses only if the asset price stays stable.

Figure 8.3 Payoff to Portfolio Containing One Call and One Put (*X* = $30)

Additional payoff patterns, like straddles, can be devised by combining options, shares and bonds, and often there are several ways to achieve the same payoff pattern.

Figure 8.4 Payoff Diagrams for Shares and Bonds

These sections illustrate that different combinations of securities can be combined to create the same payoff patterns. Spending time on each of the figures in this section can help students to grasp some of the many ways options can be used to hedge one's position in an investment.

Figure 8.5 Payoff from One Long Share and One Long Put (X=$40)

8-2d Put-Call Parity
The previous sections illustrate the *put-call parity* relationship. This is a relationship that can be used to price a put when the call price is known and vice versa – just rearrange terms of the equation with P, put price on one side to get the put price when the other variables are known, or do the same with C, call price on the left side of the equation. *Put-call parity* allows an investor to translate a call price into a put price and vice versa. If there are any pricing differences between the call and put, an investor can potentially profit from arbitrage opportunities – buy or sell the call or put and earn a riskless profit from the mispricing. Put-call parity explains the relationships between put, call, share and bond values. Put-call parity can also be used to create synthetic options. An investor can create a payoff that looks like a call or a put option by using combinations of shares, bonds, and buying and selling call and put options.

Figure 8.6 Payoff on Portfolio of One Bond (FV=$75) and One Call (X = $75)

8-3 Qualitative Analysis of Option Prices

8-3a Factors that Influence Option Values
The instructor can use the payoff diagrams for options to illustrate the impact of changes in the option pricing variables on option value. For example, if you look at the diagram for the payoff of a call option, the X axis is the value of the underlying asset. As this increases, call option value increases. If the strike price is moved to the right on the X axis, then value decreases – it will take a greater upward change in share price for the call option to be in the money. Time adds value to both put at call prices – more time means more possibilities that something will happen to change the price in the desired direction. For interest rate, think of the definitions of call and put options. A call option is the right to buy an asset. If the investor has not yet purchased the asset, he/she has money to invest that is earning interest. The higher the interest rate, the greater the value of the call option. Similarly, a put option is the right to sell an asset. If the asset is not yet sold, or converted to cash, then it cannot be earning interest rate. The greater the interest rate, the greater the opportunity cost of the put option.

Table 8-2 Prices of Option Contracts on Charybdis Shares, 18 February 2013

Table 8-3 Prices of March Option Contracts on Charybdis Shares

Table 8.4 Prices of Option Contracts on Two Companies, 18 February 2013

Options are primarily written on young, riskier companies, rather than stable, mature companies. Volatility also adds value to both put and call options. Again, the greater the possible deviation from the mean, the greater the opportunity for the option to be in the money. In some respects, this is contradictory. Volatility decreases the value of a share. (More risk means a higher beta, which means a higher share cost, and a higher weighted average cost of capital. A higher discount rate means lower share value.) Decreasing the value of the underlying share decreases call option value. Yet, increasing volatility increases the value of a call option. The answer to this apparent contradiction lies in the fact that a low volatile share might not move enough to become an in-the-money option. Greater volatility means a greater chance of the share price moving in the direction that will create value for the option holder.

8-4 Option Pricing Models

8-4a Binomial Option Pricing

The binomial model is a simplified model that assumes that an asset can take on only one of two values in the future. Looking at these values and the probability of each occurring, you can backtrack and calculate the value of an option on the asset. This model works because it assumes there is no arbitrage – it is always possible to combine the underlying asset with options to create a riskless portfolio.

The following sections detail a step-by-step solution to *a binomial option pricing* problem. This is a subject that may take several examples. After working an example in class, the instructor can divide the class into small groups to practise this skill in solving an end of chapter binomial option pricing problem.

- Step 1: Create a Risk-Free Portfolio
- Step 2: Calculate the Present Value of the Portfolio
- Step 3: Determine the Price of the Option

Figure 8-7 Binomial Option Pricing

8-4b Black and Scholes Model

The Black-Scholes option pricing model was a ground breaking (and Nobel prize-winning) achievement in pricing derivative securities. The Black-Scholes model presents a set of equations using the five variables (share price, exercise price, time to expiration, volatility and risk-free rate) from Chapter 18 that can be used to price options and other derivative securities. The equations look difficult, but can be solved using a calculator and a set of standard normal distribution tables, found in most finance and statistic textbooks. A Black-Scholes problem can be even more easily solved using Excel or using option calculators on the web: http://www.cboe.com/TradTool/OptionCalculator.asp, http://www.blobek.com/black-scholes.html, http://www.numa.com/derivs/ref/calculat/option/calc-opa.htm.

Note that the Black-Scholes model assumes continuous compounding. While this is not true in reality, it is close enough. With the increase in markets around the world, most shares can be traded 24/7 (or reasonably close to continuously.) The model makes options considerably easier to price because four of the five inputs (all except volatility) are readily observable. Volatilities are not as easy to determine. If you use past information to calculate volatility, which past period should you use? Will the past volatility be representative of the future or will volatility change in the future?

Fig. 8-8 Multistage Binomial Trees

Fig. 8.9 Standard Normal Distribution

8-5 Options in Corporate Finance

This section covers employee share options, warrants, and convertibles.

8-5a Employee Share Options

Many companies use share option grants (ESOs) as part of their compensation structure. They are essentially call options that give the employee the right to buy shares in the company for which they work at a specified price. They differ from ordinary call options in several important ways:

- Expiration: ESOs can last up to 10 years while ordinary options typically last only a few months.
- Value: Value can grow until expiration however are limited during certain vesting periods.
- No cash outlay required

ESOs have been under great scrutiny since the fall of many of the financial giants during the last decade and are priced very carefully under ASIC guidelines.

8-5b Warrants and Convertibles

Warrants are securities that are issued by companies and grant investors the right to buy shares at a fixed price for a given period of time. They are very similar to call options but can be issued only by companies. Warrants also increase the number of shares outstanding and have long expiration dates.

A *convertible bond* grants investors the right to receive payment on bonds in the form of shares of the company's underlying equity.

Fig. 8.10 The Value of a Convertible Bond

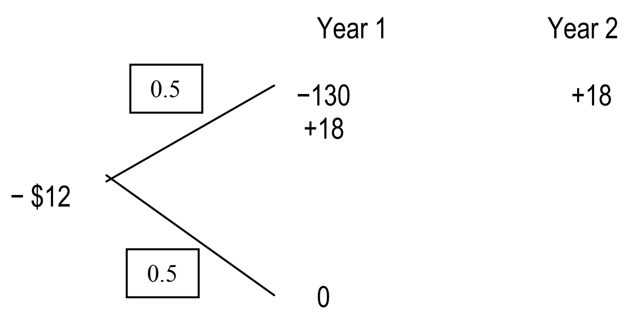
Options Summary

It is becoming more and more common to spot options in projects – real options. A company rarely accepts a project in isolation. There may be an abandonment value to a project if the project is less successful than expected, or an expansion value if the project turns out to be successful.

Enrichment Exercises

Ask students to apply the binomial pricing model in the following example. ABC Company has invented a new technology that will dramatically decrease the cost of new cars. There is a 50% chance the test results will be as expected so that whoever purchases the licence for the technology can generate incremental cash flows of $18 million in perpetuity, beginning at the end of year 1. There is a 50% chance that the technology will not work as expected, only generating cash flows of $6 million in perpetuity. For $12 million, you can purchase an option to buy the technology for $130 million. The required return on the project is 10%.

First, the value of the technology if the test is successful is 18/0.1 = $180 million. The value if the technology is not successful is 6/0.1 = $60 million. At a price of $130 million, no one will buy the technology if the test is unsuccessful. It is a good price if the technology is successful. Multiplying the value of a 'good test' by the probability of its occurring realises: 0.5 x $180 million = $90 million. This is a year 0 cash flow, since the perpetuity formula states that CF_1/r = value in year 0, and $18 million is a year 1 cash flow, if the test is successful. The cost of the investment is a 0.5 probability x $130 = $65 million.



The value to the investor is:

Year 0	Year 1	Year 2
−12	−65	
+90		
+78		

The value of the option = +78 – 65/1.1 = $18.9 million

Show the class a 60-minute PBS special, 'The Trillion Dollar Bet,' which can be ordered from pbs.org. This program talks about the development of the Black-Scholes model, including interviews with Myron Scholes and Robert Merton (who added to the model) who earned Nobel prizes for their work. It discusses the rise and fall of Long Term Capital Management (LTCM), a hedge fund sponsored in part by the option pricing model developers. LTCM earned extraordinarily high returns in its early years, but then lost billions when the market moved in the wrong direction.

Answers to Concept Review Questions

1. The share price and the option premium determine what an investor has to pay to acquire the share or the option in the market. These prices are determined by market forces, while the exercise price of the option is fixed contractually. The exercise or strike price is the price at which the option contract allows an investor to buy the share (or sell it in the case of a put option).

2. A long position means buying an option, and a short position means selling the option. The person who takes the long position has the right to buy (call) or sell (put) the underlying share, while the person who takes the short position is obligated to buy or sell if the option holder chooses to exercise. On a call option, there is no maximum gain on the long position because there is no limit to how high the share price can go. The maximum loss on the long position is simply the call premium. On the short side, just the reverse is true. The maximum gain is the option premium and the maximum loss is unlimited.

3. If the investor decides to exercise the call option, nothing happens to total outstanding ordinary shares.

4. An increase in the strike price would increase the value of a put option, because it would entitle the option holder to sell the shares for a higher price.

5. If an investor who owned a share also bought a put option with a strike price of $50 and sold a call option with a strike price of $50, the resulting portfolio would pay $50 with certainty in one year. In other words, if an investor who owns 1 share buys a put and sells a call on that share, both with a $50 strike price, then the resulting portfolio behaves like a risk-free bond with a $50 face value. You can see that this is true by rearranging Equation 8.1 like this: S + P – C = B. In this equation, the symbol '-C' means 'sell a call,' so S + P – C means buy a share and a put and sell a call, exactly the portfolio described in this question. This portfolio is equivalent to simply buying a bond.

6. Selling a call and buying a put are similar in the sense that both positions are most (least) profitable when the underlying share price falls (rises). However, the similarities end there. An investor who buys a put has a limited potential gain of $X minus the put premium and a maximum potential loss of the put premium. An investor who sells a call has a maximum potential gain equal to the call premium and an unlimited potential loss.

7. Figure 8.3 shows how an investor can profit from a share's volatility. If investors expect a share's volatility to be very high, then the cost of constructing the portfolio shown in Figure 8.3 will rise. In other words, the prices of the company's put and call options should increase if investors think volatility will be high.

8. If an asset's risk increases, its price declines. The opposite is true for options, because options have asymmetric payoffs, meaning that how an option's payoff changes as the underlying share price changes depends on the price of the share relative to the strike price. For a call option, the payoff is zero if $S < X$ on the expiration date, and it does not matter whether the share price falls below the strike price by a small or a large margin. On the other hand, if $S > X$ then the option payoff is larger if S exceeds X by a larger amount.

9. Calls and puts respond differently to changes in the underlying share price, but they both tend to increase in value as time to expiration and volatility of the underlying share increases. These two effects are related in that an option with more time until the expiration date will usually have a greater chance of moving in a direction that results in a positive option payoff. For example, if a put or a call option is out of the money today and the expiration date is tomorrow, there is little chance that the option will expire in the money. But if the expiration date is still many days in the future, then the chance that the option will finish in the money is greater.

10. To value options using the binomial method, it is not necessary to know the expected return on the share for the same reason that it is not necessary to know the probabilities of up and down moves in the tree. The binomial model is built on the idea that a combination of shares and options behaves like a risk-free bond, paying the same amount of cash whether the underlying share goes up or down. The return on this portfolio must equal the risk-free rate, and that is the rate of return that you must know to use the model to value options.

11. The binomial model assumes that if a portfolio of shares and options has a payoff identical to that provided by a risk-free bond, then the price of the portfolio must be the same as the price of the bond. If this were not true, then arbitrage would ensue. Traders could earn unlimited risk-free profits by purchasing the asset that sold at a lower price and selling the asset that sold at a higher price.

12. Employee share options are different from the options that trade on the exchanges and in the over-the-counter market in the following ways: ESOs have longer expiration dates, ESOs are subject to vesting periods, and ESOs cannot be traded on an exchange.

13. Companies should be required to show an expense on their income statement for employee share options, because when companies grant ESOs, they are exchanging value. The employees give up their labour and the company gives up options. The value that companies give up is just as much of an expense as cash compensation.

14. If a warrant and a call option have the same strike price, the same expiration date, and the same underlying asset, the call is more valuable. When a warrant is exercised, the company must issue a new share and that causes some dilution.

Solutions to Self-Test Problems

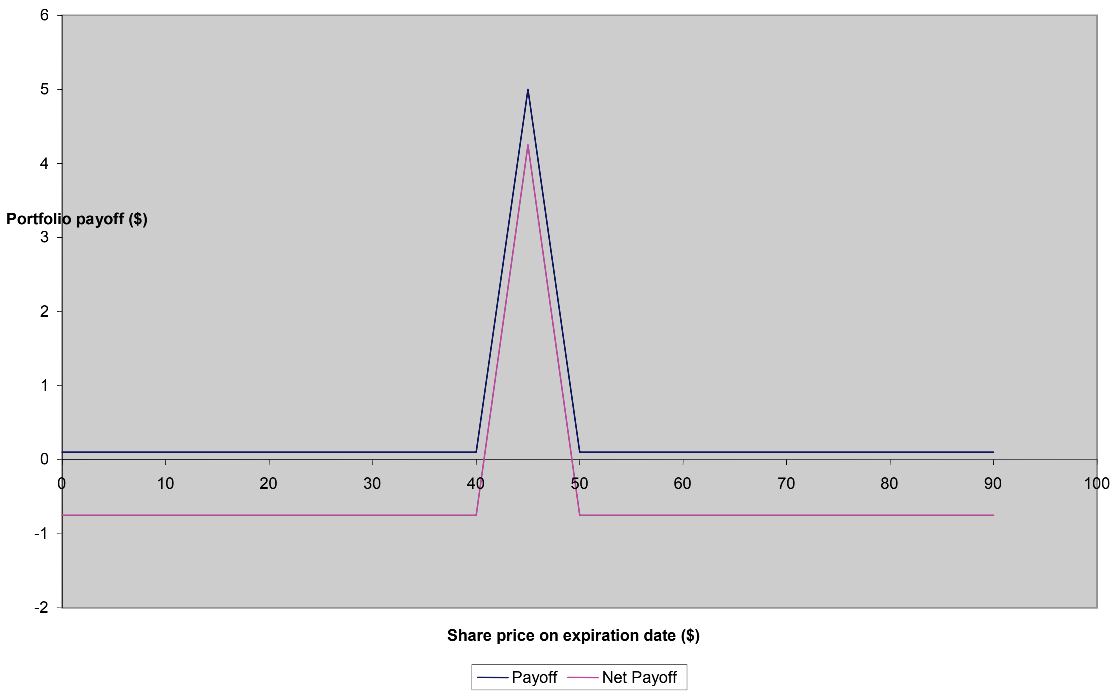
ST8-1. Several call options on Cuban Cigars Inc. are available for trading. The expiration date, strike price, and current premium for each of these options appear below.

Strike	Expiration	Premium
\$40	July	\$6.00
\$45	July	\$3.50
\$50	July	\$1.75

An investor decides to purchase one call with a \$40 strike and one with a \$50 strike. At the same time, the investor sells two of the calls with a \$45 strike price. Draw a payoff diagram for this portfolio of options. Your diagram should have two lines, one showing the portfolio's payoff on a gross basis and one showing the payoff net of the cost of forming the portfolio.

A: As the accompanying diagram shows, this portfolio has a zero payoff if the share price is between \$0 and \$40 or if it is above \$50. Between \$40 and \$45 the portfolio payoff rises with the share price, but between \$45 and \$50 the payoff falls as the share rises. To construct this portfolio, the investor pays \$7.75 to buy two call options, and the investor receives \$7 from selling two calls. Therefore, the net cost is \$0.75, and the net payoff line is \$0.75 below the gross payoff line.

Self-Test Problem 1



ST8-2. A share currently sells for \$36. In the next six months, the share will either go up to \$42 or it will fall to \$31. If the risk-free rate is 4% per year, calculate the current market price of a call option on this share with an expiration date in six months and a strike price of \$35.

A: First draw the tree illustrating how the share price will move and list the payoff of the option at each terminal node of the tree.

Share Values	Option Pays
42	\$7
36	\$0

Next, calculate the hedge ratio. To do this, you imagine that you purchase one share and 'h' call options. If the share price goes up, the payoff will be 42 + 7h, and if the share price goes down the payoff on the portfolio will be 31 + 0h. Set these expressions equal to each other to find h:

$42 + 7h = 31 + 0h$
$h = –11/7$

This means that a perfectly hedged portfolio can be formed by purchasing 1 share and selling 11/7 call options. If you plug h = –11/7 back into the equation from which it was derived you obtain

$42 + 7(-11/7) = 31 + 0(-11/7)$
$31 = 31$

This indicates that the perfectly hedged portfolio will pay \$31 with certainty in six months. This implies that the portfolio is identical to a Treasury bond that pays \$31 in six months. The price of such a Treasury bond would be 31 ÷ 1.02 = 30.39 (note: the discount factor is 1.02 because we are discounting at four per cent for six months). But 30.39 must also be the net cost of buying 1 share and selling 11/7 call options. Therefore we can write:

$30.39 = 36 - (11/7)C$
$C = 3.57$

Answers to End-of-Chapter Questions

Q8-1. Explain why an option is a derivative security.

A8-1. An option's value depends on or derives from the value of the underlying share.

Q8-2. Is buying an option more or less risky than buying the underlying share?

A8-2. The option is more risky than the underlying share if the absolute dollar amounts invested in each is equal. With options, there is a very significant chance that the investor will lose 100% of the money invested. There is also a very good chance of a very high positive return. The likelihood of such extreme returns on shares is very low. For example, investors can use options to enter a desired share position over a period of time with less risk than the ordinary shares today. I.e. suppose a company has pending litigation, which should be settled within the next year. The share currently trades at \$100 and the investor wants to own 10,000 shares, but doesn't want the risk of a possible negative outcome with the litigation. The investor could buy 100 calls (100 shares per contract × 100 calls = option to buy 10,000 shares) with a strike of \$100 for \$2.50 with a year till expiration. Now the investor is only putting up \$25,000 (the share could go to \$0 and the investor would only lose the \$25,000) purchase the option to buy 10,000 shares @ \$100. If the investor bought the share he/she would have to put up 10,000 × \$100 = \$1 million in capital. In this situation the options are less risky than the share. Say the litigation was favourable and the share went to \$115 within the year then the investor would make \$12.50 per share (giving up \$2.50 in option premium). If the litigation was negative and the share price went to \$85 the investor would only lose the \$2.50/share (option premium) instead of \$15/share if the share was purchased.

Q8-3. What is the difference between an option's price and its payoff?

A8-3. The option price or premium is what one pays for the option in the market, or what one receives for selling the option. It is a market-determined price. The payoff of the option is what it is worth when it expires.

Q8-4. List five factors that influence the prices of calls and puts.

A8-4. The share price, the time to expiration, the risk-free interest rate, the strike price, and the volatility of the share.

Q8-5. What are the economic benefits that options provide?

A8-5. They provide incentives which help align the interests of managers and investors. They permit creative trading strategies. At times they save transactions costs. They also allow companies and individuals to hedge risks that they do not want to take.

Q8-6. What is the primary advantage of settling options contracts in cash?

A8-6. Settling in cash saves transactions costs.

Q8-7. Suppose you want to invest in a particular company. What are the pros and cons of buying the company's shares as compared to buying their options?

A8-7. Buying 1 share is less risky than buying 1 option, but the capital required to buy 1 share is greater.

Q8-8. Suppose you want to make an investment that will be profitable if a company's share price falls. What are the pros and cons of buying a put option on the company's shares versus short selling the shares?

A8-8. If you buy a put option, the most you can lose is the option premium. If you short the share, losses theoretically are unlimited. On the other hand, shorting the share results in an immediate cash inflow for the investor, whereas buying a put requires a small cash outlay.

Q8-9. Suppose you own an American call option on Woolworths shares. Woolworths shares have gone up in value considerably since you bought the option, so your investment has been profitable. There is still one month to go before the option expires, but you decide to go ahead and take your profits in cash. Describe two ways that you could accomplish this goal. Which one is likely to leave you with the highest cash payoff?

A8-9. You could exercise your option, buying Woolworths at the strike price and selling it at the higher market price. Alternatively, you could simply sell your call option. The latter approach would generate more cash because if you exercise the option you capture only its intrinsic value, but if you sell it you capture both the intrinsic value and the time value.

Q8-10. Look at the St Kilda Optics call option prices in Table 8.1. Call prices increase as the strike price decreases, holding the expiration month constant. The strike prices decrease in increments of $2.50. Do the call option prices increase in constant increments? That is, does the call price increase by the same amount as the strike price drops from $35 to $32.50 to $30 and so on?

A8-10. No, the option value does not change by $2.50 each time the strike price changes by $2.50. For example, look at the May calls. When the strike drops from $35 to $32.50 the call price goes up by $0.65. But then if the strike drops from $32.50 to $30 the call goes up $0.98. Lowering the strike $2.50 more to $27.50 causes an increase in the May call price of $1.38. In general, the call price increases by less than the decrease in the strike price, but the change in the call price gets bigger as the strike price gets smaller.

Solutions to End-of-Chapter Problems

Options Vocabulary

P8-1. If the underlying share price is $25, indicate whether each of the options below is in the money, at the money, or out of the money.

Strike	Call	Put
$20		
$25		
$30		

A8-1.

Strike	Call	Put
$20	In the money	Out of the money
$25	At the money	At the money
$30	Out of the money	In the money

P8-2. The shares of Spears Entertainment currently sell for $28. A call option on this share has a strike price of $25 and it sells for $5.25. A put option on this share has a strike price of $30, and it sells for $3.10. What is the intrinsic value of each option? What is the time value of each option?

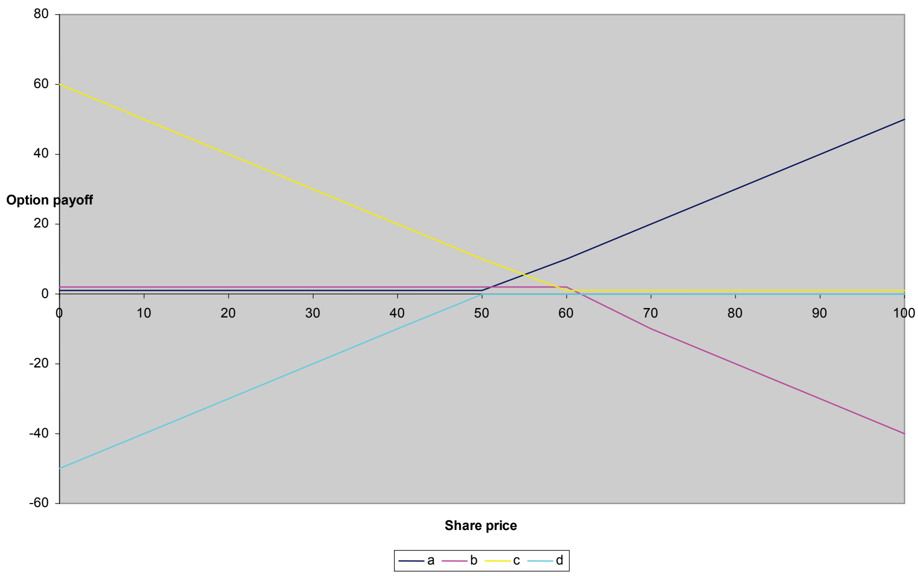
A8-2. The call's intrinsic value is $3 and its time value is $2.25. The put's intrinsic value is $2 and its time value is $1.10.

Option Payoff Diagrams

P8-3. Draw payoff diagrams for each of the positions below (X = strike price).

a. Buy a call with X = $50
b. Sell a call with X = $60
c Buy a put with X = $60
d. Sell a put with X = $50

A8-3.



P8-4. Draw payoff diagrams for each of the portfolios below (X = strike price).

a. Buy a share and short a call with X = $35
b. Buy a risk-free zero-coupon bond with a face value of $35 and sell a put with X = $35.
c. Explain how these payoff diagrams relate to the concept of put-call parity.

A8-4. The graphs in parts (a) and (b) are actually identical and look as shown immediately after problem 8-5. Put-call parity says S + P = B + C which can be rearranged like this, S – C = B – P. Part (a) graphs the left side of this equation and part (b) graphs the right side

P8-5. Draw payoff diagrams for each of the following portfolios (X = strike price):

a. Buy a call with X = \$50, and sell a call with X = \$60

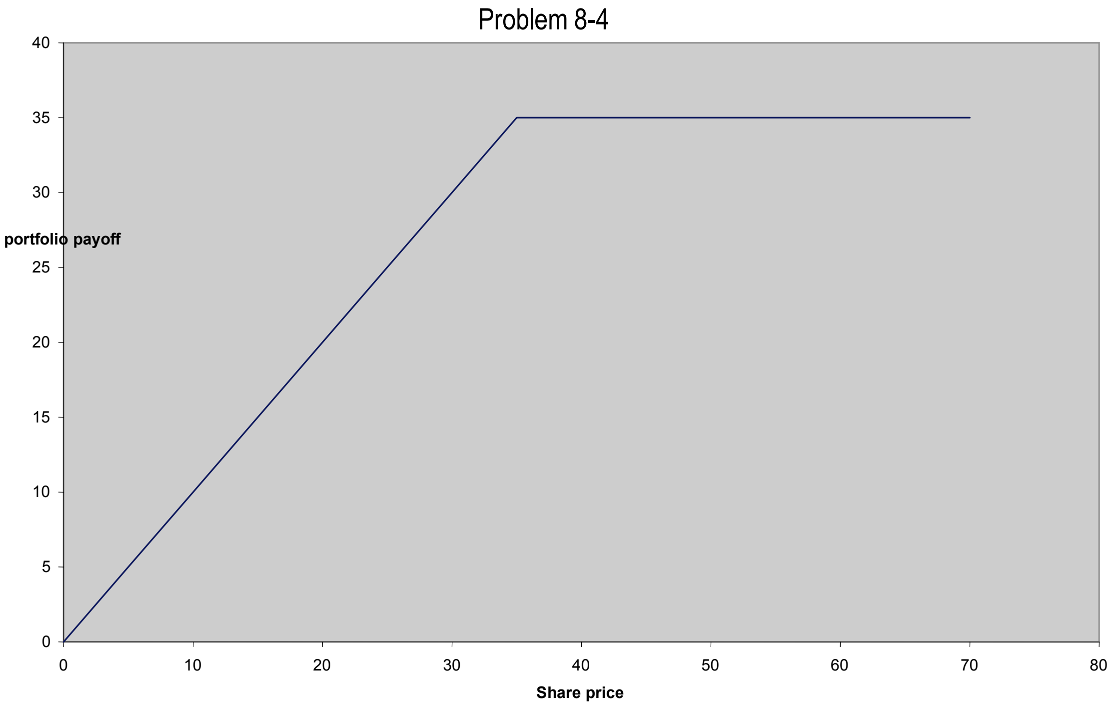
b. Buy a bond with a face value of \$10, short a put with X = \$60, and buy a put with X = \$50

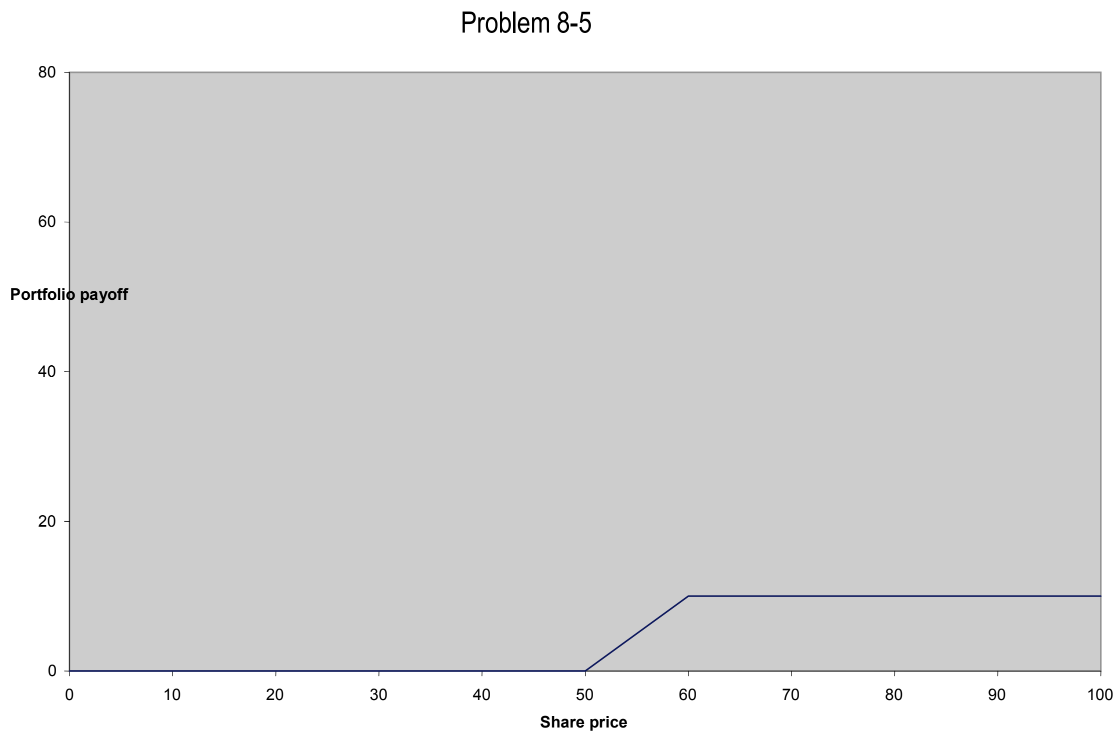
c. Buy a share, buy a put option with X = \$50, sell a call with X = \$60, short a bond (i.e., borrow) with a face value of \$50.

d. What principle do these diagrams illustrate?

A8-5. All three diagrams are exactly the same and look as shown at the bottom of the next page. The principle here is similar to put call parity. What we are showing is that there are many ways to replicate the payoffs of one portfolio by construction another portfolio containing different securities.

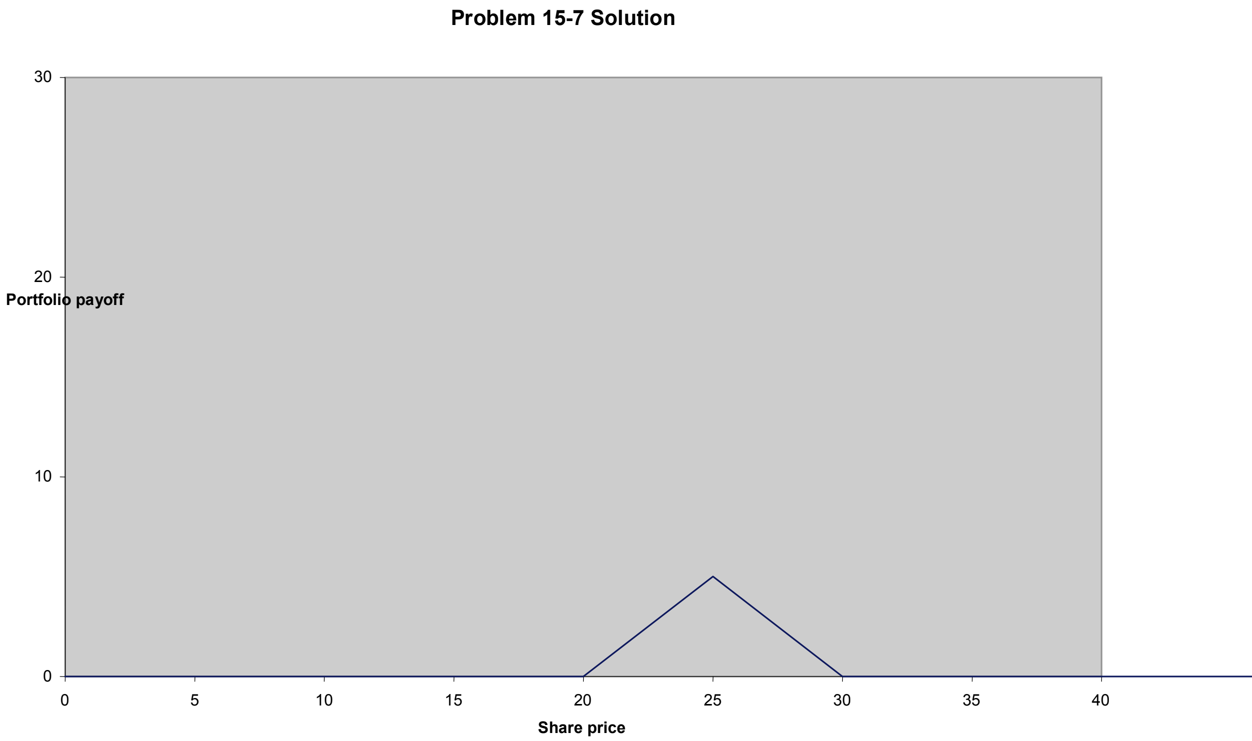
Solution to Problem 15-5





P8-6. Draw a payoff diagram for the following portfolio: Buy two call options, one with X = $20 and one with X = $30, and sell two call options, both with X = $25.

A8-6.



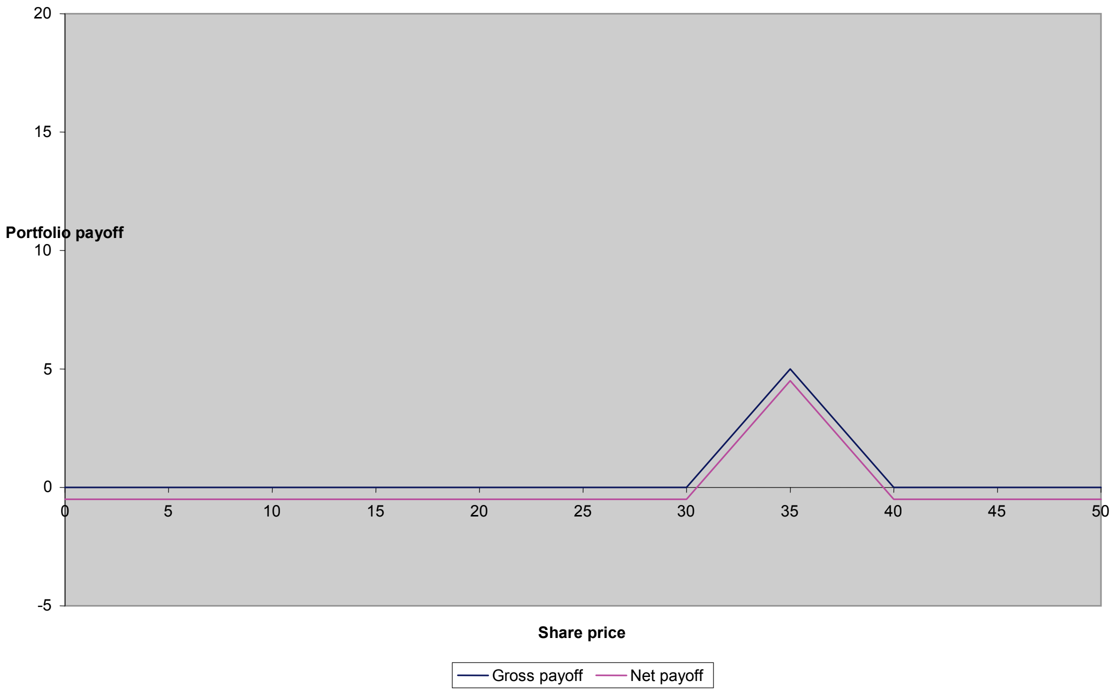
P8-7. Refer to the data in the following table.

Strike Price	**Put Price**
$30	$1.00
$35	$3.50
$40	$6.50

Suppose an investor purchases one put with X = $30 and one put with X = $40 and sells two puts with X = $35. Draw a payoff diagram for this position. In your diagram, show the gross payoff (ignoring the costs of buying and selling the options) and the net payoff. In what range of share prices does the investor make a net profit? What is the investor's maximum potential dollar profit and maximum potential dollar loss?

A8-7. The maximum net dollar gain and loss are $4.50 and –$0.50 respectively. The portfolio makes a net profit if the share price is between $30.50 and $39.50.

Problem 15-8 Solution



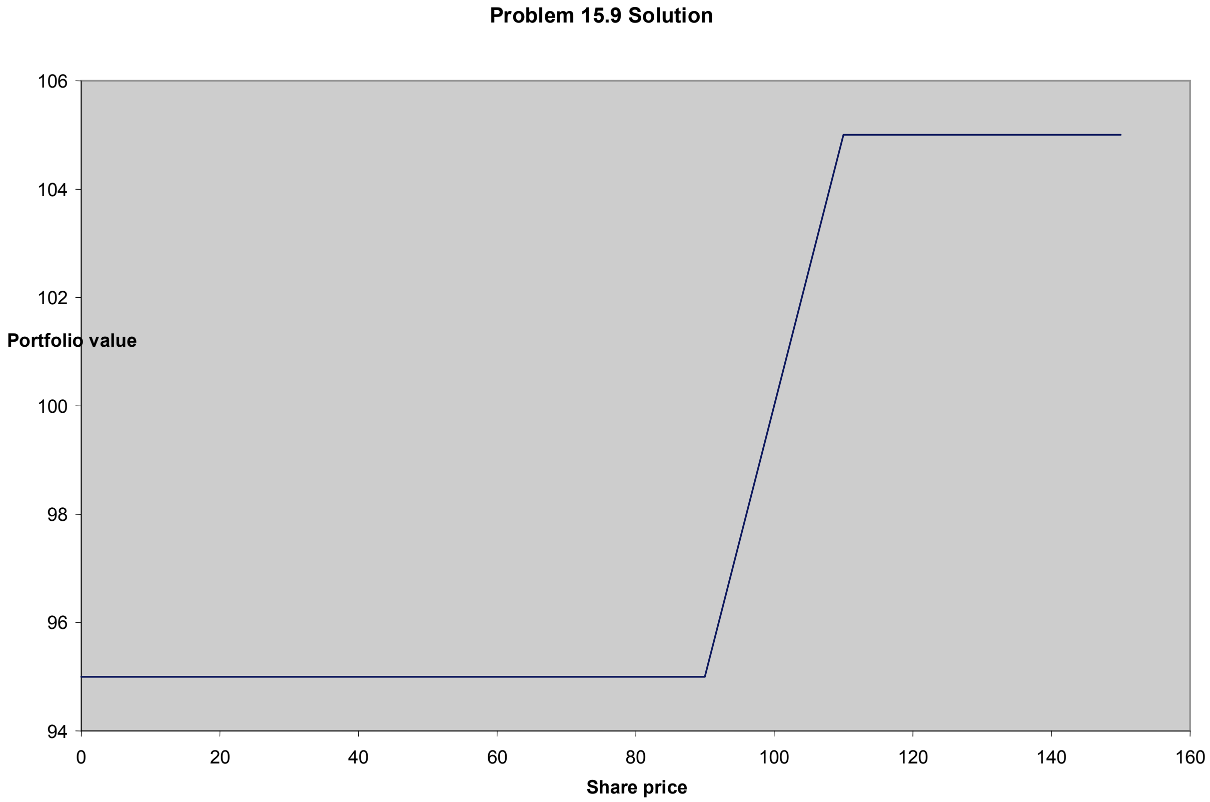
P8-8. Draw a payoff diagram for the following portfolios:

a. Buy a bond with a face value of $80, buy a call with X = $80, and sell a put with X = $80.
b. Buy a share, buy a put with X = $80, and sell a call with X = $80.
c. Buy a share, buy a put with X = $80, and sell a bond with a face value of $80.

A8-8. These are all just applications of put call parity, S + P = B + C. In part (a), the graph should look like the graph of a long share. In part (b), the graph should look like a long bond with a face value of $80. In part (c), the graph should look like a long call with X = $80.

P8-9. Suppose that Lisa Emerson owns a share of Brisbane Chemical, which is worth $100 per share. Lisa purchases a put option on this share with a strike price of $95 and she sells a call option with a strike price of $105. Plot the payoff diagram for Lisa's new portfolio.

A8-9. Lisa has put a collar around her shares. The combined portfolio cannot be worth less than $95, nor can it be worth more than $105.



P8-10. Imagine that a share sells for $33. A call option with X = $35 and an expiration date in six months sells for $4.50. The annual risk-free rate is 5 per cent. Calculate the price of a put option that expires in six months and has a strike price of $35.

A8-10. S + P = B + C so we have 33 + P = 35/1.025 + 4.50, so P = 5.65.

Qualitative Analysis of Option Prices

P8-11. Examine the data in the table below. Given that both shares trade for $50 and both options have a $45 strike price and a July expiration date, can we say that the option of Company A is overvalued or that the option of Company B is undervalued? Why or why not?

Company	Share Price	Expiration	Strike Price	Call Price
A	$50	July	$45	$7.50
B	$50	July	$45	$6.75

A8-11. We can't say that. Share A might be more volatile than Share B, and that would justify a higher call price.

P8-12. Examine the data in the table below. The call option on company #1 is out of the money by $1 and so is the call option on company #2. Given that the options expire at the same time, is it surprising that their prices are so different? Why or why not?

Company	Share Price	Expiration	Strike Price	Call Price
#1	$49	August	$50	$6.00
#2	$19	August	$20	$3.75

A8-12. No, it is not surprising that the option price is higher for company #1. On a percentage basis, it is much less out of the money (1/49) than company #2's option is (1/19).

P8-13. Suppose an American call option is in the money, so S > X. Demonstrate that the market price of this call (C) cannot be less than the difference between the share price and the exercise price. That is, explain why this must be true: C ≥ S – X. (Hint: consider what would happen if C < S – X.)

A8-13. If the call sold for less than its intrinsic value (S – X), then arbitrage would be possible. Investors could purchase the call for C and immediately exercise it for more (S – X) earning an immediate risk-free profit. As more investors tried to do this, buying pressure would drive up C until it was no longer less than S – X.

Option Pricing Models

P8-14.
a. A call option expires in three months and has X = $40. The underlying shares are worth $42 today. In three months, the shares may increase by $7 or decrease by $6. The risk-free rate is 2% per year. Use the binomial model to value the call option.
b. A put option expires in three months and has X = $40. The underlying shares are worth $42 today. In three months the shares may increase by $7 or decrease by $6. The risk-free rate is 2% per year. Use the binomial model to value the put option.
c. Given the call and put prices you calculated in parts (a) and (b), check to see if put-call parity holds.

A8-14.
a. 49 + 9h = 36 + 0h so h = −13/9. Buying 1 share and selling 13/9 calls gives a risk-free payoff of 36 in three months. The PV of this now is 35.82, so 35.82 = 42 – (13/9)C and this means that C = 4.28.

b. 49 + 0h = 36 + 4h, so h = 13/4 = 3.25. Buying 1 share and 3.25 puts gives a risk-free payoff of 49 in 3 months and the present value of this now is 48.76. Therefore, 48.76 = 42 + 3.25P and that means that P = 2.08

c. 42 + 2.08 = 40/1.005 + 4.28, so, yes, parity holds.

P8-15. A share is worth $20 today, and it may increase or decrease $5 over the next year. If the risk-free rate of interest is 6%, calculate the market price of the at-the-money put and call options on this share that expire in one year. Which option is more valuable, the put or the call? Is it always the case that a call option is worth more than a put if both are tied to the same underlying share, have the same expiration date, and are at the money? (Hint: use put-call parity to prove the statement true or false.)

A8-15. Value the call first. 25 + 5h = 15 + 0h so h = –2 and the risk-free payoff is 15. The PV of that now is 14.15. So 14.15 = 20 – 2C and C = 2.92. Now value the put. 25 + 0h = 15 + 5h so h = 2 and the risk-free payoff is 25. The PV of that now is 23.58 so 23.58 = 20 + 2P and P = 1.79. The call is worth more, and that is always true when both options are in the money. If the options are at the money then S = X. We can prove this result algebraically for bonds. Recall that at put-call parity the face value of a bond matches the strike price of the options, so the bond has a face value of X. If the face value of the bond is X, then its price is the present value of X or PV(X). Now for any positive interest rate we know X >PV(X). Now look at the put-call parity equation, S + P = B + C, and rearrange it like this: S – B = C – P. But we know from above that S = X and B = PV(X) so we have this equation X – PV(X) = C – P. But we also know that X – PV(X) must be positive because X > PV(X), and this in turn implies that C – P is positive or C > P.

P8-16. Explain the following paradox. A put option is a highly volatile security. If the underlying share has a positive beta, then a put option on that share will have a negative beta (because the put and the share move in opposite directions). According to the CAPM, an asset with a negative beta, such as the put option, has an expected return below the risk-free rate. How can an equilibrium exist in which a highly risky security such as a put option offers an expected return below a much safer security such as a bond issued by the government?

A8-16. A put option is like an insurance policy for shares because when shares go down, puts go up. Adding a put to a share portfolio provides protection against downside risk, and investors will buy this protection even if the return on the put is very low. This is much like buying insurance. We know that the average customer of an insurance company loses money (because the company makes money on average), but customers buy insurance anyway for the protection that it provides.

P8-17. A particular share sells for $27. A call option on this share is available with a strike price of $28 and an expiration date in four months. If the risk-free rate equals 6% and the standard deviation of the share's return is 40%, what is the price of the call option? Next, recalculate your answer assuming that the market price of the share is $28. How much does the option price change in dollar terms? How much does it change in percentage terms?

A8-17. According to Black and Scholes the call price is $2.286. If the share price is $28, the call price goes up to $2.835, a dollar increase of $0.549 and a percentage increase of 24%.

P8-18. Darwin Foods shares currently sell for $48. A call option on this share is available with a strike price of $45 and an expiration date six months in the future. The standard deviation of the share's return is 45%, and the risk-free interest rate is 4%. Calculate the value of the call option. Next, use put-call parity to determine the value of a Darwin Foods put option that also has a $45 strike price and six months until expiration.

A8-18. According to Black and Scholes, the call value is $7.97. Using put-call parity, the put value is $4.08.

Options in Corporate Finance

P8-19. A convertible bond has a par value of $1,000 and a conversion ratio of 20. If the underlying share currently sells for $40 and the bond sells at par, what is the conversion premium? The conversion value?

A8-19. The conversion value is $40 × 20 = $800. The conversion premium is ($1000 − $800) / $1000 = 20%.

Answer to MiniCase

Options

You have recently spent one of your Saturday afternoons at an options seminar presented by Derivatives Traders Incorporated. Interested in putting some of your new knowledge to work, you start by thinking about possible returns from an investment in the volatile ordinary shares of PurchasePro.com(PPRO). Four options currently trade on PPRO. Two are call options, one with a strike price of $35 and the other with a strike price of $45. The other two are put options, which also have strike prices of $35 and $45, respectively. To help you decide which options strategies might work, evaluate the following option positions.

Assignment

1. You believe the price of PPRO will rise and are therefore considering either (a) taking a long position in a $45 call by paying a premium of $3, or (b) taking a short position in a $45 put for which you will receive a premium of $3. If the share price is $50 on the expiration date, which position makes you better off?

2. You believe the price of PPRO will fall and are therefore considering either (a) taking a long position in a \$35 put, paying a premium of \$2, or (b) taking a short position in a \$35 call, receiving a premium of \$2. If the share price is \$30 on the expiration date, which position makes you better off?
3. Assume you can buy or sell either the call or the put options, with a strike price of \$35. The call option has a premium of \$3, and the put option has a premium of \$2. Which of these option contracts can be used to form a long straddle? What is the payoff if the share price closes at \$38 on the option expiration date? What is the payoff if the share price closes at \$28 on the option expiration date?
4. Assume you can buy or sell either the call or the put options, with a strike price of \$35. The call option has a premium of \$3, and the put option has a premium of \$2. Which of these option contracts can be used to form a short straddle? What is the payoff if the share price closes at \$38 on the option expiration date? What is the payoff if the share price closes at \$28 on the option expiration date?

Answers

1. If the share price goes from \$40 to \$50 per share you are better writing the \$45 put (a short position in the put results in a profit of \$3 per option, while the long position in the call results in a profit of \$2 per option). With the \$45 put you receive a premium of \$3 and since the put option will expire worthless your total earning per option is \$3. By buying the \$45 call option you pay a premium of \$3, but receive value of \$5 as the option approaches the expiration date. Therefore, buying the \$45 call option results in total earnings per option of \$2.

2. If the share price goes from \$40 to \$30 per share you are better buying the \$35 put (a long position in the put results in a profit of \$3 per option, while the short position in the call results in a profit of \$2 per option). With the \$35 put you pay a premium of \$2, but receive value of \$5 as the option approaches the expiration date. Therefore, buying the \$35 put option results in total earnings per option of \$3 per option. By writing the \$35 call option you receive a premium of \$2, and since the call option will expire worthless you total earning per option is only \$2.

3. To form a long straddle both the \$35 call and \$35 put options are purchased (long positions). The total cost is \$5 per straddle (the \$3 premium on the call option and the \$2 premium on the put option). If the share price is \$38 per share at the option expiration date, then there is a net loss of \$2 per long straddle (a \$3 profit on the call option less the \$5 premium). If the share price is \$28 per share at the option expiration date, then there is a net profit of \$2 per long straddle (a \$7 profit on the put option less the \$5 premium).

4. To form a short straddle one would write both the \$35 call and \$35 put options (short positions). The total cost is \$5 per straddle (the \$3 premium on the call option and the \$2 premium on the put option). If the share price is \$38 per share at the option expiration date, then there is a net profit of \$2 per short straddle (a \$3 loss on the call option plus the \$5 premium). If the share price is \$28 per share at the option expiration date, then there is a net loss of \$2 per short straddle (a \$7 loss on the put option plus the \$5 premium).