Global Financial Management

Option Contracts

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10.0 Overview

This class provides an overview of **option** contracts. As with forwards and futures, options belong to the class of securities known as **derivatives** since their value is derived from the value of some other security. The price of a stock option, for example, depends on the price of the underlying stock and the price of a foreign currency option depends on the price of the underlying currency. Options trade both on exchanges (where contracts are standardized) and over-the-counter (where the contract specification can be customized). The focus of this class is on

- Definitions and contract specifications of the major exchange-traded options,
- The mechanics of buying, selling, exercising, and settling option contracts,
- Option trading strategies including hedging, and
- The relationships between options, the underlying security, and riskless bonds. In particular, it is possible to form combinations of derivatives and the underlying security that are riskless, providing a means of valuing options.

10.1 Objectives:

After completing this class, you should be able to:

- Determine the possible payoffs of option contracts.

- Construct payoff diagrams for call and put options and portfolios of options, stocks and bonds.
- Understand the mechanics of buying, selling and exercising option contracts.
- Understand some of the applications of option contracts.
- Determine whether the put-call parity relationship is violated for some given options.
- Use the Black Scholes formula to determine the price of options.
- Understand the directional effects of relevant variables on the value of options.
- Explain how debt and equity can be understood as options on the firm.

10.2 Definitions and Conventions

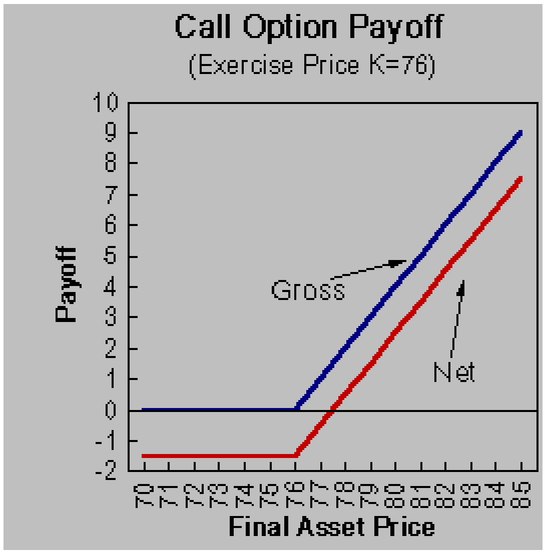
A *call option* is a contract giving its owner the right to *buy* a fixed amount of a specified underlying asset at a fixed price at any time on or before a fixed date. For example, for an equity option, the underlying asset is the common stock. The fixed amount is 100 shares. The fixed price is called the *exercise price* or the *strike price*. The fixed date is called the *expiration date*. On the expiration date, the value of a call on a per share basis will be the larger of the stock price minus the exercise price or zero.

Options are in force for a limited time. The option expires when it is executed or on the expiration date (also called the maturity date). A call option on stock XYZ with a strike price of 45 and a maturity date in January will be referred to as "The XYZ 45 January calls." All exchange-traded options in the U.S. expire on the Saturday following the third Friday of the expiration month. One can think of the buyer of the option paying a *premium* (price) for the option to *buy* a specified quantity at a specified price any time prior to the maturity of the option.

Consider an example. Suppose you buy an option to buy 1 Treasury bond (coupon is 8%, maturity is 20 years) at a price of $76. The option can be exercised at any time between now and September 19th. The cost of the call is assumed to be $1.50. Let's tabulate the payoffs at expiration.

Call Option Payoff		
T-bond Price on Sept. 19	**Gross Payoff on Option**	**Net Payoff on Option**
60	0.0	-1.5
70	0.0	-1.5
75	0.0	-1.5
76	0.0	-1.5
77	1.0	-0.5
78	2.0	0.5
79	3.0	1.5
80	4.0	2.5
90	14.0	12.5
100	24.0	22.5

Consider the payoffs diagrammatically. Notice that the payoffs are one to one after the price of the underlying security rises above the exercise price. When the security price is less than the exercise price, the option is referred to as *out of the money*.

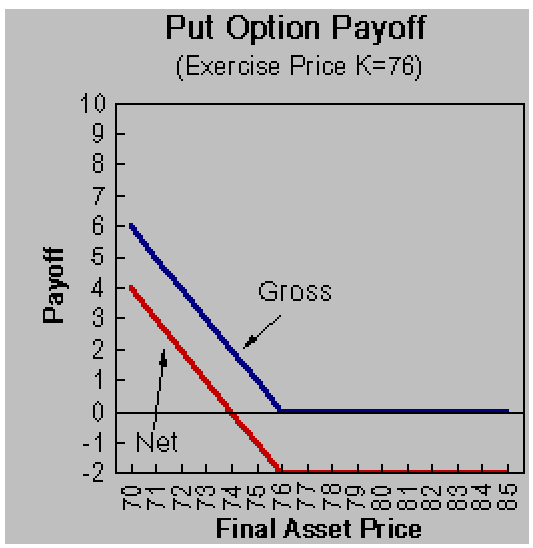


A *put option* is a contact giving its owner the right to *sell* a fixed amount of a specified underlying asset at a fixed price at any time on or before a fixed date. On the expiration date, the value of the put on a per share basis will be the larger of the exercise price minus the stock price or zero.

One can think of the buyer of the put option as paying a *premium* (price) for the option to sell a specified quantity at a specified price any time prior to the maturity of the option. Consider an example of a put on the same Treasury bond. The exercise price is $76. You can exercise the option any time between now and September 19. Suppose that the cost of the put is $2.00.

Put Option Payoff		
T-bond Price on Sept. 19	**Gross Payoff on Option**	**Net Payoff on Option**
60	16.0	14.0
70	6.0	4.0
75	1.0	-1.0
76	0.0	-2.0
77	0.0	-2.0
78	0.0	-2.0
79	0.0	-2.0
80	0.0	-2.0
90	0.0	-2.0
100	0.0	-2.0

The payoff from a put can be illustrated. Notice that the payoffs are one to one when the price of the security is less than the exercise price.

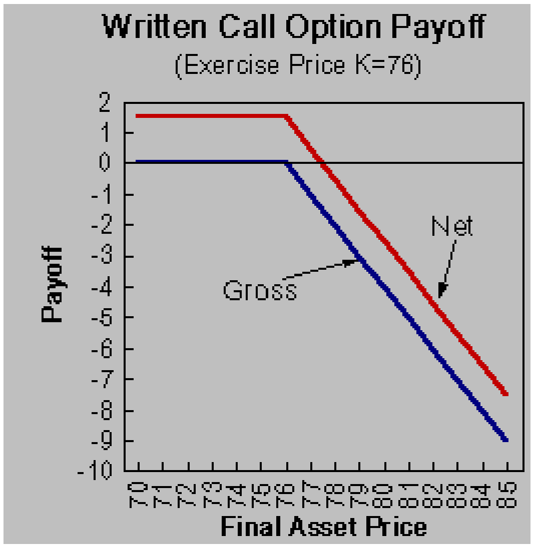


Writing or "shorting" options have the exact opposite payoffs as purchased options. The payoff table for the call option is:

Short Call Option Payoff		
T-bond Price on Sept. 19	**Gross Payoff on Option**	**Net Payoff on Option**

60	0.0	1.5
70	0.0	1.5
75	0.0	1.5
76	0.0	1.5
77	-1.0	0.5
78	-2.0	-0.5
79	-3.0	-1.5
80	-4.0	-2.5
90	-14.0	-12.5
100	-24.0	-22.5

Notice that the liability is potentially unlimited when you are writing options.

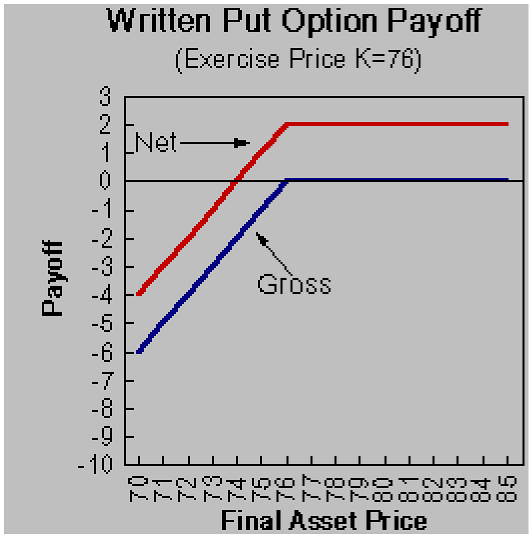


the written put option can be similarly illustrated:

Short Put Option Payoff		
T-bond Price on Sept. 19	**Gross Payoff on Option**	**Net Payoff on Option**
60	-16.0	-14.0
70	-6.0	-4.0
75	-1.0	1.0
76	0.0	2.0
77	0.0	2.0
78	0.0	2.0
79	0.0	2.0
80	0.0	2.0
90	0.0	2.0

100	0.0	2.0

As with the written call, the upside is limited to the premium of the option (the initial price). The downside is limited to the minimum asset price - which is zero.



10.3 The Mechanics of Option Contracts

Whereas a futures contract requires settlement between the buyer and seller at maturity of the contract, an **option contract** is settled at the discretion of the buyer. If settlement would involve a cash flow *from the seller to the buyer*, the buyer will exercise his option and receive a payment from the seller. Conversely, if settlement would involve a cash flow *from the buyer to the seller*, the buyer will choose not to exercise the option and no funds will change hands. The buyer will only exercise the option when it is in his interest to do so; in which case the buyer will either receive a positive cash flow or nothing when the contract matures. Clearly, the buyer must offer a payment to the seller (the **option premium**) to induce the seller to take the other side of such a contract.

Option contracts can be classified according to whether they give the holder the right to buy or sell the underlying asset. A **call option** is a contract that gives the holder the right to buy a particular asset at a specified price (called the **exercise price** or **strike price**) within a specified period of time. A **put option** is a contract that gives the holder the right to sell a particular asset at a specified price within a specified period of time.

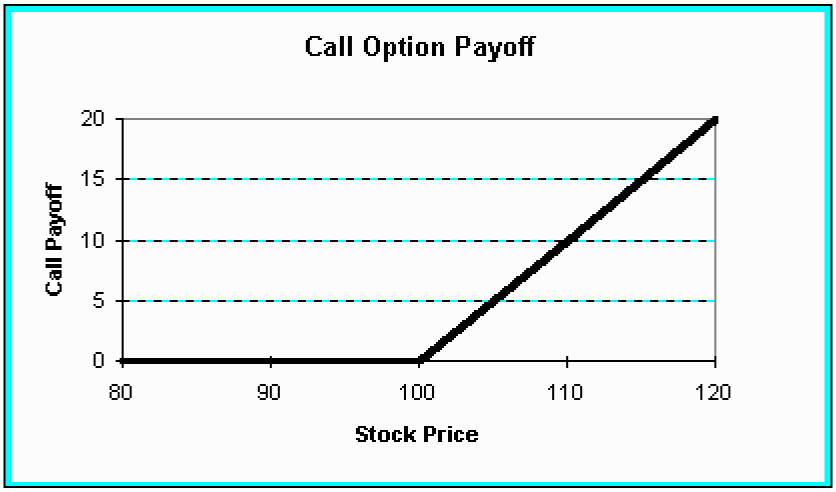
Options can be further classified according to when they may be exercised. **European options** may only be exercised on the expiration day, while **American options** may be exercised at any time up to and including the expiration day. Most options that trade on organized exchanges throughout the world are of the American kind. European options trade primarily in the over the counter market.

The following examples illustrate the mechanics of call and put options respectively.

Example 1 Exercising a call option.

> Suppose that on March 20, you purchased one contract (100) of September-100 IBM call options. At that time, the price of an IBM share was $105 and the price of the call options on the Chicago Board Options Exchange (CBOE) was $12.80. That is, at the time of entering the contract, you paid *100($12.80) = $1280* for the right to purchase 100 IBM shares for $100 each at any time before the contract matures.
>
> It is now September 20, which is the maturity date for September options, and the IBM stock price is $110. In this case, you will want to exercise the option: you pay *100($100) = $10,000* and receive 100 IBM shares (which are worth $11,000). Suppose, however, that the IBM stock price was only $95. In this case, you would let the option lapse and no funds would change hands. You would clearly be unwilling to pay $100 per share by exercising the option when the stock is only worth $95.

The payoff on the maturity date of the call option described in this example is graphed in the following figure.

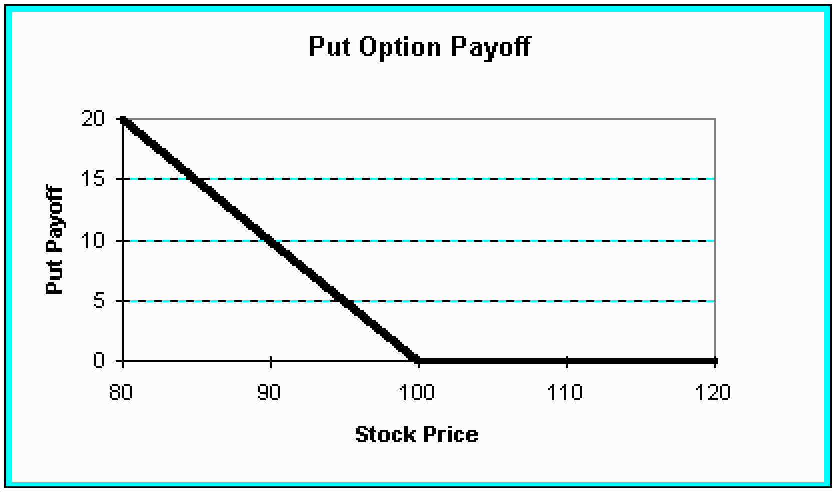


Example 2 Exercising a put option.

Suppose that on March 20, you purchased one contract (100) of September-100 IBM put options. At that time, the price of an IBM share was $105 and the price of the put options on the Chicago Board Options Exchange (CBOE) was $5.33. That is, at the time of entering the contract, you paid 100($5.33) = $533 for the right to sell 100 IBM shares for $100 each at any time before the contract matures. It is now September 20, which is the maturity date for September options, and the IBM stock price is $110.

In this case, you will not want to exercise the option: You would clearly be unwilling to sell IBM shares for $100 per share by exercising the option when the stock is actually worth $110. Suppose, however, that the IBM stock price was only $95. In this case, you would exercise the option. You receive *100($100) = $10,000* in return for 100 IBM shares (which are worth only $9,500).

The payoff on the maturity date of the put option is graphed in the following figure.



All stock options on the Chicago Board Options Exchange (CBOE), such as the IBM options in the previous examples, are of the American type. Although the above examples considered exercising at maturity, the buyer may, if he wishes, exercise at any time before maturity.

Note that if the current asset price is above the strike price, the call option is said to be **in the money** because immediate exercise would result in a positive cash flow. Conversely, if the current asset price is below the strike price the call option is **out of the money** and if the current asset price equals the strike price the call option is **at the money**. Similarly, if the asset price is above the strike price the put option is out of the money and if the asset price is below the strike price the put option is in the money.

10.4 Some Uses of Options

There are many uses for options. We will review three possible uses: writing covered calls, using options instead of stock, and obtaining portfolio insurance.

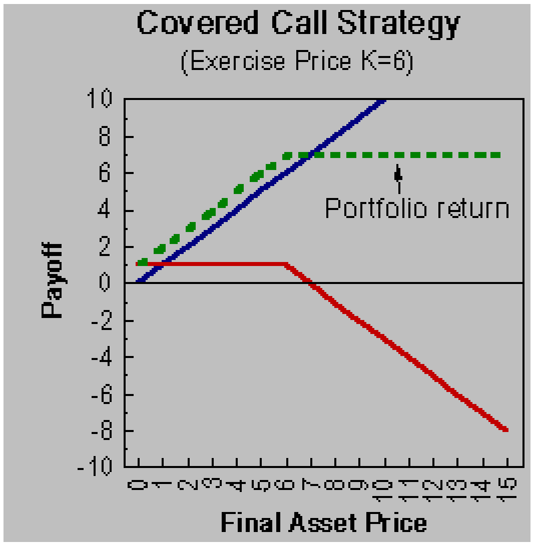
Application 1: Writing a Covered Call

Suppose you own a share of a particular stock and you decided to write a call option. Note the difference here to just writing a call. Because you already own the underlying security, you are *covered* from infinite losses if the stock price takes off.

We can describe the payoffs for this strategy. First, we need a few definitions. Let $\hat{S}^*$ be the ultimate value of the stock price on the maturity date. Let *k* be the exercise price. The call price will be denoted by *C*. The payoffs from this strategy are given in the following table and plot.

	Value on the Expiration Date	
Position	$\hat{S}^*$<=k	$\hat{S}^*$>k
Own 1 share	$\hat{S}^*$	$\hat{S}^*$
Write 1 call	C	C+(k-$\hat{S}^*$)
Total	**C+**$\hat{S}^*$	**C+k**

At expiration date if the stock price is below the strike price the holder of the call *will not* exercise the call. Under this scenario we have gained the proceeds C from selling the call and we are still in possession of the share. Conversely, if the stock price ends up above the strike price the owner of the call *will choose to exercise*. This leaves us with the original proceeds C plus the strike price k that was given in exchange of the share. These payoffs are plotted below.

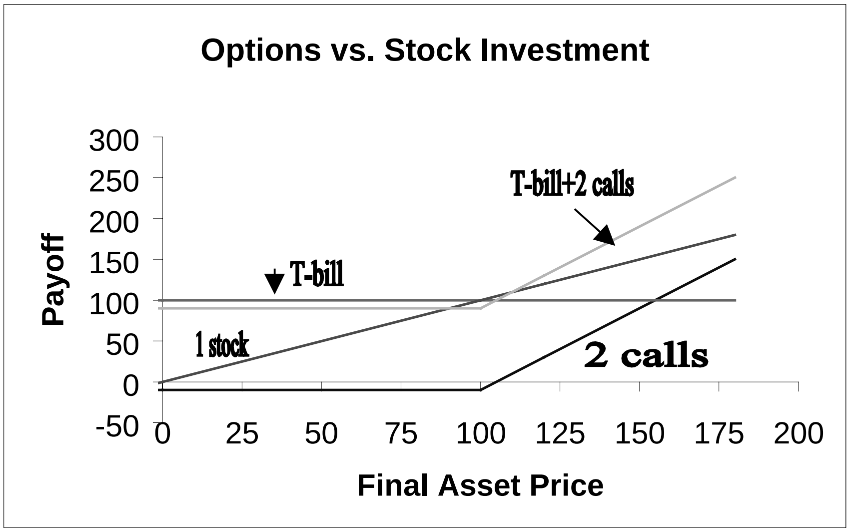


The straight line is the payoff from holding the stock long. The kinked solid line is the payoffs from shorting (writing) the call option. The dashed line is the net payoff. This is referred to as a *hedge position*. Note if the stock price stays below the exercise price we are clearly better off. We received the option price and did not have to pay anything to the person that holds the call option. Conversely, if the stock price rises dramatically, then we do not capitalize on the gain.

Application 2: Using Options Instead of Stock

Suppose you have a choice of two investment strategies. The first is to invest $100 in a stock. The second strategy involves investing $90 in 6 month T-bills and $10 in 6 month calls. So we will want to buy *10/C* calls. That is, if the call is priced at $5, then you are able to buy 2 calls.

The payoffs for this strategy are outlined below. Note that because we own 2 calls, the payoffs are two for one. That is for every dollar the stock price is above the exercise price, we make two dollars on the call. The diagram shows the payoffs from strategy 2. The slope of the call payoff is 2. The T-bill payoff is flat. As soon as the stock price goes past the exercise price, the portfolio value rises rapidly. A comparison of the two investment strategies is outlined. Note that the option substitution strategy does not do as well if the stock price does not move that much.

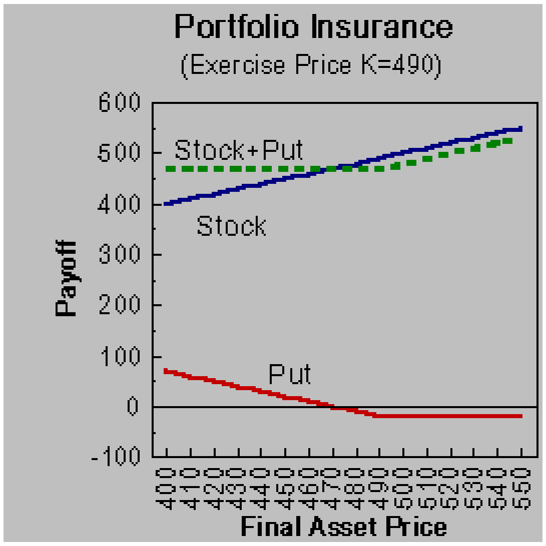


Application 3: Portfolio Insurance

One can obtain insurance on a portfolio of stocks by buying a put. So for every dollar that the stock portfolio drops, you make back by holding the put. Hence, portfolio managers can cover the downside by taking out *portfolio insurance*. Let $\hat{S}^*$ be the ultimate value of the stock portfolio on the maturity date. The put price will be denoted by P and its strike price by k. The payoffs from this strategy are given in the following table and plot.

	Value on the Expiration Date	
Position	$\hat{S}^*$<=k	$\hat{S}^*$>k
Own (long) portfolio	$\hat{S}^*$	$\hat{S}^*$
Buy (long) a put	-P+(k-$\hat{S}^*$)	-P
Total	**k-P**	$\hat{S}^*$**-P**

From the table we learn that if the portfolio value $\hat{S}^*$ at expiration is lower than the strike price k then we will choose to exercise the option. Hence we deliver the portfolio and obtain in return the strike price k. The net inflow including the cost of the put P adds up to (k-P). On the other hand, if the portfolio value $\hat{S}^*$ at expiration is higher than the strike price k then we will choose not to exercise the option. Under this scenario we still hold the portfolio but we have lost the put cost P. Consequently the payoff is equal to ($\hat{S}^*$-P). These payoffs are now displayed in the diagram below.



The solid lines represent the payoffs from the long portfolio position and long put position. The dashed line is the total return or the *hedge position*. Note that the cost of covering the downside is that we give up some of the gains if the portfolio rises in value. This can be seen as the difference between the blue and green lines (equal to P) when the portfolio price is greater than the put's strike price k..

10.5 Hedging with Currency Options

It is currently near the end of August and your company sells 10 machines to a German company. The sale price is 100,000 Deutschemarks each and payment is to be made at the end of

October. The current spot price for Deutschemarks is 0.67177. You are worried that the Deutschemark will depreciate against the US dollar between now and when payment is received. How can you hedge this exchange rate risk?

Note that since (1) the total exposure is one million Deutschemarks and (2) each option contract is for 62,500 Marks, 16 contracts are required to hedge the exposure. Further, since the company will be selling Deutschemarks (converting them back into Dollars) the position can be hedged by buying put options. To insure against the exchange rate falling much below the current level, the put options could be struck at 0.66.

To illustrate that selling sixteen put option contracts with strike price 0.66 provides an adequate hedge, first suppose that the value of the Deutschemark is 0.30 at the end of December. In this case, the company will exercise the option and sell one million Marks to the counterparty for 0.66 Dollars per Mark realizing a total of $660,000.

Now suppose the value of the Deutschemark is 0.90 at the end of December. In this case, the company will not exercise the option (why sell for 0.66 when Marks are really worth 0.90?) and the US dollar value of the payment for the machines will be 0.90 (10)(100,000) = $900,000.

Therefore, the option hedge has placed a floor of $660,000 on the proceeds of the sale without sacrificing any upside potential (if the Deutschemark should appreciate). The cost of this insurance at current prices is around *16 (62,500)(0.29) cents = $2,900*.

10.6 Put-Call Parity

One of the fundamental properties of derivatives is that their prices are closely connected to those of other assets. This is important for two reasons: (1) it allows us to price derivatives correctly on the basis of other securities (we already applied this methodology to forwards and futures, (2) it allows us to arbitrage across markets.

The price of a call and a put option are linked via the ***put-call parity relationship***. The idea here is that holding the stock and buying a put is going to deliver the exact same payoffs as buying one call and investing the present value of the exercise price in a bond. Let's demonstrate this.

Consider the payoffs of two portfolios. Portfolio *A* contains the stock and a put. Portfolio *B* contains a call and a bond. The bond, the put and the call have the same maturity, and the put and the call have the same strike price which is again equal to the face value of the bond. As in the previous sections, we denote by $\hat{S}^*$ be the ultimate value of the stock on at maturity. The call and put prices will be denoted by C and P respectively. Last, let k denote the strike price for both options.

Portfolio A		
	Value on the Expiration Date	
Action Today	$S^*<=k$	$S^*>k$
Buy one share	S^*	S^*
Buy one put	k- S^*	0
Total	K	S^*

Portfolio B		
	Value on the Expiration Date	
Action Today	S^*<=k	S^*>k
Buy one call	0	S^*-k
Invest of PV of k	K	k
Total	K	S^*

Since the portfolios always have the same final value, they must have the same current value. This is the rule of no arbitrage. We can express the put-call parity relation as:

$$S + P = C + PV(k) \quad (1)$$

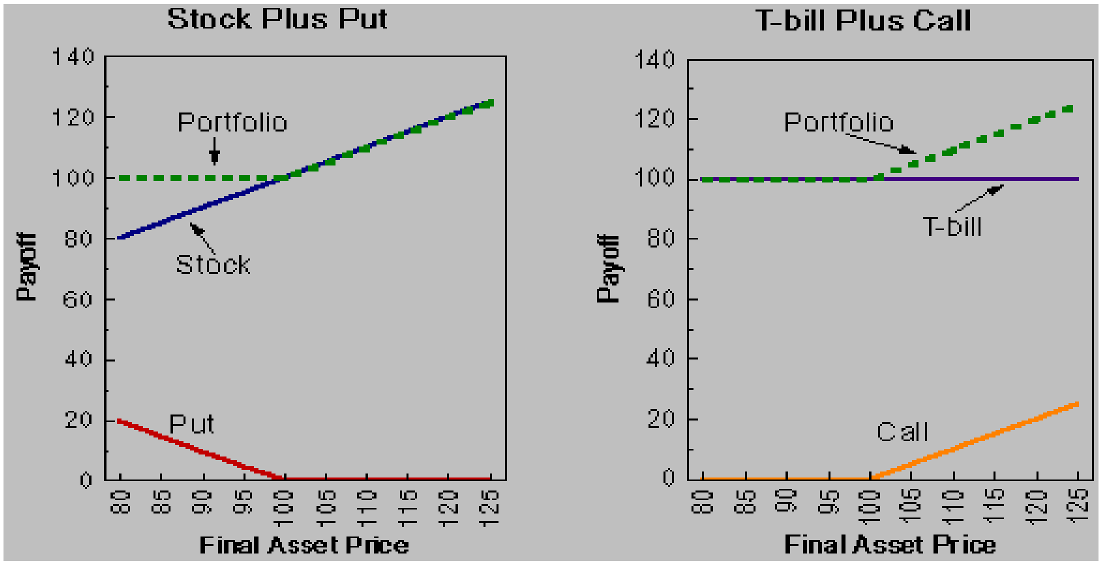
Of course, this relation can be written in many different ways:

$$P = C + PV(k) - S$$
$$C = S + P - PV(k) \quad (2)$$

and

$$C - P = S - PV(k) \quad (3)$$

where *PV(k)* is the present value of the exercise price. We can understand the relationship between portfolios A and B using the following diagrams.



The left plot constructs the payoff at maturity for portfolio A by summing the payoffs from holding the stock and the put. Similarly, the right plot gives the final payoff from holding the T-bill and the call. It can be seen that both portfolio payoffs (dashed green lines) are identical.

Here are two more examples that explain the put-call parity. In the first, the parity holds while in the second it does not. Hence, in the latter case we show how riskless profit can be made.

Example 3: Xerox Options

$$S + P = C + PV(k) \tag{4}$$

Xerox stock sells for \$61. The Xerox/April/60 call sells for \$7 3/8 and the Xerox/April/60 put sells for \$3 1/4. The call, put and a Treasury Bill all mature in 4 months. The Treasury Bill price is .9492.

Now consider the possibility of arbitrage profits today. We can use the put-call parity relation.

$$C - P - S + PV(k) = 0 \tag{5}$$

We know the value of all of these variables. The present value of the exercise price is:

$$60 \times .9492 = \mathbf{56.95}$$

So just plug into the put-call parity relation:

$$7.38-3.25-61+56.95 = \mathbf{0.08}$$

This inflow is very close to zero and will be wiped out by transactions costs and the bid-ask spread. The put-call parity condition is satisfied well.

Example 4: Intel Options

This example illustrates how an arbitrage is possible if put-call parity does not hold. Suppose that European call and put options on Intel with exercise prices of *$40* and six months to maturity are selling for *$5* and *$3* respectively, that the Intel stock price is *$40*, and that the riskless rate of interest is 8% p.a. In this case, put-call parity is violated since

$$C = 5.00 > P + S - k(1+r)^{-T} = 4.51$$

The violation occurs because of any one or all of the following possibilities: (a) the call is overpriced, (b) the put is underpriced, and (c) the stock is underpriced. The arbitrage portfolio therefore must account for all three of these possibilities simultaneously. Consider the following portfolio:

Position	**Initial Value**	$S_T \le 40$	$S_T > 40$
Sell European Call	5.00	0	$-(S_T - 40)$
Buy European Put	-3.00	$40 - S_T$	0
Buy Stock	-40	S_T	S_T
Borrow $40(1.08)^{-0.5}$	38.49	-40	-40
Net Portfolio Value	0.49	0	0

In forming the portfolio a certain arbitrage profit of $0.49 is earned immediately. Note that by forming such portfolios the price of the stock and the put will be bid up and the price of the call will decline such that, in equilibrium, the put-call parity will hold again.

10.7 The Black-Scholes Pricing Formula for Call Options

We now turn to the question of how to price options and introduce the Black-Scholes formula. First, some definitions are needed.

- S = current stock (underlying asset) price
- k = exercise price of the option
- T = time to maturity of the option *in years* (e.g. 5 months is .408)
- B = price of a zero coupon (riskless) bond that pays $1.00 at maturity. This can be represented as $e^{\{-rT\}}$.
- C = call option value
- σ = annual standard deviation of the rate of return on the stock
- $N(x)$= cumulative normal probability of value less than x

The price of the call option C is given by:

$$
\begin{aligned}
c &= S \cdot N(x_1) - PV(k) \cdot N(x_2) \\
&\quad \textit{where} \\
x_1 &= \frac{1}{\sigma\sqrt{T}} \cdot \ln\left[\frac{S}{PV(k)}\right] + \frac{\sigma\sqrt{T}}{2} \\
&\quad \textit{and} \\
x_2 &= \frac{1}{\sigma\sqrt{T}} \cdot \ln\left[\frac{S}{PV(k)}\right] - \frac{\sigma\sqrt{T}}{2}
\end{aligned}
\tag{6}
$$

There are many ways of writing the Black-Scholes formula. All of them are equivalent to the above. Many textbooks use the symbols d_1 and d_2 rather than x_1 and x_2. Note that $x_2 = x_1 - \sigma\sqrt{T}$ (this is helpful for computations).

Before working some examples, we will try to get some of the intuition behind the formula.

10.8 Some Intuition behind the Black-Scholes Formula

Usually, in Finance, we refer to people as risk averse. We defined this earlier as the preference for \$50 for sure rather than taking a 50-50 bet with payoffs of \$0 and \$100. Now let's suppose that agents are *risk neutral*. This means that they are indifferent between the \$50 for sure and the bet. If this is the case, then the value of the call can be thought of as the *expected payoff of the call at expiration discounted back to present value*. We know that the value of the call option at maturity is:

$$C_T = \begin{cases} S_T - k & if \quad S_T \geq k \\ 0 & if \quad S_T < k \end{cases} \tag{7}$$

This includes the unknown stock price at expiration, S_T. Taking expectations gives:

$$\begin{aligned} C_T &= E[S_T - k | S_T \geq k] \Pr(S_T \geq k) \\ &= E[S_T | S_T \geq k] \Pr(S_T \geq k) - k \Pr(S_T \geq k) \end{aligned} \tag{8}$$

In order to value the call option today, we need to discount this and write:

$$C_0 = e^{-rT} E[S_T | S_T \geq k] \Pr(S_T \geq k) - ke^{-rT} \Pr(S_T \geq k) \tag{9}$$

This expression says that the call price is the difference in the present values of the expected expiration price and the exercise price each multiplied by the probability the call is in the money. Going back to the Black-Scholes formula we find that these two terms match those of equation (6). This can be seen by noting that $S \cdot N(x_1)$ is the present value of the expected terminal stock price conditional upon the call option being in the money at expiration times the probability that the call will be in the money at expiration, i. e., $S \cdot N(x_1)$ matches $e^{-rT} E[S_T | S_T \geq k] \Pr(S_T \geq k)$. $N(x_2)$ can be interpreted as the probability that the call option will be in the money at expiration. Hence, the term $PV(k)N(x_2)$ matches $ke^{-rT} \Pr(S_T \geq k)$. So the Black-Scholes formula for call option has a fairly simple interpretation. ***The call price is simply the discounted expected value of the cash flows at expiration.***

10.9 Using the Black-Scholes Formula

All of the numbers that enter the Black Scholes formula can be easily obtained. You can either use a piece of software or a number of simple steps to write your own program in EXCEL.

Example 5: Using the Option Pricer

(a) Find the value of a call option on IBM with an exercise price of $260 and a time to maturity of 2 months (61 days). Assume that the current price of IBM is $265, its annual standard deviation is 30%, its dividend yield is 4% and the riskless rate of interest is 7%.

(b) Value a 5-month (153 days) IBM call with the same terms.

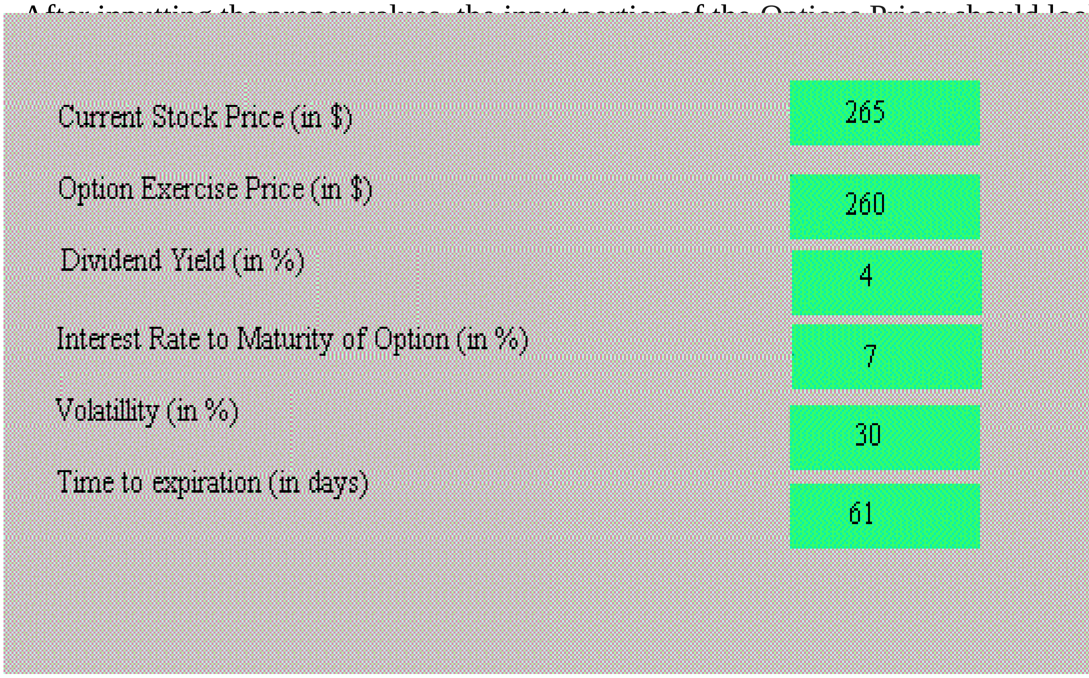
(c) If the current prices of these two calls are $15.75 for the 5-month and $12.12 for the 2-month, then are these options *overvalued* or *undervalued* according to the Black-Scholes formula.

(d) What are the potential causes of these discrepancies?

(e) What standard deviation is implied by the current market price of the 5-month call option (approximately)?

Answers

(a) We can use the Option Pricer to find the value of the call using the Black Scholes equations (alternatively, you can create your own options pricing program in *Excel*). After inputting the proper values, the input portion of the Options Pricer should look like:



After entering the data, we can calculate the call price by typing the *enter* key. The price of the call is returned as $16.1892.

(b) We can price the 5-month option by entering the number of days (153) in the input field. All other information remains the same. The price of the call is returned as $24.2547.

(c) According to these assumptions and the Black-Scholes formula, market is currently undervaluing these calls:

$12.12 < $16.19 (2 month)

and

$15.75 < $24.25 (5 month)

(d) The major sources for errors are: (1) the Black-Scholes assumptions are incorrect or (2) the estimated *sigma* is incorrect.

(e) This question asks us to calculate the *sigma* that makes the Black-Scholes call price exactly equal to the market price. The *sigma* that we get will not equal the .30 that we were given. It will be called the *implied* standard deviation. It turns out that there is no direct way to solve for this implied measure. The implied standard deviation can be obtained by using educated guesses. We can go back to the Options Pricer, and start guessing different values for the volatility. Let's be smart about our choices. We know that options prices increase when volatility increases. Our price is too high, so we need a smaller volatility. Let's try 15% (one half of our initial value). The price that is returned for the two-month option is 9.976. This is too low. The table below shows all of the guesses for both options:

Volatility (2 month)	**Black-Scholes Price**	**Volatility (5 month)**	**Black-Scholes Price**
30%	$16.19	30%	$24.25
15%	$9.98	15%	$14.59
23%	$13.28	23%	$19.72
19%	$11.62	19%	$17.15
21%	12.45	17%	$15.86
20%	$12.03	16%	$15.23
20.5%	$12.24	16.5%	$15.54
20.25%	$12.14	16.75%	$15.70
20.21%	$12.12	**16.82%**	**$15.75**

Hence, the standard deviation implied by the Black-Scholes formula for the 5-month call option is approximately 16.82%.

This method for finding the answer is called the binary method. Each step is half the former step, and the direction is determined by the sign of the error. Using linear interpolation would have produced a result in fewer steps, but would have involved more calculations.

You can also use a spreadsheet package like EXCEL to write your own program. For this it is convenient to proceed with a couple of intermediate calculations. Observe that you basically need two intermediate values:

- The present value of the exercise price, hence, for any given r, T and k you determine your first intermediate result: $y_1 = e^{-rT}$.

- The volatility over the relevant time interval, hence calculate: $y_2 = \sigma\sqrt{T}$

- Now you can calculate the numbers x_1 and x_2 in the Black Scholes formula (6) as:

$$x_1 = \frac{\ln S - \ln y_1}{y_2} + \frac{y_2}{2}$$
$$x_2 = x_1 - y_2$$

- Next, use the NORMDIST() function in EXCEL to evaluate a cumulative normal distribution function at x_1 and x_2.

- Finally, calculate the value of the call option as:

$$C = S * NORMDIST(x_1) - y_1 NORMDIST(x_2) \qquad (10)$$

simply using the appropriate cell references for x_1, x_2, y_1, and y2. If you want to determine implied volatility, you can use the EXCEL function GOALSEEK.[1]

[1] Select the cell that calculates C, select Tool/Goalseek from the Menu, specify in the dialog box that you wish to make the value of C equal to the market value (whatever value you wish to make the theoretical price equal to), and enter the field address for sigma as the field that you want to vary. EXCEL will (if it converges) the implied volatility in the field for sigma.

10.13 Determinants of Option Value

Now that we understand what option contract are and how they are valued we can examine how option prices vary with changes in the stock price, strike price, volatility, interest rates, dividends and time to expiration.

Current Stock Price

As the current stock price goes up, the higher the probability that the call will be in the money. As a result, the call price will increase. The effect will be in the opposite direction for a put. As the stock price goes up, there is a lower probability that the put will be in the money. So the put price will decrease.

Exercise Price

The higher the exercise price (or *strike price*), the lower the probability that the call will be in the money. So for call options that have the same maturity, the call with the lowest strike price will have the highest value. The call prices will decrease as the exercise prices increase. For the put, the effect runs in the opposite direction. A higher exercise price means that there is higher probability that the put will be in the money. So the put price increases as the exercise price increases.

Volatility

Both the call and put will increase in price as the underlying asset becomes more volatile. The buyer of the option receives full benefit of favorable outcomes but avoids the unfavorable ones (option price value has zero value).

Interest Rates

The higher the interest rate, the lower the present value of the exercise price. As a result, the value of the call will increase. The opposite is true for puts. The decrease in the present value of the exercise price will adversely affect the price of the put option.

Cash Dividends

On ex-dividend dates, the stock price will fall by the amount of the dividend. So the higher the dividends, the lower the value of a call relative to the stock. This effect will work in the opposite direction for puts. As more dividends are paid out, the stock price will jump down on the ex-date which is exactly what you are looking for with a put

Time to Expiration

There are a number of effects involved here. Generally, both calls and puts will benefit from increased time to expiration. The reason is that there is more time for a big move in the stock price. But there are some effects that work in the opposite direction. As the time to expiration increase, the present value of the exercise price decreases. This will increase the value of the call and decrease the value of the put. Also, as the time to expiration increase, there is a greater amount of time for the stock price to be reduced by a cash dividend. This reduces the call value but increases the put value.

Summary of Effects:

Determinants of Option Value		
Effect of Increase in	**Call Option**	**Put Option**
Current Stock Price	+	-
Exercise Price	-	+
Volatility	+	+
Interest Rates	+	-
Dividends	-	+
Time to Expiration	+	+

10.14 Claims to the Firm as Options

Throughout this section we have talked about standard exchange traded options. We conclude the section by noting that there are other situations where options can be identified.

- *Firm Common stock.* Suppose that the face value of a corporate bond is $60 million and it matures in 12 months. If the firm's value at that date is less than $60 million, then the stockholders are *out of the money*. If the firm is worth $100 million than we can say that stockholders are *in the money* since we can pay off the debt and have the residual $40 million.

  In other words, firm value takes the role of the "underlying asset", the face value of the bond is the "strike price" with maturity date the date the bond matures. Thus***, common stock is a call option on the value of the firm***, and the exercise price is the par value of the bond.

- *Coupon Bearing Corporate Bonds*. At every time that the coupon is due, the firm faces bankruptcy. Hence, there are multiple options on the value of the firm.

- *Convertible Bonds*. These are straight bonds that give the bondholders the option to convert the bond to the firm's common stock.

- *Callable Bonds*. These are straight bonds that give the issuing firm the option to retire the bonds before maturity by paying a price specified in the bond contract.

- *Warrants*. Warrants are long-term call options issued by the firm on the firm's common equity.

- *Executive Compensation*. Often stock options are issued for executive compensation.

- *Lease with option to buy*. It is common to include in a leasing contract an option to buy the equipment.

- Real Options: a number of capital budgeting decisions made by the firm can be modeled as options.

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