AN INTRODUCTION TO OPTIONS

An option is a right to buy or sell an underlying asset in the future on terms that are established now. A call option is a right to buy the underlying asset at a prespecified price. A put option is a right to sell the underlying asset at a prespecified price. Formal option contracts have explicitly stated exercise prices and expiration dates, as well as other terms (such as terms related to delivery of the asset).

Consider a company, E-Com, Inc., whose shares are publicly traded. Calls and puts on shares of E-Com are also publicly traded. They have an exercise price, *E,* of $10 per share and will expire in one year. In addition, we assume that investors can borrow or lend money at the prevailing risk-free rate of 6 percent. We want to use this information to see how the values of calls, puts, and the underlying shares are related to each other.

Value at Expiration

Notice that there are four different financial assets (calls, puts, the underlying shares, and riskless debt) and that an investor can buy or sell any one of these, or any combination of them. To study value at expiration, it is convenient to show graphically how the value of the investor's position in an asset varies with the value of an underlying share of stock. Suppose the investor buys one share of E-Com, Inc. stock. The value of the investor's position at expiration of the options is always equal to price per share. This is illustrated in Figure 4A-1, part a.

Now, suppose instead that the investor buys a call option on E-Com. Since the call option has an exercise price of $10, it is "out-of- the-money" and worthless if the stock is selling in the market for $10 or less on the expiration date of the option. An investor who wanted to buy the stock could do so less expensively on that day by simply buying it directly in the market. But suppose the stock is selling for $12. Since the option gives the investor the right to buy the stock for $10, even though it has an immediate market value of $12, the option is "in-the-money" and must have a value or $2. If the value of the call option were less than $2, investors would drive the price up by purchasing options, adding $10, and exercising the options to acquire a share of stock worth $12. Figure 4A-1, part b, shows how the value of a call option varies at expiration with the value of the underlying share of stock.

You can see from the figure that buying a call is different in two important ways from buying the underlying stock. First, the purchaser of the call is protected against declines in value of the stock below the exercise price of the option. Second, the investor does not have to pay the exercise price until the date of exercise, and then, only if the option is exercised.

An investor who sells, or "writes," a call option holds the opposite position to the buyer of the option. Thus, if the stock is selling for below the exercise price, the call writer's position also has a value of zero. If the stock is selling for more than the $10 exercise price, the call writer's position has a negative value. The gain to one party is a loss to the other.

The investment gain or loss on trading options depends on the difference between buying and selling prices. If the buyer originally paid $1 for the call option, and the stock ends up selling for $12, then the buyer makes $1 on the transaction. If the buyer originally paid $3, then the writer of the option ends up making $1.

Put options function analogously to call options, except that a put conveys the right to sell. Figure 4A-1, part c, shows how the value of a put option varies with the value of the underlying asset on the expiration date of the option. The put is "out of the money" and worthless if the price of E-Com stock is above the exercise price on the expiration day. If the stock price is less than the $10 exercise price, the put is "in the money" and its value is equal to the difference between the market price of the stock and the exercise price of the option. The writer of a put holds the opposite position of the buyer, and the gains and losses are determined in a manner similar to those on trading calls.

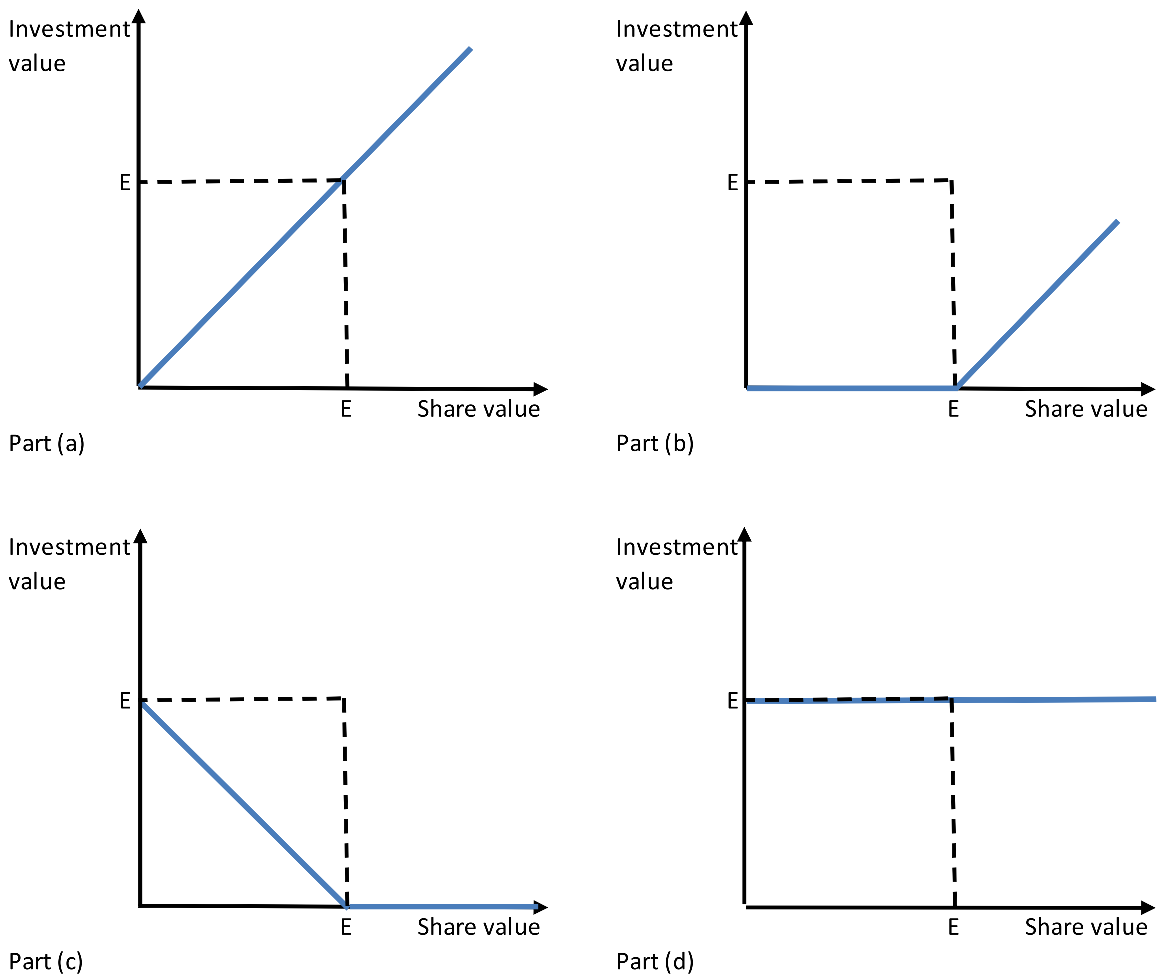

Figure 4A-1 Expiration date values of E-Com, Inc. stock, calls, and puts, and value of riskless debt. Option excercise price is *E*. (a) The value of one share of E-Com, Inc. (b) The value of a call option on one share of E-Com, Inc. (c) The value of a put option on one share of E-Com, Inc. (d) The value of an investment in riskless debt equal to the exercise price of one E-Com, Inc. option

An investor in riskless debt holds a claim, the value of which does not depend on the price of E-Com stock. At a 6 percent rate of interest, the investment will be worth $10 on the expiration date, no matter what happens to E-Com stock. Figure 4A-1, part d, shows the expiration-date value of such an investment in riskless debt.

Put-Call Parity and Market Completeness

Using Figure 4A-1, consider the following two alternative investment strategies. Strategy 1: Buy one share of E-Com stock and buy a put option. Strategy 2: Buy a call option and invest the present value of the $10 exercise price in riskless debt. Figure 4A-2 compares these two strategies. When two or more financial assets are held at the same time, the total position can be described by summing the components vertically in the figure. You can see that the payoffs at option expiration are identical for the two strategies. Each one amounts to an investment in E-Com stock that is hedged against the risk of a price decline below the exercise price of the options.

Since the two strategies have identical payoffs, they must also have the same market value before expiration of the options. If not, it would be possible for investors to risklessly arbitrage the price disparities. The potential for arbitrage exists because when these four financial assets are available, the market is complete. Market completeness implies put-call parity, as illustrated in the figure.

Sometimes put-call parity is expressed algebraically as:

Stock + Put = Call + Present Value of Exercise Price

In fact, this is what is illustrated in the figure. You can see that by rearranging the terms in the equation, when the market is complete, riskless arbitrage is possible and there are two ways to construct any financial position. You can, for example, buy a put directly, or by buying a call, investing in riskless debt, and selling the stock short. That is,

Put = Call + Present Value of Exercise Price - Stock

Riskless Arbitrage

To illustrate how riskless arbitrage gives rise to put-call parity, consider the following example. E-Com stock is selling for $8 per share. One-year calls with an exercise price of $10 are selling for $2, and one-year puts with the same exercise price are selling for $5. The interest rate on riskless debt is 6 percent.

With these market values, put-call parity is violated as follows.

Stock + Put > Call + Present Value of Exercise Price
$8 + $5 > $2 + $9.43

The securities are mispriced relative to each other. Arbitrage can be used to exploit the mispricing, even though we cannot tell specifically which security(ies) is (are) priced incorrectly. To do so, you would sell the stock and a put for a total of $13, and use the proceeds to buy a call and invest $9.43 (the present value of the $10 exercise price) in riskless debt. Doing so would leave you with $1.57 in cash as the arbitrage profit. At expiration of the options, your total position is certain to have a net value of zero. The call option, the investment in debt, and the put option you have written exactly offset the short position in the stock. Hence, the gain is riskless.

Option Values before Expiration

Before expiration, the relative values of puts and calls are enforced by riskless arbitrage. But how are the actual values of the individual securities determined? The answer is that pre-expiration values of options are affected by four factors. First, value depends on the difference between the price of the underlying asset and the exercise price (similarly to the way it depends on this difference at the time of expiration). Second, the greater the risk of an asset per unit of time, the greater is the value of a call or put option on the asset. Since the risk exposure of an option is one-sided, option value increases with risk. Consider a homeowner’s insurance policy (a put option). The greater the risk of loss due, for example, to fire or flood, the more valuable is the insurance (and probably the more expensive). If there were no risk of damage to the property, the homeowner’s insurance policy would be worthless. Third, the value of an option increases with time to expiration. An insurance policy that

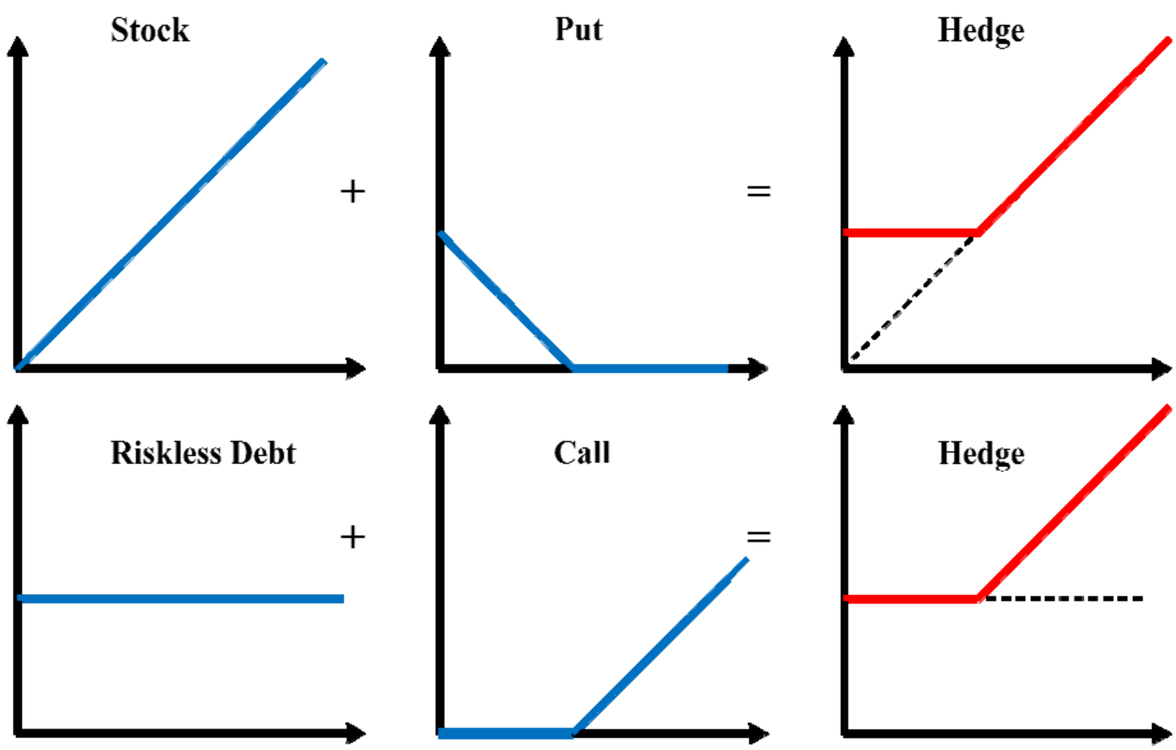

Figure 4A-2 Put-call parity.
Put-call parity is assured if there are two combinations of securities that yield identical payoffs. The figure illustrates that the payoff at expiration of buying the underlying stock and a put option is identical to the payoff of buying a call option and investing the present value of the exercise price in riskless debt.

will protect you for a year is more likely to be used than one that will protect you for a month. The one-year put option is more valuable. Fourth, the values of calls increase with the riskless rate of interest. Buying a call and writing a put with an exercise price of $10 is the same as buying the underlying stock, except that you do not have to pay the exercise price until expiration. Since this is like borrowing the exercise price for free, and a free loan is worth more, the higher the prevailing rate of interest, option values increase with the riskless rate of interest.

To get a fuller understanding of how risk of the underlying asset affects option value before the expiration date, consider a call option with an exercise price of $10. Suppose that the current price of the stock is $15 and that there is almost no chance that the price will drop below $10 by the expiration date of the option. In this case, buying the call is almost the same as buying the stock but postponing payment of the exercise price until expiration. The option affords very little protection against declines in the stock price. The option, in this case, should sell for a price slightly above $5, owing mainly to the value of delaying payment of the exercise price.

Now consider the opposite possibility—that the stock is selling for $5, and there is very little chance of it rising to above $10 before the option expires. In this case, the option is almost (but not quite) certain to end up out-of-the-money. Buying the call is almost like buying nothing. The call should sell for slightly above zero, because there is always a small chance that the underlying stock will increase in value to a price above $10.

These are extreme cases in which the call option does not contribute much to hedging the downside risk of the investor while offering the potential for positive return. Now consider that the stock is selling for a price close to $10. For simplicity, suppose the stock is equally likely to end up being worth $8 or $12. Since the option will have a value of $2 if the stock ends at $12 and will otherwise be worthless, the option is worth about $1 (i.e., $2 times the 50 percent probability), even though the stock is currently selling for $10.

To see that options on riskier assets are more valuable, suppose the underlying asset were equally likely to end up being worth $6 or $14 (the same expected value as before but with more risk). In this case, the value of the call option increases to about $2. The riskier the underlying asset, the more beneficial the insurance protection of the option.

The Black-Scholes Option Pricing Model

Formal evaluation of options exploits the principles of complete markets and riskless arbitrage to infer that investors in options should be risk-neutral. The Option Pricing Model uses risk-neutrality and the assumption that the risk of the underlying asset can be described as a normal distribution. The book Web site contains an Excel spreadsheet that you can download and use as a template to value puts, calls, and combinations of options using the Option Pricing Model.

LIMITATIONS OF FORMAL OPTION VALUATION

The Option Pricing Model depends on market completeness, continuous trading, normally distributed risk, independence, and other factors to derive option values. When these assumptions are violated (as they usually are for new ventures and for real options), formal valuation approaches can still provide insights, but the actual values of options are less certain. It is common to employ simulation and numerical methods to value options when critical assumptions are not satisfied.