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Trading Options

as a

Professional

TECHNIQUES FOR MARKET MAKERS AND EXPERIENCED TRADERS

JAMES B. BITTMAN

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McGraw Hill

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For my wife, Laura,

Thank you for loving me,
and for understanding my passion for trading.

For our daughter, Grace,

whose joy in discovering the world thrills me every day.

And for all traders,

who have opened my eyes to the camaraderie of riding the market.

I want you all to know that trading is like life. Look for opportunities, weigh the risks, and go with your instincts. Mistakes are inevitable; learn and grow from them. Work hard at it, and enjoy the process. That is the path to success.

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DISCLOSURES AND DISCLAIMERS

Throughout this book, hypothetical examples are used. Although they are meant to represent realistic scenarios, any strategies discussed, including examples using actual securities and/or actual price data, are strictly for illustrative and educational purposes only. They are not to be construed as an endorsement, recommendation, or solicitation to buy or sell securities or to employ any specific strategy.

In order to simplify computations, commissions and other transaction costs have *not* been included in the examples used in this book. Commissions will affect the outcome of stock and option strategies and should be considered in real-world situations. The investor considering options should consult a tax advisor as to how taxes may affect the outcome of any option transactions.

Options involve risk and are not suitable for everyone. Prior to buying or selling an option, a person must receive a copy of *Characteristics and Risks of Standardized Options*. Copies may be obtained from your broker or from Op-Eval, 2406 North Clark Street, Box 154, Chicago, IL 60614. A prospectus, which discusses the role of the Options Clearing Corporation, is also available without charge on request addressed to the Options Clearing Corporation, One North Wacker Drive, Suite 500, Chicago, IL 60606.

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INTRODUCTION—LEARNING TO TRADE OPTIONS AS A PROFESSIONAL

If you are a market maker in training or an individual trader who is serious about trading options, there are eight option topics you need to master. These are what I call the *eight essentials:*

- Option market fundamentals
- Option price behavior, including the Greeks
- Synthetic relationships
- Pricing arbitrage strategies
- Volatility
- Delta-neutral trading
- Setting bid and ask prices
- Managing position risk

This book is intended to give prospective market makers a thorough grounding in all advanced topics related to options trading from volatility to delta-neutral trading to setting bid and ask prices to managing position risk. For individual traders it will demonstrate how to plan option trades and how to use volatility to estimate stock-price ranges, to pick stock-price targets, and to choose option strike prices. The insights into how market makers think are designed to help individual traders enter orders for outright long and short option trades and for spreads.

Unfortunately, a thorough understanding of each essential topic requires at least a minimal understanding of one or more of the other topics. A sequential discussion, therefore, with one topic building on another, is impossible. Consider, for example, the topics of option price behavior and volatility. Because volatility is an intermediate to advanced subject in options, that chapter follows the discussion of option price behavior. Volatility, however, affects an option's price, so some understanding of volatility is necessary to understand option price behavior. Similarly, volatility and delta-neutral trading possess numerous overlapping concepts. Discussing either one before the other is problematic. Nevertheless, the topics must have some order. When you gain a greater understanding of each topic as you proceed through this book, you may find a review of previous chapters to be helpful.

The *eight essentials* will be explained in-depth with examples to illustrate each concept. Chapter 1 assumes a basic level of options knowledge and presents only a brief review of market fundamentals and strategies discussed later. Chapter 1, however, also discusses the intricacies of margin accounts, short stock rebate, and the concept of the national best bid and best offer (NBBO). Chapter 2 reviews the many features of the Op-Eval Pro software that accompanies this text, which was used to create the tables and exhibits in all chapters. The features of the software include tools for analyzing option prices, asking "what if?" questions, evaluating the risk of simple and complex positions, graphing multilegged positions, and many other critical tasks performed by option traders.

Chapter 3 explains why options have value, how the values change as market conditions change, and the differences between planning stock trades and planning option trades. Chapter 4 delves deeper into option price behavior by discussing the Greeks: delta, gamma, vega, and theta. These factors explain the impact of various pricing components. If you understand the Greeks, you will grasp the nuances of advanced spread strategies.

Chapter 5 discusses synthetic relationships, an understanding of which will reinforce your knowledge of option price behavior. Synthetic relationships also can play an important role in risk management. Chapter 6 expands on synthetic relationships, moving up to the more advanced level of arbitrage strategies, conversions, reverse conversions, and box spreads. Arbitrage is a key element of options market making.

Chapter 7 tackles the concept of volatility. It first demonstrates how historic volatility is calculated and then discusses the dynamics of implied volatility. The review of the statistics involved with expected stock-price distributions will help to clarify what is the essence of volatility. The chapter ends by introducing the subject of volatility skew. Chapter 8 presents four in-depth delta-neutral trading exercises that demonstrate the theory and reality of this strategy and how speculators and market makers might use it. The exercises reveal some important relationships between option prices and stock-price fluctuations.

In its discussion of setting and adjusting bid and ask prices, Chapter 9 brings together the topics of volatility and synthetic relationships to illustrate how market makers set bid and ask prices and evaluate alternatives for entering and exiting positions. Chapter 10 demonstrates how position Greeks are calculated and how they might be used to analyze position risk and to set risk limits. Neutralizing the Greeks, identifying which Greek to emphasize, and determining how to choose risk-reducing trades conclude the discussion.

By the end of Chapter 10, the goal is that you will have gained knowledge about option price behavior, advanced option strategies, and volatility that will increase your trading confidence. Arbitrage, using delta-neutral trading to set and adjust bid and ask prices, and managing position risk are the skills that option market makers in training need to learn. The insights into volatility and how market makers trade are designed to improve the individual trader's ability to anticipate how option strategies perform.

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Trading Options *as a* Professional

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Chapter 1

OPTION MARKET FUNDAMENTALS

As stated in the Introduction to this book, a familiarity with option market fundamentals is the first of *eight essentials* that advanced option traders must master. This chapter reviews briefly the basic terminology of options and then explains the mechanics of margin accounts, short stock rebate, and calculation of the *national best bid and best offer* (NBBO). Profit and loss diagrams of four basic strategies and eight intermediate and advanced strategies are presented with explanations. A thorough understanding of the mechanics of these strategies is a necessary foundation for the discussions in later chapters.

Fundamental Terms

Options are contracts between buyers and sellers. Option buyers get a limited-time right to buy or sell some underlying instrument at a specific price. For this right, they pay a premium, or price. The seller of an option receives payment from the buyer and assumes the obligation to fulfill the terms of the contract if the buyer exercises the right.

A *call option* gives the buyer the right to buy the underlying instrument at the strike price until the expiration date. The seller of a call option is obligated to sell the underlying instrument at the strike price until the expiration date if the call buyer exercises the right to buy.

A *put option* gives the buyer the right to sell the underlying instrument at the strike price until the expiration date. The seller of a put is obligated to buy the underlying instrument at the strike price until the expiration date if the put buyer exercises the right to sell.

The *underlying instrument*, or, simply, the *underlying*, can be a stock, a futures contract, a physical commodity, or a cash value based on some index. The *strike price*, or *exercise price*, is the specific price at which the underlying can be bought or sold, and the *expiration date* is the last day that an option can be exercised. After the expiration date, the option contract and the right cease to exist. An option not exercised by the expiration date expires worthless.

As an example, consider an "XYZ December 50 Call" that trades at a price of 3.00. The underlying is "XYZ," which, in the United States, is typically 100 shares of XYZ stock. "December" indicates the expiration date, which, for stock options traded in the United States, is the third Friday of the stated month. The strike price of "50" is the price per share the buyer who exercises the call will pay for that XYZ stock. "3.00" represents the price per share of the option, so the purchaser of this option would pay $300 ($3 on 100 shares) to the seller.

Stock Trades Compared with Option Trades

Stock trades and option trades are similar in many ways, but option trades can be much more complicated transactions. The amount of information an option trader must convey to a broker is, by itself, significantly more than in a stock trade. To illustrate this difference, the upper section of Table 1-1 shows that a typical stock trade requires four pieces of information or decisions, and the lower section shows that a typical option trade requires seven pieces of information or decisions.

As indicated by the numbers, there are four parts to the stock trader's instruction, "Buy long 1,500 XYZ at 63.50." The first part of the instruction describes the action to take. In this example, "Buy long" is the action. For stock trades, there are four possible actions or types of trades.

Table 1-1 Stock Trades versus Option Trades

Stock trade:	Buy long	1,500	XYZ	@ 63.50			
	1	2	3	4			
1 Action:	Buy long						
	Buy to cover						
	Sell long						
	Sell short						
2 Quantity:	Number of shares						
3 Stock name:	Ticker symbol						
4 Price:	The price per share						
Option trade:	Buy to open	15	XYZ	Jan	65	Calls	@ 2.80
	1	2	3	4	5	6	7
1 Action:	Buy to open						
	Buy to close						
	Sell to open						
	Sell to close						
2 Quantity:	Number of contracts						
3 Underlying:	Typically 100 shares of the stock*						
4 Expiration:	The Saturday following the third Friday of the stated month						
5 Strike price:	The price per share at which stock is traded if the option is exercised or assigned						
6 Option type:	*Call* The right to buy the underlying for the option owner and the obligation to sell the underlying for the option writer						
	Put The right to sell the underlying for the option owner and the obligation to buy the underlying for the option writer						
7 Price:	The price per underlying share paid for the option						

* The *underlying instrument* of an option contract is typically 100 shares of stock, but there are many exceptions; for example, after a three-for-two stock split, the underlying might change to 150 shares. Also, for cash-settled options, the underlying is a cash value.

Buy long means that the stock is being newly purchased. *Buy to cover* means that a short stock position is being closed. *Sell long* indicates that a trader wants to close a long stock position. *Sell short* indicates that a trader wants to create a new short stock position. In a short sale, the brokerage firm borrows shares on behalf of the trader and sells them in the market. The stock lender holds the cash proceeds from the sale. This type of action will be discussed in greater detail later in this chapter.

The second part of the stock instruction represents the quantity to be bought or sold. In this example, "1,500" is the quantity, or number, of shares being traded. The third part, "XYZ," is the ticker symbol of the stock being traded. Finally, the last part of the instruction, "at 63.50," is the price per share at which the stock is to be purchased. Essentially, a stock trader has to decide which stock, the action or type of trade, how many shares, and at what price to trade them.

In the bottom portion of Table 1-1, the option instruction is "Buy to open 15 XYZ Jan 65 Calls at 2.80." This instruction contains seven parts. As with stock trades, "Buy to open" describes the action. Also similar to stock trades, option trades may consist of four possible actions. *Buy to open* indicates that a new long option position is being created. *Buy to close* means that an existing short option position is being closed. *Sell to open* indicates that a new short option position is being created, and *Sell to close* means that an existing long option position is being closed.

When a trader sells options to open, a brokerage firm has no need to borrow anything, unlike with a short sale of stock. Options are simply contracts containing rights and obligations that are created by mutual agreement between buyers and sellers. The payment made by an option buyer is made for the right contained in the contract, not for ownership of the underlying. The option seller receives cash from the buyer in return for assuming an obligation that may or may not be fulfilled in the future. To demonstrate an ability to fulfill the terms of the contract, an option seller must deposit cash with the brokerage firm. This deposit is known as a *margin deposit* and will be discussed in greater detail later in this chapter.

The second part of the option instruction, "15," is the number of option contracts being traded. The third part, "XYZ," is the ticker symbol of the underlying stock. Typically, an option covers 100 shares of that stock. The fourth part of the instruction consists of the expiration month of the option, and in this example, the options expire in "January." Options on stocks usually stop trading on the third Friday of the month and expire on the next day, a Saturday. Cash-settled index options typically stop trading on the Thursday before the third Friday, with the final settlement value determined by Friday morning opening prices. Option traders can find detailed information about settlement procedures from the exchange where an option is traded.

The fifth piece of the instruction shown in the bottom portion of Table 1-1 is "65." This number is the *strike price*, or the price at which the underlying stock is traded if the option is exercised or assigned. *Exercise* is the action taken by option owners if they want to invoke the right contained in the option contract. *Assignment* is the selection process by which a person holding a short option position is chosen to fulfill the obligation of the short option contract.

The word *Call* denotes the type of option, and "Call" is the sixth component in the instruction. There are, of course, call and put options. Finally, the last part of the instruction, "at 2.80," is the price per share at which the option is being traded. Assuming that 100 shares of stock is the underlying, then an option traded at "2.80" actually costs $280 plus transaction costs.

In addition to the four decisions that a stock trader must make—the stock, the type of trade, how many shares, and the price—option traders also must decide on an option's type, its strike price, and its expiration date. As will be discussed in later chapters, this seemingly small difference of three more decisions for option traders has profound implications for the range of strategy alternatives, the importance of time in the market forecast, and the need for a specific stock price target.

Premium

Option traders commonly refer to the price of an option as the *premium*, a term that originates from the insurance industry and reflects one of many similarities between the language of options and the language of insurance. The similarities, in fact, extend beyond language because there are many analogies between options and insurance.

As will be discussed in later chapters, volatility in options is analogous to risk in insurance, option payoffs are similar to claims paid by insurance policies, and time decay of option values is similar to insurance premiums varying with length of coverage.

The terms *buyer*, *long*, and *owner* are interchangeable, and all describe the position of the option purchaser. Hence an option buyer also can be described as having a "long option position" or as being an "option owner."

The terms *seller*, *short*, and *writer* are also interchangeable and describe the position of the person who is obligated by an option contract. Hence an option seller is described as having a "short position" or as being the "option writer." The term *writer* also originates from the insurance industry.

When an option is traded, the buyer pays the premium to the seller. When an option is exercised, a transaction in the underlying occurs at the strike price. Consequently, if one XYZ January 50 Call trades at a price of 3, then the buyer of this call has obtained the right to buy 100 shares of XYZ stock at a price of $50 per share until the expiration date in January. For this right, the buyer pays $3 per share ($300 per option) to the seller, who assumes the obligation of selling 100 shares of XYZ stock. If the call owner exercises the right, then a stock transaction occurs; the call owner purchases 100 shares of XYZ stock at $50 per share and pays $5,000 plus commissions to the call writer, who delivers the shares and receives the payment.

The situation for puts is similar. If one QRS August 30 Put trades at a price of 2, then the buyer of this put has the right to sell 100 shares of QRS stock at a price of $30 per share until the expiration date in August. For this right, the buyer pays $2 per share ($200 per option) to the seller, who assumes the obligation of buying 100 shares of QRS stock. If the owner of the put exercises, then a stock transaction occurs. The put owner sells 100 shares of QRS stock at $30 per share and receives $3,000 less commissions from the put writer, who buys the shares and makes the payment.

The Process of Exercise and Assignment

When an option is exercised, a random process, known as *assignment*, selects an option writer to fulfill the terms of the option. An option owner triggers this process when he or she notifies a brokerage firm of an intent to exercise the option. The firm then notifies the Options Clearing Corporation (OCC), which is the central clearinghouse for listed options in the United States. The OCC randomly selects a brokerage firm holding one or more short positions in the option being exercised. Finally, that firm selects a customer from among it appropriate option writers, and that customer is given an assignment notice. The appropriate transfer of cash and shares between the option exerciser and the assigned option writer completes the transaction.

Categories of Options

Options fall into two broad categories, physical-delivery options and cash-settled options. *Physical-delivery options* require the transfer of some underlying instrument when exercise and assignment occur. The underlying for equity options in the United States, for example, is typically 100 shares of stock. The underlying for futures options is typically one futures contract. When a physical-delivery equity option is exercised, the shares are purchased or sold at the strike price. A call exerciser becomes the buyer, and the assigned call writer becomes the seller. In the case of physical-delivery equity puts, the put exerciser becomes the seller, and the assigned put writer becomes the buyer.

In contrast to physical-delivery options, when exercise of a *cash-settled option* occurs, then, as the name implies, only cash changes hands. Consider an SPX December 1500 Call that is exercised when the SPX Index is 1520. SPX is the symbol for cash-settled index options on the Standard & Poor's (S&P) 500 Stock Index. If this call were exercised when the SPX Index is at 1,520, then the option writer would deliver a cash amount equal to 20 index points to the option owner. In the case of SPX Index options, each index point has a value of $100. Therefore, if the index is 20 points above the strike price of an exercised call, the seller delivers $2,000 (20 points times $100 per point) to the buyer.

In-the-Money, At-the-Money, and Out-of-the-Money Options

The relationship of the price of the underlying to the strike price of the option determines whether the option is in the money, at the money, or out of the money. A call is *in the money* if the price of the underlying is above the strike price of the call. *At the money* for a call means that the price of the underlying is equal to the strike price, and *out of the money* indicates that the price of the underlying is below the strike price of the call. With a stock price of $100, for example, the 95 Call is in the money. Specifically, it is in the money by $5.00. The 100 Call is at the money, and the 105 Call is out of the money by $5.00.

For puts, the relationship of the underlying price to the strike price is opposite that for calls. A put is *in the money* if the price of the underlying is below the strike price of the put and *out of the money* if the price of the underlying is above the strike price of the put. With a stock price of $100, the 95 Put is out of the money by $5.00, and the 105 Put is in the money by $5.00. *At the money* has the same meaning for puts as it does for calls—the strike price equals the price of the underlying.

Although an option can be truly called *at the money* only when the underlying price exactly equals the strike price, traders commonly refer to an option as an "at-the-money option" when its strike price is closest to the underlying price. Thus, when a stock price is $101 or $99, option traders typically refer to both the 100 Call and 100 Put as the at-the-money options, even though one is slightly in the money and one is slightly out of the money.

Intrinsic Value and Time Value

The price of an option consists of two components, intrinsic value and time value. *Intrinsic value* is the in-the-money portion of an option's price, and *time value* is the portion of an option's price in excess of intrinsic value, if any. Consider a situation in which the stock price is $67, and the option prices exist as stated in Table 1-2

Column 1 in Table 1-2 contains a range of strike prices and the option types. Column 2 lists various option prices. Columns 3 and 4 contain corresponding intrinsic values and time values, respectively. The price of 3.50 of the 65 Call, in the fifth row, for example, consists of 2.00 of intrinsic value and 1.50 of time value. The intrinsic value of 2.00 is calculated by subtracting the strike price of the call of 65 from the stock price of 67. The time value of 1.50 is calculated by subtracting the intrinsic value of 2.00 from the option price of 3.50.

The option in the first row, the 55 Call, is different from all the other options in this example because its price of 12.00 consists

Table 1-2 Intrinsic Value and Time Value
Stock price: 67.00

	Column 1	Column 2	Column 3	Column 4
	Strike Price and Option Type	Option Price	Intrinsic Value	Time Value
Row 1	55 Call	12.00	12.00	0.00
Row 2	55 Put	0.10	0.00	0.10
Row 3	60 Call	7.50	7.00	0.50
Row 4	60 Put	0.30	0.00	0.30
Row 5	65 Call	3.50	2.00	1.50
Row 6	65 Put	1.10	0.00	1.10
Row 7	70 Call	1.30	0.00	1.30
Row 8	70 Put	3.90	3.00	0.90
Row 9	75 Call	0.60	0.00	0.60
Row 10	75 Put	8.10	8.00	0.10

entirely of intrinsic value. It has no time value. This option is said to be *trading at parity* because, in theory, a trader would be indifferent between buying stock at 67.00 per share and buying this 55 Call at 12.00 and exercising it. If this 55 Call were exercised, then the total price paid for the stock would be equal to the market price of 67, the strike price of 55 plus the call premium of 12. In practice, given these prices, transaction costs make buying the stock preferable to buying the call.

A review of Table 1-2 shows that near-the-money options such as the 65 and 70 Calls and Puts have the largest time values, whereas deeper-in-the-money and farther-out-of-the-money options have less time value. This concept will be discussed further in Chapter 3 in connection with option pricing.

The Market—Definition 1

Traders, financial institutions, and the financial media and press all use the term *the market* loosely, but it has two different meanings. First, the market is a location, typically an exchange, where buyers and sellers meet to make trades. An exchange can be a physical location where people gather, or it can be a centralized computer system to which traders connect through their brokers.

Historically, the New York Stock Exchange, the American Stock Exchange, and the regional stock exchanges were physical locations where people came to trade in *open outcry*. Customers from all over the world would telephone or wire their stockbrokers with buy and sell orders. These orders then would be forwarded to a representative at the exchange known as a *floor broker*. The floor broker would negotiate verbally with traders on the exchange's trading floor to buy or sell on a customer's behalf.

The over-the-counter (OTC) market was the first stock market without a physical central location. Buyers and sellers, however, did negotiate verbally over the phone. Brokers sometimes would make several phone calls to find the best price for their clients, and sometimes, when the broker called back, the shares would no longer be available.

Before the advent of listed options in 1973, options in the United States were traded by means of a telephone network known as the *Over-the-Counter Put and Call Broker Dealer Association*. A customer wanting to buy or sell an option would contact a put and call broker, who then would make phone calls until someone willing to take the other side of the trade was found. Once such a person was found, there could be several back-and-forth phone calls—with the broker in the middle—until a price agreeable to both parties was reached.

Today, the necessary functions of exchanges are aided greatly by technology. The role of human interaction to negotiate prices is rapidly diminishing. Prices and quantities of stock shares and option contracts are available via computer, and buy and sell orders can be initiated and confirmed by the click of a mouse. Computers, however, have not replaced the need for human decision makers. This book focuses on how to understand the dynamics of options to improve decision making.

The Market—Definition 2

The second meaning of the term *the market* relates to the prices at which buyers and sellers want to trade. The *bid price*, or simply the *bid*, is the highest price that someone is currently willing to pay. The *size of the bid*, or simply the *size*, is the number of shares of stock or the number of option contracts that the person bidding is willing to buy.

Over time, traders have developed a shorthand manner of referring to the bid and the size of an offer to buy or sell. For example, if Trader A bids $2.20 per share for 40 XYZ January 80 Calls, then traders commonly would say that his or her bid is "2.20 for 40." Everyone understands that "2.20" is the dollar price per share price and that "40" is the number of option contracts. The word *for* replaces *bid for*. Note that the price is stated before the quantity when a trader is bidding.

The price at which shares or option contracts are offered for sale is known as the *ask price* or the *offer price*, or simply the *ask* or the *offer*. If Trader B offers 20 XYZ January 80 Calls for sale at $2.30 per share, the shorthand reference would be "20 at 2.30." Note that quantity is stated before price when a trader is offering.

In the days of *open outcry trading*, when bids, offers, and trades all were made verbally, a broker wanting to know the current status for a client might ask, "What is the market in XYZ January 80 Calls?" Trader A would then respond, "2.20 for 40," and Trader B would follow with "20 at 2.30." The broker then would report to the client that, "The market is 2.20–2.30, 40 by 20." "2.20–2.30" describes the bid and ask prices, and "40 by 20" describes the size, or quantity of option contracts bid for and offered.

In the open outcry system, a trade occurs when a buyer and a seller agree on a price and a quantity. In the preceding example, it is possible that after some consideration, Trader B decides not to wait for someone to pay $2.30 for his or her 20 calls. Instead, he or she might lower the asking price to $2.20. If Trader A is still bidding $2.20 for 40 contracts, then Trader B can say, "Sell you 20 at 2.20." If Trader A says, "I'll buy them," then a trade of 20 calls at 2.20 per share has occurred.

In today's world of computers, it is still necessary to know the shorthand language of open outcry trading. After all, people still talk to each other! Money managers frequently work through brokers rather than entering orders themselves, and many individual traders share information about their activities with other traders. Imagine a money manager telephoning his or her broker to find out the status of an order to sell 200 calls at a price of 4.10. "How are those calls?" asks the money manager. "Sold 60 this morning. The market's 3.90–4.00, 100 by 50 right now," is the reply. This response explains everything—if the language of trading is understood.

Public Traders and Market Makers

A *public trader* is an individual or organization that is not a member of an exchange and is not a broker-dealer. In the brokerage industry, public traders are referred as *retail investors*. The term *public trader* refers to a wide range of market participants from mutual funds, pension funds, and other professionally managed money to individual investors and traders. Professionally managed pools of money, known as *hedge funds*, also can be public traders. The distinguishing aspect of public traders is that they are subject to standard margin requirements that are established by Regulation T, a stock or bond exchange, or the Options Clearing Corporation. Public traders can make bids and offers and withdraw them sporadically as their changing market forecasts motivate them to do so.

A *market maker* is an individual or organization that is a member of an options exchange and is registered with the Securities and Exchange Commission (SEC) as a broker-dealer. As an exchange member, a market maker agrees to maintain bid and ask prices at no more than specific maximum spreads and to bid for and offer options in at least minimum quantities. This requirement for market makers applies only to normal market conditions and varies by exchange and class of market maker. The role of the market maker is to ensure the existence of a market for public traders who want to open or close positions. In return for assuming the obligation of being continuously present in the market, market makers have lower margin requirements than public traders.

National Best Bid and Best Offer

In most stock, options, and futures markets in the United States, many public traders and market makers may be bidding and offering at the same time. In the stock and options markets, more than one exchange also will be open at any given time. It is therefore a complicated technical problem to identify all the bids and offers and to disseminate and prioritize them so that a new participant can find the highest bid price and the lowest offer price.

Table 1-3 presents a hypothetical example of the market in XYZ 50 Calls. The table has five columns, the first of which lists the exchange and the nature of the participant, the market maker or public trader who is participating in the market for the XYZ 50 Calls. In this scenario, three exchanges are participating in the market. Exchange 1 has two market makers that are bidding and offering and one public trader that is only offering. Market Maker 1–1 is bidding 3.60 for 50 contracts and offering 50 contracts at 3.90. Market Maker 1–2 is bidding 3.60 for 30 contracts and offering 30 contracts at 4.00. Public Trader 1–1 is offering 5 contracts at 4.20.

Exchange 2 has one market maker and one public trader. Market Maker 2–1 is bidding 3.70 for 20 contracts and offering 20 contracts at 4.00. Public Trader 2–1 is bidding 3.70 for 5 contracts. Finally, at Exchange 3, Market Maker 3–1 is bidding 3.70 for 50 contracts and offering 50 contracts at 4.00, Public Trader 3–1 is offering 10 contracts at 4.10, and Public Trader 3–2 is offering 10 contracts at 3.90.

Based on the information about the bids and offers by all market makers and all public traders at the three exchanges, the bottom row

Table 1-3 Determining the NBBO Market for the XYZ 50 Call

Col 1	Col 2	Col 3	Col 4	Col 5
	Bid Price	Bid Quantity	Ask Price	Ask Quantity
Exchange 1				
Market Maker 1–1	3.60	50	3.90*	50*
Market Maker 1–2	3.60	30	4.00	30
Public Trader 1–1			4.20	5
Exchange 2				
Market Maker 2–1	3.70*	20*	4.00	20
Public Trader 2–1	3.70*	5*		
Exchange 3				
Market Maker 3–1	3.70*	50*	4.00	50
Public Trader 3–1			4.10	10
Public Trader 3–2			3.90*	10*
National best bid best offer (NBBO)	3.70	75	3.90	60

* Indicates participation in the national best bid and offer (NBBO).

of Table 1-3 shows that the national best bid and best offer (NBBO) is 3.70 bid for 75 contracts and 60 contracts offered at 3.90. An asterisk by a price or quantity indicates participation in the NBBO. The best bid of 3.70 for 75 contracts consists of the bid of Market Maker 2–1 for 20 contracts, the bid of Public Trader 2–1 for 5 contracts, and the bid of Market Maker 3–1 for 50 contracts. The best offer of 60 contracts at 3.90 consists of the offer of Market Maker 1–1 of 50 contracts and the offer of Public Trader 3–2 of 10 contracts.

The fact that not all exchanges are participating in the NBBO raises a question for public traders. What if a new public trader, call him or her Public Trader 2–2, entered the market and bid 3.90 for 30 contracts at Exchange 2? Public Trader 2–2 clearly deserves to be sold 30 contracts at 3.90 because the national best offer is for more than 30 contracts at that price. At Exchange 2, however, there are no contracts offered at 3.90 and only 20 contracts offered at 4.00. What will happen?

An SEC rule prohibits exchanges from allowing trades outside the NBBO. Therefore, Public Trader 2–2 cannot pay 4.00 for any contracts. Two potential resolutions to this situation will enable Public Trader 2–2 to buy the desired 30 contracts at the national best offer of 3.90.

The first possibility is that Market Maker 2–1 at Exchange 2 could lower the offer price and increase the quantity and sell 30 contracts at 3.90 to Public Trader 2–2. The second possibility is that the order from Public Trader 2–2 could be forwarded to another exchange, where the contracts are offered on the NBBO and where Public Trader 2–2 would buy the contracts. In this case, more than 30 contracts are being offered at 3.90 at Exchange 1, so that is where the order would be forwarded. If neither Exchange 1 nor Exchange 3 could sell 30 contacts individually, but they could in total, then the order from Public Trader 2–2 could be divided between the two exchanges.

Both resolutions just described enable the order from Public Trader 2–2 to be filled at the NBBO. With today's advanced electronic trading systems, public traders should not be overly concerned about which exchange gets their orders because they must be filled at a price no worse than the NBBO.

Margin Accounts and Related Terms

Option traders need to be aware of margin account procedures because SEC regulations require some option strategies to be established in margin accounts. The following overview merely summarizes margin accounts and related terms.

A *cash account* is an account at a brokerage firm in which all purchases are fully paid for in cash. In a *margin account*, the brokerage firm may lend money to the customer to finance certain types of positions called *marginable transactions.* Different types of marginable transactions, according to regulations, require different amounts of equity capital from the customer. This equity capital is called a *margin deposit* or, simply, *margin.*

For example, the account equity balance of an investor who purchases stock "on margin" will be less than the value of the stock. The brokerage firm lends the balance of the purchase price to the investor, who, of course, pays interest on the loan. The use of margin debt will have a significant impact on an investor because market fluctuations will change the account equity balance at a greater percentage rate than the same fluctuation would cause in the equity balance of a cash account. This is called *leverage.*

Another common marginable transaction is selling stock short. In this transaction, the brokerage firm borrows stock on behalf of the customer, who sells it at the current market price with the hope of buying it back later at a lower price. The stock loan is "repaid" with purchased shares when the short stock position is covered. In a short stock transaction, the customer actually pays nothing when initiating the position (except commissions), but the brokerage firm will require a margin deposit to guarantee that the customer will cover any potential losses.

Some option transactions are marginable transactions, and some are not. Also, certain option transactions are required to be conducted in a margin account, and others may be conducted in either a cash account or a margin account. Before engaging in option transactions, an investor should be thoroughly familiar with the type of account required for the transactions that are planned. A simple formula to remember is

Account equity + margin debt = account value

Account value is the total market value of owned securities. The *margin debt* is the loan to the investor from the brokerage firm, and the *account equity* is the investor's share after the securities are sold and margin debt is repaid.

Initial Margin, Minimum Margin, Maintenance Margin, and Margin Call

Initial margin is the minimum account equity required to establish a marginable transaction. Initial margin requirements are frequently expressed in percentage terms of the market value of a position or its underlying security. Purchasing stock, for example, is a marginable transaction that currently has an initial margin requirement of 50 percent: Purchasing 100 shares of a $50 stock requires an initial margin of $2,500 plus commissions, or 50 percent of the purchase price plus commissions. The loan made to the buyer would equal $2,500, or the remaining 50 percent of the purchase price.

If a margined position loses money, the account equity will decrease both absolutely and as a percentage of the total account value. *Minimum margin* is the level, expressed as a percentage of account value, above which account equity must be maintained. If account equity falls below the minimum margin level, the brokerage firm will notify the investor in a *margin call* that the account equity must be raised to the level of maintenance margin. *Maintenance margin* is a level of account equity greater than minimum margin and generally below initial margin. On receiving a margin call, a customer may either deposit additional funds or securities or close the position. In the preceding case, a stock price decline from $50 to $35 would cause a decline in equity to $1,000 because the margin loan of $2,500 remains constant. This $1,000 equity would represent only 28 percent of the account value (1,000 divided by $3,500 = 0.28). If the minimum margin were 35 percent, the account equity would be under the requirement, and the customer would receive a margin call.

Although many option strategies are marginable, the important point to understand here is that the amount of equity supporting a position is a key element in capital management, and how an investor manages capital is a decisive factor in determining the risk level of a strategy—that is, whether a particular strategy is speculative or conservative in nature. The application of this concept will be developed throughout the coming chapters.

Short Stock Rebate

When stock is sold short, the purchaser pays cash for the shares, just as with a normal stock purchase transaction. In the case of shares sold short, however, the cash goes to the stock lender rather than to the stock seller. The stock lender holds the cash as collateral and invests it in Treasury bills or other cashlike, liquid investments. In the unlikely event that the stock borrower defaults, the stock lender could use the cash held in escrow to repurchase the shares and thereby repay the stock loan.

The existence of cash held in escrow is significant because of the interest it earns. Public traders do not share in this interest income; the brokerage firm and the stock lender divide it between themselves. Professional traders registered as broker-dealers, including option market makers, however, do receive a portion of the interest income. *Short stock rebate* is the portion of interest income generated by short stock positions that professional traders receive.

The interest income from short stock rebate affects the pricing of option arbitrage strategies discussed in Chapter 6. Typically, an option market maker receives 80 percent of the net interest generated from a short stock position, and the stock lender receives 20 percent. Therefore, if 100 shares are shorted at $90, then $9,000 of cash is generated, which, if invested at 4 percent annually, earns $6.92 per week ($9,000 $\times$ 0.04 $\div$ 52 = $6.92), and an option market maker would receive 80 percent of this, or $5.53. While this sum may seem inconsequential at first glance, consider that option market makers can accumulate positions involving thousands of options and millions of shares. With complicated details, suffice it to say, for option market makers, this interest amounts to an important source of income or expense—because they also borrow.

The guiding principle governing interest income from short stock rebates is that cash held in escrow by the lender must equal 100 percent of the current stock price. Cash transfers, therefore, are made each day between stock borrowers and stock lenders as the stock prices fluctuate. Declining stock prices lead to lower escrow deposits, which frees up capital and lowers costs for option market makers. Rising stock prices, however, increase escrow requirements. If a market maker must borrow more to meet these escrow demands, then costs can rise faster than interest income.

Profit/Loss Diagrams

Figures 1-1 through 1-12 illustrate basic to advanced option strategies that all experienced option traders should understand. Profit and loss diagrams show three important aspects of a strategy: the maximum profit potential, the maximum risk, and the break-even point. Highlighting these aspects helps a trader make the subjective decision as to whether or not the underlying has a sufficient chance of passing or not passing the break-even point and therefore whether or not the potential profit is worth the monetary risk created by the strategy.

Figures 1-1 through 1-4 present the four basic strategies of long and short calls and puts, the four building blocks of more complicated strategies. These figures each contain three lines. The lower line

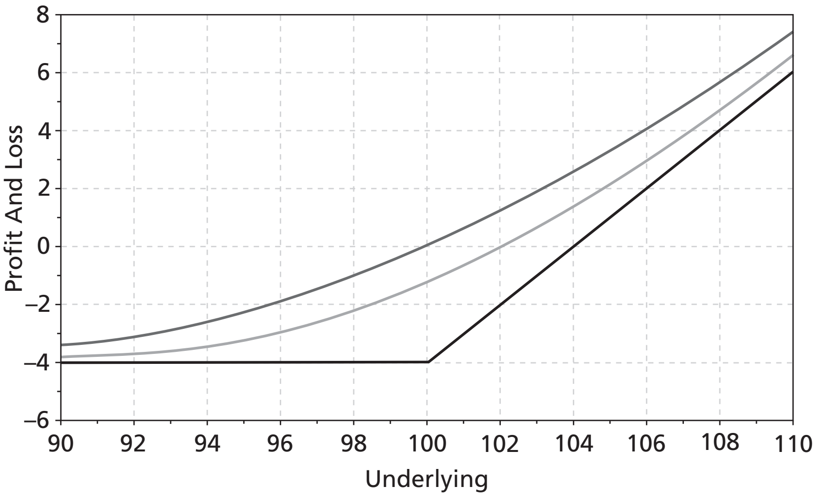


Figure 1-1 Long Call

(straight) illustrates the profit and loss of the strategy at expiration. The upper and center lines (curved) show profit and loss at 60 and 30 days prior to expiration, respectively.

Figure 1-1 illustrates the long call strategy, which has unlimited profit potential, limits risk to the premium paid, and breaks even at expiration at a stock price equal to strike price plus premium paid. For example, a 100 Call purchased for 4.00 per share carries a maximum risk of 4.00, and the break-even point at expiration is a stock price of 104. Above the break-even point, the long call has the potential for unlimited profit.

Figure 1-2 shows that the short call strategy is the mirror image of the long call. The profit potential is limited to the premium received, whereas the risk is unlimited. The short call also breaks even at expiration at a stock price equal to strike price plus premium received. If a 100 Call is sold for 4.00 per share, then the maximum profit is 4.00, and the break-even point at expiration is a stock price 104. Above the break-even point, the short call has the potential for unlimited loss.

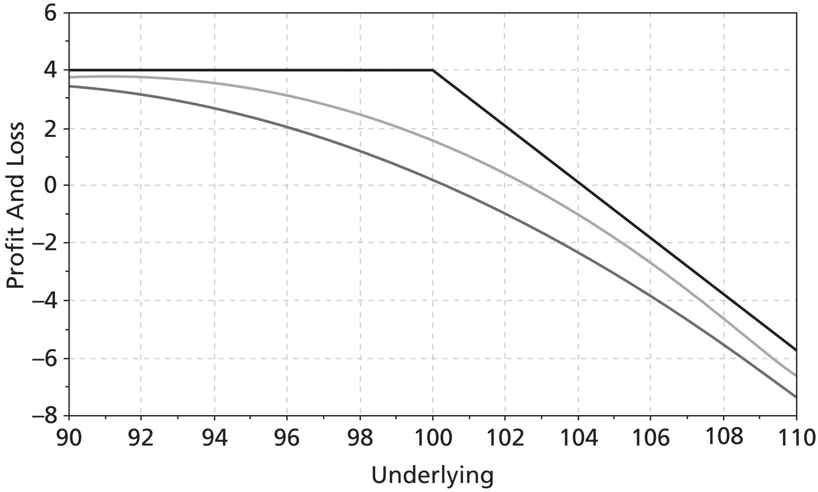


Figure 1-2 Short Call

The long put is illustrated in Figure 1-3. A long put holds the promise of substantial profit because the underlying price can drop to zero, whereas it limits risk to the premium paid. Buying a put breaks even at expiration at a stock price equal to strike price minus the premium paid. The risk of a 100 Put purchased for 3.00 per share, for example, is limited to that 3.00 per share, and the break-even point at expiration is a stock price of 97. Below the break-even point, however, the long put has substantial profit potential as the underlying stock declines toward zero.

Figure 1-4 shows the short put strategy, which holds limited profit potential but carries substantial risk. A short put breaks even at expiration at a stock price equal to strike price minus premium received. If a 100 Put is sold for 3.00 per share, for example, then the maximum profit is 3.00, and the break-even point at expiration is a stock price of 97. Below the break-even point, the short put has the potential for substantial loss.

Figures 1-5 and 1-6 show long and short variations of a basic two-part option strategy known as a *straddle*. Buying both a put and a call

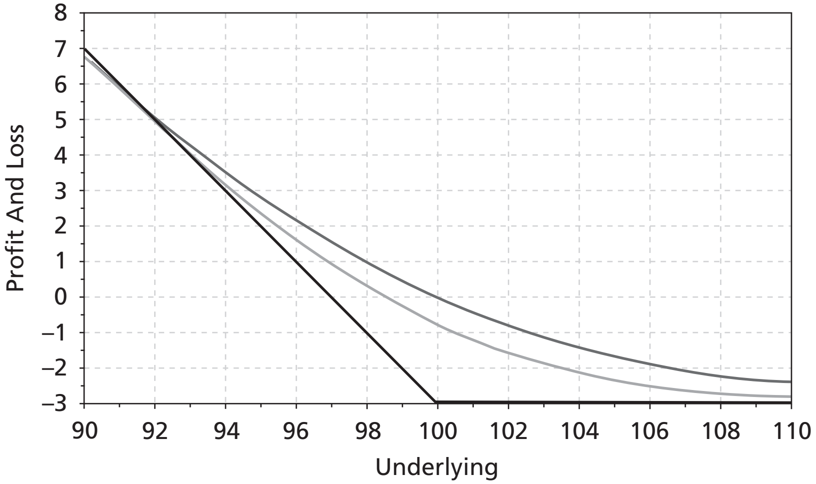


Figure 1-3 Long Put

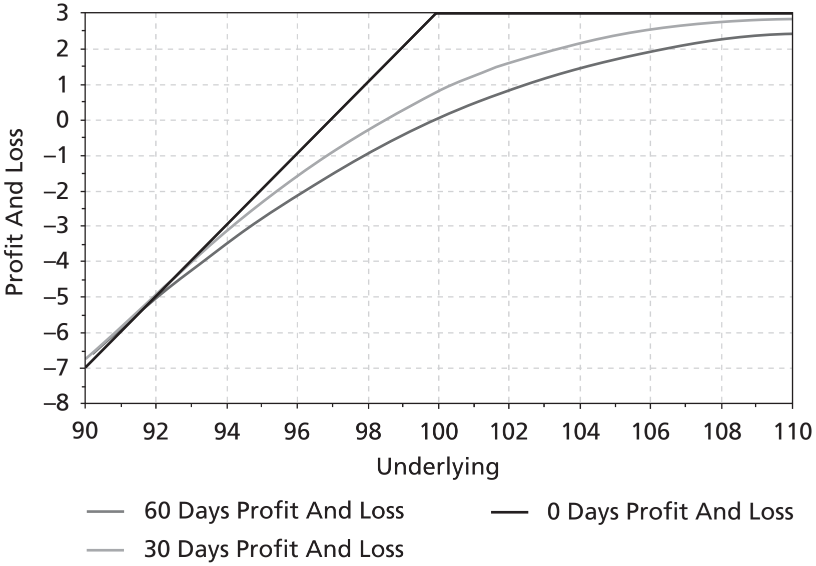


Figure 1-4 Short Put

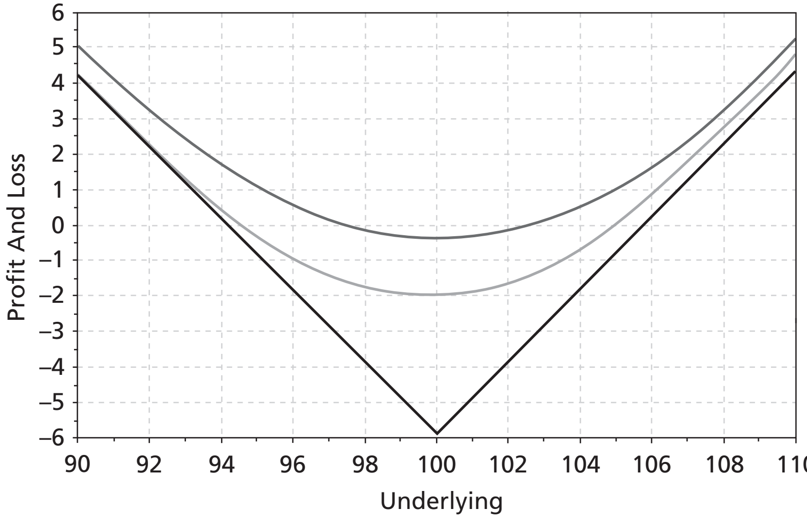


Figure 1-5 Long Straddle

with the same underlying, the same strike price, and the same expiration date creates a *long straddle,* as depicted in Figure 1-5. There are two break-even points. Strike price plus total premium marks the first break-even point, and strike price minus total premium marks the second. A long straddle has unlimited profit potential as the price of the underlying stock rises above the upper break-even point and substantial profit potential as it falls below the lower break-even point. Risk is limited to the two premiums paid. This is known as a high-volatility strategy because a "big" stock price movement—either up or down—is required for a straddle to earn a profit.

A *short straddle* is the mirror image of a long straddle, as shown in Figure 1-6. Selling both a put and a call creates a short straddle. As with the long straddle, there are two break-even points, strike price plus total premium and strike price minus total premium. In the case of the short straddle, however, the profit potential is limited to the two option premiums received. This is a low-volatility strategy because if

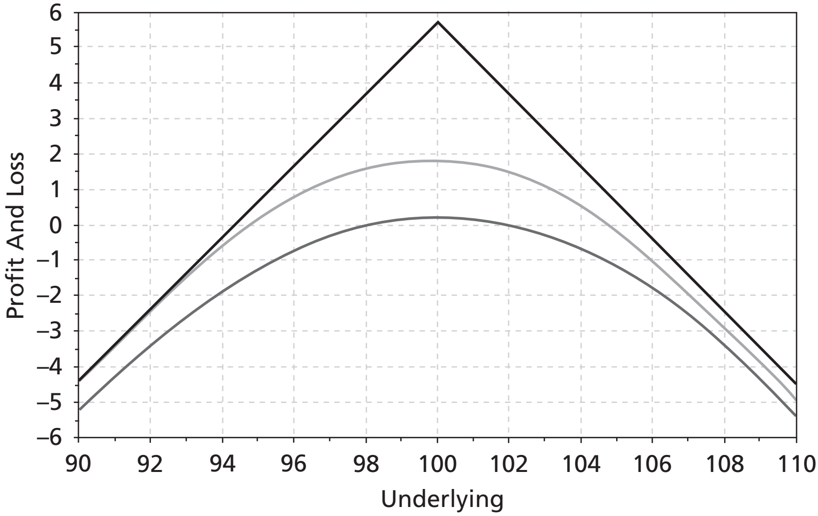


Figure 1-6 Short Straddle

the price of the underlying stock rises above the upper break-even point or falls below the lower break-even point, then losses will increase rapidly.

Figures 1-7 and 1-8 illustrate *long and short strangles*, which are also created by either buying (long) or selling (short) both a call and a put. Unlike the straddle, in which the call and put have the same strike price, in a strangle, the strike prices are different. A long 95–105 strangle, for example, might be created by simultaneously buying one 95 Put for 1.50 per share and buying one 105 Call for 2.00 per share, for a total cost of 3.50 per share. A short strangle would be created by selling both. Each strategy has two break-even points, which are the upper strike price plus the total premium paid and the lower strike price minus the total premium paid. The long strangle profits as the price of the underlying stock rises above the upper break-even point or falls below the lower one. The short strangle profits if the underlying stock price stays between the break-even points.

Straddles and strangles differ from each other in three ways that are not apparent from these figures. First, a straddle commands a higher

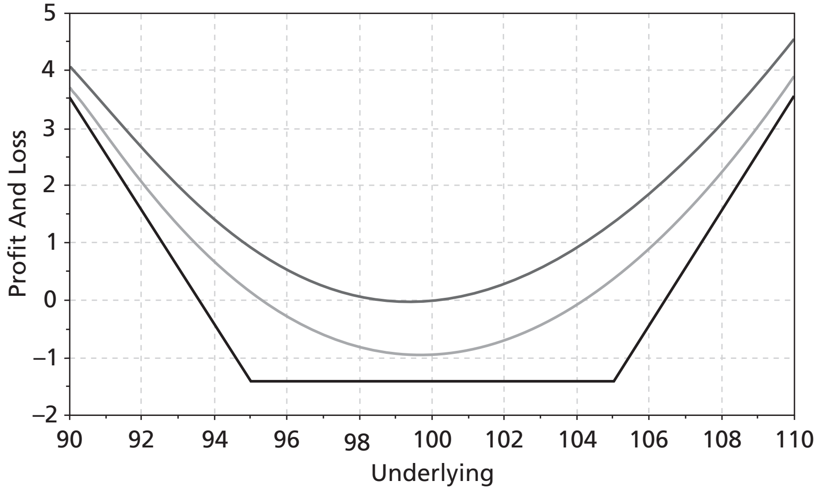


Figure 1-7 Long Strangle

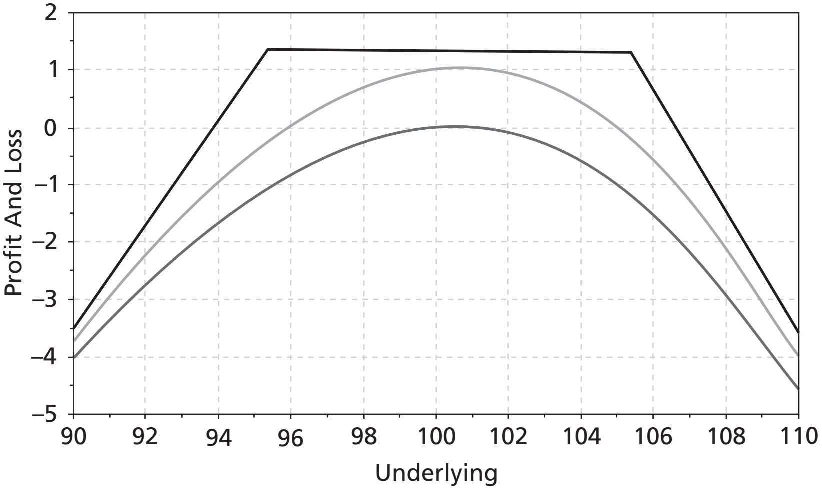


Figure 1-8 Short Strangle

price than a comparative strangle. A 100 straddle, for example, has a higher price than a 95–105 strangle. Second, the break-even points for a straddle are typically closer together than for a strangle. Therefore, if the price of the underlying stock starts to rise or fall dramatically, a straddle will begin to profit before a comparable strangle starts to profit. Third, a straddle has a smaller chance of expiring worthless than does a strangle because the stock price must settle exactly at the strike price for a straddle to incur its maximum loss. For a strangle, however, the stock price can settle anywhere in between and including the strike prices, and both the call and the put that create the strangle will expire worthless at expiration.

Figure 1-9 illustrates the *long call vertical spread*, which has both limited profit potential and limited risk. A long call vertical spread, also known as a *bull call spread*, is established for a net cost, or net debit, by buying one call at a lower strike price and selling another call with the same underlying and same expiration date but with a higher strike price. The break-even point is the lower strike price plus the net premium paid, not including commissions. An example of a long call vertical spread is buying a 100 Call for 5.00 and simultaneously selling a 110 Call for 2.00. The maximum risk, in this example, is 3.00. The maximum profit potential is 7.00, and the break-even point at expiration is a stock price of 103.

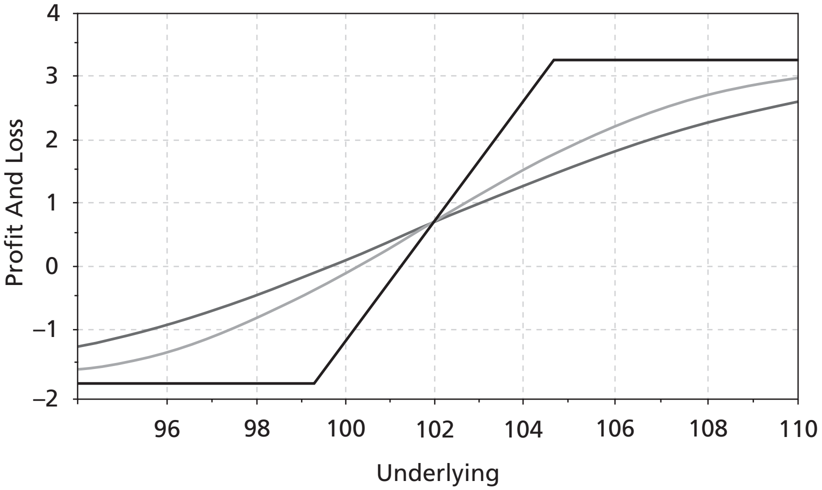


Figure 1-9 Long Vertical Call Spread

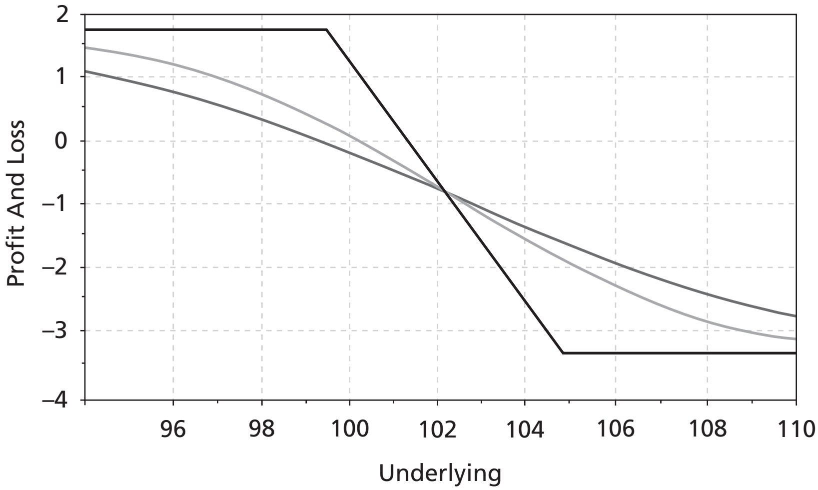


Figure 1-10 Short Vertical Call Spread

Figure 1-10 shows that the *short call vertical spread*, also known as a *bear call spread*, is the mirror image of the bull call spread. This strategy is established for a net credit, and both the profit potential and risk are limited. The break-even point for a bear call spread is the same as for the long variation, but profit is earned below the break-even point for the bear call spread, and losses are incurred as the stock rises above it.

Figures 1-11 and 1-12 briefly introduce two advanced option strategies that advanced option traders need to understand, even if they do not trade them frequently. Figure 1-11 shows a *long butterfly spread with calls*. It was established for a net debit by buying one call with a lower strike, selling two calls with a higher strike, and buying one call with an even higher strike. The three strike prices are equidistant, that is, 100–105–110 or 100–110–120, and all calls have the same underlying and same expiration date.

The final diagram, Figure 1-12, is of a *long condor spread with calls*. This strategy involves four strike prices and is created by buying one call with a lower strike, selling one call with a higher strike,

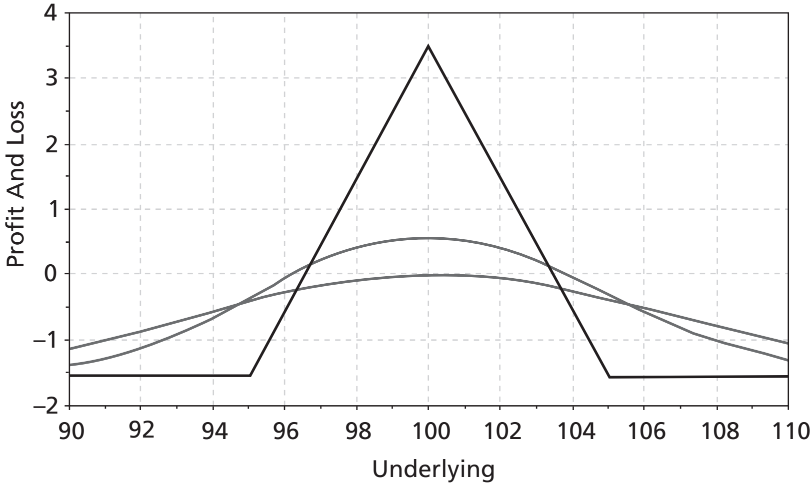


Figure 1-11 Long Butterfly Spread with Calls

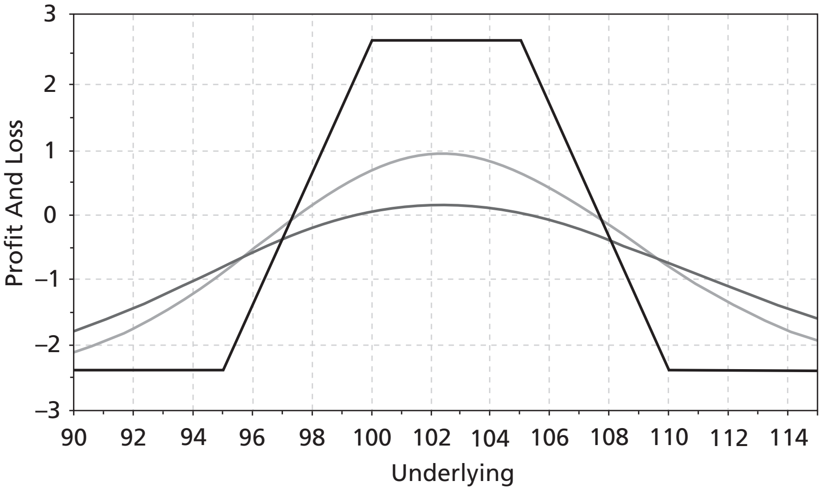


Figure 1-12 Long Condor Spread with Calls

selling another call with an even higher strike, and finally, buying one call with an even higher strike. The four strike prices are equidistant, that is, 100–105–110–115 or 100–110–120–130. Butterfly spreads and condor spreads have both limited risk and limited profit potential. They also involve several bid-ask spreads and multiple commissions. They are therefore suitable only for experienced option traders who trade with low transaction costs.

A familiarity with advanced option strategies such as butterfly spreads and condor spreads reinforces an understanding of option mechanics for all levels of strategies. This familiarity also helps with the comprehension of option prices, synthetic relationships, and arbitrage strategies.

Summary

Options are contracts between buyers and sellers involving rights and obligations. They do not involve direct ownership of the underlying instrument. Exercise or assignment of options, however, causes purchase and sale transactions that can create or eliminate existing stock positions. The typical option transaction involves seven decisions, whereas the typical stock transaction requires only four. This seemingly small difference has significant implications that will be discussed throughout this book.

The term *the market* has two meanings—one is a place where trades are made, and the other is the combination of bid and ask prices and quantities of shares or option contracts that can be bought or sold. In options markets in the United States, there are many competing market makers and exchanges. As a result, the national best bid and best offer (NBBO) might include several competing participants from several locations.

The mechanics of margin accounts are important to option traders because many option strategies must be established in margin accounts. Also, broker-dealers, including option market makers, are eligible to receive interest on short stock positions, the so-called short stock rebate. The calculation of interest income and expense, as will be discussed throughout this book, is an important consideration for option market makers.

Profit and loss diagrams reveal three important aspects of option strategies: the profit potential, the risk, and the break-even point. No strategy is "best" in an absolute sense. Rather, an understanding of option price behavior and strategy mechanics, along with a market forecast, will lead a trader to a strategy that is "best" for a given forecast.

Chapter 2

OPERATING THE OP-EVAL PRO SOFTWARE

Computer programs perform calculations quickly and improve analysis, but they do not make decisions! The Op-Eval Pro software that accompanies this book combines several features that help option traders analyze volatility and position risk and therefore plan trades. Given inputs from the user, the software calculates option theoretical values, implied volatility, and stock price distributions. It answers "What if?" questions when given hypothetical forecasts, and it graphs strategies involving options only or options and stock. It also analyzes position risk, the Greeks, and how they change. Every screen can be printed, and scenarios can be saved for future use. This chapter explains how to install and operate the program. Address questions about the software to opeval@gmail.com.

Overview of Program Features

The Op-Eval Pro software that accompanies this text consists of six screens, each of which can be printed and saved for future use. The Single Option Calculator is used for planning single-option trades. This screen calculates theoretical values, implied volatility, and Greeks for a call and put with all the same inputs.

The Spread Positions screen calculates theoretical values and Greeks for multiple-part positions of up to four different options or one underlying and three different options. It calculates implied volatility, and it allows input of different levels of volatility for different options. The buttons in the lower-right corner, "Price +1," etc., make short-term position analysis easy by automatically recalculating position value and the Greeks.

The Theoretical Graph screen produces a visual chart of positions set up on the Spread Positions screen as long as all options have the same expiration. Profit and loss, theoretical value, and the Greeks can be graphed against underlying price, volatility, time to expiration, or interest rates. These capabilities help beginning and intermediate option traders explore the nuances of option price behavior.

The Table screen presents theoretical values or the Greeks of positions in the Spread Positions screen over a range of underlying prices and days to expiration chosen by the user. To change from theoretical price to delta or another Greek, place the cursor over the table, right-click, and then select the desired output. The box in the lower-right corner enables the user to change the volatility assumption.

The Portfolio screen is a flexible graphing tool. It graphs and calculates the Greeks for positions with up to 15 different options and one underlying. The options can have both different expirations and different levels of implied volatility. This screen also has "What if?" capabilities. In other words, the user can view and analyze the impact of changing volatility and time to expiration.

The Distribution screen calculates a one-standard-deviation price range for the underlying given a volatility assumption, a time period, and other inputs from the user. This helps with selecting option strike prices and stock price targets.

Installing the Software

The CD that accompanies this book has two versions of Op-Eval Pro, one for WindowsXP and one for Windows Vista. For this reason, the CD will not start automatically. Follow these instructions:

1. Insert the setup CD in the CD drive.
2. Click on "Start," and then click on "Run." Type "e:\setup" (or "f:\setup").
3. Click on the appropriate icon for XP or Vista.
4. Double-click on "setup.exe," and follow the instructions.
5. To run the program in WindowsXP, click on the "Op-Eval Pro" icon on your desktop. In Windows Vista, you must click on "Start," then on "Programs," then on "Op-Eval Programs," and finally, on "Op-Eval Pro."

Disclosures and Disclaimers

This section contains important information about the assumptions made by Op-Eval Pro (Figure 2-1). You should read this entire section carefully. Only with a thorough understanding of the limitations of this program (or any program) can you make informed decisions. If you proceed on your own intuition and uninformed perceptions, you are not likely to do well in any area of investing or trading, let alone with options. After you have read all the disclosures and disclaimers carefully,

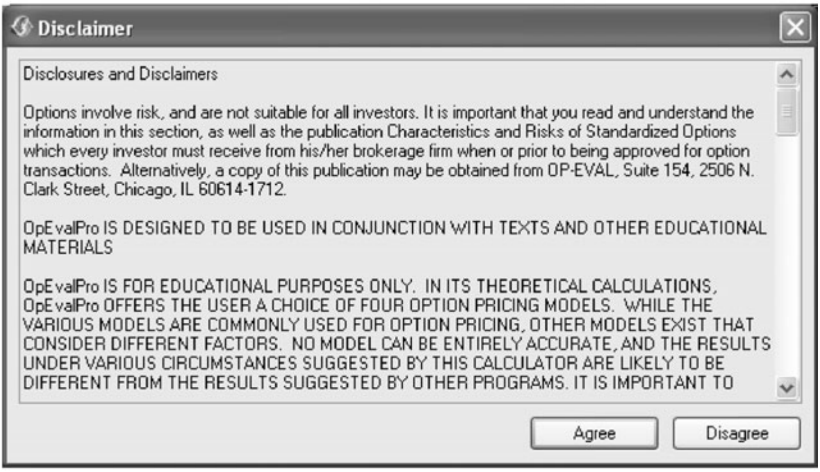


Figure 2-1 Disclaimers and Disclosures Screen

you can choose "Agree" if you accept the conditions and limitations of the program or "Disagree" to exit the program.

Choices of Pricing Formulas

Option contract specifications vary by exercise style, type of underlying security, and method of dividend payment. Op-Eval Pro can apply four different option-pricing formulas that analyze options on individual stocks, options on indexes, and options that have American-style or European-style exercise. The Single Option Calculator, the Spread Positions screen, and the Portfolio screen each have two buttons, one of which lets you choose "American" or "European," and the other of which lets you choose "Index" or "Equity." The Spread Positions screen and the Portfolio screen let you check or leave unchecked two boxes, "IsIndex" and "IsEuropean."

Choosing "American" means that the option can be exercised early, that is, prior to expiration, and that a binomial formula is used. This formula assumes a number of discrete time periods, or steps, and then performs a discounted present-value calculation on the range of possible outcomes. The number of steps in the binomial calculation is indicated in the lower-right corner of the screen and can be changed by double-left-clicking on the "Steps =" button. Generally, traders do not need to change the number of steps; "25" is satisfactory for most users.

Choosing "European" means that the option cannot be exercised early and that a Black-Scholes pricing formula is being used. This formula uses differential calculus and does not use binomial-like steps.

The difference between "Index" and "Equity" is the way that dividends are included in a formula. Equity options, which are options on individual stocks, pay dividends at discrete intervals, that is, specific dividends that are paid on dates that are announced in advanced. Index options, in contrast, are options on a market index comprised of many component stocks. Rather than attempting to identify the dates of the individual dividends, the formula for index options uses a yield percentage. This percentage assumes that dividends are paid evenly and continuously throughout the year, like interest on a savings account at a bank. Although an oversimplification, this formula is a commonly accepted method of valuing index options.

A word of warning: In most cases, the program makes calculations much faster when the choices are "Index" and "European." The binomial calculation for "American" and "Equity" options can be cumbersome, especially when creating graphs or when the number of steps in the binomial calculation is large (above 25). While it is worthwhile, for educational purposes, to compare values generated by the different formulas, the difference between results is usually quite small. You will save time but lose little accuracy, therefore, if you choose "Index" and "European" when selecting a formula.

A complete discussion of operating Op-Eval Pro will now be presented. Even experienced option traders and computer users should read this section to learn the full range of capabilities of the program.

Features of Op-Eval Pro

This program incorporates 10 features, each of which is explained in the sections that follow:

- Single Option Calculator
- Spread Calculator
- Graphing
- Theoretical Table Generator
- Portfolio Analysis and Graphing
- Probability Distribution
- Print Preview
- Print
- Save Spread
- Open Spread

The Single Option Calculator

Figure 2-2 shows the Single Option Calculator screen. This feature calculates theoretical values, delta, gamma, theta, and vega for both a call and a put with the same strike price, same expiration, and same underlying security. Definitions of all terms appear in the Help feature of the program, which is located on the tool bar at the top of the screen. Later chapters explain how you can use information in the program to analyze option prices and to estimate how those prices might change when given a forecast. This chapter describes only how the various aspects of the program work.

Moving Around the Single Option Calculator Screen

The highlighted input box can be changed either by clicking on another box or by pressing the arrow keys. The down arrow and the right arrow move the highlighted box down the inputs column first, then over to the "CALL" box, then to the "PUT" box, and finally, back to the "STOCK PRICE" box. The up arrow and the left arrow move

Op-Eval Pro: OP-EVAL: Single View

☐ EQUITY	☐ AMERICAN		CALL	PUT
STOCK PRICE	58.00	VALUE	46.73	19.28
STRIKE PRICE	60.00	DELTA	0.93	-0.24
VOLATILITY %	35.00	GAMMA	0.00	0.01
INTEREST RATE %	4.00	VEGA	0.40	0.63
DIVIDEND	0.00	7-THETA	-0.01	0.00
DAYS TO EX-DIV	0.00	RHO	2.01	-2.51
DAYS TO EXPIRY	9999.00		Decimal Places	2

Figure 2-2 Single Option Calculator

the highlighted box in the opposite direction. The boxes below the call and put values cannot be highlighted because they are "output only."

Input Ranges

The "STOCK PRICE" input box will accept any price from 0.00 to 99,999.99. If you enter a whole number, such as 50, Op-Eval Pro will assume that all numbers to the right of the decimal point are zeros. After entering a price, press the "Enter" key or an arrow key, or highlight another box by clicking on it. Any of these actions will recalculate all output values.

Strike price intervals in option markets in the United States vary by underlying security and by the price of the underlying security. Op-Eval Pro, therefore, has the flexibility to set the strike price at any number between 0 and 99,999. This feature allows Op-Eval Pro to be used for options on a wide variety of underlying instruments.

Volatility, as discussed in Chapter 7, is a statistical measure of potential price changes in an option's underlying instrument. If other factors remain constant, a wider range of possible stock prices (i.e., higher volatility) means that options have a higher theoretical value. Traders commonly express volatility as a percentage, so Op-Eval Pro also uses this practice. When the "VOLATILITY %" box is highlighted, it is possible to enter any number from 1.00 to 999.99.

The level of interest rates affects the values of options because time and the cost of money directly affect purchasing decisions. Op-Eval Pro accepts interest rate input values from 0 to 99.99 percent. Experiment with this input and observe that changes in interest rates affect option prices relatively little compared with any of the other inputs. This result is consistent with the discussion here and in Chapter 3.

For the "DAYS TO EXPIRY" box, Op-Eval Pro accepts values from 0 to 9,999. When counting the days to expiration, include the current day if you are inputting data before or during market hours, but do not include the current day if you are doing your analysis after the market close. Also, be sure to correctly input the day after the last day of trading as the expiration date. For options on individual stocks, and for American-style index options, such as OEX options, the correct expiration date is the Saturday following the third Friday of the expiration month. (Even though expiration is technically on the Saturday following the third Friday of the month, Friday is the last trading day.) For European-style index options, such as SPX, DJX, or MNX options, the correct day falls one day earlier, the third Friday of the expiration month, with the last trading day being the Thursday proceeding the third Friday.

The "DIVIDEND" box input depends on the option underlying. As discussed earlier, Op-Eval Pro has different formulas for options on stocks and for cash-settled options on indexes. If "Index" appears on the Single Option Calculator, or if the "IsIndex" box is checked on either the Spread Positions screen or the Portfolio screen, the program uses a dividend yield and assumes that dividends are paid continuously and evenly throughout the year. Find current index dividend yield percentages in the *Wall Street Journal*, *Investor's Business Daily*, and *Barron's*.

If "Equity" appears, or if the "IsIndex" box is not checked, the program assumes that there are discrete dividends. As a result, two inputs are required, the amount of the dividend and the number of days to the ex-dividend date. You will find dividend listings in daily financial newspapers or on a company's Web site. Because the binomial option valuation process involves discounting cash flows, the number of "DAYS To EX-DIV" is required to calculate the timing of the dividend payment.

Correct Inputs Are Essential

If you attempt to analyze an option without the proper inputs, the value calculated by Op-Eval Pro could differ dramatically from the prices observed in the real marketplace. Improper settings are also likely to lead to incorrect estimates of option price changes and inaccurate conclusions about strategy selection. As explained under "Disclosures and Disclaimers," this is one of the risks you assume in using the program. Op-Eval Pro can perform optimally only if you give it accurate information, so take the time necessary to gather good input data.

Calculating Implied Volatility

Assuming all inputs other than volatility on the left side of the Single Option Calculator are correct, then highlighting either the "CALL" box or the "PUT" box, typing in a value, and pressing "Enter" causes the volatility number to be recalculated. This number is the implied volatility of this option. How implied volatility can be used in making trading decisions and estimating results will be discussed in several places in this book.

If you change the value in the either the "CALL" or the "PUT" box, Op-Eval Pro will recalculate the volatility and the other value, put or call value, using the new volatility percentage. It also will recalculate all other outputs.

The Spread Positions Screen

The Spread Positions screen can be used to analyze a wide variety of positions, including one-to-one vertical spreads with only calls or only puts, ratio spreads, time spreads, spreads with both calls and puts, and stock and option spreads. The Spread Positions screen calculates position value and the Greeks. Clicking on the "SPREAD" item on the menu bar at the top of the screen brings up a new screen that looks like Figure 2-3.

The Spread Positions screen operates in a way similar to the Single Option Calculator. Left-clicking highlights boxes, and you can change the values in any highlighted box. Arrow keys also can be used to change the highlighted box and recalculate outputs. The Spread Positions screen contains several features that do not appear on the Single Option Calculator screen. The following paragraphs discuss these additional features.

Op-Eval Pro: Spread View

SPREAD POSITIONS

	Option 1	Option 2	Option 3	Option 4
IsIndex	True	True	True	True
IsEuropean	True	True	True	True
Quantity	1	-1	0	0
Type	Call	Call	Put	Put
Stock Price*	98.00	98.00	98.00	98.00
Strike Price	100.00	110.00	110.00	110.00
Volatility %	30.00	30.00	30.00	30.00
Interest %*	4.00	4.00	4.00	4.00
Dividend	0.00	0.00	0.00	0.00
Ex-Div Days	0	0	0	0
Expiry Days*	60	60	60	60
Multiplier	1	1	1	1
Value	4.14	1.27	12.55	12.55
Delta	0.48	0.20	-0.80	-0.80

SPREAD GREEKS

	Total
Value	2.87
Delta	0.28
Gamma	0.01
Vega	0.05
Theta	-0.11
Rho	0.04

Decimal Places 2

Figure 2-3 The Spread Positions Screen

Using the Asterisk (*) to Lock a Row

The Spread Positions screen can be used to analyze two or more options with the same or different volatilities or two or more options with the same or different number of days to expiration. This screen also makes it possible to analyze spreads involving calls only, puts only, or options with stock. The asterisk (*) facilitates the analysis of certain spreads. If an asterisk appears next to an item in the leftmost column ("Quantity," "Type," "Stock Price," etc.), then all items in that row will change and be the same if a change is made in any cell in that row. The absence of an asterisk indicates that the numbers in that row are set individually, and a change in the contents of one input box will not change the contents of the other boxes in that row.

Adding and Removing an Asterisk—Double-Left-Click

To add or remove an asterisk, simply double-left-click when the cursor is over the desired input box. If an asterisk resided in the cell initially, it will disappear. If an asterisk did not exist, then it will.

Choosing "Call," "Put," or "Stock"

When a cell in the "Type" row is highlighted, a drop-down arrow will appear. Left-clicking on this arrow opens a drop-down box that contains the items "Call," "Put," and "Stock." Clicking on one item closes the drop-down box and changes the content of the "Type" cell to the item selected.

Be Sure that Multipliers Are Consistent

Op-Eval Pro allows the user to adjust the multiplier for all parts of a position. Consequently, the program can value positions and draw graphs on either a per-unit basis or a dollar basis. Care must be taken, therefore, in setting the "Quantity" and "Multiplier" rows to be sure that the numbers are consistent between the options and the underlying instrument.

Be aware that the "Multiplier" affects the calculation of delta and the other Greeks, just as it affects the calculation of value.

Plus One and Minus One Buttons

In the lower-right corner of the Spread Positions screen are four command buttons. Click on one and see what happens. As expected, a click on the "Price +1" button raises all numbers in the "Stock Price" row by one full point and recalculates the option values, their deltas, the spread value, and the spread Greeks. Click on one of the other three buttons, and a one-unit change in either the stock price or days to expiration, as indicated, will occur, and all outputs will be recalculated.

These "+1" and "−1" buttons make it easy to estimate how a position will change in value given a change in the underlying security (in whole points) and/or a change in the number of days to expiration. For example, a trader might want to know how much the value of the 100–110 call spread illustrated in Figure 2-3 will change if the stock price rises $4 in five days. To answer this question, just click on the "Price +1" button four times (raising the stock price from 98 to 102), and then click on the "Days −1" button five times (decreasing the days from 60 to 55). The result is that the spread value increases from 2.87 to 4.01. The delta also rises from 0.28 to 0.32.

Spreads and Implied Volatility

You can calculate the implied volatility of an option on the Spread Positions screen just as on the Single Option Calculator screen. First, highlight a rectangle in the "VALUE" row; second, type in the market price of the option; and third, press the "Enter" key. "Volatility" now becomes a calculated output. This output is the implied volatility of the option whose price was entered. If an asterisk appears next to "Volatility %," then calculating an implied volatility for one option in one column does not affect the values of options in other columns. However, a change in any number in the "Volatility %" row will change all the numbers in that row.

Theoretical Graph Screen

Profit-and-loss diagrams are valuable for educational purposes and for strategy analysis because they provide a visual representation of a strategy. The graphing capability of Op-Eval Pro makes it possible to quickly prepare and print diagrams, such as the ones that appear throughout this book. There are two graphing capabilities, one of which is available from the Spread Positions screen.

The graphing feature from the Spread Positions screen can create two different types of graphs. First, it creates graphs of single- or multiple-part strategies consisting of one to four options or up to three options and one stock. Second, it creates graphs of strategy sensitivities known as the *Greeks*, that is, delta, gamma, theta, vega, and rho. Definitions of these terms appear in the "Help" file and are discussed in depth in Chapter 4. To select the type of graph you want, right-click on the graph, and select from the list of choices. Figure 2-4 shows a Theoretical Graph screen with the 100–110 Call spread created on the Spread Positions screen in Figure 2-3.

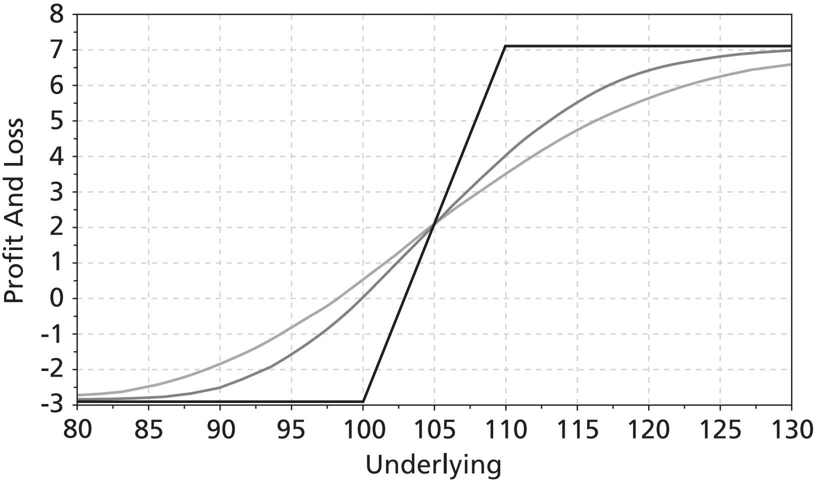


Figure 2-4 The Theoretical Graph Screen

In order for the graph feature to operate from the Spread Positions screen, all positions on the Spread Positions screen must have the same underlying price ("Stock Price"), expiration date ("Expiry Days"), dividend, "Ex-Div Days" (if applicable), and interest rate. If these inputs are not consistent, a graph cannot be created. Further, the number in the "Quantity" row must be positive or negative for a position to be graphed. On the Theoretical Graph screen, the quantity of an option can be changed by clicking on the appropriate quantity, typing a new number, and pressing the "Enter" key.

Three Lines on the Theoretical Graph Screen

The Theoretical Graph screen shows three lines. The line with straight segments is a graph of the strategy at expiration. The middle line is a graph of the strategy at half the days to expiration indicated on the Spread Positions screen in the "Expiry Days" row. The middle line may be recalculated by clicking on the "−1" or "+1" in the middle box in the lower-right corner. The third line represents the strategy at the number of days prior to expiration indicated on the Spread Positions screen.

"Quick Change" to Graph

At the bottom left of the Theoretical Graph screen are four lines that describe the strike price and quantity of Options 1, 2, 3, and 4 from the Spread Positions screen. Changing the quantity of a particular option in a position will, of course, change the total position; and Op-Eval Pro will immediately graph this new position.

Graphing a Position in the Underlying

Op-Eval Pro has the capability to graph a position in an underlying stock. When the "Type" on the Spread Positions screen is set to "Stock," the "Description" on the Theoretical Graph screen will change to "Stock," and the "Value" will be equal to the stock price.

Graphing Strategy Sensitivities (Delta, Gamma, Theta, Vega)

Right-click with the cursor over a graph, and a box containing "Value, Delta, Gamma, Theta, Vega, Rho" appears. To graph one of these items, simply left-click on that item.

Theoretical Price Table

A table of theoretical values makes it easy to quickly estimate potential profit-and-loss results of a strategy over a range of possible market changes. It would be much more time-consuming to use the Spread Positions screen because it only analyzes one price at time. This feature creates a table of theoretical values or sensitivities (delta, gamma, theta, and vega) for the net position in the Spread Positions screen. To select the type of table you want, right-click on the table, and select from the list of choices. The upper-left cell in the table contains the strategy characteristic being calculated. All limitations of the Theoretical Graph feature apply to the Table feature. Figure 2-5 contains values for the bull call spread created in the Spread Positions screen in Figure 2-3 and graphed in Figure 2-4.

Theo Price	60 days	54 days	48 days	42 days	36 days	30 days	24 days	18 days	12 days	6 days
125	9.12	9.23	9.35	9.46	9.58	9.70	9.81	9.91	9.97	9.99
120	8.51	8.64	8.78	8.93	9.09	9.27	9.47	9.66	9.85	9.98
115	7.61	7.73	7.86	8.02	8.19	8.40	8.65	8.95	9.31	9.74
110	6.40	6.47	6.56	6.67	6.79	6.94	7.13	7.39	7.76	8.35
105	4.95	4.96	4.96	4.97	4.98	4.98	4.99	5.00	5.00	5.02
100	3.44	3.37	3.29	3.20	3.08	2.94	2.75	2.50	2.14	1.56
95	2.09	1.97	1.85	1.70	1.53	1.34	1.10	0.83	0.51	0.16
90	1.07	0.96	0.84	0.71	0.58	0.44	0.30	0.16	0.05	0.00
85	0.44	0.37	0.30	0.22	0.16	0.10	0.05	0.02	0.00	0.00
80	0.14	0.11	0.08	0.05	0.03	0.01	0.00	0.00	0.00	0.00

Figure 2-5 Theoretical Price Table

The stock price range in the left-most column and the range of days and interval between days in the top row can be changed by right-clicking on the table and left clicking on "Change Axes." The user also can change the volatility assumption and set the desired number of decimal places in the output calculation. These features make it easy to adjust the analysis to the price and time ranges and volatility level desired by the user.

The Portfolio Screen

Graphing complex positions involving up to 15 options with different expiration dates and one underlying is possible with the Portfolio screen. After inputting the "Underlying Parameters" and the "Option Parameters" in the upper-left portion of the screen, simply left-click on "ADD," (does not appear in Figure, but is on the Portfolio screen) and a new component will be added to the position. Note that the multiplier can be changed with the "MULT" input box in the row of underlying parameters. The "Move volatility" and "Move days to expiry" input boxes make it possible to graph the impact of changes in these factors. Figure 2-6 shows a Portfolio screen of a six-part position.

The Distribution Screen

The discussion of volatility in Chapter 7 explains how the implied volatility component in an option's market price can be used to calculate the market's expectation for one standard deviation of price range for the underlying stock between the current date and option expiration. The Distribution screen performs this calculation for four time periods chosen by the user. Simply input the underlying price, a volatility assumption, and a time period; Op-Eval Pro will calculate a one-standard-deviation price range. Figure 2-7 is a

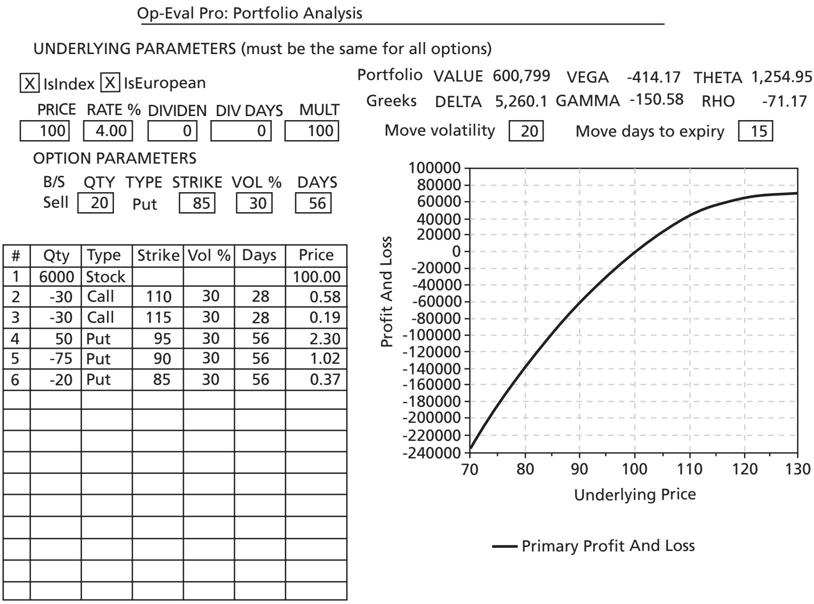


Figure 2-6 The Portfolio Screen

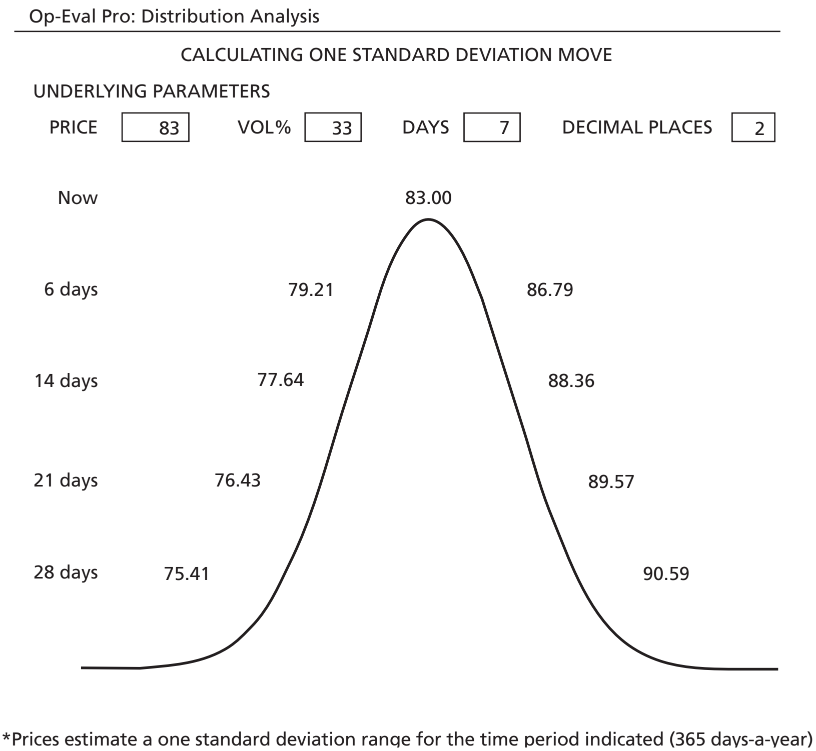


Figure 2-7 The Distribution Screen

Distribution screen showing one-standard-deviation price ranges for a stock trading at $83.00 with volatility of 33 percent for 7, 14, 21, and 28 days.

Previewing, Printing, and Saving

What good is research and analysis if you can't print it to show others or save it for future use? In Op-Eval Pro, all screens can be previewed before printing, and all scenarios can be saved. Practice with the "Save As," "Print Preview," and "Print" control buttons on the menu bar at the top of the screen. To retrieve a scenario saved previously, simply click on the "Open" button in the control bar.

Summary

Op-Eval Pro is designed to perform calculations, to draw graphs quickly, and to improve the analytic process. It is not designed to make decisions for you.

After installing the program, you must carefully read and thoroughly understand the Disclosures and Disclaimers before you attempt to use the program to analyze individual options or multiple-part option strategies.

The Single Option Calculator, the Spread Positions screen, and the Portfolio screen all present option theoretical values and their respective deltas, gammas, thetas, and vegas. If the "Stock Price" is changed on any screen, Op-Eval Pro recalculates the volatility percentage; this is known as the *implied volatility*.

The graphing and table features require consistent inputs in the Spread Positions screen. The line with straight segments is a graph of the strategy at expiration. The middle line shows the strategy at half the days to expiration and may be recalculated. The third line estimates a strategy's performance at the number of days prior to expiration indicated on the Spread Positions screen.

Complex positions, including time spreads and positions with options with different expiration dates, can be graphed on the Portfolio screen.

Practice using the many features of Op-Eval Pro. You can easily make mistakes in inputting information if you are not thoroughly familiar with the layout of the various screens. Once you become familiar with its many features, however, you will find that Op-Eval Pro is a valuable tool for analyzing option prices and strategies.

Chapter 3

THE BASICS OF OPTION PRICE BEHAVIOR

The subject of option price behavior requires two chapters to explain fully because traders must master two different aspects of option price behavior. This chapter discusses how option prices change as market conditions change. Option prices do not move in the short term the same way that stock prices and prices of futures contracts move. Traders therefore must learn to think in a different way when trading options. The next chapter discusses the Greeks—delta, gamma, theta, vega, and rho—how they change, how they are used to evaluate position risk, and how position risk shifts as the market fluctuates.

This chapter starts with a brief review of the analogy between options and insurance. Second, it describes how option values change as the various input factors change. Third, the subject of volatility and its impact on option prices is introduced. The chapter concludes with a discussion of option price changes in a dynamic environment and the unique way that option traders plan trades.

The Insurance Analogy

An option is like an insurance policy that pays its owner if certain events occur on or before the expiration date. If the events do not occur, the policy expires worthless.

The analogy between put options and insurance is perhaps easiest to understand. If the underlying stock declines in value, a put rises in value. The stock decline is similar to an insured asset being damaged, and the rise in put value is similar to an insurance policy paying a claim.

Why calls are like insurance may be less obvious because a call contains a right to buy rather than a right to sell. Nevertheless, calls are like insurance policies that insure participation in a price rise; they protect cash or liquid investments from missing a market rally. Puts insure against the risk of being in the market; calls insure against the risk of being out of the market. Puts limit risk from a price decline, and calls insure against missing a rally. Although one loss is a "real loss" and the other loss an "opportunity loss," the put and call options that protect against these events are similar to insurance policies in every respect.

Components of Insurance Premiums

Insurance companies consider five factors when calculating premiums. They first look at the value of the asset being insured. If other factors are equal, the more valuable the asset, the more expensive it is to insure. The second factor is the deductible. The higher the deductible, the lower is the insurance premium because more of the risk is being born by the owner of the asset. A policy's term, or time to expiration, is the third factor. The longer the term, the higher is the insurance premium. The fourth factor is interest rates, which influence insurance premiums because insurance companies invest the premiums they receive until claims are paid. Rising interest rates cause insurance premiums to decline.

The fifth and final factor is risk. Many components contribute to risk, such as the nature of the asset and the history of loss in that class of assets. For example, a company insuring a car might analyze the age and driving record of the driver, where the car is parked, and how many miles per year it is driven. If other factors are equal, the higher the likelihood of damage to the car, the higher is the insurance premium.

Insurance companies do not simply apply a mathematical formula to these five factors to determine the premium for a particular policy. They also consider what their competition is doing. Any difference between the market price of a policy and the company's calculated theoretical value requires the insurance company to decide whether to "meet the competition" and do business or to hold back and wait for a better opportunity. Option traders also make such judgments all the time.

Options Compared to Insurance

Corresponding to the five components for insurance are six components for pricing options: the value of the underlying instrument, the strike price, the time to expiration, interest rates, dividends, and volatility. With options, the price of the underlying stock or index corresponds to asset value in insurance. If other factors are constant, a higher price for the underlying usually translates into a higher value for an option.

The distance between the current stock price and an option's strike price corresponds to the deductible component in insurance. The deductible, remember, is the amount of risk borne by the insured party. An insurance policy with a $500 deductible, for example, means that a loss up to this level requires no payment from the insurance company. The same concept applies to options. An out-of-the-money option is like a policy with a deductible: The option pays nothing if the underlying stock does not move beyond the strike price, like an insurance policy expiring worthless. An at-the-money option, however, is similar to an insurance policy with no deductible; it has value—similar to a policy paying a claim—even if the stock price declines only a little.

The impact of time to expiration on option values is well known; option values decrease as expiration approaches. The same can be said for insurance premiums because a six-month policy costs less than a one-year policy. What is not so obvious is exactly how time affects option prices. The subject of time erosion will be discussed in detail later in this chapter.

Changes in interest rates, the fourth factor, affect call and put values in opposite ways. An increase in interest rates causes call values to increase and put values to decrease. Fortunately, changes in interest rates affect short-term option values minimally and therefore usually have little impact on short-term speculative trading decisions. Nevertheless, professional market makers must be aware of the impact of interest rates on the pricing of arbitrage strategies discussed in Chapter 6 because they can affect profits significantly.

Dividends make up the extra component of option prices not present in the insurance analogy. The effect of dividends on option values is opposite that of interest rates. An increase in dividends tends to decrease call values and increase put values. Again, since dividend changes affect option values in a minor way, they are of little consequence to speculative option traders. However, changing dividends do affect the pricing of arbitrage strategies for professional market makers, as discussed in Chapter 6.

The final component of option value, volatility, is conceptually identical to the risk factor in insurance. Just as an increase in risk assessment increases insurance premiums, so too does an increase in volatility increase option values. The subject of volatility is discussed in depth in Chapter 7 and in numerous other places in this book.

Table 3-1 summarizes the analogy between insurance premiums and option values, and Table 3-2 summarizes the impact of changes in the six factors on call and put values. In Table 3-2, *direct effect* means that, as the component increases and other factors remain constant, the option value will also increase. *Inverse effect* means that as the component increases and other factors remain constant, the option value will decrease. "Price of Underlying," for example, has a direct effect on call values and an inverse effect on put values.

Table 3-1 Components of Value: Option Values Compared with Insurance Premiums

Insurance Policy	Option
Asset Value	Price of Underlying
Deductible	Strike Price
Time	Time
Interest Rates	Interest Rates and Dividends
Risk	Volatility
= Premium	= Value

Table 3-2 Changing Components and Changing Option Values

Component	Effect on Call Value	Effect on Put Value
Price of Underlying	Direct	Inverse
Strike Price	Inverse	Direct
Time	Direct	Direct
Interest Rate	Direct	Inverse
Dividends	Inverse	Direct
Volatility	Direct	Direct

Note: Direct effect means that as the component increases and other factors remain constant, the option value also will increase. *Inverse effect* means that as the component increases and other factors remain constant, the option value will decrease.

Option-Pricing Formulas

Theoretical option values can be calculated using one of a few mathematical formulas. Two professors at the University of Chicago, Fisher Black and Myron Scholes, developed the first formula, commonly known as the *Black-Scholes option-pricing model* in 1973. This formula involves advanced calculus. Subsequently, other mathematicians created additional formulas that are generically known as *binomial option-pricing models.* The mathematics behind these formulas are beyond the scope of this book but can be found in books by J. C. Cox and S. A. Ross, M. Rubenstein, and J. Hull. The Op-Eval Pro software that accompanies this text allows the user to choose between four formulas, the Black-Scholes model and three binomial models. For educational purposes, you should compare option values generated by the different formulas with the same inputs. In most cases, however, you will find that the results vary little. Unless otherwise indicated, option values in exhibits in this book are calculated with a standard Black-Scholes model and presented in decimals rounded to the second place.

The following examples review how changes in the inputs to the option-pricing formula affect call and put values. Each example is static; only one factor changes at a time, while all other factors remain constant. Some dynamic examples will be presented later in this chapter.

Call Values and Stock Prices

Table 3-3 illustrates how call values change when the price of the underlying and time to expiration change. Table 3-3 contains 11 rows and 7 columns. The rows indicate different stock prices; the columns indicate different days prior to expiration. By looking up and down the columns and across the rows, you can see how changes in underlying price or time to expiration or both cause changes in an option's theoretical value.

An example of how call prices change starts in row 6, column 1 of Table 3-3. The stock price is 100, the call has 90 days to expiration, and the theoretical value of the 100 Call is 6.53. If the stock price rises by 1 to 101 (row 7, column1) and the other factors are unchanged, the theoretical value of the 100 Call increases by 0.58 to 7.11. If the stock price decreases by 1 to 99, the call value decreases by 0.54 to 5.99. In both cases, the call price changes less than the stock price. Looking anywhere on the table, this relationship between stock price and option value always holds. Assuming that factors other than price remain constant, with any time left until expiration, an option's theoretical value always changes less than one-for-one with a change in the stock price. Furthermore, the ratio of option-price change to stock-price change varies with the stock price and with time.

Table 3-3 Theoretical Values of 100 Call at Various Stock Prices and Days to Expiration (Interest Rate, 5%; Volatility, 30%; No Dividends)

		Col1	Col2	Col3	Col4	Col5	Col6	Col7
	Stock Price	90 Days	75 Days	60 Days	45 Days	30 Days	15 Days	0 Days
Row 11	105	9.66	9.05	8.39	7.67	6.86	5.91	5.00
Row 10	104	8.99	8.37	7.71	6.97	6.13	5.12	4.00
Row 9	103	8.34	7.72	7.05	6.30	5.44	4.39	3.00
Row 8	102	7.71	7.09	6.42	5.66	4.80	3.71	2.00
Row 7	101	7.11	6.49	5.82	5.07	4.19	3.09	1.00
Row 6	100	6.53	5.92	5.25	4.50	3.63	2.53	0.00
Row 5	99	5.99	5.38	4.72	3.98	3.12	2.04	0.00
Row 4	98	5.46	4.86	4.21	3.49	2.65	1.61	0.00
Row 3	97	4.97	4.38	3.74	3.04	2.23	1.25	0.00
Row 2	96	4.50	3.93	3.31	2.63	1.86	0.94	0.00
Row 1	95	4.06	3.51	2.91	2.26	1.53	0.70	0.00

For example, when the stock price rises by 1 from 97 to 98 at 45 days, the call value rises by 0.45 from 3.04 to 3.49, or approximately 45 percent of the stock-price change. In another situation, when the stock rises from 102 to 103 at 60 days, the call value rises by 0.63 from 6.42 to 7.05, or approximately 63 percent of the stock-price change.

Two conclusions can be drawn from Table 3-3. First, as stated earlier, option prices generally change less than stock prices. Second, the amount by which option prices change depends on the time to expiration and the relationship of the stock price to the option's strike price.

Figure 3-1 shows how call values change as stock prices change. The upper line (curved) contains call values at 90 days to expiration, like column 1 in Table 3-3. The middle line (curved) contains call values at 45 days to expiration, like column 4 in Table 3-3; and the lower line (two straight sections) contains call values at expiration, like column 7 in Table 3-3. Figure 3-1 illustrates the same two concepts from Table 3-3—that call values are directly correlated with stock prices and that the level of correlation varies depending on the relationship of the stock price to the strike price.

Call values are near zero when the stock price is significantly below the strike price. Call values rise gradually at first as the stock price moves up toward the strike price. The values then rise faster and faster as the stock price reaches and then moves above the strike price. Finally, as the stock price soars significantly above the strike price, the change in call value approaches a one-for-one relationship with change in stock price. In theory, however, call values never change exactly one for one with stock prices because, in theory, the value of the call always will contain at least a slight time premium.

Put Values and Stock Prices

The same price-change characteristics apply to puts that apply to calls with one major difference: Put values are inversely correlated with

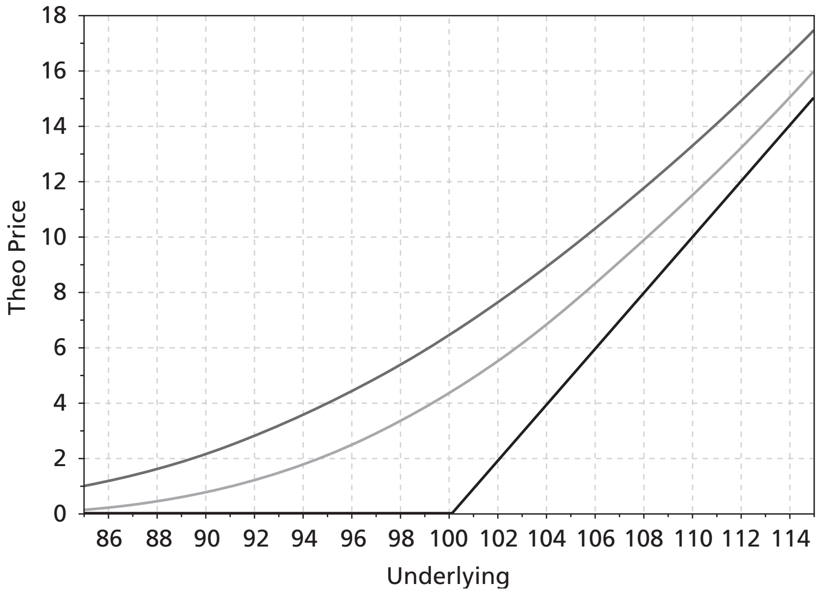


Figure 3-1 100 Call – Values at 90 Days, 45 Days, and Expiration

stock prices. Thus put values fall as stock prices rise and rise as stock prices fall. Table 3-4 contains theoretical values of a 100 Put at various stock prices and days to expiration.

An example of how put prices change starts in row 6, column 1 of Table 3-4. The stock price is 100, the put has 90 days to expiration, and the theoretical value of the 100 Put is 5.31. If the stock price falls by 1 to 99 (row 5, column1) and the other factors are unchanged, the theoretical value of the 100 Put increases by 0.45 to 5.76. If the stock price rises by 1 to 101, the put value decreases to 4.88. In both cases, the put price changes less than the stock price, and this relationship is always true for puts, just as it is for calls. Furthermore, the ratio of the change in put price to change in stock price varies with stock price and with time.

For example, when the stock price falls by 1 from 99 to 98 at 45 days, the put value rises from 4.36 to 4.89, or approximately 53 percent of the stock-price change. In another situation, when the stock rises from 103 to 104 at 60 days, the put falls from 3.23 to 2.89, or approximately 34 percent of the stock-price change.

Table 3-4 Theoretical Values of 100 Put at Various Stock Prices and Days to Expiration (Interest Rate, 5%; Volatility, 30%; No Dividends)

		Col1	Col2	Col3	Col4	Col5	Col6	Col7
	Stock Price	90 Days	75 Days	60 Days	45 Days	30 Days	15 Days	0 Days
Row 11	105	3.44	3.03	2.57	2.06	1.45	0.70	0.00
Row 10	104	3.76	3.35	2.89	2.35	1.72	0.93	0.00
Row 9	103	4.11	3.70	3.23	2.69	2.03	1.18	0.00
Row 8	102	4.49	4.07	3.60	3.05	2.39	1.50	0.00
Row 7	101	4.88	4.47	4.00	3.45	2.78	1.88	0.00
Row 6	100	5.31	4.90	4.43	3.89	3.22	2.32	0.00
Row 5	99	5.76	5.36	4.90	4.36	3.71	2.83	1.00
Row 4	98	6.24	5.84	5.40	4.89	4.24	3.40	2.00
Row 3	97	6.74	6.36	5.93	5.43	4.82	4.04	3.00
Row 2	96	7.28	6.91	6.49	6.02	5.45	4.74	4.00
Row 1	95	7.84	7.48	7.09	6.64	6.12	5.49	5.00

Figure 3-2 shows how put values change as stock prices change. The upper line (curved) reflects put values at 90 days to expiration, like column 1 in Table 3-4. The middle line (curved) contains put values at 45 days to expiration, like column 4 in Table 3-4; and the lower line (two straight sections) contains put values at expiration, like column 7 in Table 3-4. Like Table 3-4, Figure 3-2 illustrates that put values are inversely correlated with stock prices and that the level of correlation varies depending on the relationship of the stock price to the strike price.

Put values are near zero when the stock price is significantly above the strike price. Put values rise gradually as the stock price declines toward the strike price. The values then rise faster and faster as the stock price reaches and then falls below the strike price. Finally, as the stock price drops significantly below the strike price, the change in put value approaches a one-for-one relationship with change in stock price. In theory, however, put values never change exactly one for one with stock prices because, in theory, the value of a put always will contain at least a slight time premium.

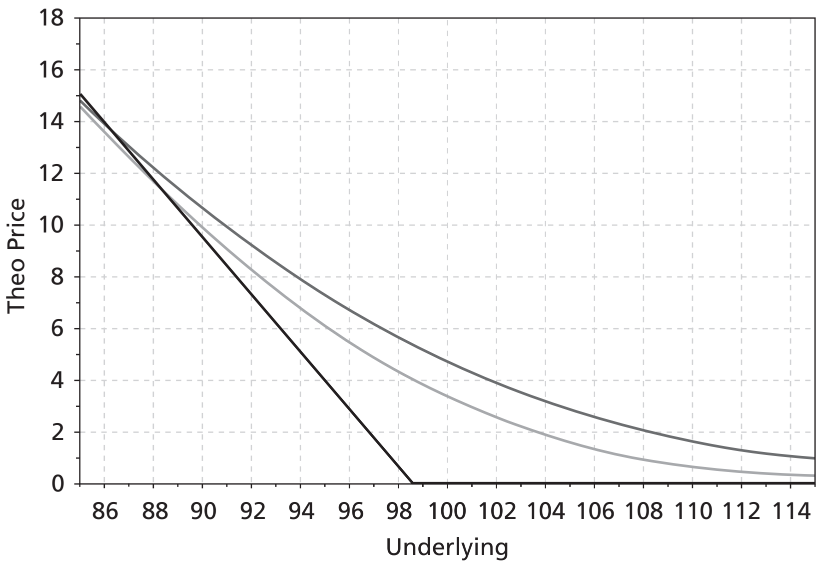


Figure 3-2 100 Put – Values at 90 Days, 45 Days and Expiration

Delta

The ratio of option-price change to stock-price change is an important aspect of option-price behavior, and it is referred to as the *delta* of an option. Specifically, delta is the change in option theoretical value given a one-unit change in price of the underlying stock. This chapter introduces delta, but Chapter 4 will discuss it in detail.

Recall the example from Table 3-3. When the stock price rose from 100 to 101 at 90 days to expiration, and the 100 Call rose 0.58 from 6.53 to 7.11, this call would be described as having a "delta of 58." Actually, the delta is 0.58, or 58 percent. This means that the 100 Call is estimated to change in price by an amount equal to 58 percent of the stock-price change. Look at a different example from Table 3-4, where the stock price declined from 100 to 99, and the 100 Put rose by 53 cents. This put would be described as having a "delta of −53," or negative 53 percent. This means that the 100 Put is estimated to change in price by 53 cents when the stock price changes by $1.

Call Values Relative to Put Values

The relationship between call and put values confuses many traders. Intuition may tell you that calls and puts with the same strike price and the same expiration should have the same value if the stock price is equal to the strike price. Actually, however, this parity does not happen. Assuming no dividends, call prices always will be greater than put prices because they contain an interest component that puts lack. Evidence of this disparity appears from a comparison of Tables 3-3 and 3-4. Row 6 in both tables shows option values with the stock price at $100. At 90 days (column 1), the 100 Call has a value of 6.53, but the 100 Put has a value of 5.31. The call value is also greater than the put value in every cell of row 6. These differences stem from an interest factor that is part of the call price but which is not part of the put price. When arbitrage strategies are explained in Chapter 6, the reason for the interest factor will become clear.

In rows other than row 6 in Tables 3-3 and 3-4, the time value of the 100 Call is greater than the time value of the 100 Put. Compare the values in row 4, column 2 of both tables, for example, where the stock price is $98, and there are 75 days to expiration. The value of the 100 Call is 4.86, all of which is time value. The value of the 100 Put of 5.84 consists of $2.00 of intrinsic value and $3.84 of time value. In this example, the time value of the 100 Put is 1.02 less than the time value of the 100 Call. As another example, consider row 9, column 5 in both tables, which is a stock price of $103 and 30 days to expiration. The value of the 100 Call of 5.44 consists of $3.00 of intrinsic value and $2.44 of time value. The value of the 100 Put of 2.03 is all time value and 0.41 less than the time value of the 100 Call.

The general concept of why call prices are greater than put prices is a relationship known as *put-call parity*, which is discussed in detail in Chapter 5. Put-call parity states that stock prices, call prices, and put prices must have a certain relationship with each other or there will be arbitrage opportunities for professional traders to make nearly riskless profits. Always on the lookout for profitable trades, professional market makers constantly watch for *market inefficiencies*—where prices are out of line with each other—and jump on the arbitrage opportunity. Because of the fierce competition among market makers, such advantages exist only for very short periods of time, and the "inefficiency" generally amounts to only a few cents per share. The large number of options that market makers trade every day, however, makes seizing these arbitrage opportunities profitable.

Option Values and Strike Price

As noted earlier, the strike price of an option is similar to the deductible of an insurance policy. Increasing the deductible of an insurance policy lowers the premium, or cost, of the policy, and decreasing the deductible raises the premium. For options, if the underlying stock price is at 100, the 100 Call is at the money, like a policy with no deductible. Raising the strike to 105 while keeping other factors such as stock price constant decreases the call value. This happens because with a stock price of 100, the 105 Call, being out of the money by five points, is like an insurance policy with a deductible. Table 3-5 shows that the value of the 100 Call falls from 6.53 to 4.37 to 2.80 as the strike price rises from 100 to 105 to 110, respectively. In the language of insurance, as the deductible rises, that is, as the strike price gets further from the stock price, the premium decreases.

Stock splits, such as two-for-one splits, are the most common reason that strike prices change, but these splits do not affect how far an option is in the money or out of the money. If a stock splits two for one from 100 to 50, for example, then the original 110 Call is 10 percent out of the money, and the new 55 Call is also 10 percent out of the money. The change in option values after a two-for-one stock split is more the result of the change in stock price than the change in strike price. There is little need to discuss changing strike price because it is extremely rare that a strike price changes while other factors remain constant. A technical note is that in 2007, the method of handling stock splits changed. Under the new method, with the exception of

Table 3-5 Effect of Increase in Strike Price

	Original Inputs	New Strike		New Strike	
Stock price	100				
Strike price	100	105		110	
Dividend yield	0%				
Volatility	30%				
Interest rate	5%				
Days to exp.	60				
	Original Values	**New Values**		**New Values**	
100 Call:	6.53	105 Call:	4.37	110 Call:	2.80
100 Put:	5.31	105 Put:	8.08	110 Put:	11.45

two-for-one and four-for-one splits, the deliverable will be adjusted but not the strike price or the premium-to-strike multiplier. For specific details refer to Securities and Exchange Commission (SEC) Release No. 34–55258.

Option Values and Time to Expiration

Option values decrease with the passage of time if all other factors remain constant. There are two ways of illustrating this graphically. First, look back at Figures 3-1 and 3-2. These figures show option prices at 90 days to expiration, 45 days to expiration, and at expiration. As time passes, the graphs approach the shape of the expiration profit-and-loss diagram, as represented by the straight lines.

Figure 3-3 presents a different perspective on time erosion. Figure 3-3A presents perhaps the best known illustration of time decay, that of a nearly straight line until 30 days before expiration and then a precipitous drop to zero at expiration. This figure is based on the prices in row 6 of Table 3-3, in which the stock price is 100. The at-the-money 100 Call declines in value from 6.53 at 90 days to 5.92 at 75 days to 5.25 at 60 days, etc. In this case, time decay affects the option value relatively little initially and relatively more as expiration approaches. Row 6 in Table 3-3 demonstrates that when one-half the time to expiration elapses, from 90 days to 45 days, only 31 percent of the 100 Call value erodes (6.53 to 4.50). A similar price/time relationship exists from 60 days to 30 days when the 100 Call declines 31 percent from 5.25 to 3.63 and from 30 days to 15 days when the decline is 30 percent from 3.63 to 2.53. Row 6 in Table 3-4 reveals a similar time-decay pattern for the 100 Put when the stock price is $100.

Theta

The name for time decay of options is *theta*. Theta is the theoretical change in option value given a one-unit change in time to expiration. The nonspecific term *one unit* could refer to one day, one week, or some other time period. In the Op-Eval Pro computer program that

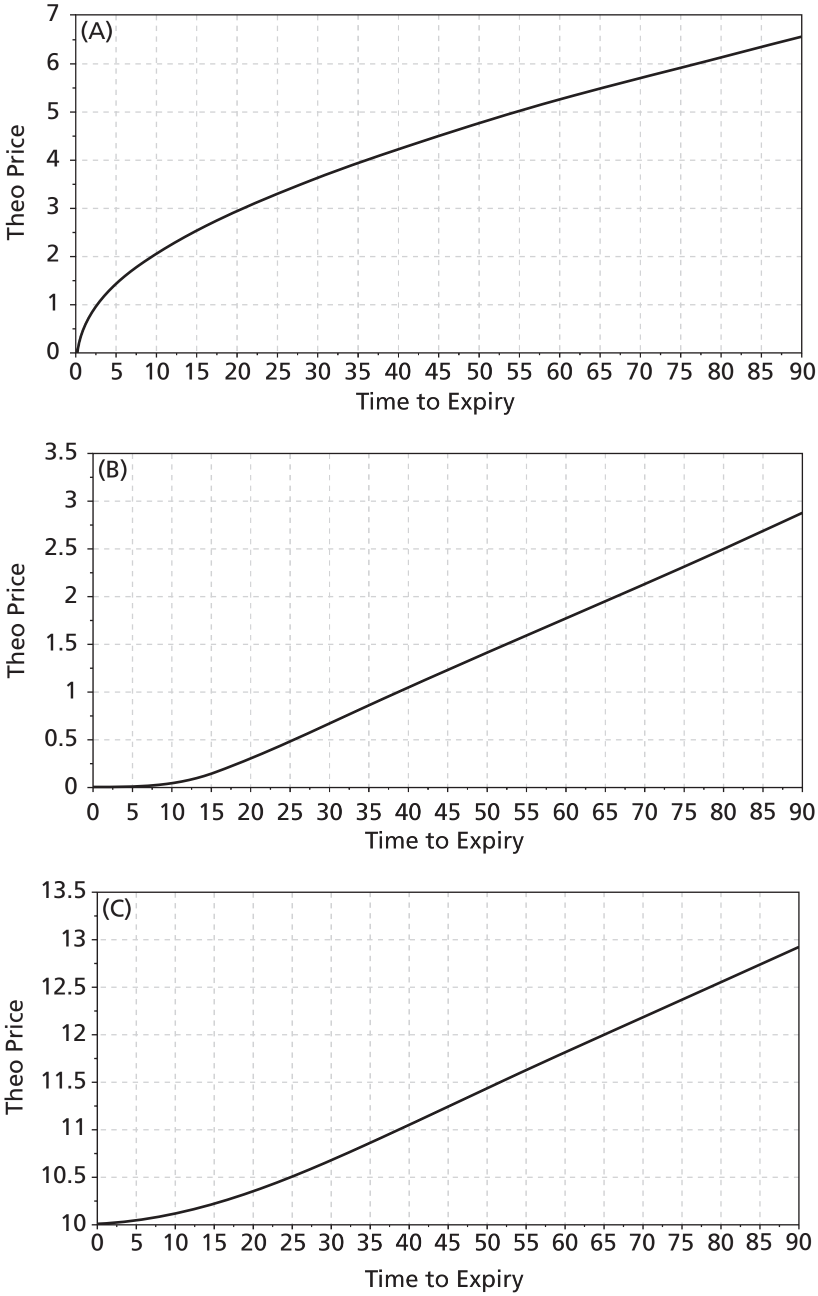


Figure 3-3 **(A)** At-the-Money Call and Time, **(B)** Out-of-the-Money Call and Time, **(C)** In-the-Money Call and Time

accompanies this book, the user can set the unit of time for theta. Chapter 4 discusses theta in depth with all the Greeks.

Time Decay Is Complicated

Unfortunately for newcomers to options, the effect of time decay on option values is not as simple as it may first appear. Figure 3-3B and C shows that time decay for in-the-money and out-of-the-money options differ from time decay for at-the-money options (Figure 3-3A).

Figure 3-3B demonstrates how time decay affects out-of-the-money calls. The assumptions are a call strike of 110, a stock price of 100, and a time period of the last 90 days to expiration. The nearly straight line contrasts sharply with the line in Figure 3-3A. Note in particular that the least amount of time decay occurs during the last week, whereas in Figure 3-3A the greatest amount of time decay occurs during that week.

Figure 3-3C shows that time erosion of in-the-money calls nearly matches the time erosion of out-of-the-money calls. The figure graphs a 90 Call with a stock price of 100 during the last 90 days to expiration. Remember, only the time-value portion of an option decays. Consequently, with a stock price of 100, 90 days to expiration, and a 90 Call value of 12.82, time decay will affect only 2.82 of this in-the-money option's value. At expiration, the value of this call will equal its intrinsic value of 10.00.

Time Decay and Volatility

An examination of Table 3-6 reveals the impact of volatility on time decay. There are nine columns and three sections in the table. Each column represents a different number of days to expiration. The three main sections of rows contain values of a 100 Call, a 105 Call, and a 110 Call. Each section contains three different volatility assumptions. The percentages under the values will help you to see the differing rates of time decay.

Table 3-6 Values of At-the-Money and Out-of-the-Money Calls at Various Levels of Volatility*

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9
56 Days	49 Days	42 Days	35 Days	28 Days	21 Days	14 Days	7 Days	Exp.
	100 Call			20% Volatility				
3.43	3.19	2.94	2.66	2.36	2.03	1.64	1.14	0
100%	93%	86%	78%	69%	59%	48%	33%	0%
				30% Volatility				
4.98	4.64	4.28	3.90	3.46	2.98	2.42	1.70	0
100%	93%	86%	78%	69%	59%	48%	33%	0%
				40% Volatility				
6.54	6.10	5.63	5.12	4.57	3.94	3.20	2.25	0
100%	93%	86%	78%	69%	59%	48%	33%	0%
	105 Call			20% Volatility				
1.48	1.28	1.08	0.87	0.65	0.43	0.22	0.05	0
100%	86%	73%	59%	44%	29%	15%	0%	0%
				30% Volatility				
2.92	2.61	2.28	1.93	1.55	1.15	0.72	0.26	0
100%	89%	78%	66%	53%	39%	25%	9%	0%
				40% Volatility				
4.44	4.01	3.56	3.08	2.56	1.99	1.35	0.61	0
100%	90%	80%	69%	58%	45%	30%	14%	0%
	110 Call			20% Volatility				
0.52	0.41	0.30	0.20	0.11	0.05	0.01	0.00	0
100%	79%	58%	38%	21%	10%	2%	0%	0%
				30% Volatility				
1.59	1.34	1.09	0.83	0.56	0.35	0.14	0.02	0
100%	84%	69%	52%	35%	22%	9%	1%	0%
				40% Volatility				
2.90	2.53	2.14	1.73	1.32	0.89	0.46	0.10	0
100%	87%	74%	60%	46%	31%	16%	3%	0%

Assumptions: Stock price, 100; no dividends; interest rate, 5%.

* Values shown in percentages indicate rate of time decay.

The first row in the upper section of Table 3-6, shows that with volatility of 20 percent, the 100 Call declines in value from 3.43 at 56 days to 2.36 at 28 days and to zero at expiration. Owing to time erosion, this call loses 31 percent of its initial value of 3.43 in the first half of its life and 69 percent in the second half. With volatility of 30 and 40 percent, the rate of decay is nearly identical. The conclusion is that for at-the-money options, regardless of the level of volatility and assuming that other factors remain constant, loss of value owing to time decay in the first half of an option's life equals only about one-third of the initial value.

For the 105 Call, which is 5 percent out of the money, the rate of time decay is noticeably different from that of the at-the-money call and changes when volatility changes. The first row in the middle section of Table 3-6 shows that with volatility of 20 percent, the 105 Call declines in value from 1.48 at 56 days to 0.65 at 28 days and to zero at expiration. Thus 56 percent of the initial value is lost owing to time erosion in the first half of the 105 Call's life, and 44 percent is lost in the second half. With volatility of 30 percent, the rate of decay is slightly less in the first half and slightly more in the second half. The decline from 56 days to 28 days is 47 percent versus 56 percent at 20 percent volatility. From 28 days to expiration, the 105 Call loses 53 percent of its value at 56 days versus 44 percent when volatility was 20 percent. With volatility of 40 percent, the 105 Call declines even less in the first half (42 percent) and more in the second half (58 percent).

The 110 Call is 10 percent out of the money in this example and reflects a third impact of volatility on time decay. The first row in the lower section of Table 3-6 shows that with volatility of 20 percent, the 110 Call declines 79 percent from 56 days to 28 days and 21 percent from 28 days to expiration. With volatility of 30 percent, the rate of decay is less in the first half (65 versus 79 percent) and more in the second half (35 versus 21 percent). With volatility of 40 percent, the 110 Call declines 54 percent in the first half of its 56-day life and 46 percent in the second half.

Table 3-6 leads to three conclusions. First, out-of-the-money options decay differently than at-the-money options. Out-of-the-money options decay more in the first half of their lives and less in the second half, whereas at-the-money options decay less initially and more as expiration approaches. Second, the further out of the money an option is, the greater is the amount of time decay in the first half of its life. Third, increasing volatility causes less value to erode in the first half of an out-of-the-money option's life and more in the second half.

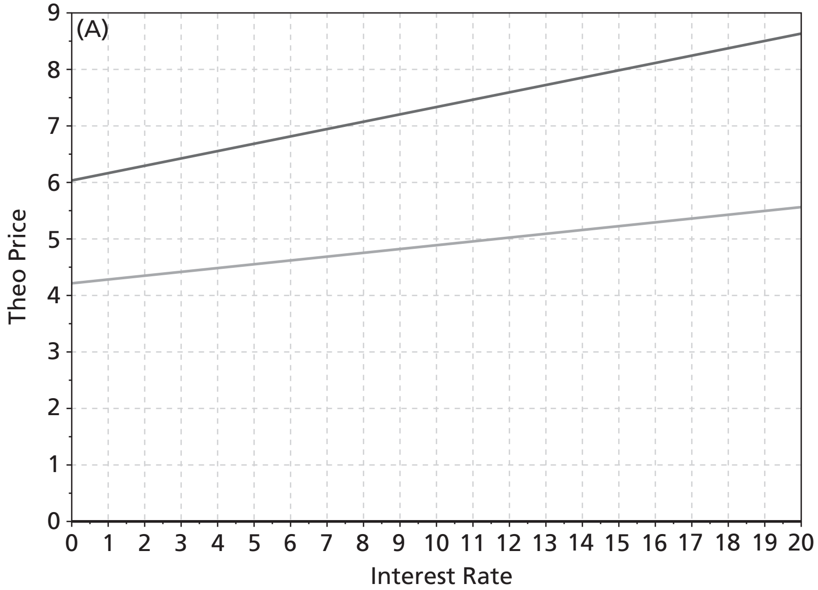
Alternatives for Premium Sellers

Table 3-6 should give pause to traders and investors who employ strategies that sell options consistently, especially if the sold options are 5 or 10 percent out of the money. These option users, who are commonly known as *premium sellers*, should study the evidence in Table 3-6 that suggests an alternative strategy to selling one-month options that are 5 or 10 percent out of the money. Table 3-6 suggests that under certain circumstances, selling a two-month option, covering it one month before expiration, and then selling the next two-month option can bring in more time premium than selling one-month options every month.

Option Values and Interest Rates

Figure 3-4A shows that call values rise when interest rates rise, and Figure 3-4B shows that put values decline. These rises and declines are a direct consequence of put-call parity explained in Chapter 5.

Fortunately, the impact of interest rates is small. When interest rates rise from 3 to 5 percent, the value of a 90-day at-the-money 100 Call rises from 6.29 to 6.53. These values assume a stock price of 100, volatility of 30 percent, and no dividends. Although rare, interest rates can change 2 percent in fairly short periods of time. Such dramatic changes in interest rates, however, always have been accompanied by other macroeconomic or global political events having equally dramatic impacts on stock prices and volatility. When compared with the



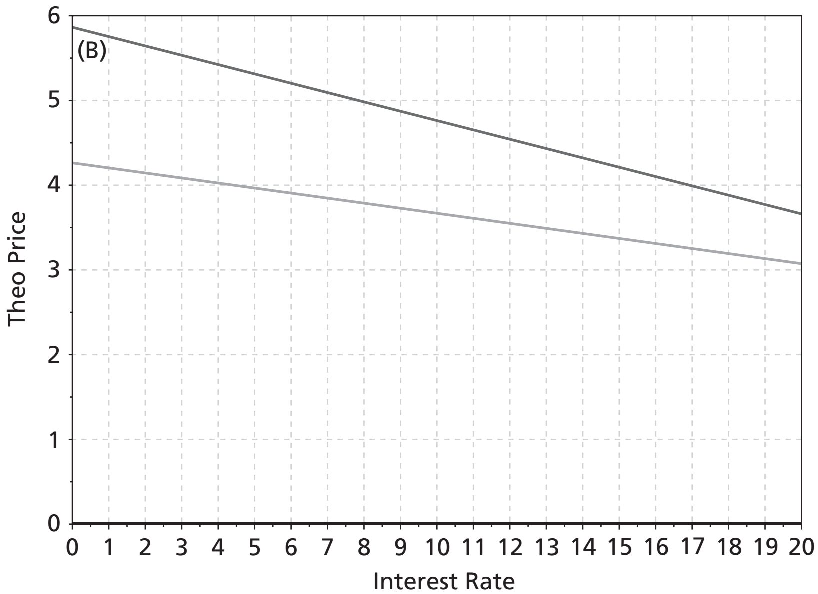


Figure 3-4 **(A)** Call Values and Interest Rates, **(B)** Put Values and Interest Rates

dramatic changes in stock prices and volatility, the impact of changing interest rates on option prices has been minor. Finally, although changes in interest rates affect option values the least of all inputs, they can have a significant impact on professional traders who engage in arbitrage strategies, as explained in Chapter 6.

Option Values and Dividends

The impact of dividends on option prices is opposite that of interest rates. With no dividends, the call value exceeds the put value by the cost of money (interest rate). Dividends, however, effectively reduce the cost of money because the dividend proceeds can be used to pay the interest. Consequently, as dividends rise, the call value decreases, and the put value increases. Call and put values are equal when the dividend yield equals the interest rate.

Option Values and Volatility

Volatility, as will be discussed in detail in Chapter 7, is a measure of stock price fluctuation without regard to direction. The greater the volatility, the higher is an option's price. Volatility is stated in percentage terms. For example, the past price action of a particular underlying security is said to "trade at 25 percent volatility," or an option's theoretical value is said to be calculated "using 30 percent volatility."

Figure 3-5B gives an example of how theoretical values of an at-the-money 100 Call change as the volatility changes from 0 to 50 percent, assuming a stock price of $100, a 4 percent interest rate, and no dividends. The upper line demonstrates values at 90 days to expiration, and the lower line shows values at 45 days to expiration. The figure shows that changing volatility is nearly linear for at-the-money options regardless of time to expiration.

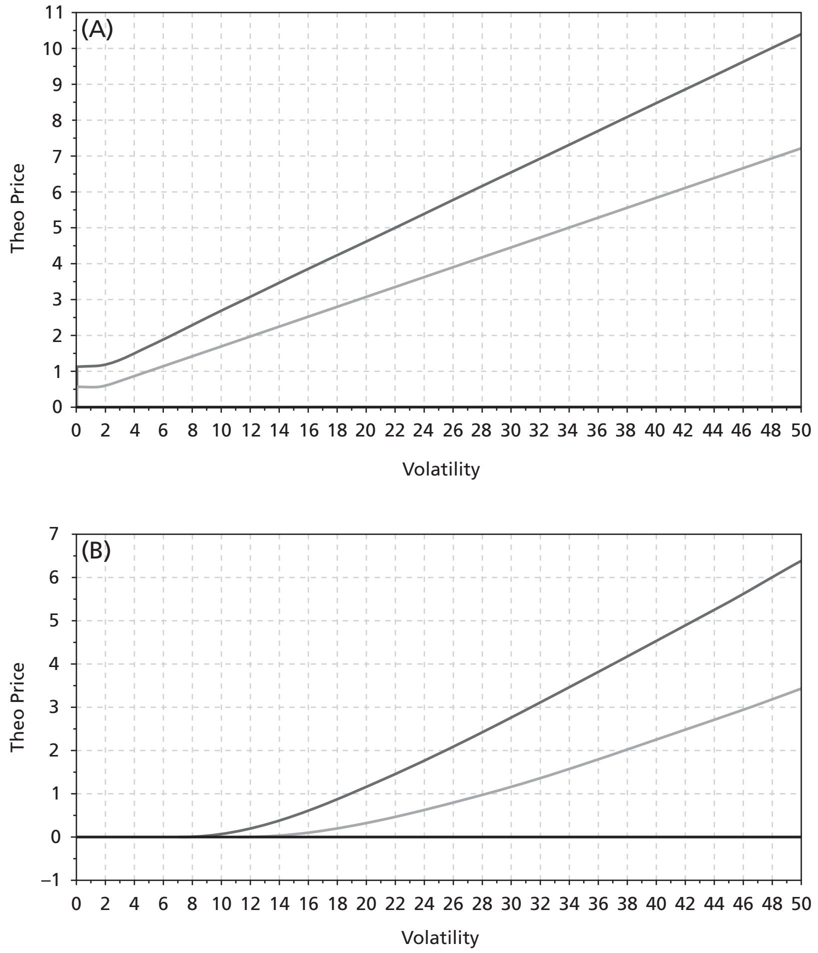


Figure 3-5 **(A)** Volatility and At-the-Money Calls, **(B)** Volatility and 10% Out-of-the-Money Calls

Figure 3-5B illustrates that changing volatility has a different impact on the value of out-of-the-money options. The lines in the figure show values of a 110 Call (10 percent out of the money) at 90 days (the upper line) and at 45 days (the lower line). The impact of volatility depends on both the distance to the strike price and the level of volatility.

Extreme Volatility

Extreme volatility means that option values rise to their limit. The limit of value for a call is the stock price because no rational investor would pay more for a call than for the stock. For a put, the limit of value is the strike price because prices cannot fall below zero. Figure 3-6 shows how prices of at-the-money calls rise when volatility rises to 1,000 percent. Although not shown, put values rise in a similar manner. Figures 3-5A and 3-6 both illustrate an at-the-money call but look different because of the range on the *x* axis. The range of volatility for Figure 3-5 is 0 to 50 percent, and for Figure 3-6 it is 0 to 1,000 percent.

Dynamic Markets

The discussion to this point has assumed that only one component of value changes while the rest stay constant. In the real world, of course, more than one component changes at a time. Many market forecasts do not generally call for a stock to move up or down on the same day

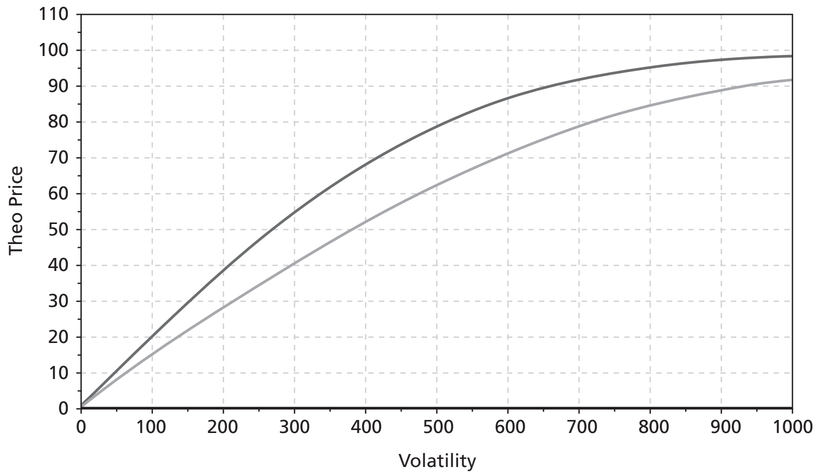


Figure 3-6 Call Values and Extreme Volatility 100 Call at 90 days and 45 days; stock price 100

while volatility remains unchanged. Rather, stock prices and volatility both can change over a period of several days or weeks, and changes in each of the three factors—stock price, time, and volatility—will affect an option's price differently. While interest rates do change, the changes are typically small, and the impact on option values is negligible. Dividend changes typically occur only once each year and are somewhat predictable, although special dividends, dividend suspensions, and deviations from past practices can cause option prices to "adjust" when the news hits the market. The topic of dividends is discussed in Chapter 6.

Three-Part Forecasts

While stock traders need to focus only on the direction of the stock price, option traders must add two components—a forecast for time and a forecast for the level of implied volatility. Chapter 7 discusses the topic of implied volatility in depth.

Back to Table 3-1. If a forecast called for the stock price to rise from $97 at 90 days to $101 at 75 days, the 100 Call price might be expected to rise from 4.97 to 6.49. If, however, the stock price rise was expected to take 15 days longer, until 60 days to expiration, then the call would be expected to rise to 5.82, an outcome that is 0.67, or approximately 40 percent, less profitable.

And what if volatility changed? The trading scenarios discussed next examine a forecast with changing volatility.

Trading Scenarios

Assume that Joe is anticipating a bullish earnings report from Jumpco, a children's playground equipment distributor. The report is due in three days, and Joe believes that good news could send the stock price, currently $67, up 10 percent to $74 shortly thereafter. To analyze how much he might make if he buys the Jumpco April 75 Call and if his forecast proves accurate, Joe creates Table 3-7. He starts with what he knows, a stock price of $67, a strike price of 75, interest rates of 4 percent, dividends of 2 percent, and 16 days to April expiration. Seeing that the market price of the call is 50 cents, Joe calculates the implied volatility at 38 percent using the method that will be described in Chapter 7.

Scenario 1 in Table 3-7 forecasts a stock price rise from $67 to $74, or approximately 10 percent, in seven days, with volatility staying at

Table 3-7 Need for a Three-Part Forecast

Scenario 1: Stock price up 10% in 7 days with volatility unchanged at 38%			
Original Inputs		**New Inputs**	
Stock price	67.00	74.00	← Increase in stock price
Strike price	75.00	75.00	
Dividend yield	2.0%	2.0%	
Volatility	38.0%	38.0%	← Volatility constant
Interest rates	4.0%	4.0%	
Days to expiration	25	18	← Decrease in days
Outputs	**Outputs**		
75 call value	0.50	2.10	← Call value up 320%

Scenario 2: Stock price up 10% in 7 days with volatility declining to 25%			
Original Inputs		**New Inputs**	
Stock price	67.00	74.00	← Increase in stock price
Strike price	75.00	75.00	
Dividend yield	2.0%	2.0%	
Volatility	38.0%	25.0%	← Decrease in volatility
Interest rates	4.0%	4.0%	
Days to expiration	25	18	← Decrease in days
Outputs	**Outputs**		
75 call value	0.50	1.25	← Call value up 150%

Scenario 3: Stock price up 5% in 7 days with volatility declining to 25%			
Original Inputs		**New Inputs**	
Stock price	67.00	70.50	← Increase in stock price
Strike price	75.00	75.00	
Dividend yield	2.0%	2.0%	
Volatility	38.0%	25.0%	← Decrease in volatility
Interest rates	4.0%	4.0%	
Days to expiration	25	18	← Decrease in days
Outputs	**Outputs**		
75 call value	0.50	0.30	← Call value down 40%

38 percent. Given these assumptions, Joe estimates that the Jumpco April 75 Call will rise 320 percent to 2.10. While such a scenario is enticing, Joe does not immediately buy a call because he also realizes that market action might differ from his forecast.

Even if his stock-price and time forecasts are accurate, Joe wants to consider the consequences of implied volatility declining. A little research, as explained in Chapter 7, shows that 25 percent is a more typical level of volatility for Jumpco options than the current level of 38 percent. Joe therefore creates Scenario 2 to estimate the impact of volatility returning to 25 percent. As a result of these calculations, the estimated price of the April 75 Call falls to 1.25, a still impressive 150 percent increase from the current price of 0.50.

Joe is not through with his analysis yet. Although he is bullish on Jumpco, Joe is curious about what would happen to the price of the call if the stock price rose only 5 percent and not the 10 percent that he is hoping for. Scenario 3 in Table 3-7 estimates that with the stock price rising to $70.50, up approximately 5 percent from $67, in seven days and with volatility decreasing to 25 percent, the Jumpco April 75 Call declines from 0.50 to 0.30, for a loss of 20 cents, or 40 percent. The maximum risk of buying a call, of course, is the full cost of the call plus commissions, or 100 percent of the investment. Nevertheless, given the confidence he has in his forecast and his willingness to risk the full investment, Joe decides to buy some Jumpco April 75 Calls.

The three-part forecast and multiple-scenario analysis that Joe used to analyze the Jumpco April 75 Calls is what distinguishes speculative option trading from speculative stock trading. Option traders need to consider the impact of both time and volatility when making trading decisions. Creating tables of theoretical values, such as presented in this chapter, helps traders to develop realistic expectations about option price behavior. The Op-Eval Pro software that accompanies this book and is explained in Chapter 2 was used to create these tables. The program can help traders to develop realistic expectations about option prices and to select a strategy that matches their forecasts. With practice, any trader can master making these multiple scenarios.

Summary

Options have value, in part, because they are similar to insurance. Puts insure owned assets against a market decline, and calls insure cash or liquid assets from missing a rally. The factors that actuaries consider in determining insurance premiums correspond to the components used by formulas such as the Black-Scholes option pricing model to calculate option theoretical values.

The asset-value component of insurance premiums corresponds to the underlying price component used to value options. The deductible in insurance corresponds to the strike price. The time factor is the same for both, but interest rates in insurance correspond to a combination of both interest rates and dividends for options. Finally, the risk factor in insurance is similar to volatility in options.

Option prices, prior to expiration, always move less than one for one with underlying stock-price changes. Delta represents the expected option-price change given a one-unit change in the stock's price. The passage of time causes option prices to decrease—all other pricing factors remaining constant. At-the-money options decrease with the passage of time in a nonlinear manner, less initially and more as expiration nears. The time decay of in-the-money and out-of-the-money options is different, increasing for a while and then slowing as expiration nears. Interest rates directly affect call prices and inversely affect put prices. Dividends are the opposite of interest rates: Dividends up, call prices down, and put prices up, and vice versa.

Volatility has a direct impact on option prices. The higher the volatility, the higher both put and call prices will be. Volatility is a measure of stock-price fluctuation without regard to direction. While it is a statistical concept not grasped easily by nonmathematicians, volatility can be understood intuitively and incorporated, subjectively, into trading decisions.

Markets are dynamic, not static, and the impact on option prices of the factors discussed in this chapter can be confusing at first. Nevertheless, realistic expectations about option-price behavior are essential, and analyzing multiple scenarios helps to better understand the potential profit and risks of contemplated strategies.

Chapter 4

THE GREEKS

This chapter discusses five indicators that traders use to estimate how option prices and position risk change in dynamic market conditions. The five indicators—delta, gamma, theta, vega, and rho—are frequently referred to as the *Greeks*, and each is an estimate of the change in option value caused by a change in one of the inputs to an option-pricing formula, assuming that other factors remain constant. Each of the Greeks will be discussed in three steps. First, each Greek will be defined, and an example will be given of how each affects option prices. Second, how each Greek changes as other factors change will be discussed. Third, the concept of *position Greeks* will be explored, and a method will be presented for measuring the Greeks of multipart option positions.

The following discussion gets fairly technical, but option traders must master the concepts. This material is also essential preparation for Chapter 10, which discusses position-risk management.

Overview

As an underlying stock price rises or falls, the value of an option will also rise or fall. *Delta* is a measure of the option value's sensitivity to those underlying price changes. Deltas themselves also change as stock prices rise and fall, with *gamma* being a measure of a delta's sensitivity to underlying price. *Vega* is a measure of an option value's sensitivity to volatility, and *theta* is a measure of an option value's sensitivity to the passage of time. *Rho* is a measure of an option value's sensitivity to interest rates. Each of these Greeks will be discussed in depth, with examples and some general rules as to how they change, when their effects on option prices are biggest and smallest, and how they change when either time or volatility changes.

Delta

As discussed in Chapter 3, the price of the underlying instrument is an important factor in the determination of option values. *Delta* is an estimate of the change in option value given a one-unit change in price of the underlying instrument, assuming that other factors remain constant. Delta answers this question: If the underlying stock rises or falls by one point, how much should I make or lose?

The Op-Eval Pro software that accompanies this text was used to create the tables and figures in this chapter. Tables 4-1 through 4-6 assume the following initial parameters: a stock price of 100, a strike price of 100, volatility of 30 percent, an interest rate of 4 percent, 60 days to expiration, and no dividends. Given these inputs, four of the outputs on the Single Option Calculator screen of Op-Eval Pro are a 100 Call value of 5.19, a 100 Call delta of +0.55, a 100 Put value of 4.59, and a 100 Put delta of −0.46.

In Table 4-1, the delta of the 100 Call estimates that if the stock rises by one point to 101 and other factors remain constant, then the 100 Call value will rise by 0.55 to 5.74. The delta of the 100 Put estimates that under the same circumstances, the 100 Put value will fall by 0.46 to 4.13. The values to the right of the arrows in the table show this. Although in this example the call and put deltas appear to state precisely the changes in call and put values, they only predict them. In most cases there will be slight differences between the predictions and the actual changes in the marketplace. The next section, which discusses gamma, will explain the reason for such differences. First, however, you need to make some observations about delta.

Mathematically, the delta of an option is the first derivative of option value with respect to a change in price of the underlying. While it is not important to know the mathematics, it is important to understand the concept that delta is an estimate of the change in option value given a change in price of the underlying with other factors remaining constant. As will be shown later, a one-unit change in price of the underlying causes relatively bigger changes in the values of in-the-money options, relatively smaller changes in the values of at-the-money options, and even smaller changes in values of out-of-the-money options.

Call Values Have Positive Deltas

The plus sign (+) associated with the delta of the 100 Call in Table 4-1 indicates a positive, or direct, relationship between a change in price of the underlying instrument and a change in theoretical value of the call. As the table illustrates, when only the underlying stock price rises, the theoretical value of the 100 Call also rises. It should be noted at this point that a plus or minus sign associated with an *option delta* may be different

Table 4-1 Illustration of Delta

	Initial Input		Input with Stock Price Up
Inputs:			
Stock price	100	→	101
Strike price	100		
Dividends	None		
Volatility	30%		
Interest rate	4%		
Days to expiration	60		
	Initial Outputs		**New Outputs**
Outputs:			
100 Call value	5.19	→	5.74
100 Call delta	+0.55		
100 Put value	4.59	→	4.13
100 Put delta	−0.46		

from the sign associated with an *option position.* The subject of position deltas will be discussed later in this chapter.

Put Values Have Negative Deltas

The negative sign (−) associated with the delta of the 100 Put indicates a negative, or inverse, relationship between a change in price of the underlying instrument and a change in value of the put. In other words, a rise in the stock price caused the put value to decline, as shown in Table 4-1.

Finding Deltas in Op-Eval Pro

Delta appears in Op-Eval Pro on three screens in two different forms. On the Single Option Calculator screen (see Figure 2-2), deltas appear under the respective call and put values. On the Spread Positions and Portfolio screens (see Figures 2-3 and 2-6), deltas appear in two places. Deltas of individual options appear in the "DELTA" row, and a "Spread delta" appears in the box labeled as such. The *spread delta* is the sum of the deltas of individual options in a position.

Gamma

As discussed earlier, in most cases the delta does not exactly predict an option's new value after a one-point change in price in the underlying. The difference occurs because the delta changes as the price of the underlying changes. *Gamma* is a measure of the change in delta for a one-unit change in price of the underlying instrument, assuming that other factors remain constant. Mathematically, gamma is the second derivative of the option value with respect to change in price of the underlying. Gamma answers this question: How much does my exposure to the market change, that is, how much does my delta change, when the price of the underlying stock changes? Gamma makes it possible to estimate more accurately the change in option value when the stock price rises or falls.

Table 4-2 illustrates the concept of gamma. It takes the information in Table 4-1 and then adds the new call and put deltas, as calculated with the options' gammas after the change in the stock price. When the stock price rises from 100 to 101, as the table shows, the delta of the 100 Call increases from +0.55 to +0.58, a rise of 0.03, a change equal to the gamma.

Similarly, the delta of the 100 Put increases by 0.03 from −0.46 to −0.43. That's right! This is an *increase* in the put delta; −0.43 is "greater" than −0.46. For readers comfortable with math, this may seem obvious. Others should take note: When watching the Greeks change, it is important to keep track of plus and minus signs and increases and decreases in value.

While the change in call and put deltas exactly equals the gamma in Table 4-2, there will frequently be small differences owing to rounding and changing gammas. In Table 4-2, the gammas of the both the 100 Call and the 100 Put do not appear to change after the stock price

Table 4-2 Illustration of Gamma (1)

	Initial Inputs		Inputs with Stock Price Up
Inputs:			
Stock price	100	→	101
Strike price	100		
Dividends	None		
Volatility	30%		
Interest rate	4%		
Days to expiration	60		
	Initial Outputs		**New Outputs**
Outputs:			
100 Call value	5.19	→	5.74
100 Call delta	+0.55	→	+0.58
100 Call gamma	+0.03	→	+0.03
100 Put value	4.59	→	4.13
100 Put delta	−0.46	→	−0.43
100 Put gamma	+0.03	→	+0.03

does because they are only calculated to the second decimal point. Calculating the values to four decimal points reveals that the gamma of the 100 Call fell from 0.0327 to 0.0321, and the gamma of the 100 Put fell from 0.0335 to 0.0328. While such small changes may seem insignificant, this example involves only a one-point, or 1 percent, change in stock price. For stock-price changes of 5 percent or more, these seemingly insignificant numbers can add up and become significant to a trader who has a large position and ignores them.

Gammas of Option Values Are Positive

Plus signs (+) are always associated with gammas of both calls and puts because change in delta is positively correlated with change in the price of the underlying. Table 4-2 illustrates this: An increase in stock price causes an increase in the deltas of both the 100 Call and the 100 Put. The delta of the 100 Call, for example, increases from +0.55 to +0.58, an amount exactly equal to the gamma of +0.03. Table 4-3, on the other hand, shows that a decrease in the stock price causes a decrease in the deltas of both options. The delta of the 100 Call decreases from +0.55 to +0.51, and the delta of the 100 Put decreases from −0.46 to −0.50. These are examples of the change in delta not being exactly equal to the change in the gamma. The difference is due to rounding. This is a positive correlation: Stock price up, delta up (Table 4-2), and stock price down, delta down (Table 4-3).

Note that the gammas of calls and puts with the same underlying, same strike, and same expiration are nearly equal. In Tables 4-2 and 4-3, they appear equal because they are calculated to only two decimal places. Gammas of same-strike calls and puts are nearly equal owing to put-call parity, a corollary of which is that the sum of the absolute values of the call delta and put delta equals +1.00 (or very nearly +1.00), assuming that the call and put have the same underlying, same strike, and same expiration. This means that if the absolute value of the delta of the call increases, then the absolute value of the put must decrease by an equal amount. Otherwise, the sum of the

Table 4-3 Illustration of Gamma (2)

	Initial Inputs		Inputs with Stock Price Down
Inputs:			
Stock price	100	→	99
Strike price	100		
Dividends	None		
Volatility	30%		
Interest rate	4%		
Days to expiration	60		
	Initial Outputs		**New Outputs**
Outputs:			
100 Call value	5.19	→	4.65
100 Call delta	+0.55	→	+0.51
100 Call gamma	+0.03	→	+0.03
100 Put value	4.59	→	5.05
100 Put delta	−0.46	→	−0.50
100 Put gamma	+0.03	→	+0.03

absolute values of the deltas would no longer equal +1.00. Since the deltas of the call and put change by nearly the same amount, their gammas also must be nearly equal because gamma is the change in delta. Put-call parity is discussed in Chapter 5.

Vega

Volatility will be discussed in depth in Chapter 7, but vega will be defined here. *Vega* is the change in option value that results from a one percentage point change in the volatility assumption, assuming that other factors remain constant. Mathematically, vega is the first derivative of option price with respect to change in volatility. Since first derivatives are theoretically *instantaneous rates of change*, and since vega estimates the impact of a *one percentage point change*, there frequently will be rounding errors. Vega answers this question: If volatility changes by one percentage point, how much do I make or lose?

Table 4-4 Illustration of Vega

	Initial Inputs		Inputs with Volatility Up
Inputs:			
Stock price	100		
Strike price	100		
Dividends	None		
Volatility	30%	→	31%
Interest rate	4%		
Days to expiration	60		
	Initial Outputs		**New Outputs**
Outputs:			
100 Call value	5.19	→	5.35
100 Call vega	+0.16		
100 Put value	4.59	→	4.75
100 Put vega	+0.16		

Table 4-4 illustrates how the 100 Call and 100 Put values change from 5.19 to 5.35 and from 4.59 to 4.75, respectively, when the volatility assumption is increased from 30 to 31 percent.

Vegas of Option Values Are Positive

Vegas of both call values and put values are always positive because changes in option value are positively correlated with changes in volatility; that is, volatility up, option value up, and volatility down, option value down.

Another result of the put-call parity concept is that vegas of calls and puts with the same underlying, strike, and expiration are equal. According to put-call parity, there is a quantifiable relationship between the price of the underlying instrument and the prices of calls and puts with the same strike and same expiration. In order for the put-call parity relationship to be maintained when the call value increases, the same-strike put must rise by an identical amount with a given change in volatility. Thus vegas of calls and puts with the same underlying, strike, and expiration must be equal.

Vega Is Not Greek

Readers familiar with the Greek alphabet may note that vega is not a Greek letter. The derivation of this term's use remains murky, but one belief postulates that option traders wanted a short word beginning with a *v* (for *volatility*) that sounds like delta, gamma, and theta. Exactly who coined the term and when it was first used are not known. Some mathematicians and traders use another Greek letter such as kappa or lambda instead of vega. Why no uniform terminology exists to represent a concept as important as volatility is one of the many quirks of the options business.

Theta

Theta is an estimate of the change in option value given a one-unit change in time to expiration, assuming that other factors remain constant. Theta answers this question: If time passes, how much do I make or lose? Table 4-5 illustrates what happens to call and put values when days to expiration are reduced from 60 to 53. The call value decreases from 5.19 to 4.86, a change equal to the theta of −0.33. The put value decreases from 4.59 to 4.33, a change also equal to its theta of −0.26. Although the amount of change in option values exactly equals the thetas in this example, slight differences may occur owing to rounding, especially when the calculation goes out to several decimal points.

The definition of theta raises an important question: What is *one unit of time*? Mathematically, theta is the first derivative of option value with respect to change in time to expiration. This means, theoretically, that one unit of time is instantaneous. Such a concept, however, does not help traders who need a tool they can use to estimate the impact of time decay on their position. While many professional traders use a one-day theta, nonprofessional traders generally use a different time frame, perhaps one week, 10 days, or some other time frame that is a percentage of a typical holding period. Consequently, there is no "right" answer to what one unit of time is.

Table 4-5 Illustration of Theta

	Initial Inputs		Inputs with Changed Days to Expiration
Inputs:			
Stock price	100		
Strike price	100		
Dividends	None		
Volatility	30%		
Interest rate	4%		
Days to expiration	60	→	53
	Initial Outputs		**New Outputs**
Outputs:			
100 Call value	5.19	→	4.86
100 Call theta (7-day)	−0.33		
100 Put value	4.59	→	4.33
100 Put theta (7-day)	−0.26		

Op-Eval Pro allows you to set the number of days in the theta calculation. Simply double-click on “Theta” in the bottom-right section of the screen, and the “Applications Settings” box will open. Any number of days up to 999 can be entered. Note, however, that when the “Days to Expiry” input is equal to or less than the number of days in the theta calculation, then Op-Eval Pro automatically calculates a one-day theta because it would make no sense to calculate a seven-day theta when there are six or fewer days until expiration.

Different software programs, of course, define the term *unit of time* differently, so be sure to know how theta is quantified in a particular program before attempting to use it to estimate option price behavior.

An important observation to make from Table 4-5 is that the theta of the 100 Call of −0.33 does not equal the theta of the 100 Put of −0.26. For options on stocks, exchange-traded funds (ETFs), and other deliverable underlying instruments, calls and puts with the same underlying, same strike, and same expiration have different thetas. The thetas differ because the call and put have different time-value amounts. Different time values decaying to zero over the same time period means different rates of decay and hence different thetas. Calls and puts on deliverable underlying instruments have different time values because there is an interest component in the call value that is not found in the put value.

Thetas of Option Values Are Negative

The minus sign (−) associated with thetas sometimes confuses new option traders. Option values are directly correlated with changes in the days to expiration: The more time to expiration, the higher is an option's value, and the less time to expiration, the lower is the value, assuming that other factors are constant. Consequently, one might think that thetas should be preceded by plus signs. But they are preceded by minus signs! Why?

Option traders routinely place a minus sign in front of thetas because options decrease in value over time while other factors remain constant. The minus sign associated with thetas assumes that the option is owned and that it decays, or loses money, as expiration approaches.

Experienced option traders may be aware of one exception to the rule that thetas are preceded by negative signs. The theoretical value of deep in-the-money European-style options can be less than their intrinsic value because these options cannot be exercised early and because of arbitrage pricing relationships, as discussed in Chapter 6. When such situations exist, the options have a positive theta that indicates that the theoretical values will increase to intrinsic values as expiration approaches.

Rho

Rho is an estimate of the change in option value given a one percentage point change in interest rates, assuming that other factors remain constant. Rho answers this question: If the interest rate changes by 1 percent, how much do I make or lose? Table 4-6 illustrates how the 100 Call and 100 Put values change when the interest rate is increased from 4 to 5 percent. The 100 Call value has a direct relationship with

Table 4-6 Illustration of Rho

	Initial Inputs		Inputs with Interest Rate Up
Inputs:			
Stock price	100		
Strike price	100		
Dividends	None		
Volatility	30%		
Interest rate	4%	→	5%
Days to expiration	60		
	Initial Outputs		**New Outputs**
Outputs:			
100 Call value	5.19	→	5.27
100 Call rho	+0.08		
100 Put value	4.59	→	4.52
100 Put rho	−0.07		

interest rates. It increases from 5.19 to 5.27, a change equal to the call's rho of +0.08. The 100 Put value, however, has an opposite relationship with interest rates. The one percentage point change in the interest rate decreased the value of the 100 Put from 4.59 to 4.52, a change equal to the put's rho of −0.07.

Why rhos of call values are positive and rhos of put values are negative is another consequence of the put-call parity relationship. For options on deliverable underlying instruments, the time value of a call exceeds the time value of a put with the same strike and expiration by an amount equal to the *cost of carry*. Cost of carry, as explained in Chapter 6, is the expense of financing the ownership of the underlying stock, and it consists mostly of interest adjusted for dividends, if any.

When interest rates rise, the cost of carry increases. As a result, the time value of the call must increase relative to the time value of the put. A newcomer to options might think that the call value could increase while the put value remained constant or that the put value could decrease while the call value remained constant. In reality, however, a little of both occurs. The call value rises, and the put value decreases. It is the net difference between the two that equals the cost of carry. This combination of changes explains why rhos are positive for calls and negative for puts.

For most option traders, the impact of changes in interest rates on short-term option values is small. As a result, rho is of little concern to nonprofessional traders of short-term stock options. Professional traders, however, who engage in arbitrage strategies, as explained in Chapter 6, must pay attention to the impact of interest rates. Rho is the guide to judging the impact of changing interest rates.

How the Greeks Change

Trying to measure something when the measure itself changes poses obvious problems. Consequently, estimating changes in option values is complicated by the fact that the Greeks change when market conditions change. For example, when the stock price, time to expiration, volatility, or any combination of these factors change, so do the delta, gamma, theta, and vega. Sometimes an individual Greek will change significantly and have a great impact on an option's value, but sometimes the change will have little impact. Both graphs and tables are effective ways to illustrate changing Greeks, so the following discussion uses both to make several points about each Greek.

Changes in underlying price, time to expiration, and volatility matter most to traders, so Tables 4-7 and 4-8 focus on changes in these three inputs. Table 4-7 depicts a grid of 100 Call values, 100 Put values, and corresponding Greeks at three stock prices and various days to expiration. A study of this table reveals how delta, gamma, vega, and theta change as stock price, time to expiration, or both change.

Table 4-8 is a grid of 90 Call, 100 Call, and 110 Call values and corresponding Greeks at 25 and 50 percent volatility and at various days to expiration. A study of this table reveals how the Greeks of in-the-money, at-the-money, and out-of-the-money options change as volatility, time to expiration, or both change. The concepts in Tables 4-7 and 4-8 help option traders to analyze the impact of changing market conditions on their positions.

Table 4-7 The Greeks of In-the-Money, At-the-Money, and Out-of-the-Money Options

		Col 1	Col 2	Col 3	Col 4	Col 5
		56 Days	42 Days	28 Days	14 Days	Exp.
Row			Stock Price 110			
A	**100 Call**	**12.06**	**11.47**	**10.88**	**10.32**	**10.00**
	Delta	0.82	0.85	0.89	0.95	1.00
	Gamma	0.02	0.02	0.02	0.01	0.00
	Vega	0.11	0.09	0.06	0.02	0.00
	Theta (1-day)	−0.04	−0.04	−0.04	−0.03	0.00
	Rho	0.12	0.09	0.07	0.04	0.00
B	**100 Put**	**1.31**	**0.90**	**0.50**	**0.13**	**0.00**
	Delta	−0.18	−0.15	−0.11	−0.05	0.00
	Gamma	0.02	0.02	0.02	0.01	0.00
	Vega	0.11	0.09	0.06	0.02	0.00
	Theta (1-day)	−0.03	−0.03	−0.03	−0.02	0.00
	Rho	−0.03	−0.02	−0.01	0.00	0.00
			Stock Price 105			
C	**100 Call**	**8.19**	**7.52**	**6.75**	**5.84**	**5.00**
	Delta	0.71	0.72	0.75	0.81	1.00
	Gamma	0.03	0.03	0.04	0.04	0.00
	Vega	0.14	0.12	0.09	0.05	0.00
	Theta (1-day)	−0.05	−0.05	−0.06	−0.07	0.00
	Rho	0.10	0.08	0.06	0.03	0.00
D	**100 Put**	**2.46**	**1.96**	**1.38**	**0.65**	**0.00**
	Delta	−0.30	−0.28	−0.25	−0.19	0.00
	Gamma	0.03	0.03	0.04	0.04	0.00
	Vega	0.14	0.12	0.09	0.05	0.00
	Theta (1-day)	−0.04	−0.04	−0.05	−0.06	0.00
	Rho	−0.04	−0.03	−0.02	−0.01	0.00
			Stock Price 100			
E	**100 Pall**	**5.08**	**4.36**	**3.52**	**2.45**	**0.00**
	Delta	0.55	0.54	0.53	0.52	0.00
	Gamma	0.03	0.04	0.05	0.07	0.00
	Vega	0.16	0.14	0.11	0.08	0.00
	Theta (1-day)	−0.05	−0.06	−0.07	−0.09	0.00
	Rho	0.08	0.06	0.04	0.02	0.00
F	**100 Put**	**4.38**	**3.83**	**3.16**	**2.27**	**0.00**
	Delta	−0.45	−0.46	−0.47	−0.48	0.00
	Gamma	0.03	0.04	0.05	0.07	0.00
	Vega	0.16	0.14	0.11	0.08	0.00
	Theta (1-day)	−0.04	0.04	−0.05	−0.08	0.00
	Rho	−0.06	−0.05	−0.03	−0.02	0.00

Assumptions: Volatility, 30%; interest rate, 5%; dividends, none.

Table 4-8 The Greeks and Changing Volatility

		Col 1	Col 2	Col 3	Col 4	Col 5
		56 Days	42 Days	28 Days	14 Days	Exp.
Row		Volatility 50%				
A	110 Call	4.39	3.38	2.19	0.92	0.00
	Delta	0.36	0.33	0.28	0.18	1.00
	Gamma	0.02	0.02	0.02	0.03	0.00
	Vega	0.14	0.12	0.10	0.05	0.00
	Theta (1-day)	−0.07	−0.08	−0.09	−0.09	0.00
	Rho	0.05	0.03	0.02	0.01	0.00
B	100 Call	8.20	7.06	5.73	4.02	0.00
	Delta	0.55	0.55	0.54	0.53	0.00
	Gamma	0.02	0.02	0.03	0.04	0.00
	Vega	0.16	0.14	0.11	0.08	0.00
	Theta (1-day)	−0.08	−0.09	−0.11	−0.15	0.00
	Rho	0.07	0.05	0.04	0.02	0.00
C	90 Call	13.94	13.00	11.95	10.82	10.00
	Delta	0.75	0.77	0.80	0.87	1.00
	Gamma	0.02	0.02	0.02	0.02	0.00
	Vega	0.12	0.11	0.07	0.04	0.00
	Theta (1-day)	−0.06	−0.07	−0.07	−0.08	0.00
	Rho	0.09	0.07	0.05	0.03	0.00
		Volatility 25%				
D	110 Call	1.02	0.67	0.32	0.05	0.00
	Delta	0.30	0.28	0.25	0.19	0.00
	Gamma	0.03	0.03	0.03	0.01	0.00
	Vega	0.11	0.08	0.05	0.01	0.00
	Theta (1-day)	−0.03	−0.03	−0.02	−0.01	0.00
	Rho	0.03	0.02	0.01	0.00	0.00
E	100 Call	4.30	3.68	2.97	2.06	0.00
	Delta	0.55	0.54	0.54	0.53	0.00
	Gamma	0.04	0.05	0.06	0.08	0.00
	Vega	0.16	0.14	0.11	0.08	0.00
	Theta (1-day)	−0.04	−0.05	−0.06	−0.08	0.00
	Rho	0.08	0.06	0.04	0.02	0.00
F	90 Call	11.26	10.87	10.50	10.19	10.00
	Delta	0.89	0.91	0.95	0.99	1.00
	Gamma	0.02	0.02	0.02	0.01	0.00
	Vega	0.07	0.06	0.03	0.01	0.00
	Theta (1-day)	−0.03	−0.03	−0.03	−0.02	0.00
	Rho	0.12	0.09	0.06	0.03	0.00

Assumptions: Stock price, 100; interest rate, 5%; dividends, none.

How Delta Changes

Delta, as stated earlier, estimates how much an option value changes when the underlying stock price changes and other factors remain constant. Five general rules govern how deltas change. Because calls have positive deltas and puts have negative deltas, the five rules will be stated using the absolute values of the deltas.

Deltas and Stock Price

The first rule describes how deltas change as the price of the underlying stock changes. Deltas of both calls and puts increase as the stock price rises and decrease as the stock price falls. Table 4-7 and Figures 4-1A and 4-1B illustrate this concept. At first glance, the graphs may appear identical, but they are not. Moving up the *x* axis, the call delta rises from 0 to +1.00, whereas the put delta rises from −1.00 to 0. Column 1 in Table 4-7 shows that as the stock price rises from 100 to 105 to 110 at 56 days, the delta of the 100 Call increases from +0.55 (row E) to +0.71 (row C) to +0.82 (row A), and the delta of the 100 Put rises from −0.45 (row F) to −0.30 (row D) to −0.18 (row B). Remember to keep increases and decreases straight when minus signs are involved! The same concept—deltas rising with an increasing stock price and falling with a decreasing stock price—holds true for any column in Table 4-7.

Deltas and Strike Price

The second rule on deltas concerns the relative level of deltas of in-the-money, at-the-money, and out-of-the-money options. In-the-money options have deltas with absolute values greater than +0.50. At-the-money options have deltas with absolute values of approximately +0.50, and out-of-the-money options have deltas with absolute values less than +0.50 regardless of time to expiration. Table 4-7 illustrates this rule. With a stock Price of 110, the 100 Call is in the money, and the 100 Put is out of the money. Row A shows that the absolute value of the delta of the 100 Call is always above +0.50, and row B shows that the absolute value of the delta of the 100 Put is always below +0.50.

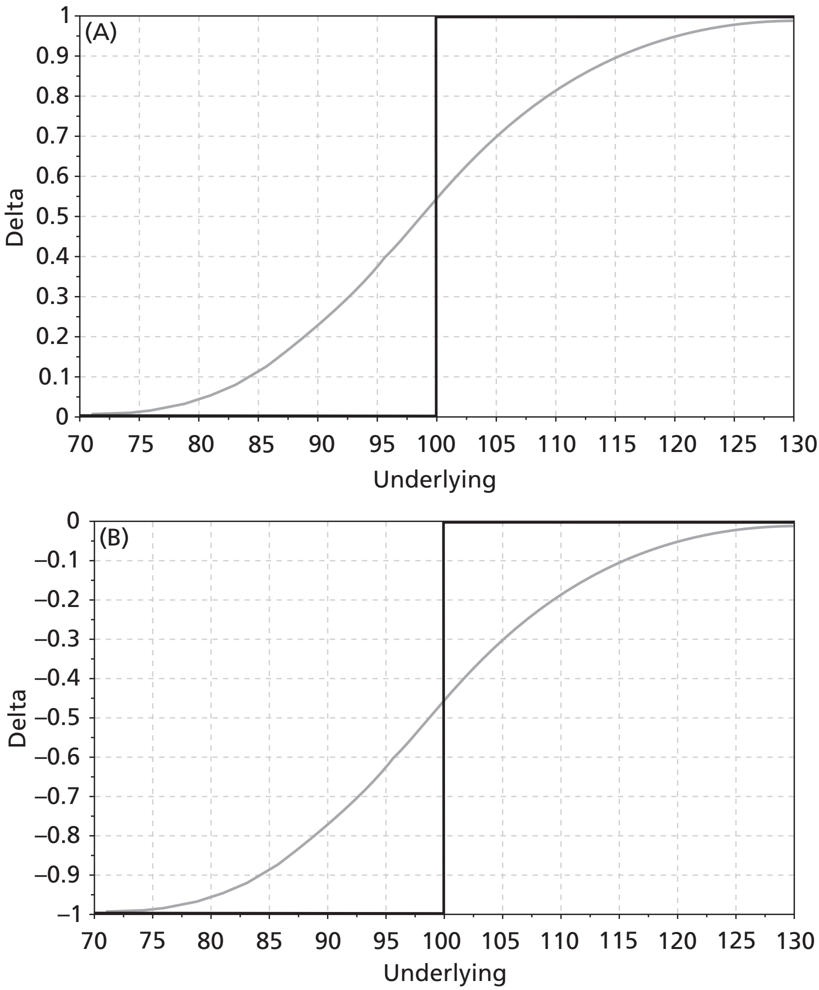


Figure 4-1 **(A)** Delta of 100 Call vs. Stock Price **(B)** Delta of 100 Put vs. Stock Price

Deltas and Time to Expiration

The third rule on delta concerns how deltas change as expiration approaches. The absolute values of deltas of in-the-money options increase toward +1.00 as expiration approaches. This rule is illustrated graphically in Figure 4-2A and numerically in Table 4-7. In row A of the table, for example, the stock price is 110, which means that the 100 Call is in the money, and its delta increases from +0.82 at 56 days (column 1) to +0.89 at 28 days (column 3) to +1.00 at expiration (column 5).

Note that "Time to Expiry" on the *x* axis in Figures 4-2A, 4-2B, and 4-2C decreases from right to left. While it is generally intuitive to have lower numbers on the left and higher numbers on the right (see Figures 4-1, 4-3, 4-4, and others), this is not true with time to expiration and options. Take a few moments, therefore, to accustom yourself to reading and understanding these three graphs.

The absolute values of deltas of at-the-money options remain near +0.50. In rows E and F of Table 4-7, where the stock price is 100, both the 100 Call and 100 Put are at the money. In these rows, the absolute value of the deltas remain near +0.50 in all columns. This concept is illustrated graphically in Figure 4-2B.

The absolute values of deltas of out-of-the-money options decrease toward zero as expiration approaches. This is illustrated graphically in Figure 4-2C and in row D of Table 4-7, where the stock price is 105, and the 100 Put is out of the money. The absolute value of the delta in this row decreases from −0.30 at 56 days (column 1) to −0.25 at 28 days (column 3) to 0.00 at expiration (column 5).

Deltas of Calls and Puts with the Same Strike

The fourth rule on deltas is that the sum of the absolute values of the call delta and the put delta is approximately +1.00. With the stock at 100 at 56 days to expiration (column 1, rows E and F), for example, the delta of the 100 Call is +0.55, and the delta of the 100 Put is −0.45. The sum of the absolute values of these numbers, +0.55 and +0.45, is +1.00. At any point in Table 4-7, this relationship holds true and is another result of put-call parity.

Deltas and Volatility

The fifth rule on deltas explains how deltas change as volatility changes. The rule is that as volatility increases, the absolute value of a delta

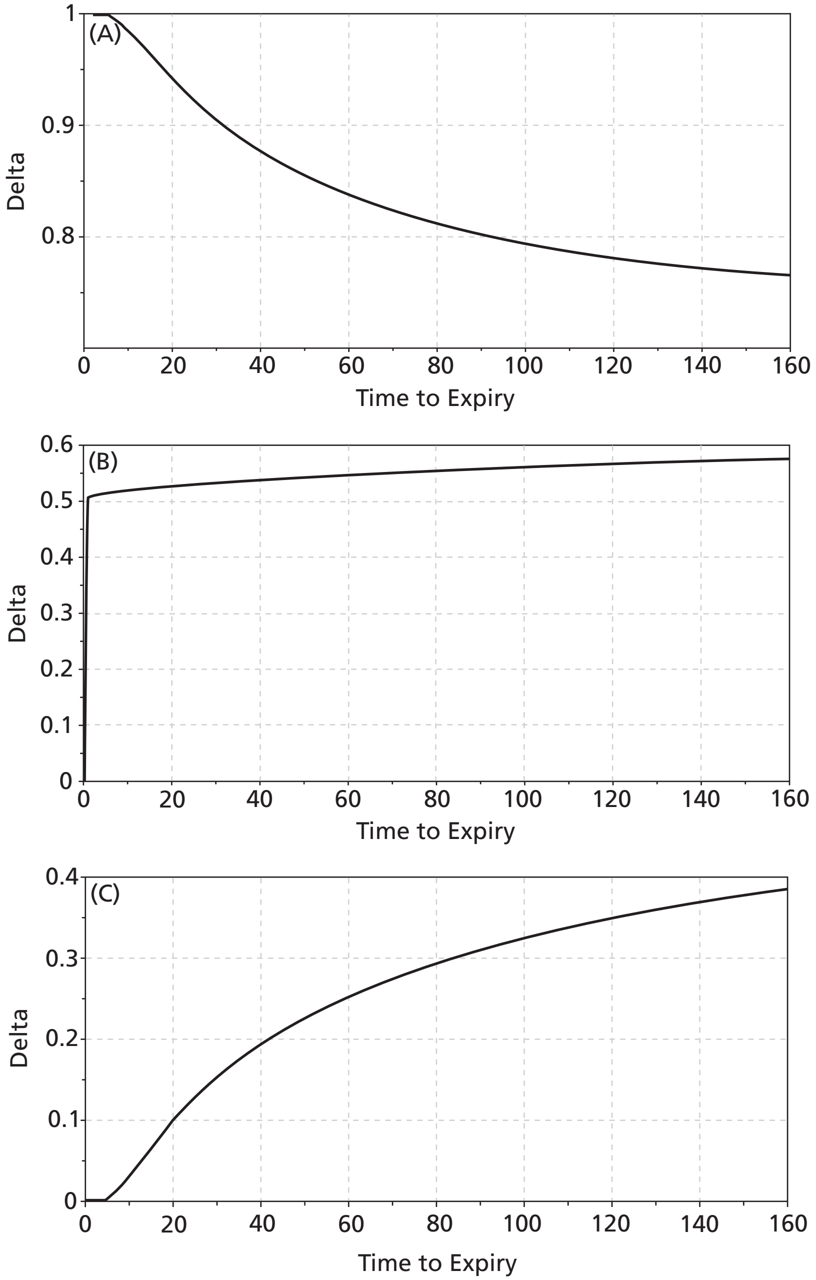


Figure 4-2 **(A)** Delta of In-The-Money 90 Call vs. Time **(B)** Delta of At-the-Money 100 Call vs. Time **(C)** Delta of Out-of-the-Money 110 Call vs. Time

changes toward +0.50. In other words, deltas of out-of-the-money options increase, and deltas of in-the-money options decrease. This rule is illustrated in Table 4-8, which has two sections. In both sections, the stock price is 100, so the 90 Call is in the money, the 100 Call is at the money, and the 110 Call is out of the money. The bottom section of Table 4-8 (rows D, E, and F) assumes a volatility of 25 percent, and the upper section (rows A, B and C) assumes a volatility of 50 percent. With volatility of 25 percent and 56 days to expiration, the in-the-money 90 Call has a delta of +0.89 (column 1, row F). Raising the volatility to 50 percent (column 1, row C) lowers the delta to +0.75. Comparing any two corresponding deltas in rows F and C yields the same result: The increase in volatility causes the delta of the in-the-money 90 Call to decrease. This concept is illustrated graphically in Figure 4-3A.

For the delta of the out-of-the-money 110 Call, the change is opposite. In Table 4-8, with volatility of 25 percent and 56 days to expiration, the delta of the 110 Call is +0.30 (column 1, row D). Raising the volatility to 50 percent increases the delta to +0.36 (column 1, row A). Comparing any two corresponding deltas in rows D and A yields the same result: The increase in volatility causes the delta of the out-of-the-money 110 Call to increase. This concept is illustrated graphically in Figure 4-3C.

Deltas of at-the-money options remain near +0.50 (absolute value of delta) over a wide range of volatility, as illustrated in Figure 4-3B and rows E and B in Table 4-8. As the figure demonstrates, deltas of at-the-money options increase to +1.00 at very low levels of volatility because the option value itself is very low and has a high correlation with stock-price movement. Consider a hypothetical situation in which the stock price is 100, there are 60 days to expiration, and the volatility is 1 percent. In this example, a 60-day at-the-money 100 Call might have a value of 0.82 and a delta of +0.98. An increase of 10 cents to 100.10 would cause the call value to rise to 0.92 and the delta to rise to +0.99. Although a stock with 1 percent volatility is highly improbable, this exercise can help traders to think through what might happen in unusual market conditions—which actually may occur in a 20- or 30-year trading career.

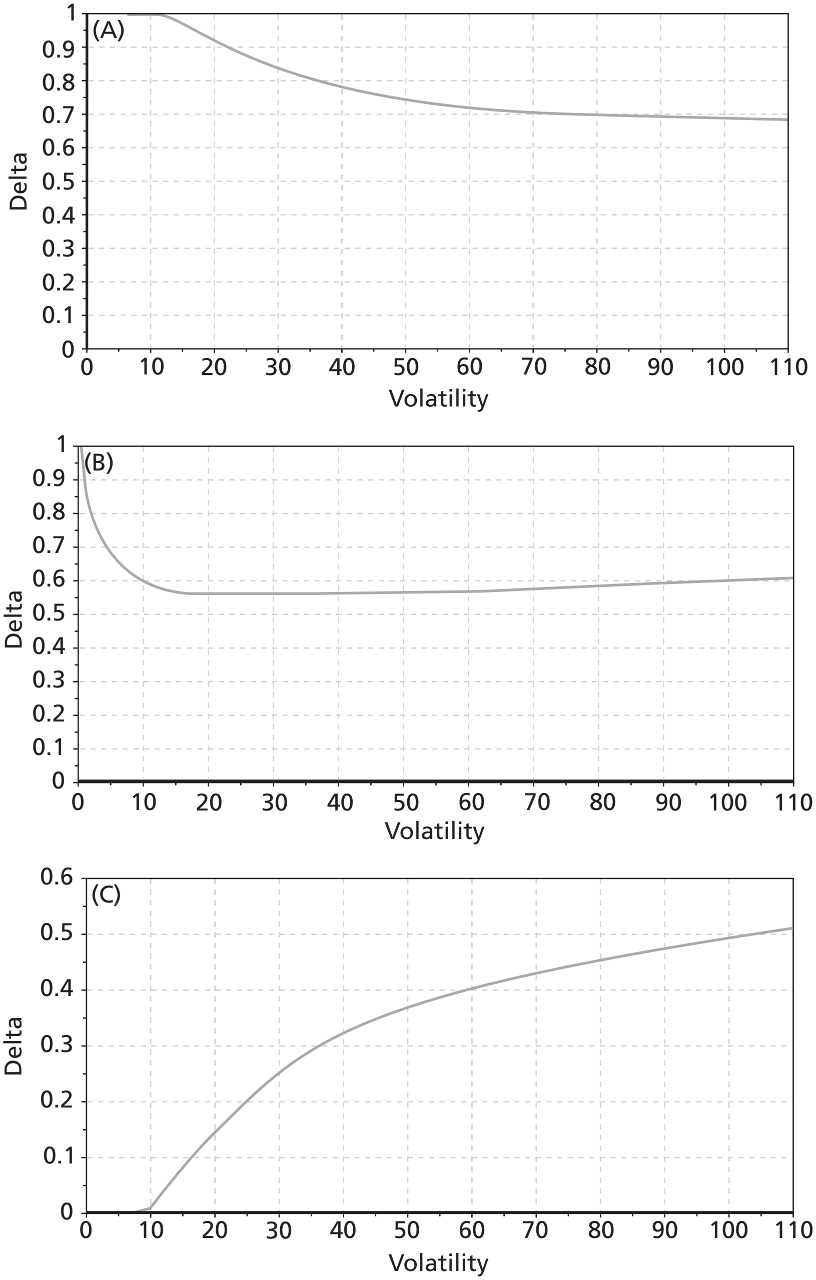


Figure 4-3 **(A)** Delta of In-the-Money 90 Call vs. Volatility **(B)** Delta of At-the-Money 100 Call vs. Volatility **(C)** Delta of Out-of-the-Money 110 Call vs. Volatility

Deltas change toward +0.50 when volatility increases and away from +0.50 when volatility decreases because a change in volatility changes the size of one standard deviation while the distance from stock price to strike price remains constant. Consider a situation in which the stock price is 100, one standard deviation is 5 percent, or five points, and the 105 Call has a delta of +0.35. Under these circumstances, the strike price of 105 is one standard deviation (5 percent) away from the current stock price of 100. If volatility were to double to 10 percent with the stock price unchanged, then the 105 Call would be only one-half of a standard deviation from the stock price. Since the 105 Call is now closer to the stock price—in volatility terms—then it's delta must be closer to +0.50.

Similarly, if volatility were to decrease with the stock price unchanged, then the 105 Call would be further out of the money in volatility terms; that is, it would be more than one standard deviation above the stock price. Since options that are further out of the money have deltas with lower absolute values, the delta of the 105 Call would decrease given a decrease in volatility and other factors remaining constant.

Option Prices and Volatility

In addition to information about the Greeks, Table 4-8 also reveals something significant about the impact of changing volatility on option prices. When volatility increases, values of out-of-the-money options increase exponentially, whereas values of at-the-money options remain approximately linear. The impact on in-the-money options is less than one for one. In column 1 of Table 4-8, for example, the doubling of volatility from 25 to 50 percent causes the in-the-money 90 Call to increase by 24 percent from 11.26 to 13.94. In comparison, the at-the-money 100 Call increases significantly by 90 percent from 4.30 to 8.20, but the out-of-the-money 110 Call shoots up dramatically by 430 percent from 1.02 to 4.39.

As discussed in Chapter 3 in the section on planning trades, the significance of changing implied volatility cannot be ignored. Positions involving only out-of-the-money options face increased percentage risk from changes in implied volatility relative to positions involving only at-the-money or in-the-money options. For this reason, full-time traders holding out-of-the-money options often employ strategies, such as vertical spreads, that reduce exposure to the risk of changing implied volatility.

How Gamma Changes

Table 4-7 and Figure 4-4 show that gammas are biggest when options are at the money, and they increase as expiration approaches. This concept is significant to option traders because it explains the way option prices behave as an underlying stock price changes and as an option changes from being out of the money to at the money and then in the money. Out-of-the-money options, with low deltas and smaller gammas, do not respond dramatically to small price changes in the underlying stock. However, as the stock approaches the strike price, the newly at-the-money option seems to "explode," moving noticeably more than its delta. Such option-price behavior brings tears of joy to option owners and screams of horror to option writers.

Consider the case of Debra, who bought a 100 Call for 5.08 when the stock price was 100 at 56 days to expiration (Table 4-7, column 1,

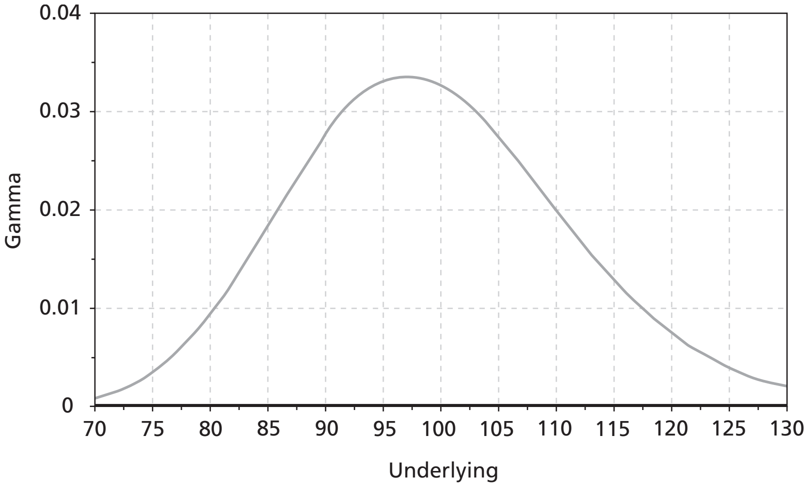


Figure 4-4 Gamma of 100 Call vs. Stock Price

row E). If the stock rises to 110 at 28 days to expiration and Debra's Call rises to 10.88 (column 3, row A), then she will have an unrealized profit of 5.80, or $580 per option, on the 10-point rise in the stock in 28 days. However, if the stock then falls $5.00 in the next two weeks, her call will decline to 5.84 (column 4, row C). Thus, in only one-half the time and one-half the stock-price change, almost all of Debra's profit is lost. It is the delta of +0.89, up from +0.55 initially, that explains the potential for loss. If Debra were aware of the new sensitivities to market changes, she may be inclined to close her position and take a profit more quickly if the market starts to move down.

Equality of Call and Put Gammas

Table 4-7 shows that gammas are the same for calls and puts with the same strike, same days to expiration, and same underlying. This equality is a result of put-call parity, one part of which states that the sum of the absolute values of the call and put with the same strike price and expiration date must total +1.00. Therefore, if the absolute value of the delta of the call (or put) rises or falls, then the absolute value of the put (or call) must fall or rise an equal amount so that the sum of the two remains at +1.00.

Rows A, B, C and D in Table 4-7 and rows A, C, D and F in Table 4-8 and Figures 4-5A and 4-5C show that gammas of in-the-money and out-of-the-money options increase only slightly until about 30 days before expiration, and then they decrease to zero. Since gamma is the change in delta, a slightly changing gamma is saying that deltas change at a nearly constant rate until the last month, when they change less. For an in-the-money call with four or five months to expiration, for example, a $1.00 stock-price rise might increase the delta from +0.75 to +0.77. This is a gamma of +0.02. With only one week to expiration, however, the same $1.00 stock-price rise would raise the delta only from +0.75 to +0.76, which indicates a gamma of +0.01. Similarly, for out-of-the-money options, a $1.00 stock-price rise at 90 days might cause a delta to rise from +0.33 to +0.35, whereas the same $1.00 price rise at 10 days might cause the delta to rise only from +0.35 to +0.36.

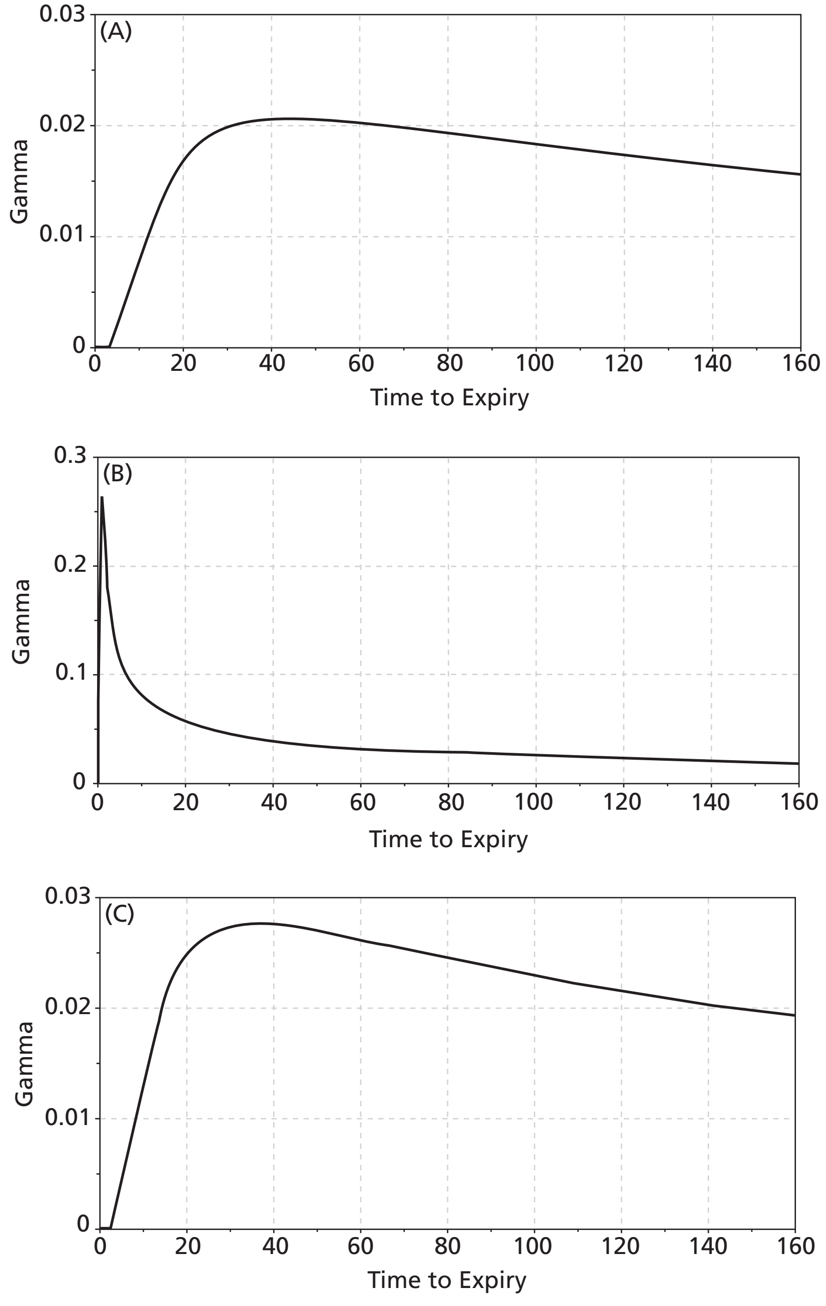


Figure 4-5 **(A)** Gamma of In-the-Money 90 Call vs. Time **(B)** Gamma of At-the-Money 100 Call vs. Time **(C)** Gamma of Out-of-the-Money 110 Call vs. Time

Rows E and F of Table 4-7 and rows B and E of Table 4-8 and Figure 4-5B show that gammas of at-the-money options behave differently from gammas of in-the-money and out-of-the-money options. Gammas of at-the-money options are very small and nearly constant, rising only slightly, until about one month before expiration. Then they rise dramatically until immediately before expiration, at which point they drop to zero. You can understand why gammas respond this way by considering option mechanics at expiration. Traders exercise in-the-money options, converting them into stock positions. Therefore, their deltas at expiration are +1.00. Out-of-the-money options, however, expire worthless, so their deltas are zero. Now consider the change in delta as an option moves from slightly out of the money to in the money immediately at expiration. The absolute value of its delta rises instantaneously from near zero to near +1.00. This is a very large gamma, nearly infinite, as a 2 cent stock price rise from 99.99 to 100.01 changes a call's delta from 0.00 to +1.00 and a put's delta from −1.00 to 0.00.

Gammas and Volatility

Figures 4-6A and 4-6C illustrate the impact of volatility on gamma for in-the-money and out-of-the-money options. At low levels of volatility—from roughly 10 to 20 percent—gammas rise with volatility. As volatility rises above 30 percent, however, gamma decreases as volatility rises. This happens because, as discussed earlier, as volatility rises, the absolute value of delta changes toward +0.50. With absolute deltas closer to +0.50, the change in delta is smaller, and that is a smaller gamma.

Figure 4-6B shows that gammas of at-the-money options change differently as volatility changes. Since the absolute value of deltas of at-the-money options is near +0.50 regardless of the level of volatility, rising volatility does not change the gamma. However, at very low levels of volatility, gammas of at-the-money options rise dramatically. This quick rise happens because low volatility means a low standard deviation. While a $1.00 price change in a high-volatility stock might equate to a one-half-standard-deviation move or less, the same price change in a low-volatility stock might equate to a two-standard-deviation move.

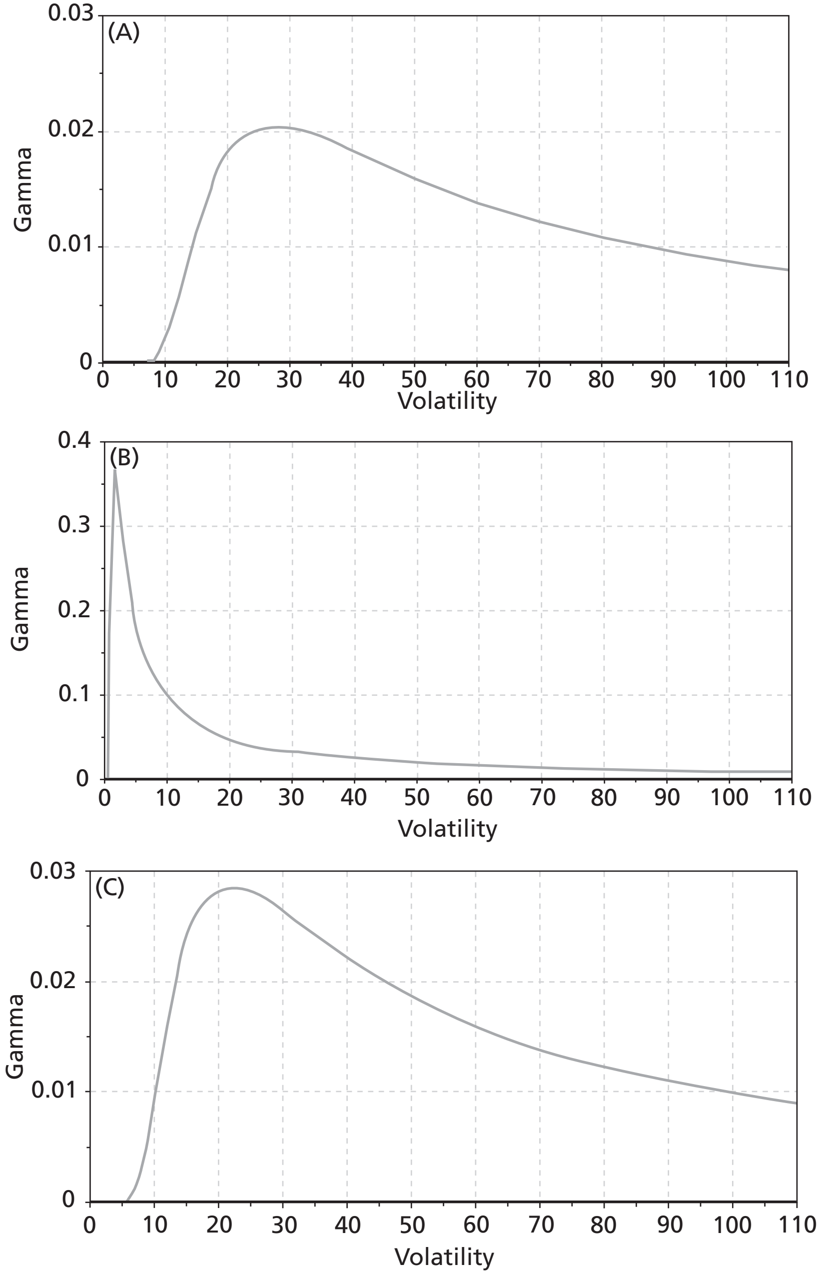


Figure 4-6 **(A)** Gamma of In-the-Money 90 Call vs. Volatility **(B)** Gamma of At-the-Money 100 Call vs. Volatility **(C)** Gamma of Out-of-the-Money 110 Call vs. Volatility

Since deltas are related to the distance to the mean in standard deviation terms, an option that is two standard deviations in the money will have a delta the absolute value of which is much greater than an option that is only one-half of a standard deviation in the money. Such an option will have a high gamma because that stock-price change would cause the absolute delta to move from +0.50 to nearly +1.00. Similar logic applies to out-of-the-money options and their deltas.

How Vega Changes

Tables 4-7 and 4-8 and Figure 4-7 show that vegas, the change in option value from a one percentage point change in volatility, are biggest when options are at the money. In any column, vegas are biggest when the 100 Call and 100 Put are at the money (rows E and F in Table 4-7 and rows B and E in Table 4-8). At-the-money options have the largest vegas because a change in volatility has the biggest absolute impact on the price of at-the-money options. In Table 4-8 (column 1), for example, the increase in volatility from 25 to 50 percent causes the 90 Call to increase in price from 11.26 (row F) to 13.94 (row C), an increase of 2.68. The at-the-money 100 Call, however, increases by the larger amount of 3.90 from 4.30 (row E) to 8.20 (row B). The 110 Call also increases more than the out-of-the-money call but less than the at-the-money call by 3.37 from 1.02 (row D) to 4.39 (row A).

Vegas and Time to Expiration

Tables 4-7 and 4-8 and Figures 4-8A, 4-8B, and 4-8C show that vegas decrease as expiration approaches for in-the-money, at-the-money, and out-of-the-money options. Looking across any row from column 1 to column 5 in Table 4-7, the vegas get smaller. Not only do option prices decrease, but vegas also decrease as expiration approaches because the potential for stock-price movement is less when there is less time. Figures 4-8A, 4-8B, and 4-8C show the same concept. However, for

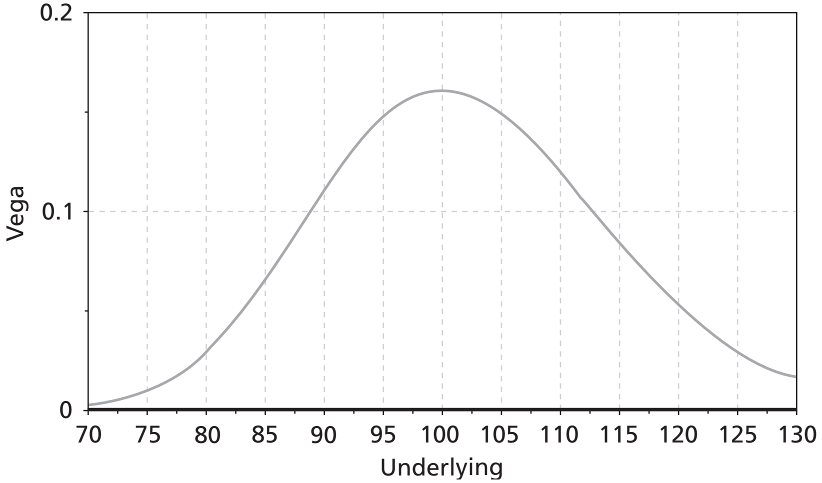


Figure 4-7 Vega of 100 Call vs. Stock Price

at-the-money options (see Figure 4-8B), vegas remain higher and take longer to get to zero than vegas of in-the-money and out-of-the-money options.

Vegas and Volatility

Table 4-8 and Figures 4-9A, 4-9B, and 4-9C show how vegas change as volatility changes. The message is that for at-the-money options (see Figure 4-9B) at 10 percent volatility and higher, vega is constant. Consequently, changing volatility has a linear impact on prices of at-the-money options: If volatility rises or falls by 5 percent—from any level to any other level—then the rise or fall in option value will be five times the vega. Consider, for example, the change in price of the 100 Call in column 1 of Table 4-8 from 4.30 (row E, 25 percent volatility) to 8.20 (row B, 50 percent volatility). The vega in row E is +0.16. Then 25 times 0.16 plus 4.30 equals 8.30, which is approximately 8.20, the value that appears in row B, column 1. The difference is due to rounding because the vega is rounded to two decimal places.

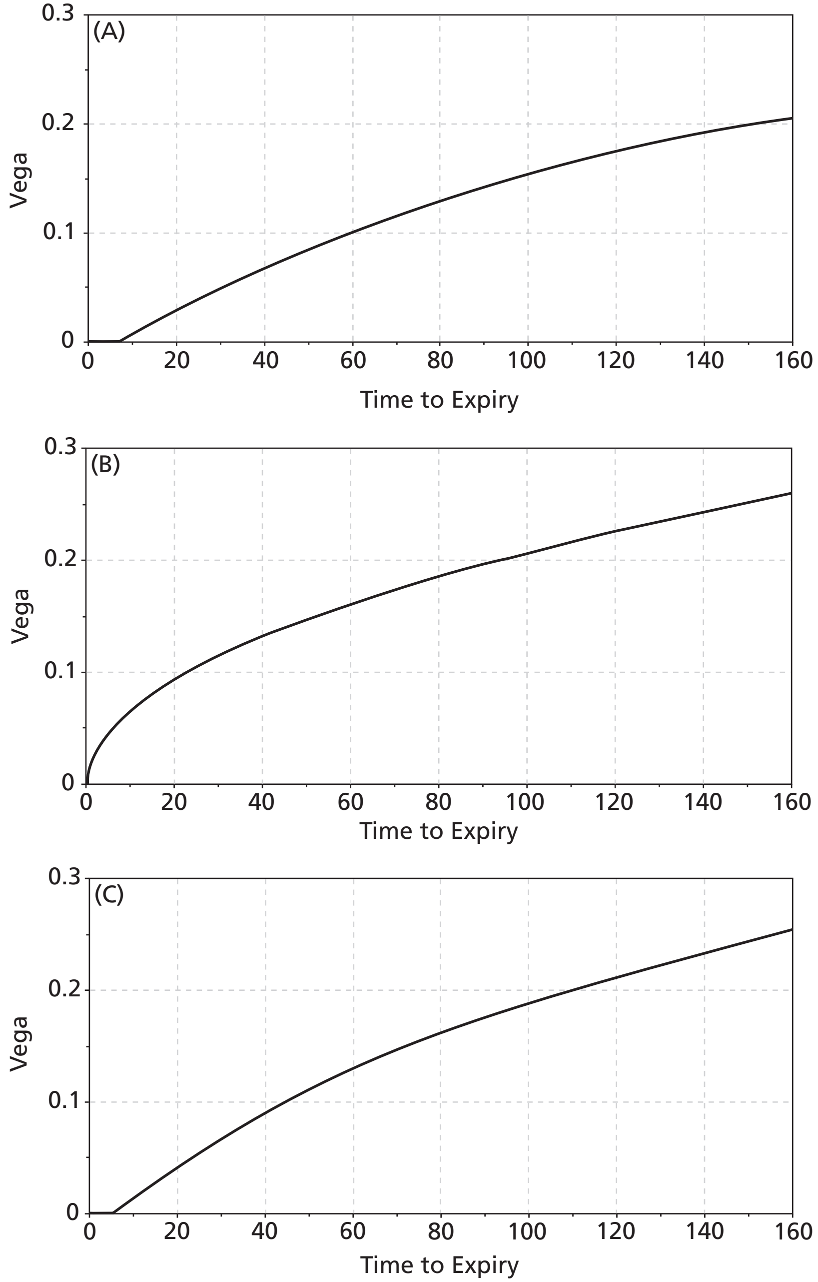


Figure 4-8 **(A)** Vega of In-the-Money 90 Call vs. Time **(B)** Vega of At-the-Money 100 Call vs. Time **(C)** Vega of Out-of-the-Money 110 Call vs. Time

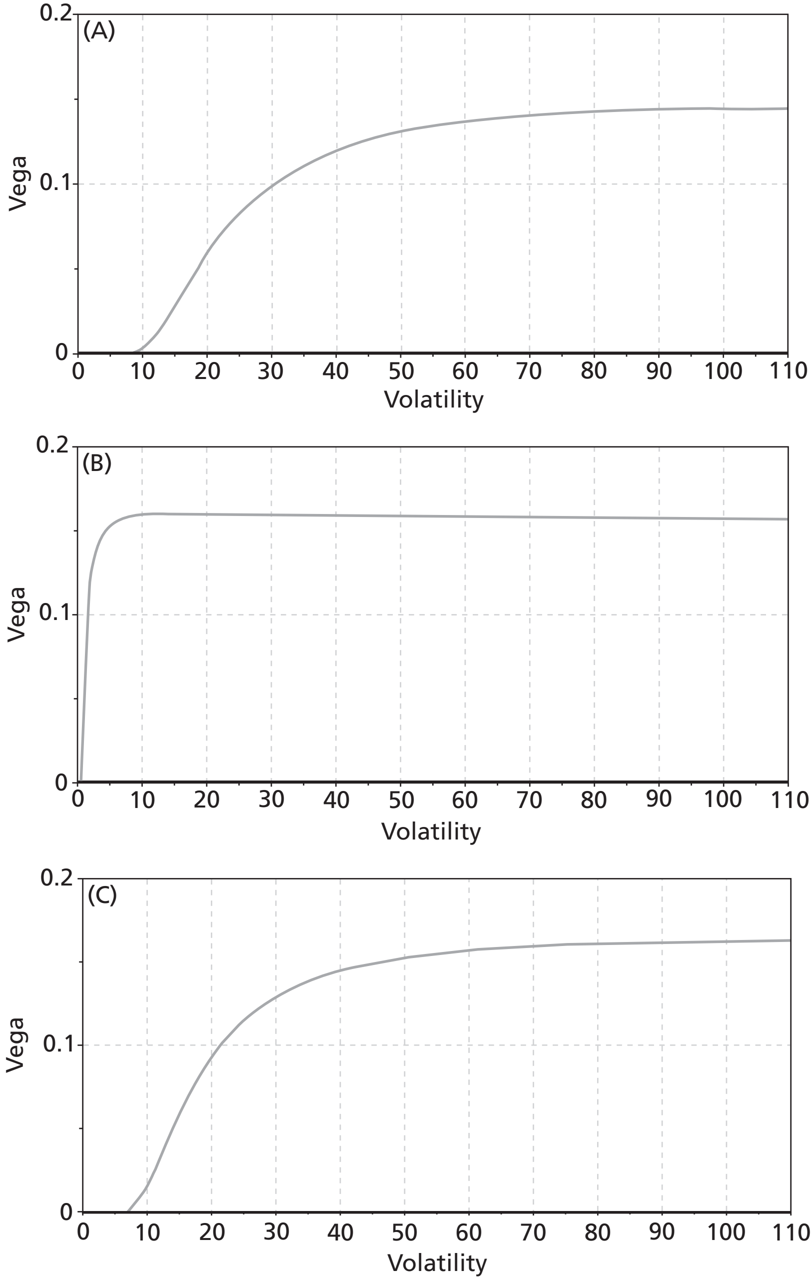


Figure 4-9 **(A)** Vega of In-the-Money 90 Call vs. Volatility **(B)** Vega of At-the-Money 100 Call vs. Volatility **(C)** Vega of Out-of-the-Money 110 Call vs. Volatility

Vegas and Strike Price

For in-the-money and out-of-the-money options, vega is near zero at low levels of volatility (below 10 percent) and rises gradually until about 50 percent volatility, at which point it levels out even as volatility continues to rise. Changing volatility, therefore, does not have the same linear impact on prices of in-the-money and out-of-the-money options as it does for at-the-money options. Consider the change in price of the 110 Call in column 1 of Table 4-8 from 1.02 (row D, 25 percent volatility) to 4.39 (row A, 50 percent volatility). The vega in row D is +0.11. Then 25 times 0.11 plus 1.02 equals 3.77, which is not very close to the value of 4.39 that appears in row A, column 1 of Table 4-8. The at-the-money estimation technique fails to work here because of the different impact volatility has on in-the-money and out-of-the-money options.

How Theta Changes

Traders need to understand how thetas change because the impact of time erosion on option prices will directly affect trading strategies. Surprisingly, traders frequently misunderstand or oversimplify this concept, usually with unfortunate results. A word of warning: Theta, the estimate of the impact of time on option values, is preceded by a minus sign, which can be confusing when discussing "biggest" and "smallest" values. Read this section carefully!

Table 4-7 and Figure 4-10 show that thetas are smallest (the highest absolute value) when options are at the money. The differences show up more clearly in the figure than they do in the table because, on an absolute level, the numbers seem small, between 0.00 and −0.05. Also, even though rows E and F of Table 4-7 reflect thetas at their smallest (highest absolute value) when the 100 Call and 100 Put are at the money, the differences are not obvious because the numbers are rounded to two decimal places. At-the-money options have larger time values than in-the-money or out-of-the-money options, and it is the time-value portion of an option's price that erodes. Therefore,

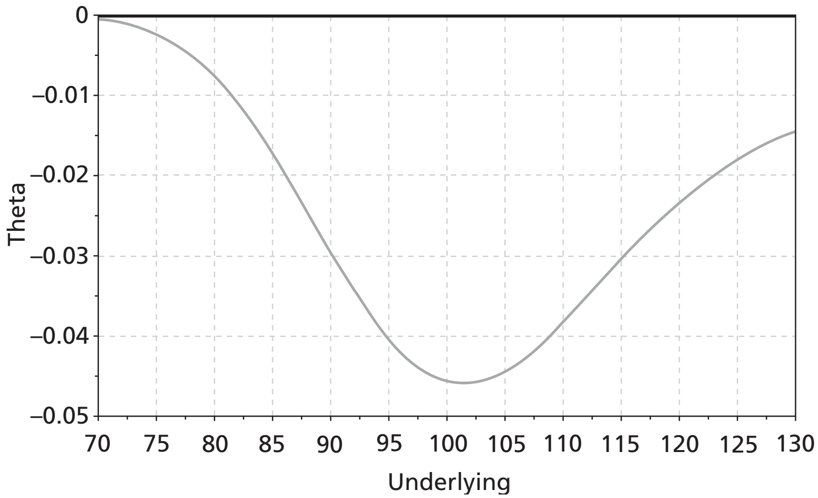


Figure 4-10 Theta of 100 Call vs. Stock Price

given the same amount of time to expiration, at-the-money options lose more value per unit of time than in-the-money or out-of-the-money options.

Thetas and Time to Expiration

Tables 4-7 and 4-8 and Figure 4-11B show that thetas of at-the-money options decrease (increase in absolute value) as expiration approaches. Then, almost immediately before expiration, they go to zero. Thetas of at-the-money options are smallest (largest absolute value) during the last unit of time prior to expiration. In row E of Table 4-7, in which the stock price is 100, the theta of the 100 Call starts at −0.05 (column 1) and then decreases to −0.06, −0.07, and −0.09 before going to zero at expiration. The theta of the at-the-money put behaves similarly.

Table 4-7 and Figures 4-11A and 4-11C show that thetas of in-the-money and out-of-the-money options behave differently than thetas of at-the-money options. They get smaller (absolute value increases) for a while, but then they get larger (absolute value decreases) as expiration approaches. Because thetas behave differently for in-the-money, at-the-money, and out-of-the-money options, traders must be careful

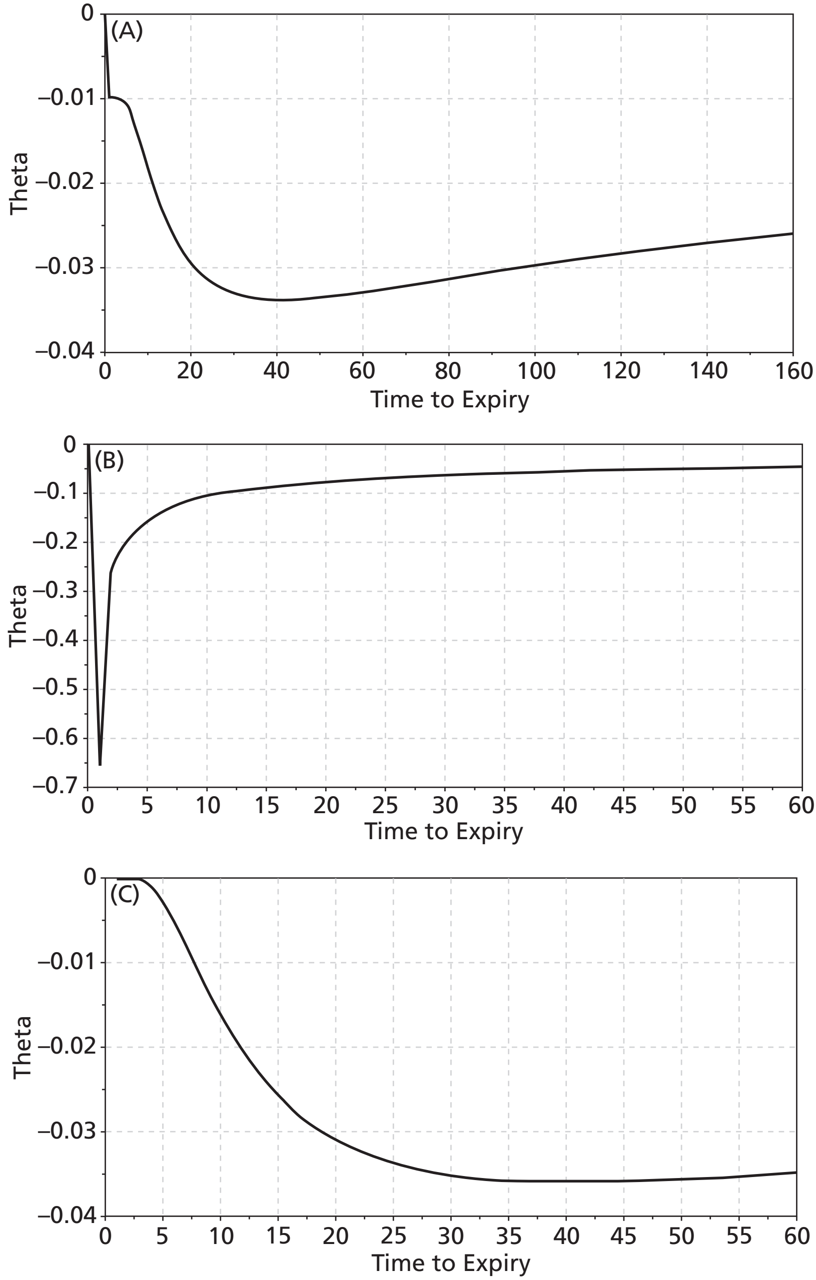


Figure 4-11 (A) Theta of In-the-Money 90 Call vs. Time **(B)** Theta of At-the-Money 100 Call vs. Time **(C)** Theta of Out-of-the-Money 110 Call vs. Time

when making generalizations about the impact of time decay on option values.

Using Theta with Delta

How does a trader use theta? Since theta estimates how much a position will make or lose over some period of time, a trader buying options can use theta in conjunction with delta to estimate how much the underlying stock price must change in price in a specific time period for the delta effect (price movement of the underlying) to make more than the theta effect (time decay). Assume, for example, that an option has a one-day theta of −0.05 and a delta of +0.35. The buyer of this option therefore needs a $1.00 price rise in the stock in seven days to offset the time erosion—the delta effect of +0.35 will offset the theta effect of seven times −0.05. Although market forecasting is an art, not a science, having a time period and a price target give the trader a frame of reference on which to base a subjective trading decision.

Thetas and Volatility

Table 4-8 and Figures 4-12A, 4-12B, and 4-12C show that thetas of in-the-money, at-the-money, and out-of-the-money options decrease (increase in absolute value) as volatility increases. This result is logical because an increase in volatility increases option values. And, given the same time to expiration, a higher option value contains more time erosion per unit of time.

How Rho Changes

Rho estimates how much an option value changes when the interest rate changes and other factors remain constant. Rho is generally of least concern to option traders because rhos are small in absolute terms and because interest rates generally do not change dramatically, that is, more that 1 percent, in a short period of time. Nevertheless, traders need to learn four rules about how rhos change.

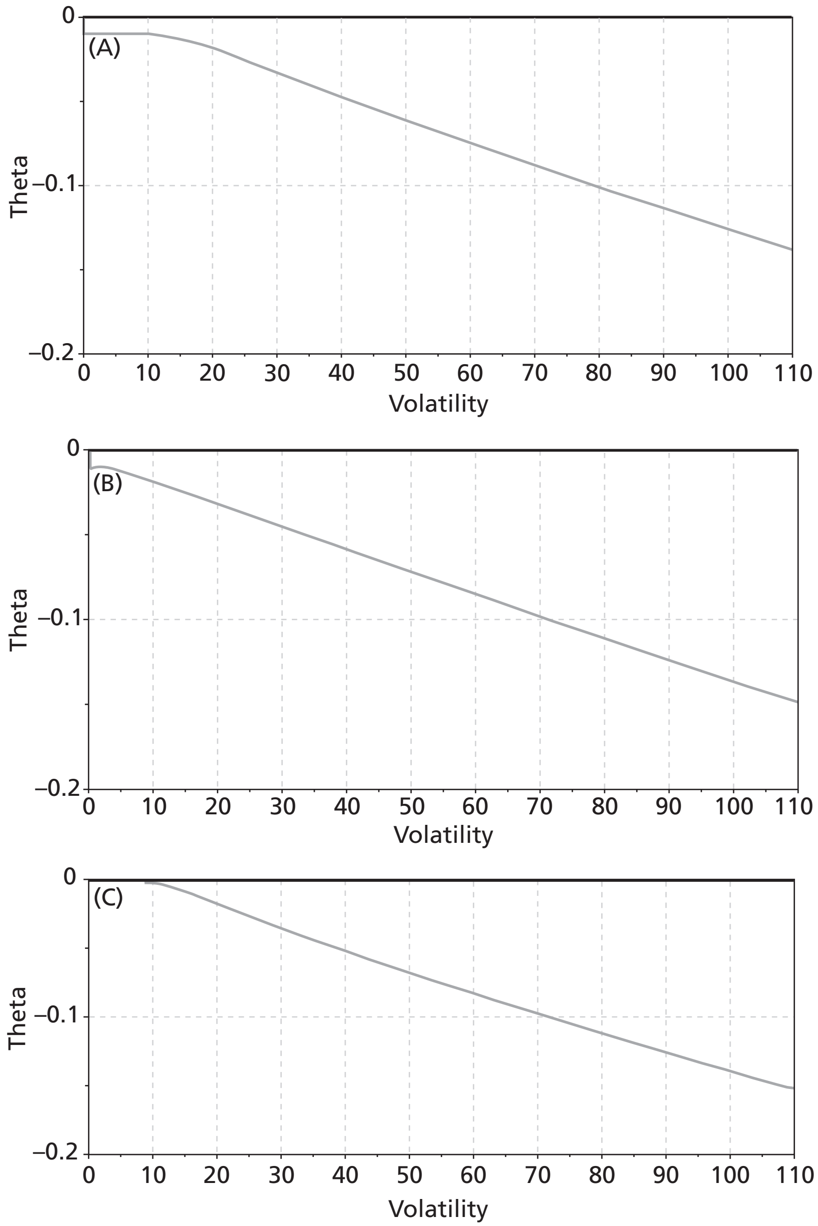


Figure 4-12 **(A)** Theta of In-the-Money 90 Call vs. Volatility **(B)** Theta of At-the-Money 100 Call vs. Volatility **(C)** Theta of Out-of-the-Money 110 Call vs. Volatility

The first rule is that rhos of calls are positive and rhos of puts are negative. This is a result of the cost-of-carry concept explained in Chapter 6, where the conversion strategy is discussed. With rising interest rates, the cost to finance a stock position increases. As a result, the time value of a call must increase relative to the time value of the put. Therefore, if interest rates rise while stock prices and put prices remain constant, then call prices must increase to pay for the increased financing costs. Rhos of calls therefore are positive.

Similarly, if interest rates rise while stock prices and call prices remain constant, then put prices must decrease so that the put-call time-premium differential increases enough to pay for the increased financing costs. Rhos of puts therefore are negative. In reality, neither a call nor a put remains constant while the other changes. What happens is that call premiums rise a little and put premiums fall a little.

Rhos and Stock Price

The second rule governing rhos describes the relative level of rhos as the underlying stock price changes. Table 4-7 and Figures 4-13A and 4-13B show that rhos increase as the stock price rises. Column 1 in Table 4-7, for example, shows that as the stock price rises from 100 to 105 to 110 at 56 days (column 1), the rho of the 100 Call rises from +0.08 (row E) to +0.10 (row C) to +0.12 (row A), and the rho of the 100 Put rises from −0.06 (row F) to −0.04 (row D) to −0.03 (row B). Remember to keep increases and decreases straight when minus signs are involved! The same concept—that rhos rise with a rising stock price and fall with a falling stock price—holds true for any column in Table 4-7. Figures 4-13A and 4-13B demonstrate this concept graphically. At first glance, the graphs may appear identical, but they are not. The rho of the call rises from 0 to +0.17, and the rho of the put rises from approximately −0.17 to 0.

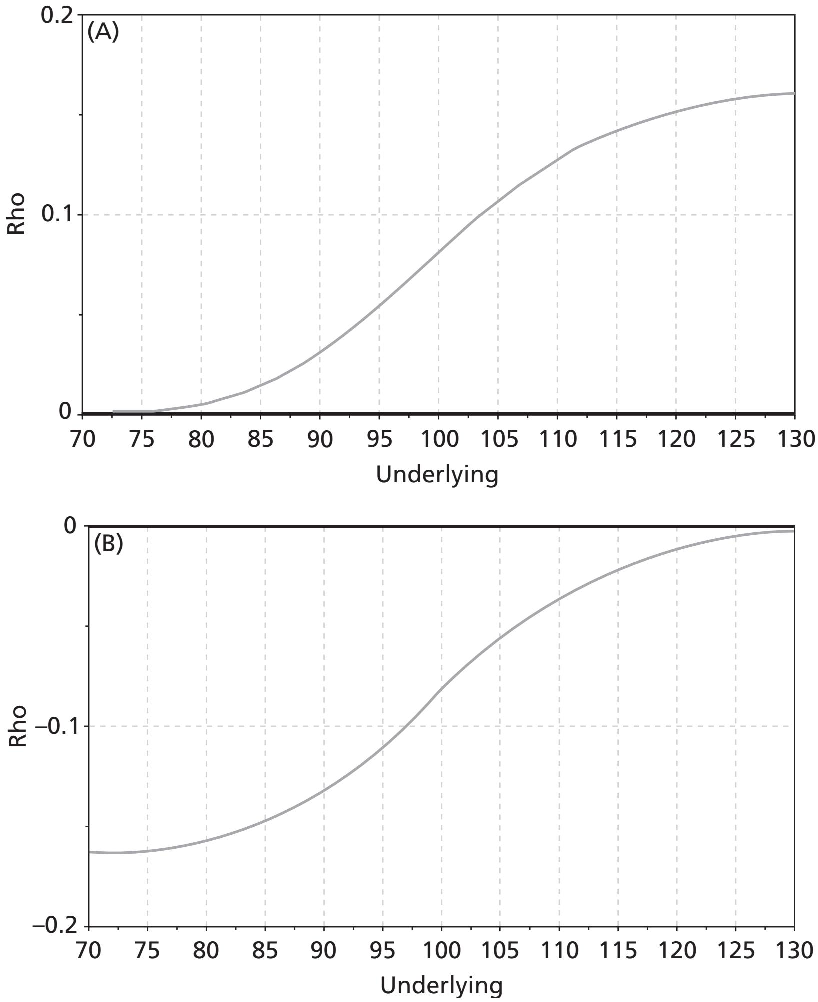


Figure 4-13 (A) Rho of 100 Call vs. Stock Price **(B)** Rho of 100 Put vs. Stock Price

That rhos increase with rising stock prices is another result of the cost-of-carry concept. Higher-priced stocks are more expensive to finance than lower-priced stocks, and changes in interest rates have a greater impact on the absolute cost of financing high-priced stocks than on low-priced stocks.

Rhos and Time to Expiration

Figures 4-14A, 4-14B, and 4-14C show the third rule. Rhos increase in an almost linear manner with increases in time. The cost-of-carry concept also explains this consequence. At a given interest rate, financing costs are higher—in a linear relationship—for longer time periods than for shorter periods. And if interest rates change, the absolute impact will be higher—linearly—for the longer time period than for the shorter.

Rhos and Volatility

The fourth rule describes the impact of volatility on rho. This concept is complicated. Table 4-8 and Figures 4-15A, 4-15B, and 4-15C show that volatility has different effects on rhos of in the money, at the money, and out of the money options. The difficult aspect to grasp is that volatility only affects rho indirectly through its impact on option prices.

Consider rows D and A in column 1 of Table 4-8, which show that an increase in volatility from 25 to 50 percent increases the rho of the 110 Call from 0.03 to 0.05. Note also that the call price rises from 1.02 to 4.39. In addition to the change in cost of carry of the underlying stock, a change in the interest rate also would affect the cost (foregone interest) of owning the call. The foregone interest on 4.39 is 400 percent that of the foregone interest on 1.02 regardless of the level of interest rates. Therefore, the effect of a change in the interest rate must be greater when volatility is higher than when it is lower. Figure 4-15C shows that rising volatility has an exponential impact on the rho of an out-of-the-money call from approximately 10 to 50 percent volatility. Above 50 percent, the impact of rising volatility levels off, and rho approaches its limit, just as the option price approaches its limit at high levels of volatility (see Figure 2-6).

Figure 4-15B shows that the impact of volatility on rhos of at-the-money calls is more linear—and actually declining—than for out-of-the-money calls, and Figure 4-15A shows that rising volatility causes

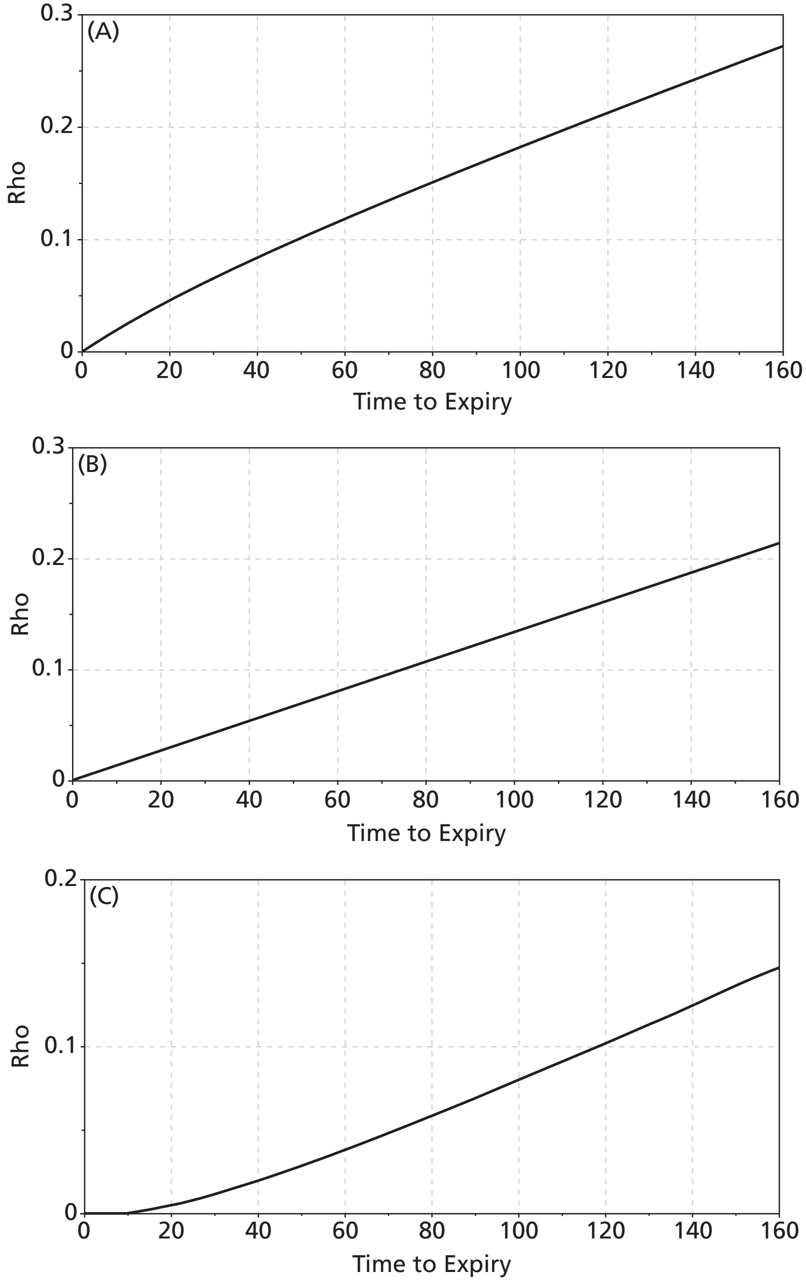


Figure 4-14 **(A)** Rho of In-the-Money 90 Call vs. Time **(B)** Rho of At-the-Money 100 Call vs. Time **(C)** Rho of Out-of-the-Money 110 Call vs. Time

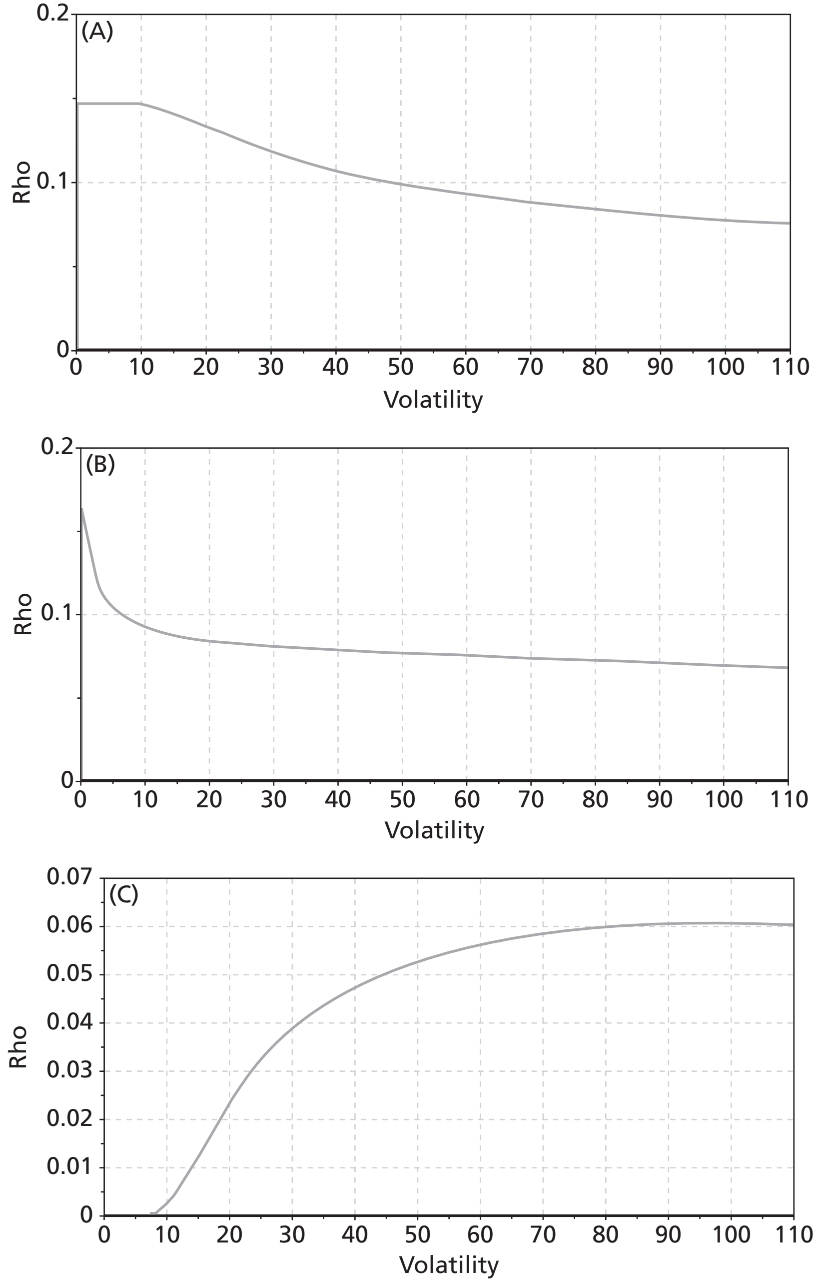


Figure 4-15 (A) Rho of In-the-Money 90 Call vs. Volatility **(B)** Rho of At-the-Money 100 Call vs. Volatility **(C)** Rho of Out-of-the-Money 110 Call vs. Volatility

rhos of in-the-money calls to decrease. Fortunately, this complicated interaction of volatility and rho is of little importance to the vast majority of traders, even full-time ones.

Position Greeks

The term *position* refers to whether an option is purchased (i.e., long) or written (i.e., short). For example, if Adam buys 25 XYZ November 100 Calls, his "position" is long 25. If Matthew buys 15 QRS April 45 Puts and sells 15 QRS April 40 Puts, his position is long 15 April 45 Puts and short 15 April 40 Puts.

What Adam and Matthew and all traders need is a method of estimating how their position will perform if market conditions change, that is, if one or more of the inputs to the option-pricing formula changes. *Position Greeks* indicate whether an entire position will experience profit or loss when a particular input to the option-pricing formula is changed.

You will learn how to calculate and interpret position Greeks after the following discussion about the use of positive and negative signs. In options trading, plus and minus signs can have three different meanings.

"+" And "−" Have Three Different Meanings

First, *when associated with a quantity of options*, plus signs mean "long," and minus signs mean "short." The position description "+3 NDX January 2200 Puts at 12.50" is read as "long 3 NDX 2200 Puts at 12.50 each." The position description "−15 XSP November 145 Calls at 9.10" is read as "short 15 XSP November 145 Calls at 9.10 each."

Second, *when associated with an option's delta, vega, theta, or rho*, plus and minus signs mean that the option value is positively or negatively correlated with changes in the respective input. "The call has a delta of +0.65" means that the value of the call is positively correlated with changes in the price of the underlying stock; that is, if the stock price rises, the call value will rise, and if it falls, the call value also will fall.

A second example uses the phrase, "the put has a rho of −0.08," which means that the value of the put is negatively correlated with changes in interest rates. If interest rates rise, then the put value will decrease. And a third example, "the put has a vega of +0.20," means that the value of the put is positively correlated with changes in volatility. If volatility rises, put value rises; if volatility decreases, put value decreases.

Plus signs associated with gamma mean that the delta of the position is positively correlated with changes in price of the underlying; that is, stock price up, delta up; stock price down, delta down. And negative signs associated with gamma mean that the option's delta is negatively correlated with changes in price of the underlying stock: Stock price up, delta down; stock price down, delta up.

Finally, *when associated with the Greek of an entire option position*, plus and minus signs, with one exception, indicate whether a position will profit from or lose from an increase in the corresponding factor. Consider, for example, "the vega of Sally's three long calls is +2.73." The plus sign means that Sally's position will profit by 2.73 points if volatility rises 1 percent, and other factors remain constant. Another example is "the theta of Bill's four long puts is –3.64." The minus sign means that Bill's position will lose 3.64 points if time changes by one unit, and other factors remain constant.

The three different meanings may be hard to remember without some practice, so keep this in mind: (1) long or short, (2) positively or negatively correlated, and (3) profit or loss. During the following discussion of position Greeks, keep in mind that plus and minus signs can mean any of these depending on usage.

Introduction to Tables 4-9 through 4-18

Position Greeks are illustrated with 10 tables that have the same format. Each table contains two examples. The first example involves four XYZ 80 Calls initially purchased or sold for 4.20 each. The second example involves 10 QRS 40 Puts initially purchased or sold for 0.81 each. Each example has several steps in numbered rows. The six rows state (1) the initial position, (2) the relevant input and the change (i.e., stock price, days to expiration, volatility, etc.), (3) the Greek of an individual option, (4) the beginning position Greek, (5) the beginning and ending position values, and (6) a conclusion that summarizes the significance of the example.

These examples fulfill two purposes. The first purpose is to show how to calculate position Greeks. The second is to explain how to use a position Greek to estimate the change in a position value.

Position Delta

A position with a positive delta will profit if the price of the underlying rises and will lose if it declines, assuming that other factors remain constant. Long call positions and short put positions have positive deltas, and Table 4-9 shows an example of each. Column 1, row 1 of the long call example describes the position as long four XYZ 80 Calls. The purchase price is 4.20 for each option, and the ending price is 4.77 (column 3). Row 2 shows that the stock price rises from 80 to 81, and row 3 indicates that the delta is +0.55 when the calls are purchased. Row 4 shows that the position delta of +2.20 (column 2) is the product of the quantity of long calls (+4) and the option delta (+0.55). Row 5 shows that the initial position value is the product of the quantity of calls (+4) and the price of each call (4.20). The resulting position value, 16.80 debit, is reflected in column 2. *Debit* means that a trader makes a payment to establish the position and receives money when the position is closed. Thus an increase in a debit position is a profit and a decrease is a loss. In this case, an amount equal to 16.80 points, or $1,680, is the amount invested in the initial position. Column 3, row 5 indicates that the ending position value is "19.08 debit," or $1,908. This is an increase and represents a profit of 2.28 ($228) from the beginning position value.

The conclusion in row 6 of the long call example in Table 4-9 states that "the position delta of +2.20 estimates that a one-point stock-price rise will cause the position to profit by $220, but the actual profit was $228 owing to the increasing delta." In real trading situations, the actual result will not always exactly equal the estimate for a number of reasons. First, depending on the size of the stock-price change, the gamma may change the delta significantly enough to make the result vary from the estimate. Second, rounding of numbers easily can lead to differences between an actual result and an estimate. Third, the assumption that all other factors, such as time and volatility, remain constant may not hold.

Table 4-9 Positive Delta Positions—Long Calls and Short Puts

Long Call Example	Col 1		Col 2		Col 3
1 Position	Long 4 XYZ 80 Calls		4.20 each	→	4.77
2 Stock price			80.00	→	81.00
3 Option delta			+0.55		
4 Position delta	+4 × +0.55	=	+2.20		
5 Position value	+4 × 4.20	=	16.80 debit	→	19.08 debit
6 *Conclusion:* The position delta of +2.20 estimates that a one-point stock-price rise will cause the position to profit by $220, but the actual profit was $228 (from 16.80 debit to 19.08 debit) owing to the increasing delta.					

Assumptions: Days to exp., 60; volatility, 30%; interest rate, 5%; no dividends.

Short Put Example	Col 1		Col 2		Col 3
1 Position	Short 10 QRS 40 Puts		0.81 each	→	0.52
2 Stock price			41.00	→	42.00
3 Option delta			−0.34		
4 Position delta	−10 × −0.34	=	+3.40		
5 Position value	−10 × 0.81	=	8.10 credit	→	5.20 credit
6 *Conclusion:* The position delta of +3.40 estimates that a one-point stock-price rise will cause the position to profit by $340, but the actual profit was $290 (from 8.10 credit to 5.20 credit) owing to decreasing delta.					

Assumptions: Days to exp., 40; volatility, 25%; interest rate, 5%; no dividends.

The short put example in Table 4-9 is 10 short QRS 40 Puts at 0.81 each. The position delta of +3.40 (row 4) estimates that these 10 short puts (−10) will make a profit of 3.40, or $340, if QRS stock rises by one point or will lose this amount if the stock falls by one point and other factors remain constant. Row 2 shows that the stock price rises by $1.00 from 41 to 42, and row 5 shows that the position value changes from an 8.10 Credit to a 5.20 Credit for a profit of 2.90 ($290). *Credit* means that a trader receives money when a position is established and makes a payment when the position is closed. Thus a decrease in a credit position is a profit and an increase is a loss. In this example, the estimated result, a profit of $340, does not exactly equal the actual result, a profit of $290. As with the long call example, the difference in the actual result is caused by the changing delta.

Table 4-10 shows that short call positions and long put positions have negative deltas. A position with a negative delta will lose if the price of the underlying rises and profit if it declines, assuming that other factors remain constant.

Position Gammas

Gammas of positions do not indicate profit or loss. Rather, they indicate how the position delta will change when the price of the underlying changes. A positive gamma indicates that the position delta will change in the same direction as the change in price of the underlying. A negative gamma indicates that the position delta will change in the opposite direction from the change in price of the underlying.

Table 4-11 shows that long call and long put positions have positive gammas. In the first example in Table 4-11, each long call has a gamma of +0.04 (row 4), and the position gamma is +0.16 (row 5). The positive position gamma estimates that if the stock price rises one point, and other factors remain constant, then the position delta will rise by +0.16 from +2.20 to +2.36. The beginning and ending position deltas presented in row 6 verify this. Positive gamma means this: Stock price up, position delta up, or stock price down, position delta down.

Table 4-10 Negative Delta Positions—Short Calls and Long Puts

Short Call Example	Col 1	Col 2		Col 3
1 Position	Short 4 XYZ 80 Calls	4.20 each	→	4.77
2 Stock price		80.00	→	81.00
3 Option delta		+0.55		
4 Position delta	−4 × +0.55 =	−2.20		
5 Position value	−4 × 4.20 =	16.80 credit	→	19.08 credit
6 *Conclusion:* The position delta of −2.20 estimates that a one-point stock-price decline will cause the position to lose \$220, but the actual loss was \$228 (from 16.80 credit to 19.08 credit) owing to decreasing delta.				

Assumptions: Days to exp., 60; volatility, 30%; interest rate, 5%; no dividends.

Long Put Example	Col 1	Col 2		Col 3
1 Position	Long 10 QRS 40 Puts	0.81 each	→	0.52
2 Stock price		41.00	→	42.00
3 Option delta		−0.34		
4 Position delta	+10 × −0.34 =	−3.40		
5 Position value	+10 × 0.81 =	8.10 debit	→	5.20 debit
6 *Conclusion:* The position delta of −3.40 estimates that a one-point stock-price rise will cause the position to lose \$340, but the actual loss was \$290 (from 8.10 debit to 5.20 debit) owing to increasing delta.				

Assumptions: Days to exp., 40; volatility, 25%; interest rate, 5%; no dividends.

With a positive gamma, the change in delta works to the advantage of the position. Referring back to Table 4-2, as the underlying stock increases from 100 to 101, the delta of the 100 Call increases from +0.55 to +0.58. Underlying price up, delta up! This benefits the call owner because the market exposure, that is, the delta, is changing in the call owner's favor. Initially, the call owner's exposure to the market was a delta of +0.55, which means that for every one-point increase in the underling, with other factors constant, the call owner participates by approximately 55 percent. After a one-point price rise in the stock, however, the call owner's exposure has increased to approximately 58 percent. And as the market continues to rise, the call owner makes more and more per unit of price change because the delta of the position is increasing toward +1.00.

Table 4-11 Positive Gamma Positions—Long Calls and Long Puts

Long Call Example	Col 1		Col 2		Col 3
1 Position	Long 4 XYZ 80 Calls		4.20 each		
2 Stock price			80.00	→	81.00
3 Option delta			+0.55	→	0.59
4 Option gamma			+0.04		
5 Position gamma	+4 × +0.04	=	+0.16		
6 Position delta	+4 × +0.55	=	+2.20	→	+2.36
7 *Conclusion:* The position gamma of +0.16 estimates that a one-point stock-price rise will cause the position delta to rise by 0.16, and the actual rise was 0.16 (from +2.20 to +2.36).					

Assumptions: Days to exp., 60; volatility, 30%; interest rate, 5%; no dividends.

Long Put Example	Col 1		Col 2		Col 3
1 Position	Long 10 QRS 40 Puts		0.81 each		
2 Stock price			41.00	→	42.00
3 Option delta			−0.34	→	−0.24
4 Option gamma			+0.11		
5 Position gamma	+10 × +0.11	=	+1.10		
6 Position delta	+10 × −0.34	=	−3.40	→	−2.40
7 *Conclusion:* The position gamma of +1.11 estimates that a one-point stock-price rise will cause the position delta to rise by 1.10, and the actual rise was 1.00 (from −3.40 to −2.40) owing to rounding.					

Assumptions: Days to exp., 40; volatility, 25%; interest rate, 5%; no dividends.

What about a price decline? Look back at Table 4-3. As the price of the underlying declines and other factors remain constant, the call owner loses less than the amount estimated by the initial delta. This result happens because the delta decreases. Losing less than the amount estimated by the original delta is a benefit to the call owner.

The second example in Table 4-11 shows that a positive position gamma also has a beneficial impact on a long put position when the market rises. As the stock price rises from 41 to 42 (row 2), the delta of the position in row 6 rises from −3.40 to −2.40, only slightly different from the position gamma of +1.10. Consequently, less is lost than estimated by the original delta.

Negative Gamma

Table 4-12 shows that short call and short put positions have negative gammas. Negative gamma means that the delta of the position will change in the opposite direction from the change in price of the underlying: Stock up, position delta down, or stock down, position delta up.

The first example in Table 4-12 is short four XYZ 80 Calls at 4.20 each. The position gamma of −0.16 (row 5) estimates that as the stock price rises, the delta of the position will decrease by 0.16. The actual change in position delta, from −2.20 to −2.36 in row 6, exactly equals this estimate.

In the short put example in Table 4-12 the position gamma of −1.10 estimates that the position delta will decrease by this amount if the stock rises one point and will increase by this amount if the stock price falls by one point, other factors remaining constant. The actual change in delta is −1.00 as the position delta in row six changes from +3.40 to +2.40. The difference between the actual and the estimate is due to rounding.

When a position has a negative gamma, any change in delta works to the disadvantage of the position. Assume, for example, that a trader sells the 100 Call in Table 4-2. The initial delta of the short call position is −0.55, and the position gamma is −0.03. This position gamma estimates that an increase in the stock price from 100 to 101 causes the position delta to decrease by 0.03 from −0.55 to −0.58. Underlying price up, delta down! This stock increase hurts the short call position because the loss becomes larger than the loss estimated by the initial delta. As the market continues to rise, the position loses more and more per unit of price rise as the exposure to the market of the short call position continues to decline toward −1.00 per short call.

Table 4-3 shows that a negative gamma also works to the disadvantage of a short call position when the stock price declines. Assuming again that a trader sells the 100 Call in Table 4-3, the initial delta is −0.55. As the stock declines from 100 to 99, the short call position profits less than the amount estimated by the delta. The profit is less because the delta of the short call is increasing from −0.55 to −0.51.

Table 4-12 Negative Gamma Positions—Short Calls and Short Puts

Short Call Example		Col 1				Col 2		Col 3
1	Position	Short 4 XYZ 80 Calls				4.20 each		
2	Stock price					80.00	→	81.00
3	Option delta					+0.55	→	0.59
4	Option gamma					+0.04		
5	Position gamma	−4	×	+0.04	=	−0.16		
6	Position delta	−4	×	+0.55	=	−2.20	→	−2.36
7	*Conclusion:* The position gamma of −0.16 estimates that a one-point stock-price rise will cause the position delta to decline by 0.16, and the actual decline was 0.16 (from −2.20 to −2.36).							

Assumptions: Days to expiration, 60; volatility, 30%; interest rate, 5%; no dividends.

Short Put Example		Col 1				Col 2		Col 3
1	Position	Short 10 QRS 40 Puts				0.81 each		
2	Stock price					41.00	→	42.00
3	Option delta					−0.34	→	−0.24
4	Option gamma					+0.11		
5	Position gamma	−10	×	+0.11	=	−1.10		
6	Position delta	−10	×	−0.34	=	+3.40	→	+2.40
7	*Conclusion:* The position gamma of −1.10 estimates that a one-point stock-price rise will cause the position delta to fall by 1.10, but the actual decrease was 1.00 (from +3.40 to +2.40).							

Assumptions: Days to exp., 40; volatility, 25%; interest rate, 5%; no dividends.

Making less than the amount estimated by the original delta is a disadvantage for the call writer.

Position Vegas

A position with a positive vega will profit if volatility rises and other factors remain constant. Table 4-13 shows that long option positions have positive vegas. The vega of +0.52 of the long call position in Table 4-13 means that if volatility rises by 1 percent and other factors remain constant, then the position of long four XYZ 80 Calls will profit by 0.52, or $52, which is exactly equal to the actual increase in value in row 5.

Table 4-13 Positive Vega Positions—Long Calls and Long Puts

Long Call Example		Col 1				Col 2		Col 3
1 Position	Long 4 XYZ 80 Calls					4.20 each	→	4.33
2 Volatility						30%	→	31%
3 Option vega						+0.13		
4 Position vega	+4	×	+0.13	=		+0.52		
5 Position value	+4	×	4.20	=		16.80 debit	→	17.32 debit
6 *Conclusion:* The position vega of +0.52 estimates that a 1 percent increase in volatility will cause the position to profit by $52, and the actual profit was $52 (from 16.80 debit to 17.32 debit).								

Assumptions: Stock price, 80; days to exp., 60; interest rate, 5%; no dividends.

Long Put Example		Col 1				Col 2		Col 3
1 Position	Long 10 QRS 40 Puts					0.81 each	→	0.86
2 Volatility						25%	→	26%
3 Option vega						+0.05		
4 Position vega	+10	×	+0.05	=		+0.50		
5 Position value	+10	×	0.81	=		8.10 debit	→	8.60 debit
6 *Conclusion:* The position vega of +0.50 estimates that a 1 percent increase in volatility will cause the position to profit by $50, and the actual profit was $50 (from 8.10 debit to 8.60 debit).								

Assumptions: Stock price, 41; days to exp., 40; interest rate, 5%; no dividends.

A position with a negative vega will lose if volatility rises and profit if volatility declines, assuming that other factors remain constant. Table 4-14 shows that short option positions have negative vegas. The vega of the short put position of −0.50 in Table 4-14 means that if volatility rises by 1 percent and other factors are the same, then this position will lose 0.50, or $50. This estimate exactly equals the loss in row 5 as the value of the short option position rises from 8.10 to 8.60. The negative vega also estimates that if volatility falls by 1 percent, then the position will profit by $50.

Position Thetas

The theta of a position estimates whether the passing of time will cause a position to sustain a profit or a loss. Since option values decay over

Table 4-14 Negative Vega Positions—Short Calls and Short Puts

Short Call Example		Col 1		Col 2		Col 3
1	Position	Short 4 XYZ 80 Calls		4.20 each	→	4.33
2	Volatility			30%	→	31%
3	Option vega			+0.13		
4	Position vega	−4 × +0.13	=	−0.52		
5	Position value	−4 × 4.20	=	16.80 credit	→	17.32 credit
6	*Conclusion:* The position vega of −0.52 estimates that a 1 percent increase in volatility will cause the position value to lose $50, and the actual loss was $50 (from 16.80 credit to 17.23 credit).					

Assumptions: Stock price, 80; days to exp, 60; interest rate, 5%; no dividends.

Short Put Example		Col 1		Col 2		Col 3
1	Position	Short 10 QRS 40 Puts		0.81 each	→	0.86
2	Volatility			25%	→	26%
3	Option vega			+0.05		
4	Position vega	−10 × +0.05	=	−0.50		
5	Position value	−10 × 0.81	=	8.10 credit	→	8.60 credit
6	*Conclusion:* The position vega of −0.50 estimates that a 1 percent increase in volatility will cause the position to lose $50, and the actual loss was $50 (from 8.10 credit to 8.60 credit).					

Assumptions: Stock price, 41; days to exp., 40; interest rate, 5%; no dividends.

time, short option positions profit if time passes, so those positions have positive thetas. The short call position in Table 4-15 has a position theta of +0.16 (row 4), which estimates that the position will profit by $16 if time to expiration is reduced by "one unit." In this example, one unit of time is one day, and the theta exactly estimates the change in position value from 16.80 to 16.64 as days to expiration decrease from 60 to 59. The short put position has a theta of +0.10 (row 4), which estimates that the position will profit by $10 in one unit of time.

A position with a negative theta will incur a loss if only the time to expiration changes. Long option positions have negative thetas. In Table 4-16, the theta of the long call position of −0.16 means that if only time to expiration is reduced by one day, then the position will lose 0.16, or $16. The theta of −0.10 of the long put position means that $10 will be lost if one day passes and other factors remain constant.

Table 4-15 Positive Theta Positions—Short Calls and Short Puts

Short Call Example		Col 1				Col 2		Col 3
1 Position	Short 4 XYZ 80 Calls					4.20 each	→	4.16
2 Days to expiration						60	→	59
3 Option theta						−0.04		
4 Position theta	−4	×	−0.04	=		+0.16		
5 Position value	−4	×	4.20	=		16.80 credit	→	16.64 credit

6 *Conclusion:* The position theta of +0.16 estimates that the passing of one day will cause the position to profit by $16, and the actual profit was $16 (from 16.80 credit to 16.64 credit).

Assumptions: Stock price, 80; volatility, 30%; interest rate, 5%; no dividends.

Short Put Example		Col 1				Col 2		Col 3
1 Position	Short 10 QRS 40 Puts					0.81 each	→	0.80
2 Days to expiration						40	→	39
3 Option theta						−0.01		
4 Position theta	−10	×	−0.01	=		+0.10		
5 Position value	−10	×	0.81	=		8.10 credit	→	8.00 credit

6 *Conclusion:* The position theta of +0.10 estimates that the passing of one day will cause the position to profit by $10, and the actual profit was $10 (from 8.10 credit to 8.00 credit).

Assumptions: Stock price, 41; volatility, 25%; interest rate, 5%; no dividends.

Position Rhos

The rho of a position estimates whether the position will profit or lose as the interest rate changes and other factors remain constant. Long calls and short puts have positive rhos. The long call position in Table 4-17 has a position rho of +0.28 (row 4), which estimates that the position will profit by $28 if the interest rate rises by 1 percent. The position rho of the short put example in Table 4-17 is +0.20. The actual profit of the position of 10 short puts, however, is only $10, as they decrease in price from 0.81 to 0.80. The difference is due to rounding.

Short calls and long puts have negative rhos. Table 4-18 shows that the short call example has a rho of −0.28, and this exactly estimates the loss as the short call value increases when the interest rate rises from 5 to 6 percent. The rho of −0.20 of the long put position in Table 4-18

Table 4-16 Negative Theta Positions—Long Calls and Long Puts

Long Call Example		Col 1			Col 2		Col 3
1 Position	Long 4 XYZ 80 Calls				4.20 each	→	4.16
2 Days to expiration					60	→	59
3 Option theta					−0.04		
4 Position theta	+4	×	−0.04	=	−0.16		
5 Position value	+4	×	4.20	=	16.80 debit	→	16.64 debit
6 *Conclusion:* The position theta of −0.16 estimates that the passing of one day will cause the position to lose $16, and the actual loss was $16 (from 16.80 debit to 16.64 debit).							

Assumptions: Stock price, 80; volatility, 30%; interest rate, 5%; no dividends.

Long Put Example		Col 1			Col 2		Col 3
1 Position	Long 10 QRS 40 Puts				0.81 each	→	0.80
2 Days to expiration					40	→	39
3 Option theta					−0.01		
4 Position theta	+10	×	−0.01	=	−0.10		
5 Position value	+10	×	0.81	=	8.10 debit	→	8.00 debit
6 *Conclusion:* The position theta of −0.10 estimates that the passing of one day will cause the position to lose $10, and the actual loss was $10 (from 8.10 debit to 8.00 debit).							

Assumptions: Stock price, 41; volatility, 25%; interest rate, 5%; no dividends.

over estimates the loss in value as the interest rate rises. In row 5 of the long put example in Table 4-18, the price of each put decreases from 0.81 to 0.80, and this causes the value of 10 long puts to decrease. The actual loss of −0.10 differs from the estimated loss of −0.20 because of rounding.

Position Greeks Summarized

Table 4-19 matches long and short options with positive and negative position Greeks. Long calls have positive deltas, gammas, and vegas and negative thetas. Short calls have negative deltas, gammas, and vegas and positive thetas. Long puts have negative deltas and thetas, and positive gammas and vegas. Short puts have positive deltas and thetas and negative gammas and vegas.

Table 4-17 Positive Rho Positions—Long Calls and Short Puts

Long Call Example			Col 1		Col 2		Col 3
1 Position	Long 4 XYZ 80 Calls				4.20 each	→	4.27
2 Interest rates					5%	→	6%
3 Option rho					+0.07		
4 Position rho	+4	×	+0.07	=	+0.28		
5 Position value	+4	×	4.20	=	16.80 debit	→	17.08 debit
6 *Conclusion:* The position rho of +0.28 estimates that a 1 percent increase in interest rates will cause the position to profit by $28, and the actual profit was $28 (from 16.80 debit to 17.08 debit).							

Assumptions: Stock price, 80; days to exp., 60; volatility, 30%; no dividends.

Short Put Example			Col 1		Col 2		Col 3
1 Position	Short 10 QRS 40 Puts				0.81 each	→	0.80
2 Interest rates					5%	→	6%
3 Option rho					−0.02		
4 Position rho	−10	×	−0.02	=	+0.20		
5 Position value	−10	×	0.81	=	8.10 credit	→	8.00 credit
6 *Conclusion:* The position rho of +0.20 estimates that a 1 percent increase in interest rates will cause the position to profit by $20, but the actual profit was $10 (from 8.10 credit to 8.00 credit) owing to rounding.							

Assumptions: Stock price, 41; days to exp., 40; volatility, 25%; no dividends.

No two rows in Table 4-19 are the same. Each option position has its own unique sensitivities to changes in price of the underlying, volatility, and time to expiration, and the sensitivities vary depending whether an option is in the money, at the money, or out of the money. Although confusing at first, an understanding of position Greeks separates good traders from bad. The Greeks provide an estimate of how a position will change in value as market conditions change. Interpreting such an estimate is the key to selecting appropriate strategies.

Summary

The Greeks are tools used by option traders to estimate the profit or loss impact of changes in market conditions. Delta is an estimate of

Table 4-18 Negative Rho Positions—Short Calls and Long Puts

Short Call Example				Col 1		Col 2		Col 3
1	Position	Short 4 XYZ 80 Calls				4.20 each	→	4.27
2	Interest rates					5%	→	6%
3	Option rho					+0.07		
4	Position rho	−4	×	+0.07	=	−0.28		
5	Position value	−4	×	4.20	=	16.80 credit	→	17.08 credit
6	*Conclusion:* The position rho of −0.28 estimates that a 1 percent increase in interest rates will cause the position to lose $28, and the actual loss was $28 (from 16.80 credit to 17.08 credit).							

Assumptions: Stock price, 80; days to exp, 60; volatility, 30%; no dividends.

Long Put Example				Col 1		Col 2		Col 3
1	Position	Long 10 QRS 40 Puts				0.81 each	→	0.80
2	Interest rates					5%	→	6%
3	Option rho					−0.02		
4	Position rho	+10	×	−0.02	=	−0.20		
5	Position value	+10	×	0.81	=	8.10 debit	→	8.00 debit
6	*Conclusion:* The position rho of −0.20 estimates that a 1 percent increase in interest rates will cause the position to lose $20, but the actual loss was $10 (from 8.10 credit to 8.20 credit) owing to rounding.							

Assumptions: Stock price, 41; days to exp., 40; volatility, 25%; no dividends.

the change in option theoretical value given a one-point change in price of the underlying instrument. Gamma is a measure of change in delta for a one-point change in the price of the underlying. Vega is an estimate of the change in option value resulting from a one percentage point change in volatility, and theta is an estimate of the change in option value resulting from a one-unit change in time to expiration. Traders who use computer programs should be sure to know the definition of *one unit of time* used by the program.

The Greeks change as market conditions change, and these constant changes complicate the job of estimating how position values will behave as market conditions change. The absolute values of deltas of in-the-money options are greater than +0.50 initially and increase toward +1.00 as expiration approaches. The absolute values of deltas

Table 4-19 Summary of Position Greeks

Position	Delta	Gamma	Vega	Theta
Long Call	+	+	+	−
Short Call	−	−	−	+
Long Put	−	+	+	−
Short Put	+	−	−	+

+ indicates that a position will profit, or benefit, from an increase in an input and incur a loss from, or be hurt by, a decrease, assuming that other inputs remain constant.
− indicates that a position will incur a loss from, or be hurt by, an increase in an input and profit, or benefit, from a decrease, assuming other inputs remain constant.

of at-the-money options remain near +0.50 as expiration approaches, whereas the absolute values of deltas of out-of-the-money options start at less than +0.50 and decrease toward 0 as expiration approaches.

Gammas are biggest for at-the-money options and tend to increase as expiration approaches. Vegas are biggest for at-the-money options and decrease as expiration approaches. Thetas are smallest (largest absolute value) for at-the-money options. The behavior of thetas as expiration approaches differs for at-the-money options versus in-the-money or out-of-the-money options.

Plus signs ("+") and minus signs ("−") indicate "long" or "short" when associated with a quantity of options in a position. They indicate "positive correlation" or "negative correlation" when associated with Greeks of individual options, and they indicate "profit" or "loss" when associated with position Greeks.

Long calls and short puts have positive deltas. If other factors remain constant, these positions enjoy a profit with a rise in price of the underlying instrument and suffer a loss with a decline. Short calls and long puts are positions with negative deltas and profit from a stock price decline.

Positive gamma means that the delta of a position changes in the same direction as the change in price of the underlying. Stock up, delta up, and stock down, delta down. Long calls and long puts have positive gammas. Negative gamma means that the delta of a position changes in the opposite direction from the change in price of the underlying. Stock up, delta down, and stock down, delta up. Short calls and short puts have negative gammas.

Positive vega means that a position will profit if volatility rises and lose if volatility declines, assuming that other factors remain constant. Long calls and long puts have positive vegas. Negative vega means that a position will lose if volatility rises and gain if volatility declines. Short calls and short puts have negative vegas.

Long calls and long puts have negative thetas because they lose money as time passes toward expiration and other factors remain constant. Short calls and short puts have positive thetas. They profit as time passes toward expiration and other factors remain constant.

Knowing how to interpret the Greeks is a valuable skill. It helps a trader to anticipate how strategies will perform as market conditions change.

Chapter 5

SYNTHETIC RELATIONSHIPS

The prices of calls, puts, and the underlying stock are linked to each other by a relationship known as *put-call parity*. One corollary of put-call parity is that a position in one instrument (stock, calls, or puts) can be replicated by a two-part position using the other two instruments. These two-part positions are known as *synthetic positions*. Another corollary is that if the put-call parity relationship is not met, then there will be arbitrage opportunities.

This chapter will first explain the six basic synthetic positions without taking into consideration interest rates or dividends. It will then discuss the put-call parity equation and finish with the impact of interest rates and dividends on option prices. The use of synthetic relationships to create arbitrage strategies will be discussed in the next chapter.

Synthetic Relationships

There are six *real* trading positions: long and short stock, long and short call, and long and short put. Traders can replicate each of these real positions with a *synthetic* position that consists of the other two instruments. For example, a two-part position consisting of a call position and a put position can replicate a stock position. Similarly, a call position can be replicated with a combined stock and put position, and a combined stock and call position can replicate a put position. A *synthetic position* is a two-part position that has the same theoretical risk, the same theoretical break-even point, and the same theoretical profit potential as a real position.

In theory, traders should not prefer one type of position to another. In practice, however, there are some differences that do influence preference. Primarily because synthetic positions have two bid-ask spreads instead of one, two transaction costs instead of one, and different margin requirements, the trading of synthetic relationships typically falls into the realm of the professional trader. Understanding synthetic relationships is the first step in learning about arbitrage strategies.

The term *effective price* means the stock price that takes into account the option premium. Option exercise or assignment creates a stock transaction at the strike price, but the strike price does not accurately reflect the full price to the trader of synthetic positions. If, for example, a 100 Call purchased for 2.00 per share is exercised, then the *effective price* of the resulting long stock position is 102 per share. This term will be used throughout this chapter.

The introductory explanation of synthetic relationships that follows makes four simplifying assumptions. First, it assumes that there is a one-to-one relationship between options and shares of stock. In other words, each option covers one share of stock rather than 100 shares. Second, it assumes an interest rate of zero so that time to expiration is irrelevant. Third, no commissions and no dividends are assumed. Fourth and finally, it assumes an available amount of capital equal to the stock price. This amount of capital is necessary because, in the real world, purchasers of stock and options must pay cash, and short sellers of stock and options must post margin.

The assumptions for the examples that follow are a stock price of 100, a 100 Call price of 3.00, and a 100 Put price of 3.00. It is also assumed that $100 of cash is held in reserve to either buy the stock or serve as the margin deposit for a short stock or short option position.

Synthetic Long Stock

A synthetic long stock position is created with a two-part option position consisting of a long call and a short put, where the call and put have the same underlying, the same strike price, and the same expiration date. Table 5-1 and Figure 5-1 illustrate that the two-part position consisting of a long 100 Call at 3.00 and a short 100 Put at 3.00 is equivalent to long stock at $100. Table 5-1 shows profit-and-loss calculations for each component of the synthetic position, for the combined position, and for the corresponding real position at various stock prices. Figure 5-1 graphs the component positions and the combined position.

Table 5-1 Synthetic Long Stock: Long 100 Call at 3.00 and Short 100 Put at 3.00 Compared with Long Stock at 100

	Col 1	Col 2	Col 3	Col 4	Col 5
	Stock Price at Expiration	Long 100 Call @ 3.00	Short 100 Put @ 3.00	Combined P/(L)	Long Stock @ 100
Row 1	90	−3.00	−7.00	−10.00	−10.00
Row 2	95	−3.00	−2.00	−5.00	−5.00
Row 3	100	−3.00	+3.00	-0-	-0-
Row 4	105	+2.00	+3.00	+ 5.00	+5.00
Row 5	110	+7.00	+3.00	+10.00	+10.00

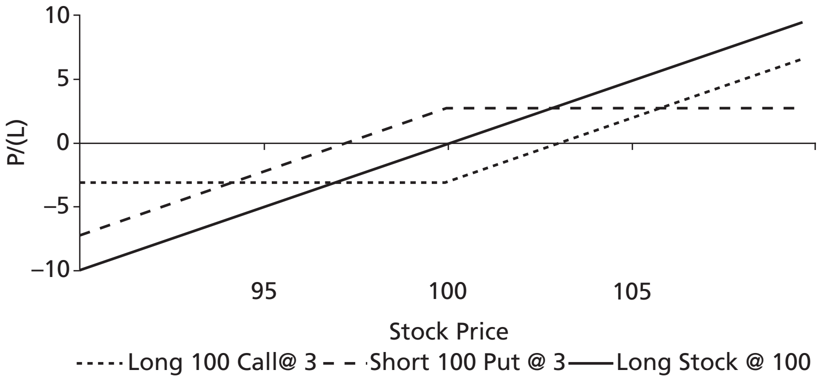


Figure 5-1 Synthetic Long Stock = Long Call and Short Put

Row 4 in Table 5-1 assumes a stock price of $105 at option expiration (column 1). The 100 Call purchased for 3.00 makes a profit of 2.00 per share (column 2), and the 100 Put sold at 3.00 generates a profit of 3.00 per share (column 3). Adding the two profits yields a total profit of 5.00 per share (column 4), the same profit per share of 5.00 that is earned from stock purchased at $100 (column 5). In any row in Table 5-1, the combined result of the long call and short put in column 4 is the same result as purchasing stock at $100 per share in column 5. The results are the first indication that the two-part position of long call and short put equals a long stock position.

Synthetic Long Stock—Mechanics at Expiration

Consider what happens via exercise and assignment to the option position at expiration. Three outcomes are possible: The closing stock price at expiration can be above the strike price of 100, below the strike price, or exactly at the strike price. Each of these possibilities will be considered.

If the stock price closes above $100 at expiration, then the short 100 Put is out of the money and expires worthless. The long 100 Call, however, is in the money and is exercised. Exercising a call creates a stock purchase transaction, and it is assumed that the $100 cash reserve is used to pay for the stock. The result is that a long stock position is created. The effective price of the long stock position is $100 per share.

The *effective stock price* is the price of the stock that takes into account the total or net option premiums. In general, an effective stock price is calculated by adding or subtracting the net option premium from the strike price. In this example, the net option premium is zero because the call was purchased for 3 per share and the put was sold at 3 per share. Adding zero to the strike price of 100 yields an effective stock price of $100. Although this calculation yields an effective stock price that is equal to the strike price, the result would be different if either the call price, the put price, or both were different. The conclusion is that with the stock price above the strike price at expiration, the synthetic long stock position described in Table 5-1 and Figure 5-1 becomes a real long stock position with exactly the same profit as buying stock at $100 per share.

If the stock price falls below $100 at expiration, then the long 100 Call is out of the money and expires worthless. The short 100 Put, however, is in the money and is assigned. Assignment of a short put creates a stock purchase transaction, and as above, it is assumed that the $100 cash reserve is used to pay for the stock. The result is that a long stock position is created at an effective price of $100. Thus, with the stock price below the strike price at expiration, the synthetic long stock position described in Table 5-1 and Figure 5-1 becomes a real long stock position with exactly the same profit as buying stock at $100 per share.

The third possible outcome is that the stock price is exactly at $100 at expiration. If this happens, then both the 100 Call and 100 Put expire worthless, and the result is no position with no profit or loss. However, the $100 cash reserve could be used to purchase a real long stock position. If stock were purchased at $100 after both options expired worthless, the result would be a long stock position with no profit or loss, which is the same result as buying real stock originally at $100 per share.

The conclusion is that the two-part position of long call and short put behaves exactly the same as a real long stock position. It therefore deserves its name, *synthetic long stock*.

Synthetic Short Stock

A synthetic short stock position is created with a short call and a long put. Table 5-2 and Figure 5-2 illustrate that a short 100 Call at 3.00 and a long 100 Put at 3.00 are equivalent to short stock at $100. Table 5-2 shows the profit-and-loss calculations for each component of the synthetic position, for the combined position, and for the corresponding real position at various stock prices. Figure 5-2 graphs the components and the combined position.

Table 5-2 Synthetic Short Stock: Short 100 Call at 3.00 and Long 100 Put at 3.00 Compared with Short Stock at 100

	Col 1	Col 2	Col 3	Col 4	Col 5
	Stock Price at Expiration	Short 100 Call @ 3.00	Long 100 Put @ 3.00	Combined P/(L)	Short Stock @ 100
Row 1	90	+3.00	+7.00	+10.00	+10.00
Row 2	95	+3.00	+2.00	+5.00	+5.00
Row 3	100	+3.00	−3.00	-0-	-0-
Row 4	105	−2.00	−3.00	−5.00	−5.00
Row 5	110	−7.00	−3.00	−10.00	−10.00

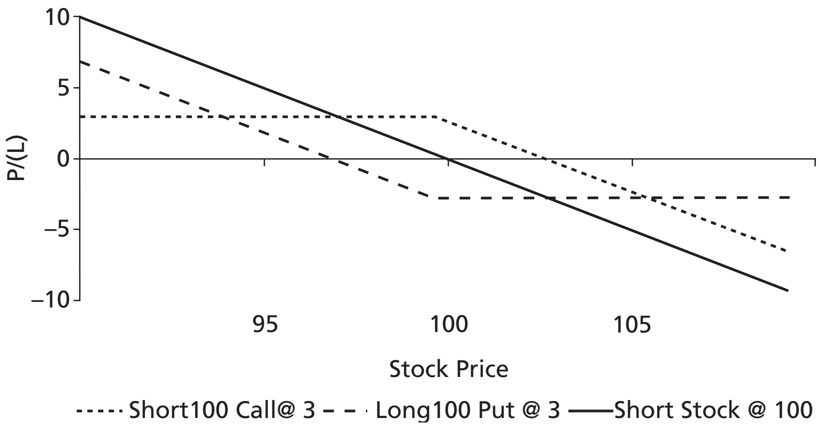


Figure 5-2 Synthetic Short Stock = Short Call and Long Put

Row 2 in Table 5-2 assumes a stock price of $95 at expiration (column 1). The 100 Call sold at 3.00 makes a profit of 3.00 per share (column 2), and the 100 Put purchased for 3.00 makes 2.00 per share (column 3). Adding the two profits yields a total profit of 5.00 per share (column 4), the same profit per share of 5.00 that is earned on stock sold short at $100 per share (column 5). In any row in Table 5-2, the combination of the short call and long put in column 4 reaches the same result as selling stock short at $100 per share in column 5.

Synthetic Short Stock—Mechanics at Expiration

Comparing the results of the positions when the stock price closes above, below, or at the strike price at expiration leads to the conclusion that the synthetic short stock position results in the same position, with the same profit or loss, and with the same effective price as if real stock has been sold short at $100 per share.

With a stock price above $100 at expiration, the long 100 Put is out of the money and expires worthless. The short 100 Call, however, closes in the money and is assigned. Assignment of a short call creates a stock sale transaction. It is assumed that the $100 cash reserve is used as margin to support the resulting short stock position.

If the stock price falls below $100 at expiration, then the short 100 Call is out of the money and expires worthless, but the long 100 Put is in the money and is exercised. Exercise of a put creates a stock sale transaction, which creates a short stock position at an effective price of $100. As above, the $100 cash reserve is used as margin.

If the stock price closes exactly at $100 at expiration, then both the 100 Call and the 100 Put expire worthless, resulting is no position and no profit or loss. However, stock could be sold short at $100 after both options expire worthless, and the result would be a short stock position with no profit or loss—the same result as shorting real stock originally at $100 per share.

The conclusion is that a two-part position of a short call and a long put behaves exactly the same as a real short stock position. It therefore deserves its name, *synthetic short stock.*

Synthetic Long Call

A synthetic long call consists of long stock and long puts on a share-for-share basis. Table 5-3 and Figure 5-3 illustrate that long stock at 100 and a long 100 Put at 3.00 are equivalent to a long 100 Call at 3.00. Table 5-3 shows the profit-and-loss calculations for each component of the synthetic position, for the combined position, and for the corresponding real position at various stock prices. Figure 5-3 graphs the components and the combined position.

Table 5-3 Synthetic Long Call: Long Stock at 100 and Long 100 Put at 3.00 Compared with Long 100 Call at 3.00

	Col 1	Col 2	Col 3	Col 4	Col 5
	Stock Price at Expiration	Long Stock @ 100	Long 100 Put @ 3.00	Combined P/(L)	Long 100 Call @ 3.00
Row 1	90	−10.00	+7.00	−3.00	−3.00
Row 2	95	−5.00	+2.00	−3.00	−3.00
Row 3	100	-0-	−3.00	−3.00	−3.00
Row 4	105	+5.00	−3.00	+2.00	+2.00
Row 5	110	+10.00	−3.00	+7.00	+7.00

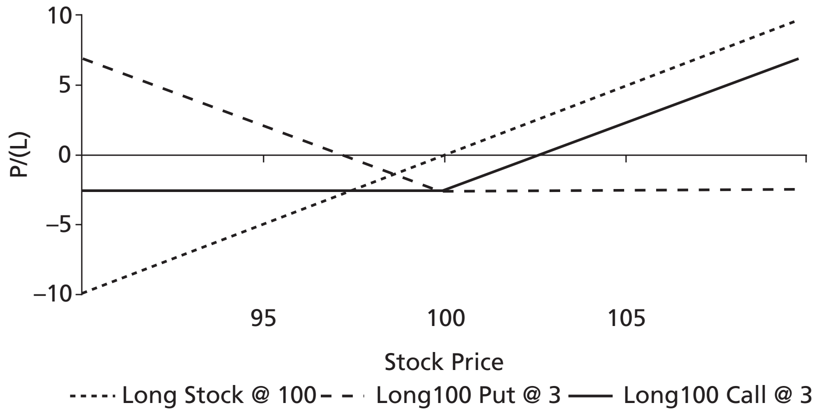


Figure 5-3 Synthetic Long Call = Long Stock and Long Put

Row 4 in Table 5-3 assumes a stock price of $105 at expiration (column 1). The stock purchased for $100 per share makes a profit of 5.00 (column 2), and the 100 Put purchased for 3.00 suffers a loss of 3.00 (column 3). Subtracting the put loss from the stock profit yields a net profit of 2.00 (column 4), the same profit per share of 2.00 that is earned on a 100 Call purchased for 3.00 per share (column 5). Any row in Table 5-3 proves that the combination of the long stock and long put in column 4 reaches the same result as purchasing a 100 Call at 3.00 in column 5.

Synthetic Long Call—Mechanics at Expiration

Consideration of what happens with the stock price above, below, or at the strike price at expiration leads to the conclusion that the synthetic long call results in the same position, with the same profit or loss, and with the same effective price as if a real 100 Call had been purchased for 3.00.

When the stock price closes above $100 at expiration, the long 100 Put is out of the money and expires worthless, but the long stock position remains intact. The effective price of the long stock position in this example is $103, which is calculated by adding the 3.00 cost of the put to the purchase price of the stock of $100. Thus, with the stock price above the strike price at expiration, the synthetic long call position described in Table 5-3 and Figure 5-3 becomes a real long stock position at an effective price of $103—the same result as buying a real 100 Call for 3.00 and exercising it.

If the stock price falls below $100 at expiration, then the long 100 Put is in the money and is exercised. Exercise of a long put creates a stock sale transaction, which means that the stock is sold at $100. The result is a loss of 3.00 per share (from the cost of the put) and no position other than the $100 cash reserve. Thus, with the stock price below the strike price at expiration, the synthetic long call position described in Table 5-3 and Figure 5-3 becomes a cash position with a loss equal to 3.00. This result is the same as buying a 100 Call for 3.00 and holding a $100 cash reserve; at expiration, the call expires, and the cash reserve remains intact.

In the third outcome, the stock price closes exactly at $100 at expiration, the long 100 Put expires worthless, and the long stock position remains intact. However, if the stock were sold at $100 after the put expires, then the result would be a loss of the cost of the put of 3.00 and no position other than the $100 cash reserve. This result is the same as buying a 100 Call at 3.00 and holding a cash reserve of $100; at expiration, the call expires worthless, and the cash reserve remains intact.

The conclusion is that the two-part position of long stock and a long put behaves exactly the same as a real long call position. It therefore deserves its name, *synthetic long call*.

Synthetic Short Call

A synthetic short call is created with short stock and a short put. Table 5-4 and Figure 5-4 illustrate that short stock at $100 and a short 100 Put at 3.00 are equivalent to a short 100 Call at 3.00. Table 5-4 shows the profit-and-loss calculations for each component of the synthetic position, for the combined position, and for the corresponding real position at various stock prices. Figure 5-4 graphs the components and the combined position.

Row 2 in Table 5-4 assumes a stock price of $95 at expiration (column 1). The stock sold short at $100 makes a profit of 5.00 per share (column 2), and the 100 Put sold at 3.00 suffers a loss of 2.00 per share (column 3). Subtracting the put loss from the stock profit yields a net profit of 3.00 per share (column 4). A 100 Call sold at 3.00 (column 5) would generate the same profit per share. Any row in Table 5-4 proves that the combination of the short stock and short put listed in column 4 produces the same result as selling a 100 Call at 3.00 in column 5.

Table 5-4 Synthetic Short Call: Short Stock at 100 and Short 100 Put at 3.00 Compared with Short 100 Call at 3.00

	Col 1	Col 2	Col 3	Col 4	Col 5
	Stock Price at Expiration	Short Stock @ 100	Short 100 Put @ 3.00	Combined P/(L)	Short 100 Call @ 100
Row 1	90	+10.00	−7.00	+3.00	+3.00
Row 2	95	+5.00	−2.00	+3.00	+3.00
Row 3	100	-0-	+3.00	+3.00	+3.00
Row 4	105	−5.00	+3.00	−2.00	−2.00
Row 5	110	−10.00	+3.00	−7.00	−7.00

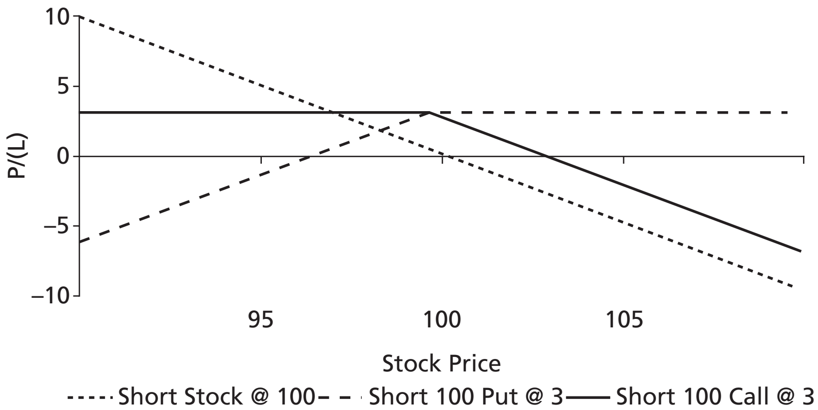


Figure 5-4 Synthetic Short Call = Short Stock and Short Put

Synthetic Short Call—Mechanics at Expiration

A consideration of what happens with the stock price above, below, or at the strike price at expiration leads to the conclusion that the synthetic short call results in the same position, with the same profit or loss, as if a real 100 Call had been sold at 3.00.

If the stock price is above $100 at expiration, then the short 100 Put lands out of the money and expires worthless, whereas the short stock position remains intact. The effective sale price of the short stock position in this example is $103 because the put premium received of 3.00 is added to the sale price of the stock of $100. Thus, with the stock price above the strike price at expiration, the synthetic short call position described in Table 5-4 and Figure 5-4 becomes a short stock position, just as a real short call would be assigned and become a short stock position.

When the stock price falls below $100 at expiration, then the short 100 Put is in the money and is assigned. Assignment of a short put creates a stock purchase transaction, meaning that the short stock position is covered. The result is a profit of 3.00 and no position other than the cash reserve of $100. Thus, with the stock price below the strike price at expiration, the synthetic short call position described in Table 5-4 and Figure 5-4 becomes a cash position with a profit equal to 3.00. This result is the same as selling a 100 Call for 3.00 and holding a $100 cash reserve; at expiration, the call expires, and the cash reserve remains intact.

In the third outcome, the stock price closes exactly at $100 at expiration, the short 100 Put expires worthless, and the short stock position remains intact. However, if the short stock were covered after the put expires, then the result would be a profit of 3.00 and no position other than the $100 cash reserve. This result is the same as selling a 100 Call at 3.00 and holding a cash reserve of $100; at expiration, the call expires, and the cash reserve remains intact.

The conclusion is that the two-part position of short stock and short put behaves exactly the same as a real short call position. It therefore deserves its name, *synthetic short call.*

Synthetic Long Put

A synthetic long put is created with short stock and a long call on a share-for-share basis. Table 5-5 and Figure 5-5 illustrate that short stock at 100 and a long 100 Call at 3.00 are equivalent to a long 100 Put at 3.00. Table 5-5 shows the profit-and-loss calculations for each component of the synthetic position, for the combined position, and for the corresponding real position at various stock prices. Figure 5-5 graphs the components and the combined position.

Table 5–5 Synthetic Long Put: Short Stock at 100 and Long 100 Call at 3.00 Compared with a Long 100 Put at 3.00

	Col 1	Col 2	Col 3	Col 4	Col 5
	Stock Price at Expiration	Short Stock @ 100	Long 100 Call @ 3.00	Combined P/(L)	Long 100 Put @ 3.00
Row 1	90	+10.00	−3.00	+7.00	+7.00
Row 2	95	+5.00	−3.00	+2.00	+2.00
Row 3	100	-0-	−3.00	−3.00	−3.00
Row 4	105	−5.00	+2.00	−3.00	−3.00
Row 5	110	−10.00	+7.00	−3.00	−3.00

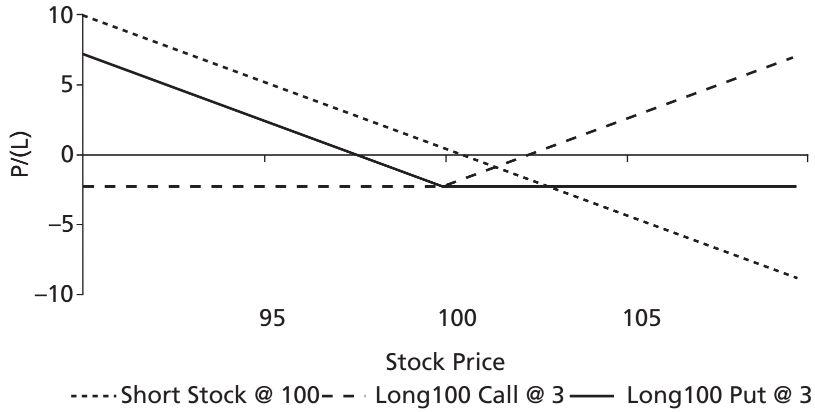


Figure 5-5 Synthetic Long Put = Short Stock and Long Call

Row 2 in Table 5-5 assumes a stock price of $95 at expiration (column 1). The stock sold short at $100 makes a profit of 5.00 per share (column 2), and the 100 Call purchased for 3.00 incurs a loss of 3.00 per share (column 3). Subtracting the call loss from the stock profit yields a net profit of 2.00 per share (column 4). This profit per share of 2.00 is the same as would be earned had a 100 Put been purchased for 3.00 (column 5). In any row in Table 5-5, the combination of the short stock and long call in column 4 reachs the same result as purchasing a 100 Put for 3.00 in column 5.

Synthetic Long Put—Mechanics at Expiration

Considering what happens with the stock price above, below, or at the strike price at expiration leads to the conclusion that the synthetic long put position results in the same position, with the same profit or loss, as if a 100 Put had been purchased for 3.00 per share. If the stock price is above $100 at expiration, then the long 100 Call is in the money and is exercised. Exercising a long call creates a stock purchase transaction, which covers the short stock. The effective price of purchasing stock in this example is $103 because the cost of the call of 3.00 is added to the strike price of 100. Thus, with the stock price above the strike price at expiration, the synthetic long put position described in Table 5-5 and Figure 5-5 results in no stock position with a loss of 3.00 per share, just as a real long 100 Put purchased for 3.00 would expire worthless and leave no position except the cash reserve.

When the stock price is below $100 at expiration, then the long 100 Call is out of the money and expires worthless, and the short stock position remains intact. The effective sale price of the short stock position in this example is $97, which is calculated by subtracting the cost of 3.00 of the put from the short sale price of the stock of $100. Thus, with the stock price below the strike price at expiration, the synthetic long put position described in Table 5-5 and Figure 5-5 becomes a real short stock position at an effective price of $97—the same result as buying a real 100 Put for 3.00 and exercising it.

In the third outcome, the stock price closes exactly at $100 at expiration, the long 100 Call expires worthless, and the short stock position remains intact. However, if the short stock were covered at $100 after the call expires worthless, then the result would be a loss of 3.00 and no position other than the $100 cash reserve—the same result as buying a 100 Put at 3.00 and holding a cash reserve of $100; at expiration, the put expires worthless, and the cash reserve remains intact.

The conclusion is that the two-part position of short stock and long call behaves exactly the same as a real long put position. It therefore deserves its name, *synthetic long put.*

Synthetic Short Put

The last synthetic position, the synthetic short put, is created with long stock and a short call on a share-for-share basis. Table 5-6 and Figure 5-6 illustrate that long stock at $100 and a short 100 Call at 3.00 are equivalent to a short 100 Put at 3.00. Table 5-6 shows the profit-and-loss calculations for each component of the synthetic position, for the combined position, and for the corresponding real position at various stock prices. Figure 5-6 graphs the components and the combined position.

Row 4 in Table 5-6 assumes a stock price of $105 at expiration (column 1). The stock purchased at $100 makes a profit of 5.00 per share (column 2), and the 100 Call sold at 3.00 incurs a loss of 2.00 per share (column 3). Subtracting the call loss from the stock profit yields a net profit of 3.00 per share (column 4), which is the same profit per share that would be earned had a 100 Put been sold at 3.00 per share (column 5). Any row in Table 5-6 proves that the combination of the long stock and short call in column 4 is equal to selling a 100 Put at 3.00 in column 5.

Table 5-6 Synthetic Short Put: Long Stock at 100 and Short 100 Call at 3.00 Compared with Short 100 Put at 3.00

	Col 1	Col 2	Col 3	Col 4	Col 5
	Stock Price at Expiration	Long Stock @ 100	Short 100 Call @ 3.00	Combined P/(L)	Short 100 Put @ 3.00
Row 1	90	−10.00	+3.00	−7.00	−7.00
Row 2	95	−5.00	+3.00	−2.00	−2.00
Row 3	100	-0-	+3.00	+3.00	+3.00
Row 4	105	+5.00	−2.00	+3.00	+3.00
Row 5	110	+10.00	−7.00	+3.00	+3.00

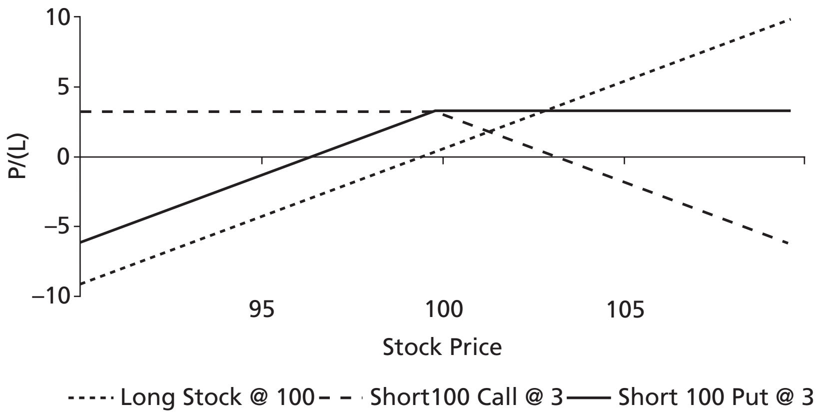


Figure 5-6 Synthetic Short Put = Long Stock and Short Call

Synthetic Short Put—Mechanics at Expiration

As with all the other synthetic positions, a consideration of what happens with the stock price above, below, or at the strike price at expiration leads to the conclusion that the synthetic short put position results in the same position, with the same profit or loss, as if a real 100 Put had been sold at 3.00 per share.

When the stock price closes above $100 at expiration, the short 100 Call is in the money and is assigned. Assignment of a short call creates a stock sale transaction, which sells the long stock. The effective price of selling stock in this example is $103 because the premium received for the call is added to the strike price of 100. Thus, with the stock price above the strike price at expiration, the synthetic short put position described in Table 5-6 and Figure 5-6 results in a profit of 3.00 and no stock position, just as a real short 100 Put sold at 3.00 would expire and leave no position.

If the stock price falls below $100 at expiration, then the short 100 Call is out of the money and expires worthless, and the long stock position remains intact. The effective purchase price of the long stock position in this example is $97, because the call premium received of 3.00 is substracted from the purchase price fo the stock of $100. Thus, with the stock price below the strike price at expiration, the synthetic short put position described in Table 5-6 and Figure 5-6 becomes a real long stock position at an effective price of $97—the same result as selling a real 100 Put at 3.00 and being assigned.

In the third outcome, the stock price closes exactly at $100 at expiration, the 100 short Call expires worthless, and the long stock position remains intact. However, if the stock were sold at $100 after the call expires worthless, then the result would be a profit of 3.00 from the short call and no position other than the cash reserve of $100. This is the same result as selling a 100 Put at 3.00 and holding a cash reserve of $100; at expiration, the put expires worthless, and the cash reserve remains intact.

The conclusion is that the two-part position of long stock and short call behaves exactly the same as a real short put position. It therefore deserves its name, *synthetic short put.*

When Stock Price ≠ Strike Price

Tables 5-1 through 5-6 and Figures 5-1 through 5-6 assumed that the stock price and the strike prices of the call and put were all 100. In the real world, however, the stock price is rarely equal to the strike price of the options. If the stock price were different in the preceding examples, the call and put prices also would vary. The resulting equivalencies, however, are the same! Table 5-7 and Figure 5-7 illustrate a real long stock position and a synthetic long stock position, assuming a stock price of $103, a 100 Call price of 4.50, and a 100 Put price of 1.50. In every row of Table 5-7, the profit or loss of the synthetic long stock position summarized in column 4 equals the profit or loss of the real long stock position in column 5. The price differences do not matter: The two-part position of a long 100 Call at 4.50 and a short 100 Put at 1.50 is equal to the long stock at $103.

Table 5-7 **Synthetic Long Stock When Stock Price ≠ Strike Price: Long 100 Call at 4.50 and Short 100 Put at 1.50 Compared with Long Stock at 103.00**

	Col 1	Col 2	Col 3	Col 4	Col 5
	Stock Price at Expiration	Long 100 Call @ 4.50	Short 100 Put @ 1.50	Combined P/(L)	Long Stock @ 103
Row 1	95	−4.50	−3.50	−8.00	−8.00
Row 2	100	−4.50	+1.50	−3.00	−3.00
Row 3	103	−1.50	+1.50	-0-	-0-
Row 4	105	+0.50	+1.50	+2.00	+2.00
Row 5	110	+5.50	+1.50	+7.00	+7.00

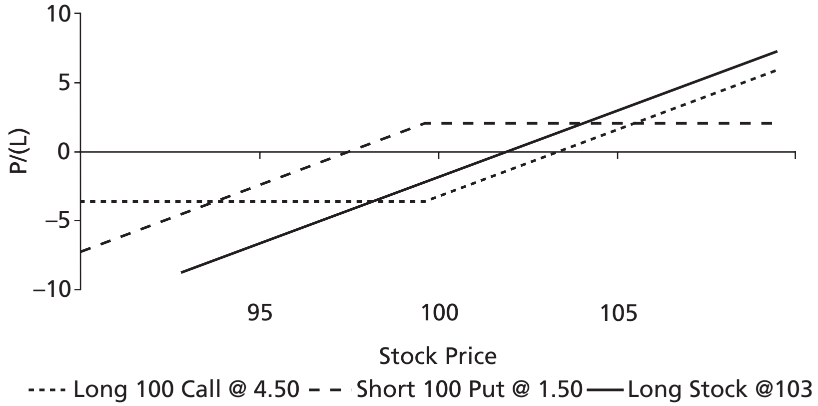


Figure 5-7 Synthetic Long Stock: Stock Price <>Strike Price

Table 5-8 Synthetic Long Call When Stock Price ≠ Strike Price: Long 100 Stock at 97.00 and Long 100 Put at 5.50 Compared with Long 100 Call at 2.50

	Col 1	Col 2	Col 3	Col 4	Col 5
	Stock Price at Expiration	Long Stock @ 97	Long 100 Put @ 5.50	Combined P/(L)	Long 100 Call @ 2.50
Row 1	90	−7.00	+4.50	−2.50	−2.50
Row 2	95	−2.00	−0.50	−2.50	−2.50
Row 3	97	-0-	−2.50	−2.50	−2.50
Row 4	100	+3.00	−5.50	−2.50	−2.50
Row 5	105	+8.00	−5.50	+2.50	+2.50

Table 5-8 and Figure 5-8 present a comparison of a long 100 Call and its synthetic equivalent assuming a stock price of $97, a 100 Call price of 2.50, and a 100 Put price of 5.50. As in all the other examples, the profit or loss of the synthetic long call summarized in column 4 always equals the profit or loss of the real long call in column 5. As explained next, all six synthetic relationships are related in the same way to their corresponding real positions through the put-call parity equation.

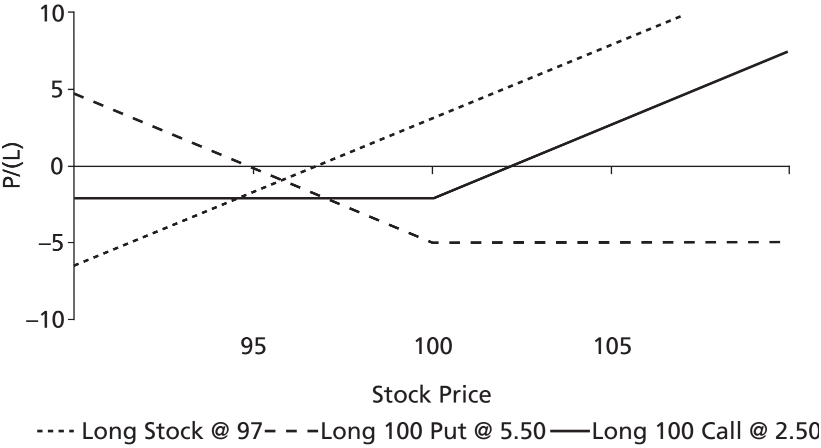


Figure 5-8 Synthetic Long Call: Stock Price <>Strike Price

The Put-Call Parity Equation

Synthetic positions exist because of the put-call parity relationship defined in line 1 of Table 5-9 as follows:

$$+\text{Stock} = +\text{call} - \text{put}$$

where + means "long" and − means "short."

This *put-call parity equation* can be read as "long stock equals long call plus short put." The assumptions of Table 5-9 are that the call and put have the same underlying, the same strike price, and the same expiration date; that the interest rate is zero; and that there are no dividends.

Lines 2 through 6 in Table 5-9 illustrate that the other five synthetic relationships can be derived from the first relationship. They follow algebraically from the basic equation in line 1. Consider line 2, in which "+put" is added to both sides of the equation in line 1. The result is "+Stock +put = +call" or, in words, "Long stock plus long put equals long call." Table 5-9 continues with lines 3 through 6, in which each of the remaining synthetic relationships is expressed as an equation.

Table 5-9 The Put-Call Parity Equation and Derived Variations

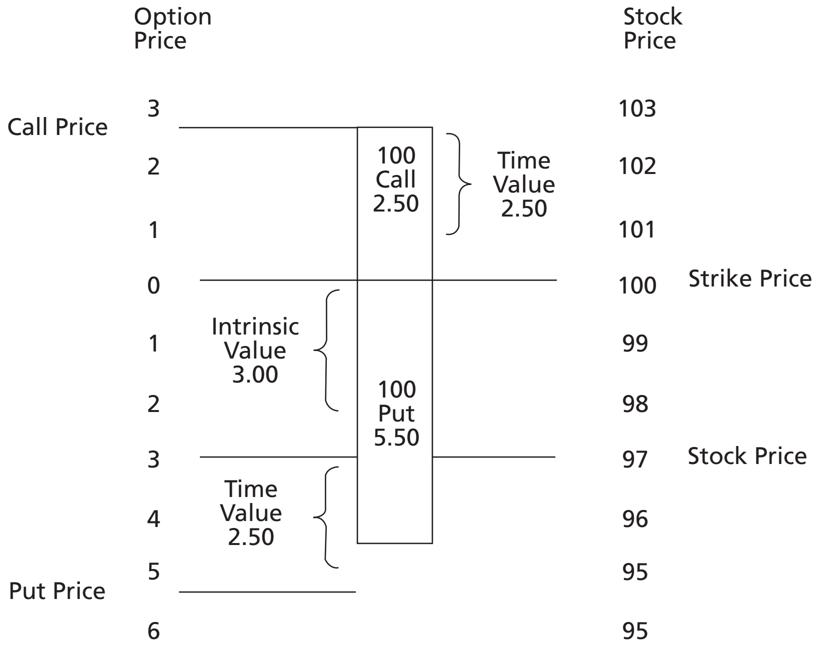
1	+Stock = +call – put (Long stock equals long call and short put.)	Basic put/call parity equation
2	+Stock + put = + call (Long call equals long stock and long put.)	Add put to both sides of 1.
3	+Put = +call – stock (Long put equals long call and short stock.)	Subtract stock from both sides of 2.
4	+Put – call = – stock (Short stock equals long put and short call.)	Subtract call from both sides of 3.
5	– Call = – stock – put (Short call equals short stock and short put.)	Subtract put from both sides of 4.
6	– Call + stock = – put (Short put equals long stock and short call.)	Add stock to both sides of 5.

Equality of Call and Put Time Premiums

The common element in the examples presented in Tables 5-1 through 5-8 and Figures 5-1 through 5-8 is the equality of call and put time premiums. As explained in Chapter 1, time premium (or time value) is the portion of an option's price in excess of intrinsic value, if any. In tables and figures 5-1 through 5-6, the prices of the 100 Call and 100 Put were both 3 and consisted entirely of time value because the stock price was \$100. Therefore, the time premiums of these options were equal.

In Table 5-7 and Figure 5-7, the stock price is \$103, the price of the 100 Call is 4.50, and the price of the 100 Put is 1.50. The price of the 100 Call consists of 3.00 of intrinsic value and 1.50 of time value. The 100 Put is out of the money, so its entire price of 1.50 consists of time value. Thus the time premiums of these options are also equal.

In Table 5-8 and Figure 5-8, the stock price is \$97, the price of the 100 Call is 2.50, and the price of the 100 Put is 5.50. The 100 Put, being in the money, has 3.00 of intrinsic value and 2.50 of time value. The price of the out-of-the-money 100 Call of 2.50 consists entirely of time value, which, again, equals the time value of the 100 Put. Figure 5-9 illustrates graphically how the time values of the 100 Call and 100 Put are equal in the example in Table 5-8 and Figure 5-8.



Stock Price	97.00
100 Call	2.50
100 Put	5.50

Figure 5-9 Equality of Time Premiums

Applying the Effective Stock Price Concept

The effective stock price concept is useful in calculating synthetic prices. The price of a call increases the effective stock price because if a call is exercised or assigned, the effective purchase or sale price of the stock is the strike price plus the call price. The price of a put, however, decreases the effective stock price because the effective purchase or sale price of the stock for an exercised or assigned put is the strike price minus the put price.

When the interest rate and dividends are assumed to be zero, the synthetic stock price is simply the effective stock price. Consider the prices in Tables 5-1 and 5-2 and Figures 5-1 and 5-2—a stock price of

$100, a 100 Call price of 3, and a 100 Put price of 3. The synthetic stock price is calculated by adding or subtracting the net option premium to or from the strike price. Specifically, 100 (the strike price) plus 3.00 (the price of the 100 Call) minus 3.00 (the price of the 100 Put) equals 100, which is the synthetic stock price.

In Table 5-7 and Figure 5-7, the synthetic stock price of $103 also can be derived from the call and put prices and the strike price: 100 (the strike price) plus 4.50 (the price of the 100 Call) minus 1.50 (the price of the 100 Put) equals $103 (the stock price). Finally, the stock price of $97 in Table 5-8 and Figure 5-8 can be calculated by adding the strike price (100) and the 100 Call price (2.50) and subtracting the 100 Put price (5.50). Once again, strike price plus call price minus put price equals stock price. The assumptions here are an interest rate of zero, no dividends, and no transaction costs. The next section considers differences in these factors.

The Role of Interest Rates and Dividends

Imagine that an investor with $100 cash available to invest wants to invest in the stock in Table 5-1 and Figure 5-1. Let's call the stock XYZ, and for simplicity, let's assume that options cover one share and that commissions are zero. This investor has two strategy choices. He or she can buy one share of XYZ for $100, or he or she can buy synthetic stock by simultaneously buying one XYZ 100 Call for 3.00 and selling one XYZ 100 Put for 3.00, for a net cost of zero. An understanding of the role of interest rates and dividends will tell us whether the investor will choose the real stock or the synthetic stock. This example also will reveal something about the relationship of option prices in the real world.

First, assume that the interest rate is above zero and that the stock does not pay a dividend. If the investor uses the $100 cash to buy the real stock, then the profit or loss will be determined solely by the price action of the stock. If, however, the investor creates a synthetic long stock position by buying a 100 Call for 3.00 and selling a 100 Put for 3.00 (net cost of zero), then the $100 cash will be available to earn interest. At expiration, if stock XYZ is above or below $100, then the synthetic stock position will become a real stock position via exercise of the call or assignment of the put. Regardless of whether the stock price is up, down, or unchanged, however, the investor will earn interest on the $100 in addition to the profit or loss from the stock price action. The conclusion is obvious: If the interest rate is above zero and there are no dividends, then the investor would choose the synthetic long stock over the real long stock.

Second, assume that the stock pays a dividend and that the interest rate is zero. In this scenario, there is no advantage to holding cash. The profit or loss of synthetic long stock will be determined solely by the price action of the stock. A real long stock position, however, will receive the dividend in addition to the profit or loss from the stock price action. Again, the conclusion is obvious: With positive dividends and an interest rate of zero, the investor would choose the real long stock over the synthetic long stock.

Third, assume that the interest rate is positive and that the stock pays a dividend. In this case, there is no clear choice. If the interest rate is higher than the dividend yield, then the synthetic long stock is preferred. If dividends are higher, however, then the real stock is preferred.

Given that the interest rate is above zero, the conclusion from the preceding example is that the prices in Table 5-1 and Figure 5-1 cannot exist in the real world. If investors could buy synthetic stock for the same price as real stock and earn interest during the life of the options, then no rational investor would ever buy stock. Rational investors would continue to buy calls and to sell puts as the call prices rose and the put prices declined until the choice between buying real stock and synthetic stock was equal. Consequently, in the real world, one would expect that the price of the 100 Call would be higher and that the price of the 100 Put would be lower than Table 5-1 and Figure 5-1 indicate.

Figure 5-10 shows a Single Option Pricing screen from Op-Eval Pro, the software that accompanies this book. The assumptions in the left columns are a stock price of $100, a strike price of $100, volatility of 25 percent, an interest rate of 5 percent, no dividends, and 30 days to expiration. Given these inputs, two of the outputs in the top rows of the columns are the 100 Call price of 3.08 and the 100 Put price of 2.70. These prices verify the thinking presented in the preceding paragraphs, that the time value of the 100 Call is greater than the time value of the 100 Put. While the exact monetary difference between the two prices is 38 cents, one might reasonably ask, "Is this significant?" or "Is there some rule that this follows?" The answer to both questions is, "Yes."

The interest-rate assumption, 5 percent, is the annual rate earned on short-term investments, such as the rate on 90-day Treasury bills. If one were to invest $100 for 30 days at 5 percent, the interest income would be 41 cents (100 × 0.05 × 30/365 = 0.41), which is very close to the 38-cent difference between the time values of the 100 Call and the 100 Put. Therefore, the rule to keep in mind is that for calls and

Op-Eval Pro: OP-EVAL - Single View

☐ EQUITY ☐ AMERICAN			CALL	PUT
STOCK PRICE	100.00	VALUE	3.08	2.70
STRIKE PRICE	100.00	DELTA	0.54	–0.47
VOLATILITY %	25.00	GAMMA	0.06	0.06
INTEREST RATE %	5.00	VEGA	0.11	0.11
DIVIDEND	0.00	7-THETA	–0.40	–0.32
DAYS TO EX-DIV	0.00	RHO	0.04	–0.03
DAYS TO EXPIRY	30.00	Decimal Places		2

Figure 5-10 First Example - Single Option Screen from Op-Eval Pro

puts with the same underlying, the same strike price, and the same expiration date, the difference in time values—call time value over put time value—is almost exactly equal to the interest on the strike price. The 3-cent difference between the calculated interest of 41 cents and the difference in time value of 38 cents stems partly from rounding and partly from some technical assumptions in the option-pricing formula.

The difference in time values—calls over puts—is significant because it proves there is no theoretical advantage to trading synthetic stock over real stock. Theoretically, an investor should be indifferent between trading the two. In the real world, however, factors such as transaction costs and bid-ask spreads lead most nonprofessional investors to trade real stock rather than synthetic stock. Chapter 6 will explore the role that interest rates and dividends play in arbitrage strategies.

To reinforce the concept that the time value of calls is greater than the time value of puts by the amount of interest, Figure 5-11 presents a second example of a Single Option Pricing screen from Op-Eval Pro. The assumptions in this example are a stock price of \$88, a strike price of \$85, volatility of 30 percent, an interest rate of 4 percent, no dividends, and 90 days to expiration. Given these inputs, the price of the 85 Call is 7.27, and the price of the 85 Put is 3.48. These prices also verify the theory asserting no theoretical advantage to trading synthetic stock. The time value of the 85 Call (4.27) is 79 cents greater than the time value of the 85 Put ($4.27 - 3.48 = 0.79$), and the interest on the strike price is 84 cents ($85 \times 0.04 \times 90/365 = 0.84$). Again, the difference between the calculated interest of 84 cents and the difference in time value of 79 cents is partly due to rounding and partly due to technical assumptions in the option-pricing formula. Nevertheless, a rule of option pricing is that for calls and puts with the same underlying, strike price, and expiration, the time value of the call is greater than the time value of the put by the amount of interest.

Op-Eval Pro: OP-EVAL - Single View

☐ EQUITY	☐ AMERICAN		CALL	PUT
STOCK PRICE	88.00	VALUE	7.27	3.48
STRIKE PRICE	85.00	DELTA	0.65	–0.36
VOLATILITY %	30.00	GAMMA	0.03	0.03
INTEREST RATE %	4.00	VEGA	0.16	0.16
DIVIDEND	0.00	7-THETA	–0.23	–0.17
DAYS TO EX-DIV	0.00	RHO	0.12	–0.07
DAYS TO EXPIRY	90.00	Decimal Places		2

Figure 5-11 Second Example - Single Option Screen from Op-Eval Pro

Summary

There are six *real* positions—long and short stock, long and short call, and long and short put. Corresponding to these real positions are six *synthetic* positions, each of which consists of positions in the other two instruments. The basic put-call parity equation is "+Call−put = + stock" or, in words, "Long call plus short put equal long stock," assuming that the call and put have the same underlying, the same strike price, and the same expiration date. The five other synthetic relationships logically follow from this basic equation.

Whether a stock price lands above, below, or at the strike price at expiration, a synthetic position results in the same position as a real position, with the same profit or loss, and with the same effective price as a real position.

If the interest rate is zero and there are no dividends, then the time value of calls and puts in synthetic positions would be equal. In the real world, however, the relationship of the time values depends on the relationship of the interest rate and dividends. Theoretically, investors should be indifferent between trading real positions and synthetic positions, but factors such as transaction costs and bid-ask spreads affect which types of positions traders actually choose.

Chapter 6

ARBITRAGE STRATEGIES

Arbitrage is skill number four that must be mastered by professional option traders. Knowledge of arbitrage strategies enables a trader to value options on a relative price basis, compare alternative strategies, and potentially lock in nearly riskless profits. Arbitrage strategies can be complicated, with higher and more numerous transaction costs. These strategies therefore fall primarily into the realm of professional option traders. Even advanced nonprofessional traders must be cautious in this area. This chapter will define arbitrage and explain three arbitrage strategies involving options: the conversion, the reverse conversion, and the box spread. Each explanation contains three parts: (1) an explanation of the concept of the strategy, (2) a presentation of the mechanics of the strategy, along with profit-and-loss diagrams, and (3) a discussion of pricing considerations.

Arbitrage—the Concept

Arbitrage is the trading process of buying in one market and selling in another market with the goal of earning nearly riskless profits. The classic example of arbitrage is a situation in which gold for June delivery in New York is trading at $800 per ounce and gold for July delivery in London is trading in $820 per ounce when delivery costs (i.e., shipping, insurance, and finance charges) are \$10 per ounce and delivery time is less than one month.

In such a situation, an arbitrager would, first, buy gold for June delivery in New York; second, sell gold for July delivery in London; third, take delivery in New York in June; and fourth, ship the gold to London in time for July delivery. When the buying, selling, and shipping agreements are finalized, the arbitrager would feel confident about realizing a \$10 per-ounce profit. The arbitrager seized the opportunity to "lock in a nearly riskless profit."

Note the profit is not risk-free. It can only be "nearly riskless" because unexpected things can happen to reduce or eliminate it. If the financing agreement called for a floating-rate loan, for example, the interest rate could rise. Also, export or import rules or tariffs could change and cause an increase in costs. There also could be shipping delays owing to a strike- or weather-related port closing. Any number of unpredictable events could turn opportunity into disaster. Although the risks of such events occurring may be low, they do exist and are what create the potential for arbitrage profits. Arbitragers earn profits—or incur losses—by assuming these risks.

This example illustrates that an *arbitrage pricing relationship* exists between gold prices in New York and gold prices in London. The example also illustrates that the pricing relationship is based on delivery costs. Similarly, arbitrage pricing relationships exist between any two markets where delivery between the markets is possible.

For option traders an arbitrage pricing relationship exists between options and stocks. Using synthetic relationships, a trader can buy shares of stock at a stock exchange and then sell those shares synthetically in the options market. A trader also can do the reverse by buying shares synthetically in the options market and selling them in the stock market. The next section explains the process of option-to-stock and option-to-option arbitrage and how professional option traders attempt to price certain strategies to profit from any arbitrage opportunities that might exist.

The Conversion

The basic options arbitrage strategy is known as the *conversion*, and it involves the purchase of real stock and the sale of synthetic stock. It is the fundamental building block of arbitrage techniques: All option-to-stock arbitrage techniques are based on the concepts involved in this strategy. A *conversion* is a three-part strategy consisting of long stock, long puts, and short calls on a share-for-share basis. The calls and puts have the same strike price and same expiration date. As the following examples show, in order for a conversion to be profitable, the time value of the call must be greater than the time value of the put by an amount sufficient to cover transaction costs, the cost of carry, and the desired profit.

Table 6-1 and Figure 6-1 illustrate a conversion that yields a gross profit of 75 cents per share before transaction costs and the cost of carry. The three-part position consists of one share of long stock purchased for $103, one long 100 Put purchased for 4.50, and one short 100 Call sold at 8.25. As column 5 in Table 6-1 and the solid line in Figure 6-1 show, the final outcome at expiration, a profit of 75 cents per share, is the same regardless of how high or low the stock price might rise or fall.

Assuming that the purchase price of the stock is borrowed, the net profit or loss of a conversion depends on the cost of carry. *Cost of carry*

Table 6-1 The Conversion: Long Stock at 103, Long 100 Put at 4.50, and Short 100 Call at 8.25

	Col 1	Col 2	Col 3	Col 4	Col 5
Row	Stock Price at Expiration	Long Stock @ 103	Long 100 Put @ 4.50	Short 100 Call @ 8.25	Combined P/(L)
1	90	−13.00	+5.50	+8.25	+0.75
2	95	−8.00	+0.50	+8.25	+0.75
3	100	−3.00	−4.50	+8.25	+0.75
4	105	+2.00	−4.50	+3.25	+0.75
5	110	+7.00	−4.50	−1.75	+0.75

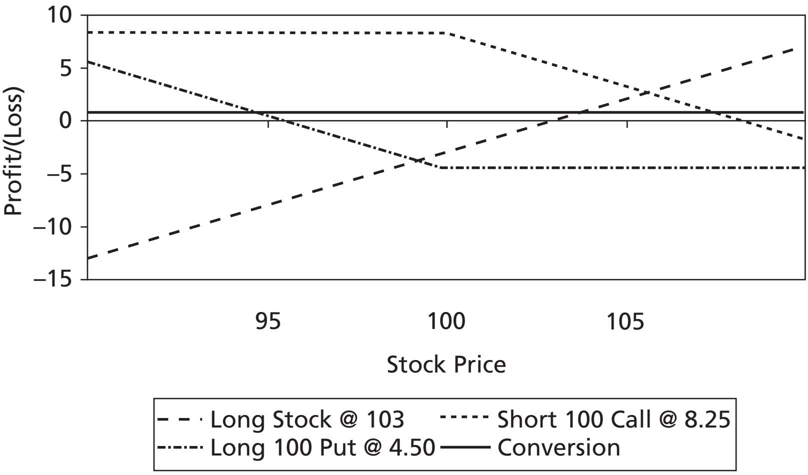


Figure 6-1 The Conversion

consists of borrowing costs and transaction costs associated with financing and trading stock and option positions.

Conversion—Outcomes at Expiration

Just as synthetic positions have three possible outcomes at expiration, Table 6-2 summarizes the same three possibilities for conversion positions. If the stock price closes below the strike price at expiration, outcome 1, then the long put is in the money. It therefore will be exercised, and the stock will be sold at the strike price. If the stock price is above the strike price at expiration, outcome 3, then the short call is in the money. It therefore will be assigned, and the stock will be sold at the strike price.

As Table 6-2 demonstrates, if the stock price is above or below the strike price at expiration, the stock will be sold at the strike price, and the conversion position will be closed. This result is the desired outcome because a profit will be realized, and no open position will remain with an attendant risk that could reduce the profit or create a loss.

A problem occurs, however, if the stock price closes exactly at the strike price.

Table 6-2 The Conversion at Expiration

Short	1 XYZ 100 Call @	8.25	= Short stock (synthetically) at 103.75
Long	1 XYZ 100 Put @	4.50	

Long XYZ stock @ 103.00 = *long stock at 103.00*
Combined position at expiration = no position (gross profit 0.75)

Three Possible Outcomes at Expiration

#1 XYZ < Strike	#2 XYZ = Strike	#3 XYZ > Strike
Call expires worthless	Call expires worthless	Call assigned (sell stock)
Put exercised (sell stock)	Put expires worthless	Put expires worthless
Shares sold at strike price	Shares are kept	Shares sold at strike price
Result: No position	Result: Long stock	Result: No position

Pin Risk

Pin risk is the possibility that the stock price closes exactly at the strike price at expiration. When this happens, the stock is said to be *pinned to the strike.*

As outcome 2 in Table 6-2 indicates, if the stock price settles exactly at the strike price at expiration, then, in theory, both the call and the put expire worthless, leaving the long stock position intact. Exercising the puts could eliminate the risk of the long stock position. This action assumes, however, that none of the short calls will be assigned. In reality, some of the calls will be assigned, but it is impossible to predict how many.

If all the puts are exercised, and if some of the calls are assigned, a trader will be left with a short stock position. This position involves substantial risk because exercise and assignment at expiration always occur on Friday afternoon, but the resulting short stock position cannot be closed until Monday morning at the earliest. This sequence produces what traders call *over-the-weekend risk.* Similarly, if none of the puts are exercised, and if only some of the calls are assigned, then the trader will be left with a long stock position that must be carried over the weekend.

Given the uncertainty about how many calls, if any, will be assigned, a trader has to decide how many puts to exercise. No solution exists that eliminates the over-the-weekend risk created by pin risk. However, market makers have developed a common practice to deal with this situation.

Marker makers typically respond to pin risk by exercising half the long puts in their conversion, hoping that only half their short calls will be assigned. Undoubtedly, either more or less than half the calls will be assigned, so there will be a stock position to close on Monday morning. All a trader can do is hope that the experience will not be too costly. You can be sure that pin risk has caused many market makers to endure some sleepless weekends. Pin risk points up one of the reasons arbitrage is best left to professional traders.

Pricing a Conversion

One way to conceptualize how to price conversions is to compare them with Treasury bills. Anyone can purchase Treasury bills for an amount less than the face value, that is, at a discount, and receive the face value at maturity. A one-year $1,000 Treasury bill, for example, might be purchased for $970. One year later, at maturity, the purchaser gets back a $1,000 payment, $30 of which is interest income and $970 of which is return of principal. The interest rate earned in this example is 30 divided by 970, or approximately 3.1 percent.

Conceptually, the value of a conversion is the discounted present value (DPV) of its strike price. The DPV is the investment, like the amount paid for a Treasury bill. The strike price is the amount received at expiration, like the Treasury bill maturing at face value. The difference between DPV and strike price is the income earned, like the difference between what was paid for the Treasury bill and the face value received at maturity.

Consider, for example, stock purchased for $92.20, a 40-day 90 Put purchased for $2.30, and a 40-day 90 Call sold at $4.80. This conversion's net investment totals $89.70 (92.20 + 2.30 − 4.80 = 89.70), and the profit before costs equals 0.30 (90.00 – 89.70). \$0.30 income in 40 days from an investment of \$89.70 approximately equates to an annual interest rate of 3 percent (0.30 ÷ 89.70 × 365/40).

Note for mathematicians: The calculations in the preceding paragraph and the calculations throughout this book are made using simple interest rather than compound interest. Simple interest is used for ease of presentation. The discussions are intended to be conceptual and accessible to nonmathematicians. For short periods of time, which is typical for arbitrage positions, the difference is insignificant.

After seeing how a conversion is constructed and how its profitability is calculated, you may reasonably ask, "How much profit is sufficient to justify a conversion position?" The answer depends on three factors: costs (including borrowing costs), the target profit, and the competitive environment.

Tables 6-3 through 6-5 provide an example, in three parts, of how a conversion might be priced. Table 6-3 states the 11 initial assumptions. The strike price (1) is 55. The stock price (2) is \$57.70. The price of the 55 Put (3) is 1.45, and the price of the 55 Call (4) is unknown. The borrowing rate (5) of 5 percent and the 60 days to expiration (6) lead to the DPV of the strike price (7) of 54.55. There are also trading costs (8–10) of 1 cent per share to trade stock (buy and sell), to trade each option, and for option exercise or assignment. These transaction costs lead to total costs of 4 cents per share for opening the position (i.e., buy stock, buy put, and sell call) and for closing (i.e., either the put is exercised or the call is assigned). Finally, the target profit (11) is 5 cents per share in this example.

The 10 known assumptions are used to solve for the unknown one, which is the price of the 55 Call (4). The question is, "What sale price for the 55 Call will yield the target profit?"

Table 6-4 contains the second part of pricing a conversion, which calculates the sale price of the 55 Call in two steps. The first step figures the net investment per share. In the case of a conversion, the *net investment per share* is the net cost of the position that yields the target profit if held to expiration. The net investment per share equals

Table 6-3 Pricing a Conversion—Part 1: Stating the Assumptions

Assumptions:	1	Strike price	55.00	
	2	Stock price	57.70	
	3	Price of 55 Put	1.45	
	4	Price of 55 Call	?	
	5	*Borrowing rate*	5%	
	6	Days to expiration	60	
	7	DPV of strike price = strike ÷ [1 + (0.05 × 60/365)]	54.55	
	8	Stock cost	0.01 per share	Transaction costs = 0.04
	9	Option Cost (call and put)	0.02 per share	
	10	Exercise/ assignment cost	0.01 per share	
	11	Target profit	0.05 per share	
Question:		What is the sale price of the 55 Call?		

the DPV of the strike price (line 7 in Table 6-3) minus the sum of costs plus target profit (lines 8–11). The net investment per share, therefore, is $54.46. Calculations are made on a per-share basis because a market maker cannot know in advance how many options will come into the marketplace and, as a result, how many shares will need to be traded. Calculating a per-share amount facilitates flexible trades—a trader may trade in small or large quantities but use the same pricing system.

Remember that the conceptual value of a conversion is the DPV of its strike price. The strike price is used for the DPV calculation because the strike price is the amount received at expiration after the call is assigned or the put is exercised. Regardless of whether the stock price is above, below, or at the strike price, when a conversion is established, the net investment always will be less than the strike price because stock plus call minus put must equal the DPV of the strike price in order for the conversion to be profitable.

Step 2 in Table 6-4 uses basic algebra to calculate 4.69 as the price of the 55 Call that makes the conversion position (stock plus put minus call) equal the net investment of 54.46.

Table 6-4 Pricing a Conversion—Part 2: Calculate the Sale Price of the 55 Call

Step 1:	Calculate the net investment per share (NI) NI = DPV of strike minus the sum of transaction costs plus target profit NI = \$54.55 − (0.04 + 0.05) = \$54.46
Step 2:	Sell the 55 Call at a price so that the net cost of the three-part position (long stock, long 55 Put, and short 55 Call) equals the NI in step 1. 2-1 If + stock + 55 Put − 55 Call = + NI 2-2 Then + 55 Call = + stock + 55 Put − NI 2-3 Therefore, + 55 Call = 57.70 + 1.45 − 54.46 = 4.69

The third and final part of pricing a conversion consists of analyzing cash flows, net profit, and time values, which is accomplished in Table 6-5. The revenue (1) is the amount received at expiration, which is equal to the strike price of 55.00 per share in this example. The cost of the position (2) is the net investment, and the difference between revenue and cost is the gross profit (3), or 0.54 per share in this example. The borrowing costs (4) are calculated by multiplying the net investment times the borrowing rate and come to 0.44. The gross profit minus the borrowing costs leaves a profit before transaction costs (5) of 10 cents per share. Subtracting transaction costs of 4 cents per share (6) results in the net profit (7) of 6 cents per share. The actual net profit of 6 cents exceeds the target profit of 5 cents owing to rounding.

Lines 8 through 10 in Table 6-5 analyze the relationship of the time value of the 55 Call and the time value of the 55 Put. In this case, the stock price is 55.70, and the prices of the 55 Call and 55 Put are 4.69 and 1.45, respectively. The time value of the 55 Call (8) therefore is 1.99, the time value of the 55 Put (9) is 1.45, and the difference between them (10) is 0.54. From Table 6-4, 0.54 is the difference between the strike price and the net investment (55.00 – 54.46).

The conclusion of this three-part exercise is stated at the bottom of Table 6-5. For a conversion, the difference between the time value of the call and the time value of the put equals the gross profit, which is the difference between the strike price and the net investment.

Table 6-5 Pricing a Conversion—Part 3: Analysis of Cash Flows, Net Profit, and Time Values

1	Revenue = amount received at expiration = strike price	= 55.00
2	− Cost = net debit paid for position (NI)	−54.46
3	= Gross profit	= 0.54
4	− Borrowing costs = 54.46 × (0.05 × 60/365)	−0.44
5	= Profit before transaction costs	= 0.10
6	− Transaction costs	−0.04
7	= Net profit	= 0.06
Analysis of Time Values		
8	Time value of 55 Call = price − intrinsic = 4.69 − 2.70	= 1.99
9	Time value of 55 Put = price − intrinsic = 1.45 − 0.00	= 1.45
10	Time value of call − time value of put	= 0.54

Conclusion: For a conversion, the difference between the time value of the call and the time value of the put (10) equals the gross profit (3).

In the specific example illustrated in Tables 6-3 through 6-5, the conversion position yields a profit of 6 cents per share because the time value of the 55 Call is 54 cents greater than the time value of the 55 Put. The result will differ if the borrowing rate or the transaction costs or both change. Market makers therefore must constantly keep their interest rate and costs up to date.

The Role of Competition

Competition may force market makers to accept conversion positions that produce a profit less than the target profit. In the preceding example, for instance, with the stock being offered at $57.70 and the 50 Put being offered at 1.45, a market maker seeking a 5-cent-per-share profit would offer the 50 Call at 4.69. However, if this call is offered at 4.67 by other traders, then the market maker must choose between doing some business at a lower rate of profit or foregoing that opportunity. Of course, there may be options at other strike prices that offer higher-yielding conversions, and there might be other stocks with better opportunities. Deciding which conversion opportunities are "acceptable" is part of the art of being a market maker.

Pricing a Conversion with Dividends

A *dividend* is a payment made by a company to its shareholders. Not all companies with publicly traded stocks pay dividends, but those that do pay dividends typically pay them on a regular and predictable basis. Many companies pay dividends quarterly, but some pay dividends semiannually or annually, and some pay a relatively small quarterly dividend and then an extra dividend at year end if earnings are good enough to support such a payment.

Dividends have an impact on the pricing of conversions because a dividend is extra income for the stockowner. Tables 6-6 through 6-8 show the three-part process of pricing a conversion when dividends are included.

Table 6-6 makes the same assumptions for stock price, put price, borrowing rate, etc. as stated in Table 6-3 with one addition of a 22-cent dividend. Tables 6-6 through 6-8 demonstrate that the addition of a 22-cent dividend reduces the price of the 55 Call by 22 cents, from 4.69 to 4.47.

Line 8 of Table 6-6 calculates the DPV of the *strike price plus dividend* rather than just the strike price, as in Table 6-3, because the dividend revenue to the stock owner affects the price of a conversion position. Although there is a timing difference between receipt of the strike price (at expiration) and receipt of the dividend (generally later), the thinking is that getting $55 at expiration and getting 22 cents about a month later is almost the same thing as getting $55.22 today. Traders also generally ignore the lost interest on the dividend, 22 cents in this example, because it usually amounts to less than 1 cent.

Table 6-7 shows how the sale price of the 55 Call is calculated using the DPV of the strike price plus dividend from line 8 in Table 6-6, and Table 6-8 analyzes the cash flow, net profit, and time values.

Table 6-6 Pricing a Conversion with Dividends—Part 1: Stating the Assumptions

Assumptions:	1	Strike price	55.00		
	2	Stock price	57.70		
	3	Price of 55 Put	1.45		
	4	Price of 55 Call	?		
	5	Borrowing rate	5%		
	6	Dividend (ex-date before expiration) 0.22			
	7	Days to expiration	60		
	8	DPV of strike price + dividend = (strike + div) ÷ [1 + (0.05 × 60/365)]	54.77		
	9	Stock cost	0.01 per share		Transaction costs = 0.04
	10	Option cost (call and put)	0.02 per share		
	11	Exercise/assignment cost	0.01 per share		
	12	Target profit	0.05 per share		
Question:		What is the sale price of the 55 Call?			

Table 6-7 Pricing a Conversion with Dividends—Part 2: Calculate the Sale Price of the 55 Call

Step 1:	Calculate the net investment per share (NI) NI = DPV of strike + dividend minus the sum of costs plus target profit NI = \$54.77 − (0.04 + 0.05) = \$54.68
Step 2:	Sell the 55 Call at a price so that the net cost of the three-part position (long stock, long 55 Put, and short 55 Call) equals the NI in step 1. 2-1 If + stock + 55 Put − 55 Call = + NI 2-2 Then + 55 Call = + stock + 55 Put − NI 2-3 Therefore, + 55 Call = 57.70 + 1.45 − 54.68 = 4.47

The conclusion of pricing conversions with dividends is stated at the bottom of Table 6-8. For a conversion when there is a dividend, the difference between the time value of the call and the time value of the put equals the gross profit. The net investment, however, is reduced by the dividend.

Table 6-8 **Pricing a Conversion with Dividends—Part 3: Analysis of Cash Flows, Net Profit, and Time Values**

1	Revenue = amount received at expiration = strike price	= 55.00
2	− Cost = net debit paid for position (NI)	−54.68
3	= Gross profit	= 0.32
4	− Borrowing costs = 54.46 × (0.05 × 60/365)	− 0.45
5	= Loss before transaction costs	= −0.13
6	− Transaction costs	− 0.04
7	= Loss before dividend	= −0.17
8	+ Dividend	+ 0.22
9	= Net profit	= +0.05
Analysis of Time Values		
10	Time value of 55 Call= price – intrinsic = 4.47 − 2.70	= 1.77
11	Time value of 55 Put= price – intrinsic = 1.45 − 0.00	= 1.45
12	Time value of call – time value of put	= 0.32

Conclusion: For a conversion when there is a dividend, the difference between the time value of the call and the time value of the put (12) equals the gross profit (3). The net investment, however, is reduced by the dividend.

The Ex-Dividend Date

Timing is important when dividends are involved because there are specific dates that are significant in the dividend-paying process. The *ex-dividend date* is the first day that a new stock purchaser will not receive the next dividend. On this day, the stock is trading without the dividend, or ex-dividend. In Table 6-6, the ex-dividend date, or ex-date, is prior to option expiration.

The ex-date is crucial because of its relationship to another date that follows called the *record date*. The record date is the day that a stock purchaser must be a shareholder on the company's books to qualify for the dividend payment. Stock transactions typically are processed in a manner known as $T + 3$, which means "transaction date plus three business days." The *transaction date* is the day of the stock trade. The *settlement date* is three days after the transaction date, when cash and ownership certificates are exchanged. In order to receive a dividend, the settlement date must be on or before the record date. A trade made two days before the record date will not be settled until the day after the record date. That day, therefore, is the ex-date.

For example, assume that the record date is Friday, May 7. Stock must be owned on this date in order to receive the dividend. If stock is purchased on Tuesday, May 4, the transaction date, the settlement date will be on Friday, May 7, which is $T + 3$. The new owner receives the dividend as the owner on the record date. Shares purchased on Wednesday, May 5, however, will not be settled until Monday, May 10, and will not be eligible to receive the dividend. May 5 is the ex-date in this example.

Pricing Conversions by Strike Price

The strike price affects the conversion-pricing relationship because the DPV changes as the strike price changes. As a result, the amount by which the time value of the call must exceed the time value of the put also changes. Table 6-9 uses the same assumptions as Tables 6-3 through 6-5. The stock price is 57.70, there are 60 days to expiration, the borrowing rate is 5 percent, and there are no dividends.

Table 6-9 Pricing Conversions by Strike Price

	Col 1	Col 2	Col 3	Col 4	Col 5
Row	Strike Price	DPV of Strike	Strike Minus DPV of Strike	Costs Plus Target Profit	Time Value of Call Minus Time Value of Put
1	45	44.63	0.37	0.09	0.46
2	50	49.59	0.41	0.09	0.50
3	55	54.55	0.45	0.09	0.54
4	60	59.51	0.49	0.09	0.58
5	62	64.47	0.53	0.09	0.62

DPV = discounted present value.

Assumptions: 60 days to expiration, interest rate of 5%, no dividends, costs of 0.04, and target profit of 0.05.

Sample DPV calculation: 55 ÷ [1 + (0.05 × 60/365)] = $54.55.

In row 1 of Table 6-9, the strike price is 45 (column 1), the DPV of the strike is 44.63 (column 2), the difference between the strike price and the DPV is 0.37 (column 3), and the costs and target profit are 9 cents per share (column 4). In order to make a profit in this example, the time value of the 45 Call therefore must be greater than the time value of the 45 Put by 46 cents (column 5). In row 2, the strike price is 50, and the difference of time value of the call minus time value of the put is 50 cents.

As the strike price rises by $5.00 in each row in Table 6-9, the difference between call and put time values increases by 4 cents. Since the DPV of the strike price increases as the strike price increases, a market maker must borrow more money to finance a conversion position. Thus borrowing costs increase. The difference between call time value and put time value increases to cover these additional costs.

The Concept of Relative Pricing

The essence of the conversion relationship is that given a strike price, costs, and a target profit, a constant difference between the time value of the call and the time value of the put always will exist. *Relative pricing* means that the price of a call, a put, or a stock can be calculated if prices of the other two are known. In Table 6-3, the time value of the 55 Call had to be 69 cents greater than the time value of the 55 Put. Therefore, if the prices of the stock and the 55 Put are known, then the price of the 55 Call can be calculated. Also, if the prices of the stock and the 55 Call are known, then the price of the 55 Put can be calculated, and if the prices of the 55 Call and 55 Put are known, then the price of the stock can be calculated.

In the days when option trading was conducted in open outcry, market makers would start their days by calculating the relative prices of calls to puts by strike price. If trading the 60-strike options in row 4 of Table 6-9, for example, a market maker would note that the time value of the 60 Call must be 58 cents greater than the time value of the 60 Put in order to make a 5-cent-per-share profit on a conversion.

Then, during the day, if 60 Puts were offered at 3.10 when stock was offered at 60.47, the market maker would offer 60 Calls at 4.15. If someone were to buy the calls for 4.15 (and the market maker sold them), the market maker would then simply buy the stock at 60.47 and buy the puts at 3.10 to complete the conversion and thereby lock in a 5-cent-per-share profit.

As stock prices changed and as option orders entered the pit, the market maker would constantly use the 58-cent difference to calculate the relative prices of 60 Calls and 60 Puts and make bids and offers accordingly.

In today's electronic trading environment, computers handle the pricing of options—and therefore the pricing of conversions. Nevertheless, the same concepts apply, and today's option traders must understand these concepts for those occasions when they need to override the computer or adjust its assumptions.

The Reverse Conversion

As its name implies, the reverse conversion or, simply, the reversal is the opposite of the conversion. It involves the purchase of synthetic stock and the sale of real stock. A *reverse conversion* is a three-part strategy consisting of short stock, short puts, and long calls on a share-for-share basis. The calls and puts have the same strike price and same expiration date. A reverse conversion is established for a net credit, which is invested at the risk-free rate. To be profitable, the interest earned from the net credit must be greater than transaction costs plus the difference of call time value minus put time value.

Table 6-10 and Figure 6-2 illustrate a reverse conversion that yields a gross profit of 75 cents per share before transaction costs and interest. The three-part position consists of one share of stock sold short at $102, one short 100 Put sold at 5.25, and one long 100 Call purchased for 6.50. As column 5 in Table 6-10 and the solid line in Figure 6-2 show, the final outcome at expiration, 75 cents per share profit, is the same regardless of the stock price.

Table 6-10 The Reverse Conversion: Short Stock at 102, Short 100 Put at 5.25, and Long 100 Call at 6.50

	Col 1	Col 2	Col 3	Col 4	Col 5
Row	Stock Price at Expiration	Short Stock @ 102	Short 100 Put @ 5.25	Long 100 Call @ 6.50	Combined P/(L)
1	90	+12.00	−4.75	−6.50	+0.75
2	95	+7.00	+0.25	−6.50	+0.75
3	100	+2.00	+5.25	−6.50	+0.75
4	105	−3.00	+5.25	−1.50	+0.75
5	110	−8.00	+5.25	+3.50	+0.75

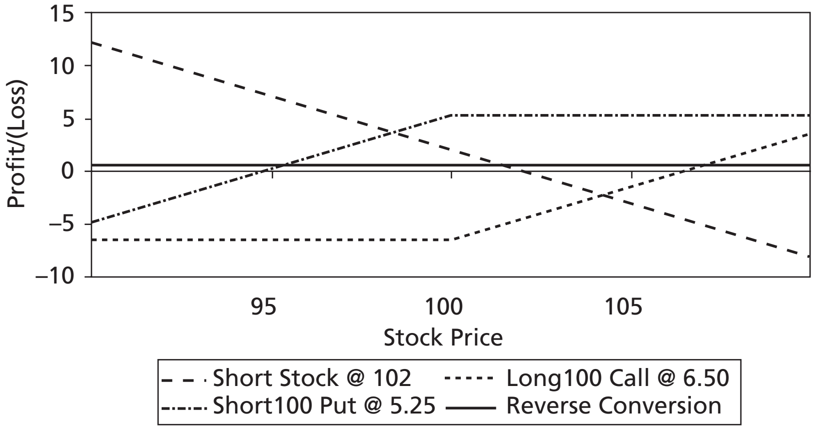


Figure 6-2 The Reverse Conversion

This example assumes that the net credit proceeds from the reverse conversion are invested. Consequently, the net profit or loss of a reverse conversion depends on the amount of interest earned.

Reverse Conversion—Outcomes at Expiration

As with synthetic positions and conversions, there are three possible outcomes at expiration for reverse conversions. Table 6-11 summarizes the possibilities. If the stock price closes below the strike at expiration, outcome 1, then the short put is in the money. It therefore will be assigned, and the stock will be purchased at the strike price. If the stock price is above the strike price at expiration, outcome 3, then the long call is in the money. It therefore will be exercised, and the stock will be purchased at the strike price.

It does not matter if the stock price closes above or below the strike price at expiration; the stock will be purchased, and the reverse conversion position will be closed. This result is the desired outcome because a profit will be realized, and the position will be closed. Then there will be no open position with the attendant risk that could reduce the profit or create a loss.

Reverse Conversion—Pin Risk

Pin risk poses as much of a problem for the reverse conversion as it does for the conversion. When the stock price closes exactly at the strike price at expiration, the trader must make a difficult decision.

Table 6-11 The Reverse Conversion at Expiration

Long 1 XYZ 100 Call @ 6.50 Short 1 XYZ 100 Put @ 5.25	= Long stock (synthetically) @ 101.25

Short XYZ stock @ 102.00 = *short stock @ 102.00*
Combined position at expiration = no position (gross profit 0.75)

Three Possible Outcomes at Expiration

1 XYZ < Strike	2 XYZ = Strike	3 XYZ > Strike
Call expires worthless	Call expires worthless	Call exercised (buy stock)
Put assigned (buy stock)	Put expires worthless	Put expires worthless
Shares bought for strike price	Short shares are kept	Shares bought for strike price
Result: No position	Result: Short stock	Result: No position

The three-part position of short stock, short puts, and long calls produces uncertainty about how many puts, if any, will be assigned. If all the calls are exercised but only some of the puts are assigned, then a long stock position is created.

Similarly, if the calls are not exercised, and if some of the puts are not assigned, then a short stock position remains. In either case, a stock position must be carried over the weekend with all the related risk. Just as with a conversion, there is no solution that eliminates this over-the-weekend risk. One common practice is to exercise half the calls and hope that only half the puts are assigned. Whatever stock position remains is then closed at the open on Monday.

Pricing a Reverse Conversion

Given the high probability that the stock price will be above or below the strike price at expiration, traders can reasonably expect that the call will be exercised or the put will be assigned. Consequently, the reverse conversion strategy will result in a cash payment equal to the strike price at expiration. Unlike the conversion, which resembles a Treasury bill, the reverse conversion can be compared to borrowing money that is repaid with a maturing investment. When a reverse conversion is established, stock is sold short. The proceeds from that short sale are invested at the risk-free rate. Subsequently, at option expiration, the money-market funds, including interest earned, are used to repurchase the stock at the strike price.

For example, a trader creating a reverse conversion might sell stock short at $34.55, sell a 55-day 35 Put for $2.10, and purchase a 55-day 35 Call for $1.75. The net credit available to invest is $34.90 (34.55 + 2.10 − 1.75 = 34.90). This position results in a loss before interest of 0.10 (35.00 paid at expiration minus 34.90 net credit received for establishing the position). Assuming 4 percent interest for 55 days on $34.90, the interest income is approximately 21 cents (34.90 × 0.04 × 55/365). Therefore, the loss before interest of 0.10 becomes a net profit after interest of 0.11, or 11 cents per share, before transaction costs.

The profitability of a reverse conversion depends on three factors: transaction costs, the lending rate, and the competitive environment.

Tables 6-12 through 6-14 show, in three parts, how a reverse conversion might be priced. Table 6-12 makes 11 initial assumptions. The strike price (1) is 55. The stock price (2) is $57.70. The price of the 55 Put (3) is 1.45, and the price of the 55 Call (4) is unknown. The lending rate (5) of 4 percent and the days to expiration (6) of 60 lead to the DPV of the strike price (7) of 54.64. Trading costs (8–10) consist of 1 cent per share to trade stock, to trade each option, and for option exercise or assignment. These transaction costs lead to total costs of 4 cents per share for opening the position (i.e., short stock, short put, and buy call) and for closing the position (i.e., either the call is exercised or the put is assigned). Finally, the target profit (11) is 5 cents per share in this example.

The 10 known assumptions provide all the information needed to solve for the unknown price of the 55 Call. The question is, "What is the purchase price of the 55 Call that yields the target profit?"

Part 2 of pricing a reverse conversion in Table 6-13 shows that the purchase price of the 55 Call can be calculated in two steps. The first

Table 6-12 Pricing a Reverse Conversion—Part 1: Stating the Assumptions

Assumptions:	1	Strike price	55.00	
	2	Stock price	57.70	
	3	Price of 55 Put	1.45	
	4	Price of 55 Call	?	
	5	*Lending rate*	4%	
	6	Days to expiration	60	
	7	DPV of strike price = strike ÷ [1 + (0.04 × 60/365)]	54.64	
	8	Stock cost	0.01 per share	Transaction costs =0.04
	9	Option cost (call and put)	0.02 per share	
	10	Exercise/assignment cost	0.01 per share	
	11	Target profit	0.05 per share	
Question:		What is the purchase price of the 55 Call?		

step calculates the funds required to invest, or the net credit, which is the DPV of the strike price plus costs plus the target profit. From line 7 in Table 6-12, the DPV of 55, using the lending rate of 4 percent, is $54.64. Adding costs of 0.04 and the target profit of 0.05 yields a net credit required of 54.73. Note that this formula uses the strike price for the DPV calculation because it is the strike price that will be paid at expiration.

Step 2 in Table 6-13 uses basic algebra to find that the price of the 55 Call should be 4.42 to make the target profit.

As with the conversion, this formula for reverse conversions calculates costs and target profit on a per-share basis because a trader cannot know in advance how many options might come into the marketplace and how many shares need be traded. A per-share estimate makes it possible to trade in small or large quantities and still get the target profit.

The third and final part of pricing a reverse conversion involves analyzing the cash flows, net profit, and time values, as shown in Table 6-14. The revenue (1) is 54.73, which is the net credit received when the reverse conversion is established, as calculated in step 1 of Table 6-13. The cost (2) is the amount paid at expiration, which is the strike price of 55, and the gross loss (3) of −0.27 is the difference between cost and revenue. The interest income (4) of 0.36 is based

Table 6-13 **Pricing a Reverse Conversion—Part 2: Calculate the Purchase Price of the 55 Call**

Step 1:	Calculate the net credit required per share (NC) NC = DPV of strike plus transaction costs plus target profit margin NC = $54.64 + 0.04 + 0.05 = $54.73
Step 2:	Buy the 55 Call at a price so that the NC for the three-part position (short stock, short 55 Put, and long 55 Call) equals the NC in step 1. 2-1 If − stock − 55 Put + 55 Call = −NC 2-2 Then + 55 Call = + stock + 55 Put − NC 2-3 Therefore, + 55 Call = +57.70 + 1.45 − 54.73 = 4.42

on the net credit and the lending rate. The profit before transaction costs (5) of 0.09 is the difference between the interest income and the gross loss. Subtracting transaction costs of 4 cents per share (6) results in the net profit (7) of 5 cents per share.

Lines 8 through 10 in Table 6-14 analyze the relationship of the time value of the 55 Call and the time value of the 55 Put. In this case, the time value of the 55 Call (8) is 1.72, and the time value of the 55 Put (9) is 1.45, for a difference (10) of 0.27.

The conclusion of this exercise is stated at the bottom of Table 6-14. For a reverse conversion, the difference between the time value of the call and the time value of the put equals the absolute value of the gross loss.

Competition and Reverse Conversions

Competition may force market makers to accept reverse conversion positions that produce a profit less than the target profit. In the

Table 6-14 Pricing a Reverse Conversion—Part 3: Analysis of Cash Flows, Net Profit, and Time Values

1	Revenue = net credit received for establishing position	54.73
2	−Cost = amount paid at expiration = strike price	= −55.00
3	= Gross loss	= (0.27)
4	+ Interest income = 54.73 × (0.04 × 60/365)	+ 0.36
5	= Profit before transaction costs	= 0.09
6	− Transaction costs	−0.04
7	= Net profit	= 0.05
	Analysis of Time Values	
8	Time value of 55 Call = price − intrinsic = 4.42 − 2.70	= 1.72
9	Time value of 55 Put = price − intrinsic = 1.45 − 0.00	= 1.45
10	Time value of call − time value of put	= 0.27

Conclusion: For a reverse conversion, the difference between the time value of the call and the time value of the put (10) equals the absolute value of the gross loss (3).

preceding example, for instance, when the bid price for the stock is $57.70 and the bid price for the 55 Put is 1.45, a market maker seeking a 5-cent-per-share profit would bid 4.42 for the 55 call. However, if other market makers are bidding 4.44 for this call, then the market maker must choose between doing some business at a lower rate of profit and doing no business. Of course, there may be options at other strike prices that offer higher-yielding reverse conversions, and there may be other stocks with better opportunities. Deciding which opportunities are "acceptable" is part of the art of being a market maker.

Pricing a Reverse Conversion with Dividends

When stock that pays a dividend is sold short, the borrower of the stock must pay the dividend to the lender, or owner, of the stock. Dividends therefore increase costs for a reverse conversion position rather than reducing costs, as they do for conversion positions.

Tables 6-15 through 6-17 expand the pricing calculation for reverse conversions to include dividends. Table 6-15 states the same assumptions for stock price, put price, borrowing rate, etc. as stated in Table 6-12 with one difference, the addition of a 22-cent dividend that reduces the call price by 22 cents, from 4.42 (Table 6-13, line 2–3) to 4.20.

In Table 6-15, line 8, the DPV calculation begins with "Strike + dividend" rather than "Strike," as in Table 6-12, because the dividend is an extra cost to the short seller of stock. Although there is a timing difference between payment of the strike price (at expiration) and payment of the dividend, the thinking is that paying $55 today and paying 22 cents in about a month is almost the same thing as paying $55.22 today. Traders generally ignore the interest on the 22 cents because it usually amounts to less than 1 cent.

Table 6-16 shows how to calculate the purchase price of the 55 Call using the DPV of the strike price plus dividend from line 8 in Table 6-15, and Table 6-17 analyzes the cash flow, net profit, and time values. The conclusion of pricing reverse conversions with dividends

Table 6-15 Pricing a Reverse Conversion with Dividends—Part 1: Stating the Assumptions

Assumptions:	1	Strike price	55.00	
	2	Stock price	57.70	
	3	Price of 55 Put	1.45	
	4	Price of the 55 Call	?	
	5	*Lending rate*	4%	
	6	Dividend (ex-date before expiration)	0.22	
	7	Days to expiration	60	
	8	DPV of strike price plus dividend = (strike + div) ÷ [1 + (0.04 × 60/365)]	54.86	
	9	Stock cost	0.01 per share	Transaction costs = 0.04
	10	Option cost (call and put)	0.02 per share	
	11	Exercise/assignment cost	0.01 per share	
	12	Target profit	0.05 per share	

Question: What is the purchase price of the 55 Call?

Table 6-16 Pricing a Reverse Conversion with Dividends—Part 2: Calculate the Purchase Price of the 55 Call

Step 1: Calculate the net credit required per share (NC)
NC = DPV of strike plus transaction costs plus target profit margin
NC = $54.86 + 0.04 + 0.05 = $54.95

Step 2: Buy the 55 Call at a price so that the NC for the three-part position (short stock, short 55 Put, and long 55 Call) equals NC in step 1.
2-1 If − stock − 55 Put + 55 Call = − NC
2-2 Then + 55 Call = + stock + 55 Put − NC
2-3 Therefore, + 55 Call = +57.70 + 1.45 − 54.95 = 4.20

is stated at the bottom of Table 6-17. For a reverse conversion, the difference between the time value of the call and the time value of the put equals the absolute value of the gross loss. The net credit, however, is increased by the dividend.

Table 6-17 Pricing a Reverse Conversion with Dividends—Part 3: Analysis of Cash Flows, Net Profit, and Time Values

1	Revenue = net credit received for establishing position	54.95
2	− Cost = amount paid at expiration = strike price	−55.00
3	= Gross loss	= (0.05)
4	+ Interest income = 54.95 × (0.04 × 60/365)	+ 0.36
5	= Profit before transaction costs	= 0.31
6	− Transaction costs	−0.04
7	= Profit before dividend	= 0.27
8	− Dividend	−0.22
9	= Net profit	= 0.05
Analysis of Time Values		
10	Time value of 55 Call = price − intrinsic = 4.20 − 2.70	= 1.50
11	Time value of 55 Put = price − intrinsic = 1.45 − 0.00	= 1.45
12	Time value of call − time value of put	= 0.05

Conclusion: For a reverse conversion, the difference between the time value of the call (11) and the time value of the put (12) equals the absolute value of the gross loss (3). The net credit, however, is increased by the dividend.

Pricing Reverse Conversions by Strike Price

Table 6-18 demonstrates the pricing implication of changing strike prices in reverse-conversion positions. In essence, the net credit required changes as the strike price changes, and as a result, the amount by which the time value of the call must exceed the time value of the put changes.

In row 1 of Table 6-18, the strike price is 45 (column 1), the DPV of the strike is 44.70 (column 2), the difference between the strike price and the DPV is 0.30 (column 3), and given costs and a target profit of 9 cents per share (column 4), the time value of the 45 Call must be greater than the time value of the 45 Put by 39 cents (column 5). Compare this 39-cent difference to the 42-cent difference in column 5 of row 2, where the strike price is 50. Note also that as the strike price rises by $5.00 in each row, the difference between call time value and put time value increases by 3 cents. The difference increases as

Table 6-18 Pricing Reverse Conversions by Strike Price

	Col 1	Col 2	Col 3	Col 4	Col 5
Row	Strike Price	DPV of Strike	Strike Minus DPV of Strike	Costs Plus Target Profit	Time Value of Call Minus TimeValue of Put
1	45	44.70	0.30	0.09	0.39
2	50	49.67	0.33	0.09	0.42
3	55	54.64	0.36	0.09	0.45
4	60	59.61	0.39	0.09	0.48
5	65	64.58	0.42	0.09	0.51

DPV = discounted present value.
Assumptions: 60 days to expiration, interest rate of 4%, no dividends, costs of 0.04, target profit of 0.05.
Sample DPV calculation: 55 ÷ [1 + (0.04 × 60/365)] = $54.64.

the strike price increases because interest income increases. With a higher strike price, more funds are available for investment.

Box Spreads

A *box spread* is a four-part options-only arbitrage strategy consisting of a long call and short put at one strike price and a short call and long put at a second strike price. There are two variations of this strategy. A long box spread or, simply, a long box is established for a net cost or net debit. A short box spread or, simply, a short box is established for a net credit.

The Long Box Spread

A *long box spread* consists of a long call and short put at a lower strike price and a short call and long put at a higher strike price. A long box is established for a net debit and is profitable when the difference between the strike prices minus the cost of the position is greater than the cost of carry. As with a conversion, this strategy assumes that a trader borrows the net cost of a long box.

Table 6-19 and Figure 6-3 illustrate a long box spread that yields a gross profit of 75 cents per share at expiration before transaction costs and cost of carry. The four-part position consists of one long 90 Call purchased for 6.50, one short 90 Put sold at 2.00, one short 100 Call sold at 2.25, and one long 100 Put purchased for 7.00.

This strategy can be described in two ways. First, it can be described as the combination of long synthetic stock at the lower strike price and

Table 6-19 The Long Box Spread: Long 90 Call at 6.50, Short 90 Put at 2.00, Short 100 Call at 2.25, and Long 100 Put at 7.00

	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Row	Stock Price at Exp	Long 90 Call @ 6.50	Short 90 Put @ 2.00	Short 100 Call @ 2.25	Long 100 Put @ 7.00	Combined P/(L)
1	80	−6.50	−8.00	+2.25	+13.00	+0.75
2	90	−6.50	+2.00	+2.25	+3.00	+0.75
3	100	+3.50	+2.00	+2.25	−7.00	+0.75
4	110	+13.50	+2.00	−7.75	−7.00	+0.75

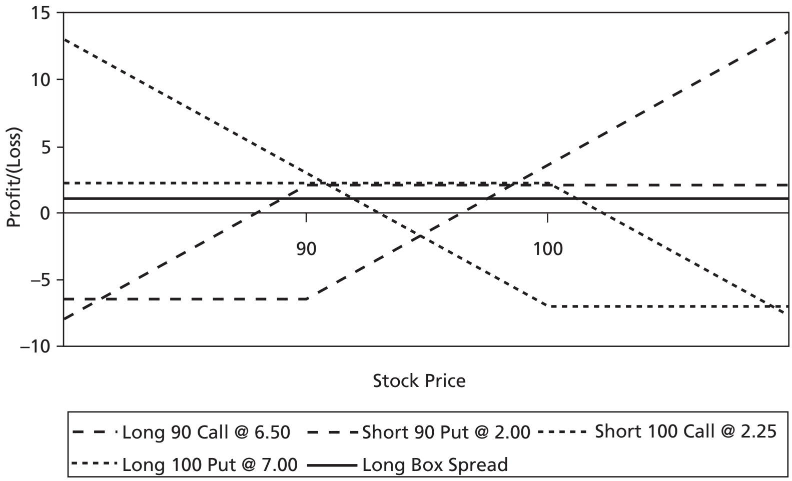


Figure 6-3 The Long Box Spread

short synthetic stock at the higher strike price. Second, it can be described as the combination of a bull call spread and a bear put spread with the same strike prices.

Matching the calls and puts with the same strike price together, the long 90 Call and short 90 Put create a synthetic long stock position, and the short 100 Call and long 100 Put create a synthetic short stock position. Matching the calls together and the puts together, the 90 Call and the 100 Call create a bull call spread, and the 100 Put and the 90 Put create a bear put spread.

The net profit or loss of a box spread will equal the difference between the strike prices minus the cost of creating the position, including transaction and borrowing costs.

Just as a conversion is compared with buying a Treasury bill at a discount and receiving full value at maturity, so too does a long box cost less than the difference between the strike prices to establish. The trader receives that difference at expiration.

Long Box Spread—Outcomes at Expiration

A long box position has five possible outcomes at expiration. As summarized in Table 6-20, the stock price can be below the lower strike price, exactly at the lower strike price, between the two strike prices, exactly at the higher strike price, or above the higher strike price.

If the stock price closes below the lower strike price at expiration, outcome 1 in Table 6-20, then both calls are out of the money and expire worthless. Both puts, however, are in the money. The long 100 Put is exercised, creating a stock sale transaction at 100, and the short 90 Put is assigned, creating a stock purchase transaction at 90. The simultaneous purchase and sale of stock incurs two commission costs but does not result in a stock position. However, a net amount equal to the difference between the strike prices, or 10 in this example, is received. This amount pays back the borrowed funds, the transaction costs, the borrowing costs, and the net profit, if any. If the amount received is less than the loan plus costs, however, then the result is a loss.

Table 6-20 The Long Box Spread at Expiration

Long	1 XYZ 90 Call @ 6.50	= Long stock (synthetically) @ 94.50
Short	1 XYZ 90 Put @ 2.00	
Short	1 XYZ 100 Call @ 2.25	= Short stock (synthetically) @ 95.25
Long	1 XYZ 100 Put @ 7.00	

Combined position at expiration = no position (gross profit 0.75)

Five Possible Outcomes at Expiration

#1 XYZ < 90 (Lowest Strike)	**#2 XYZ = 90 (Lower Strike)**
90 Call expires worthless	90 Call expires worthless
100 Call expires worthless	100 Call expires worthless
90 Put assigned (buy stock)	90 Put expires worthless
100 Put exercised (sell stock)	100 Put exercised (sell stock)
Result: No position	Result: Short stock
#3 90 < XYZ < 100 (Between Strikes)	**#4 XYZ = 100 (Higher Strike)**
90 Call exercised (buy stock)	90 Call exercised (buy stock)
100 Call expires worthless	100 Call expires worthless
90 Put expires worthless	90 Put expires worthless
100 Put exercised (sell stock)	100 Put expires worthless
Result: No position	Result: Long stock
#5 XYZ > 100 (Highest Strike)	
90 Call exercised (buy stock)	
100 Call assigned (sell stock)	
90 Put expires worthless	
100 Put expires worthless	
Result: No position	

If the stock price closes between the strike prices, outcome 3, then the short call and short put are out of the money and expire worthless. The long call and long put, however, are in the money and are exercised. Exercising the 90 Call creates a stock purchase transaction at 90, and exercising the 100 Put creates a stock sale transaction at 100. As in the preceding outcome, simultaneously buying and selling stock creates a net result equal to the difference between the strike prices, or 10.

If the stock price rises above the higher strike price, outcome 5, then both puts are out of the money and expire worthless. Both calls, however, are in the money. The long 90 Call is exercised, creating a stock purchase transaction at 90, and the short 100 Call is assigned, creating a stock sale transaction at 100. Again, the trader would receive an amount equal to the difference between the strike prices of 10.

Therefore, if the stock price is below the lower strike price, between the strike prices, or above the higher strike price at expiration, then the long box position will be closed. As a result, a trader will not be left with an open stock position and the attendant risk that could reduce the profit or create a loss.

Long Box—Double Pin Risk

A stock price closing exactly at one of the strike prices at expiration, outcomes 2 and 4, creates a pin-risk situation. The out-of-the-money option will expire worthless, and in theory, both the at-the-money call and the at-the-money put will expire worthless. The in-the-money option from the other strike price, however, will create a stock position with pin risk.

If the stock price closes exactly at the lower strike price of 90, outcome 2 in Table 6-20, then exercise of the in-the-money 100 Put will create a short stock position. If the stock price closes exactly at the higher strike price of 100, outcome 4, then exercise of the in-the-money 100 Call will create a long stock position. As with pin risk in conversion and reverse conversion positions, it is impossible to predict how many of the short at-the-money options will be assigned. Consequently, market makers typically respond by exercising half the long at-the-money options, hoping that only half the short options will be assigned. Undoubtedly, more or less than half the short options will be assigned, and a trader will need to close a stock position on Monday. As with conversions and reversals, all a trader can do is hope that the experience will not be too costly.

Pricing a Long Box Spread

Given the high probability that a box spread will result in a cash payment equal to the difference between the strike prices at expiration, the value of a long box spread is equal to the DPV of the difference between the strike prices less costs and a profit margin. The next example discusses a box spread involving 100 and 110 strike prices, not 90 and 100 strike prices, as in the preceding example.

Tables 6-21 through 6-23 show, in three parts, how a 100–110 box spread might be priced. Table 6-21 states the assumptions. The price of the 100 Call (1) is 9.10. The price of the 100 Put (2) is 2.30. The price of the 110 Call (3) is unknown. The price of the 110 Put (4) is 6.70. The borrowing rate (5) of 5 percent and the days to expiration (6) of 60 lead to the DPV of the difference between the strike prices (7) of 9.92. There are also trading costs (8 and 9) of 1 cent per share to trade an option and for option exercise or assignment. The total costs therefore are 6 cents, 4 cents for opening the four-part position plus 2 cents for exercise or assignment of the in-the-money options at expiration that close the position. Finally, the target profit (10) is 5 cents per share in this example.

Table 6-21 Pricing a Long 100–110 Box Spread—Part 1: Stating the Assumptions

Assumptions:	1	Price of 100 Call	9.10	
	2	Price of 100 Put	2.30	
	3	Price of 110 Call	?	
	4	Price of 110 Put	6.70	
	5	*Borrowing rate*	5%	
	6	Days to expiration	60	
	7	DPV of difference between the strike prices = (110 – 110) ÷ (1 + 0.05 × 60/365)	9.92	
	8	Option cost (4 options, 0.01/share)	0.04 per share	Transaction costs = 0.06
	9	Exercise/assignment (2 options)	0.02 per share	
	10	Target profit	0.05 per share	

Question: What is the sale price of the 110 Call?

Given the nine known assumptions, the unknown price of the 110 Call must be determined. The question is, "What is the sale price of the 110 Call that yields the target profit?"

Table 6-22, which contains the second part of pricing a long box, calculates the sale price of the 110 Call in two steps. The first step requires calculating the net investment per share. In the case of a long box, the *net investment per share* is the net cost of the position that yields the target profit if held to expiration. The net investment per share equals the DPV of the difference between the strike prices (line 7 in Table 6-21) minus the sum of costs plus target profit (lines 8–10). The net investment per share is therefore 9.81. As with conversions and reverse conversions, calculations are made on a per-share basis because this method makes the quantity of contracts irrelevant to obtaining the target profit.

Step 2 in Table 6-22 uses basic algebra to find the price of the 110 Call that makes the cost of the long box equal the net investment, and that price is 3.69.

The third and final part of pricing a long box spread involves analyzing the cash flows, the net profit, and the spread values, as shown in Table 6-23. The revenue (1) is the amount received at expiration, which is the difference between the strike prices, or 10.00 per share

Table 6-22 Pricing a Long 100–110 Box Spread—Part 2: Calculate Sale Price of 110 Call

Step 1:	Calculate the net investment per share (NI) NI = DPV of difference between strikes minus sum of costs plus target profit NI = 9.92 − (0.06 + 0.05) = 9.81
Step 2:	Sell the 110 Call at a price so that the net cost of four-part position (long 100 Call, short 100 Put, short 110 Call, long 110 Put) equals the NI in step 1. 2-1 If + 100 Call −100 Put − 110 Call + 110 Put = + NI 2-2 Then +110 Call = +100 Call − 100 Put + 110 Put − NI 2-3 Therefore, + 110 Call = 9.10 − 2.30 + 6.70 − 9.81 = 3.69

in this example. The cost of the position (2) is the net investment of 9.81, and the difference between revenue and cost is the gross profit (3) of 0.19 per share. The borrowing costs (4) of 0.08 are based on the net investment and the borrowing rate. The gross profit minus the borrowing costs leaves a profit before transaction costs (5) of 0.11 per share. Finally, subtracting transaction costs of 6 cents per share (6) results in the net profit (7) of 5 cents per share.

Lines 8 through 10 of Table 6-23 analyze the relationship of the values of the two spreads. In this case, the call spread has a value of 5.41 (8), and the put spread has a value of 4.40 (9). The sum of the spread values (10) therefore is 9.81, which equals the net investment.

The conclusion of this three-part exercise is stated at the bottom of Table 6-23. For a long box spread, the sum of the debit call spread plus the debit put spread equals the net investment.

Relative Pricing and Box Spreads

The concept of relative pricing applies to box spreads just as it does to conversions and reversals. Basically, if the value of the box spread and

Table 6-23 **Pricing a Long 100–110 Box Spread—Part 3: Analysis of Cash Flows, Net Profit, and Spread Values**

1	Revenue = amount received at expiration = 110 – 100	10.00
2	− Cost = net investment per share paid for position	− 9.81
3	= Gross profit	= 0.19
4	− Borrowing costs = 9.81 × (0.05 × 60/365)	− 0.08
5	= Profit before transaction costs	= 0.11
6	− Transaction costs	− 0.06
7	= Net profit	= 0.05
Analysis of Vertical Spread Values		
8	Value of 100-110 call spread = 9.10 − 3.69	= 5.41
9	Value of 100-110 put spread = 6.70 − 2.30	= 4.40
10	Sum of spread values	= 9.81

Conclusion: For a long box spread, the sum of the debit call spread plus the debit put spread (10) equals the net investment per share (2).

the prices of three of the components are known, then the price of the fourth component can be calculated. Also, if the price of either the call spread or put spread is known, then the other can be calculated.

If, for example, the value of a 50–55 long box were 4.85, and if the 50–55 Call spread were offered at 2.65, then a market maker would bid 2.20 for the 50–55 put spread. If someone were to sell the put spread at 2.20 so that the market maker bought it, that market maker then would simply buy the call spread at 2.65 to complete the long box for a net cost of 4.85 and thereby lock in a profit.

The Short Box Spread

A *short box spread* consists of a short call and long put at a lower strike price and a long call and short put at a higher strike price. A short box is established for a net credit and is profitable when the credit received plus interest earned exceeds the difference between the strike prices plus costs.

Table 6-24 and Figure 6-4 illustrate a short box spread that yields a gross profit of 50 cents per share before transaction costs and interest earned. The four-part position consists of one short 90 Call sold at 6.50, one long 90 Put purchased for 2.00, one long 100 Call purchased for 1.50, and one short 100 Put sold at 7.50.

Table 6-24 The Short Box Spread: Short 90 Call at 6.50, Long 90 Put at 2.00, Long 100 Call at 1.50, and Short 100 Put at 7.50

	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Row	Stock Price at Exp	Short 90 Call @ 6.50	Long 90 Put @ 2.00	Long 100 Call @ 1.50	Short 100 Put @ 7.50	Combined P/(L)
1	80	+6.50	+8.00	−1.50	−12.50	+0.50
2	90	+6.50	−2.00	−1.50	−2.50	+0.50
3	100	−3.50	−2.00	−1.50	+7.50	+0.50
4	110	−13.50	−2.00	+8.50	+7.50	+0.50

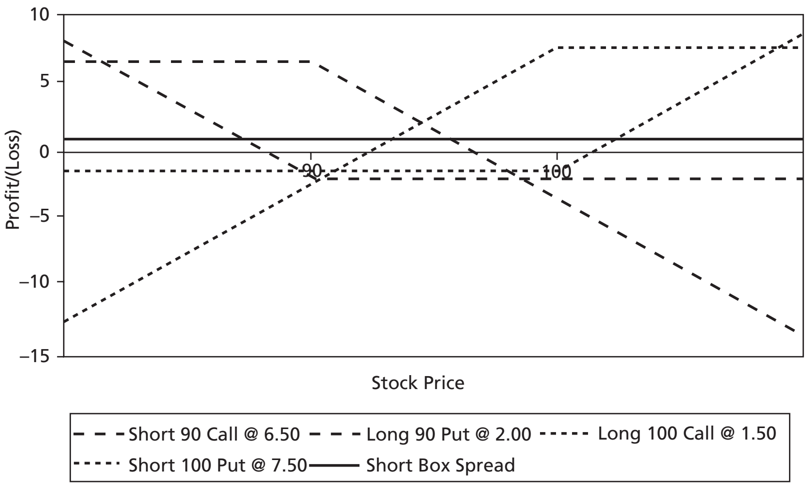


Figure 6-4 The Short Box Spread

A short box can be described in two ways. First, it can be described as the combination of a short synthetic stock at the lower strike price and a long synthetic stock at the higher strike price. Second, it can be described as the combination of a bear call spread and a bull put spread with the same strike prices.

Matching the calls and puts with the same strike prices together, the short 90 Call and the long 90 Put create a synthetic short stock position, and the long 100 Call and the short 100 Put create a synthetic long stock position. Matching the calls together and the puts together, the short 90 Call and the long 100 Call create a bear call spread, and the short 100 Put and long 90 Put create a bull put spread.

A reverse conversion was compared earlier with making an investment with borrowed funds and then repaying the loan when the investment matures. Similarly, a short box spread brings in a credit when established and requires a payment when closed at expiration.

Short Box Spread—Outcomes at Expiration

A short box can result in five possible outcomes at expiration, just like a long box. As summarized in Table 6-25, if the stock price closes below the lower strike price, between the strike prices, or above the higher strike price at expiration, then the short box spread position will be closed. This result is the goal because the trader will not be left with an open position and the attendant risk that could reduce the profit or create a loss.

The stock price closing exactly at one of the strike prices at expiration, outcomes 2 and 4, creates a pin-risk situation. As with the other arbitrage positions discussed earlier, it is impossible to predict how

Table 6-25 The Short Box Spread at Expiration

Short	1 XYZ 90 Call @ 6.50	= Short stock (synthetically)
Long	1 XYZ 90 Put @ 2.00	@ 94.50
Long	1 XYZ 100 Call @ 1.50	= Long stock (synthetically)
Short	1 XYZ 100 Put @ 7.50	@ 94.00

Combined position at expiration = no position (gross profit 0.50)

Five Possible Outcomes at Expiration

#1 XYZ < 90 (Lowest Strike)	#2 XYZ = 90 (Lower Strike)
90 Call expires worthless	90 Call expires worthless
100 Call expires worthless	100 Call expires worthless
90 Put exercised (sell stock)	90 Put expires worthless
100 Put assigned (buy stock)	100 Put assigned (buy stock)
Result: No position	Result: Long stock

#3 90 < XYZ < 100 (Between Strikes)	#4 XYZ = 100 (Higher Strike)
90 Call assigned (sell stock)	90 Call assigned (sell stock)
100 Call expires worthless	100 Call expires worthless
90 Put expires worthless	90 Put expires worthless
100 Put assigned (buy stock)	100 Put expires worthless
Result: No position	Result: Short stock

#5 XYZ > 100 (Highest Strike)
90 Call assigned (sell stock)
100 Call exercised (buy stock)
90 Put expires worthless
100 Put expires worthless
Result: No position

many of the short at-the-money options will be assigned. Consequently, market makers typically respond by exercising half the long at-the-money options, hoping that only half the short options will be assigned.

Pricing a Short Box Spread

Given the high probability that a short box spread will require a cash payment equal to the difference between the strike prices at expiration, the *value* of a short box is equal to the DPV of the difference between the strike prices plus costs plus a profit margin.

Tables 6-26 through 6-28 show, in three parts, how a short 100–110 box spread might be priced. Table 6-26 states the assumptions. The price of the 100 Call (1) is 9.10. The price of the 100 Put (2) is 2.30. The price of the 110 Call (3) is unknown, and the price of the 110 Put (4) is 6.70. The lending rate (5) of 4 percent and the days to expiration (6) of 60 lead

Table 6-26 Pricing a Short 100–110 Box Spread—Part 1: Stating the Assumptions

Assumptions:	1	Price of 100 Call	9.10	
	2	Price of 100 Put	2.30	
	3	Price of 110 Call	?	
	4	Price of 110 Put	6.70	
	5	*Lending rate*	4%	
	6	Days to expiration	60	
	7	DPV of difference between the strike prices = (110 – 100) ÷ [1 + (0.04 × 60/365)]	9.93	
	8	Option cost (4 options, 0.01/share)	0.04 per share	Transaction costs = 0.06
	9	Exercise/assignment (2 options)	0.02 per share	
	10	Target Profit	0.05 per share	

Question: What is the purchase price of the 110 Call?

to the DPV of the difference between the strike prices (7) of 9.93. Trading costs (8 and 9) consist of 1 cent per share to trade an option and for option exercise or assignment. The total costs therefore are 6 cents, 4 cents for opening the four-part position plus 2 cents for exercise or assignment of the in-the-money options at expiration that close the position. Finally, the target profit (10) in this example is 5 cents per share.

Given the nine known assumptions, it is possible to solve for the unknown one, the price of the 110 Call. The question is, "What is the purchase price of the 110 Call that yields the target profit?"

Table 6-27 contains the second part of pricing a short box spread and shows how to determine the purchase price of the 110 Call in two steps. The first step involves calculating the net credit required per share. Similar to a reverse conversion, the *net credit required per share* (NC) is the net funds per share received for establishing the position that yields the target profit if held to expiration. The net credit required per share equals the DPV of the difference between the strike prices (line 7 in Table 6-26) plus the sum of costs plus target profit (lines 8–10). The net credit required per share therefore is 10.04. As with conversions and reverse conversions, calculations are made on a per-share basis, allowing a trader to determine a target profit regardless of the quantity of option contracts traded.

Table 6-27 Pricing a Short 100–110 Box Spread—Part 2: Calculate Purchase Price of 110 Call

Step 1:	Calculate the net credit required per share (NC) NC = DPV of difference between strikes plus sum of costs plus target profit NC = 9.93 + (0.06 + 0.05) = 10.04
Step 2:	Buy the 110 Call at a price so that the net credit received for the four-part position (short 100 Call, long 100 Put, long 110 Call, short 110 Put) equals the NC in step 1. 2-1 If − 100 Call + 100 Put + 110 Call − 110 Put = − NC 2-2 Then + 110 Call = + 100 Call − 100 Put + 110 Put − NC 2-3 Therefore, + 110 Call = 9.10 − 2.30 + 6.70 − 10.04 = 3.46

Step 2 in Table 6-27 uses basic algebra to find the price of the 110 Call that makes the price of the box spread equal the net funds required, and that price is 3.46.

The third and final part of pricing a short box involves analyzing the cash flows, the net profit, and the spread values, as illustrated in Table 6-28. The revenue (1) of 10.04 is the net credit received when the short box position was established. The cost (2) of 10.00 is the difference between the strike prices because this is the amount paid at expiration when the in-the-money options are exercised or assigned.

The gross profit (3) of 0.04 per share is the difference between revenue and cost. The interest income (4) is based on the funds invested (net credit) and the borrowing rate and come to 0.07. The funds invested of 10.00 are the revenue of 10.04 minus the cost of establishing the position of 0.04. The profit before transaction costs (5) of 0.11 is the sum of the gross profit and the interest income. Finally, subtracting transaction costs of 6 cents per share (6) results in the net profit (7) of 5 cents per share.

Lines 8 through 10 in Table 6-28 analyze the relationship of the values of the two spreads. In this case, the call spread has a value of

Table 6-28 Pricing a Short 100–110 Box Spread—Part 3: Analysis of Cash Flows, Net Profit, and Spread Values

1	Revenue = net credit per share for establishing the position =	10.04
2	− Cost = net debit paid at expiration = 110 − 100 =	−10.00
3	= Gross profit	= 0.04
4	+ Interest income = 10.00 × (0.04 × 60/365)	+ 0.07
5	= Profit before transaction costs	= 0.11
6	− Transaction costs	−0.06
7	= Net profit	= 0.05
Analysis of Vertical Spread Values		
8	Value of 100-110 call spread = 9.10 − 3.46 =	5.64
9	Value of 100-110 put spread = 6.70 − 2.30	= 4.40
10	Sum of spread values	= 10.04

Conclusion: For a short box spread, the sum of the credit call spread plus the credit put spread (10) equals the net credit per share (1).

5.64 (8), and the put spread has a value of 4.40 (9). The sum of the spread values (10) therefore is 10.04, which equals the revenue (1) and is the net credit received for establishing the short box spread.

The conclusion of this three-part exercise is stated at the bottom of Table 6-28. For a short box spread, the sum of the credit call spread plus the credit put spread equals the net credit required per share.

Motivations for Establishing a Short Box Spread

Whether paid on borrowed funds or earned on funds invested, interest is an essential component of arbitrage strategies. Option market makers who trade in several stocks frequently will find that they have conversion positions in one stock and reverse-conversion positions in another. As a result, they might borrow from or lend to themselves. After all, a borrower who pays 5 percent to borrow funds from a bank and receives 4 percent on funds invested with the bank would save 1 percent by using the invested funds directly instead of borrowing.

Consider a market maker who prices conversions and long box spreads assuming a borrowing rate of 5 percent and who prices reverse conversions and short box spreads assuming a lending rate of 4 percent. Further assume that this market maker has accumulated a conversion position in stock 1 that requires $1 million in borrowings. The question is, "Does this position affect how reverse conversions and short box spreads should now be priced?" The answer is yes because funds received from these positions will reduce the funds that need to be borrowed. In theory, one might think that the lending rate on net credit positions could be dropped to zero because the borrowed funds on net debit positions cost 5 percent, but there is a complicating factor—the market maker's capital requirement.

Every position involves risk, and therefore, every position requires a supporting equity requirement to cover that risk. Stock purchased on margin or sold short, for example, requires an equity deposit of 50 percent. While option arbitrage positions involve significantly less risk than long or short stock positions, they still require some equity. Therefore, the decision of how low to lower the lending rate when pricing a net credit arbitrage to fund a net debit arbitrage depends partly on the availability of equity. When the size of trading positions expands to the limit of available equity, it may not be possible to create additional positions, let alone positions at lower-than-normal interest rates. At other times, when equity is plentiful because positions are small, pricing short box spreads and reverse conversion positions at near-zero lending rates may be practical. This decision will depend on a market maker's individual circumstances.

Summary

Arbitrage, conceptually, involves trading in two different markets with the goal of profiting from small price differences. Options arbitrage involves buying real stock and selling synthetic stock or, vice versa, buying synthetic stock and selling real stock.

A strategy known as the conversion consists of buying stock, buying puts, and selling calls on a share-for-share basis. The call and put have the same strike price and the same expiration date. All options arbitrage strategies are based on the conversion concept. A conversion makes a profit if the time value of the call exceeds the time value of the put by an amount sufficient to cover transaction costs, including borrowing costs.

The reverse conversion, as its name implies, is the opposite of a conversion. It consists of short stock, short puts, and long calls on a share-for-share basis and is established for a net credit. A reverse conversion will make profit if the interest earned exceeds transaction costs plus the difference of call time value minus put time value.

Box spreads are four-part options-only arbitrage strategies. They consist of a long synthetic stock position at one strike price and a short synthetic stock position at another strike price. A long box spread is established for a net cost, or net debit, and a short box spread is established for a net credit.

Although market makers can price arbitrage strategies with a target profit in mind, competition in the marketplace often influences whether the target profit can be achieved. Frequently, market makers must choose between accepting a lower profit and not making a trade. Deciding whether or not to accept a lower profit is part of the art of trading as a market maker.

Knowledge of arbitrage strategies and synthetic pricing relationships helps all traders to evaluate trading strategies and make trading decisions. Knowing that puts are in line with calls or that the options are in line with the stock gives a trader confidence that prices are fair in the current market environment.

Chapter 7

VOLATILITY

It has been said that *volatility* is the most used and least understood word in the options business. On the most basic level, the term *volatility* means movement in general, not movement in a particular direction. Because traders tend to think in terms of up or down, however, this concept can be confusing. Nevertheless, option traders need to gain an accurate understanding of volatility because it significantly affects option prices, trading decisions, and risk analysis. While a detailed knowledge of option-pricing formulas is not required to trade options, there are some simple mathematical relationships that are handy to know because they help traders to recognize good trading opportunities.

This chapter has six parts, three of which discuss volatility as it relates to stock prices and three of which discuss volatility as it relates to option prices. First, the volatility of stock prices is examined from the mathematician's point of view. The discussion, however, is conceptual, not technical. Volatility is defined, and the notion of standard deviation is introduced by comparing the price action of two stocks. The next section demonstrates how traders might use volatility to estimate stock price ranges and the probabilities of those ranges occurring. Realized volatility and expected volatility then are defined and illustrated with some examples. The fourth part discusses volatility as it relates to option prices, specifically, implied volatility. The fifth section discusses how to evaluate option prices and the meaning and usefulness of the terms *overvalued option* and *undervalued option*. Finally, the chapter introduces the phenomenon of volatility skew.

Volatility Defined

Volatility is a measure of price changes without regard to direction. Thus, for example, in volatility terms, a 1 percent price rise will equal a 1 percent price decline. With volatility, it is the percentage change that matters, not the absolute amount of change, the stock price, or the direction.

This nondirectional nature of volatility can be difficult to grasp for traders who tend to think in terms of direction and in terms of good and bad. A trader with a bullish opinion, for example, views a price rise as good and a price decline as bad. A trader with a bearish opinion thinks the opposite. Regardless of the size of the movement, a movement in the "right direction" is good. Years of trading with this mind-set can impede one's full understanding of the nondirectional nature of volatility.

A second complicating aspect of volatility is that one price change, in and of itself, is not important. Rather, only a series of price changes over several trading days, evaluated together, determines a stock's volatility. Just as a "shallow river" that averages 6 inches in depth can have one or two places that are 9 feet deep, so too can a "low-volatility stock" have an occasional big-price-change day. Similarly, a "high-volatility stock" can have some days when there is very little or no price change. One day's price change is just one number; volatility describes a series of numbers.

Historic Volatility

Mathematicians look at a series of price changes over several days, weeks, or months and derive what is called the *standard deviation* of movement. Mathematically, for option traders, *historic volatility* is the annualized standard deviation of daily returns over a specific time period. A *standard deviation* is the average difference between each of the daily returns and the mean return over the period observed. Do not let this definition intimidate you because the following discussion is conceptual, not mathematical.

Price observations typically are made over 30 days, 90 days, or over some other defined period. To make meaningful comparisons of volatility, the exact observation period must be specified. Daily closing prices typically are used, but daily opening prices or weekly closing prices or some other consistent method of observation also could be used.

Comparing one specific price change with another seems like a simple process, but comparing two series of prices changes is more difficult. Figure 7-1, for example, contains graphs of daily closing

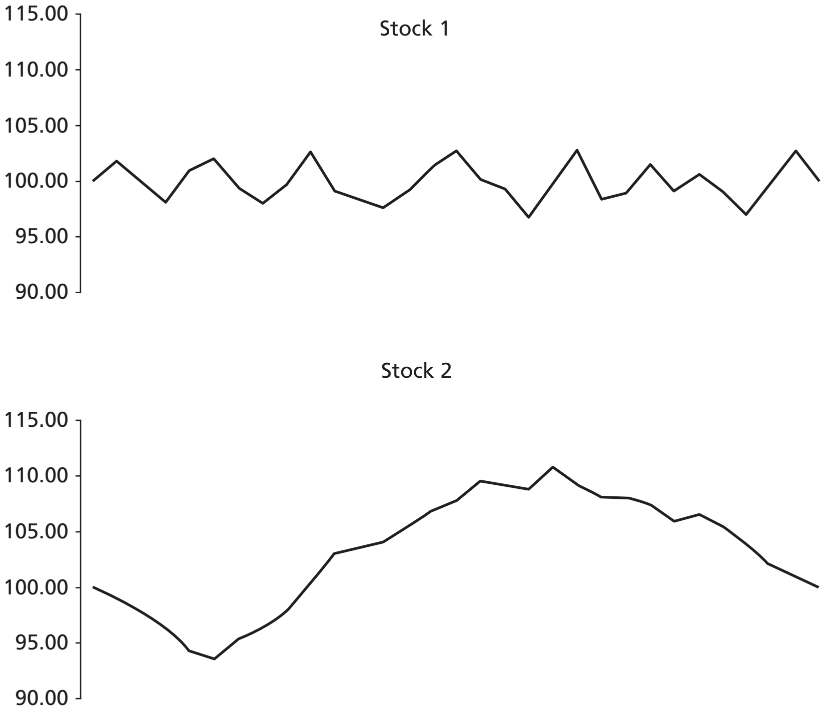


Figure 7-1 Which Stock is More Volatile?

prices of two stocks over 31 days. Both stocks start at $100 and end at $100, but they have very different price actions in between. Stock 1 trades in a narrow range around $100, whereas stock 2 falls fairly quickly below $94, then rises to $110, and then falls back to $100.

The question is: "Is stock 1 or stock 2 *more volatile*?" Take a moment to reflect on this question, and then compare your answer, which is based on your own subjective, visual evaluation with the technical answer that is presented below.

The historic volatility of stock 1 is calculated from the information in Table 7-1. The left column, "Day," simply assigns a number to each closing price; in the real world, this number would be a date. The middle column, "Closing Price," contains the 31 closing prices that are plotted in Figure 7-1. The right column, "Daily Return," contains percentage changes in price from the previous day's price.

The daily return takes two steps to calculate. The closing price of the previous day is subtracted from the closing price of the current day, and then the difference is divided by the closing price of the previous day. The daily return for day 1 of 1.80 percent, for example, is calculated as follows: The closing price on day 0 of 100 is subtracted from the closing price on day 1 of 101.80 to yield a difference of +1.80. This difference then is divided by the closing price on day 0 of 100. The result is +1.80, or +1.80 percent. There is no daily return for day 0 because this day marks the first price observation; the previous price is unknown.

Using the data in the right column in Table 7-1, the standard deviation of these daily returns can be calculated. A *standard deviation* is a measure of the spread of values in a set of data. In practice, the standard deviation of these daily numbers is converted to an annual standard deviation by multiplying it by the square root of the number of days in a year. This calculation produces 37.55 percent, which is shown at the bottom of the table. The calculation of a standard deviation is a standard spreadsheet function, so the mathematically inclined may easily do their own research. However, if you are not mathematically inclined, do not worry; Op-Eval Pro performs the many important volatility calculations.

Table 7-1 Stock 1: Calculation of Historic Volatility

Day	Closing Price	Daily Return (Day 2 – Day 1)/Day 1
0	100.00	
1	101.80	1.80%
2	99.80	−1.96%
3	98.10	−1.70%
4	100.90	2.85%
5	102.10	1.19%
6	99.50	−2.55%
7	97.90	−1.61%
8	99.70	1.84%
9	102.60	2.91%
10	99.10	−3.41%
11	98.40	−0.71%
12	97.60	−0.81%
13	99.10	1.54%
14	101.30	2.22%
15	102.70	1.38%
16	100.20	−2.43%
17	99.30	−0.90%
18	96.70	−2.62%
19	99.70	3.10%
20	102.80	3.11%
21	98.30	−4.38%
22	98.90	0.61%
23	101.50	2.63%
24	99.10	−2.36%
25	100.60	1.51%
26	99.10	−1.49%
27	96.90	−2.22%
28	99.90	3.10%
29	102.80	2.90%
30	100.00	−2.72%

Note: Annualized standard deviation of daily returns = 37.55-–%.

While option traders do not need to know advanced calculus, they do need to understand what 37.55 *percent volatility* means and what a standard deviation is. These concepts can best be explained by the following discussion that compares the price action of the two stocks in Figure 7-1.

Historic Volatility—Comparison 1

Table 7-2 shows one method of comparison; it lists daily closing prices and daily returns for both stocks. As you look down the "Daily Return" column for each stock, you will first observe that the absolute value of every percentage change of stock 1 exceeds the corresponding percentage change of stock 2. This difference indicates that the volatility of stock 1 is higher than the volatility of stock 2. The second indication appears at the bottom of Table 7-2. The annualized standard deviation for stock 1 is 37.55 percent, and for stock 2 it is 22.11 percent.

The conclusion is clear: Stock 1 is more volatile than stock 2. Some may find this result surprising because stock 2 fell $7.00, then rose $18.00, and then fell $8.00, whereas stock 1 traded within a five-point range. Remember, though, that volatility is a statistical measure of daily price action, not the accumulated size of price change or direction. Stock 2 experiences several smaller percentage changes in the same direction relative to stock 1. When discussing volatility, *several smaller percentage changes* is the operative term.

Historic Volatility—Comparison 2

In the real world, of course, every percentage change in one stock will hardly ever be larger or smaller than every corresponding percentage change in another stock. Table 7-3 presents another method of comparing the volatilities of stocks 1 and 2—ranking the absolute values of the percentage changes (daily returns) from smallest to largest.

Table 7-3 compares two samples of the 30 price-change observations for each stock. The following discussion illustrates some basic probability concepts that are helpful in understanding why volatility is important when trading options. The first sample consists of the smallest 20 observations, or two-thirds of the total. For stock 1, the smallest 20 changes are less than 2.63 percent and average 1.67 percent. In contrast, the smallest 20 changes for stock 2 are less than 1.53 percent and average 0.86 percent. The comparison of this subgroup indicates that stock 1 has a higher volatility than stock 2.

Table 7-2 Comparing Historic Volatility: Method 1

	Stock 1		Stock 2	
Day	Closing Price	Daily Return	Closing Price	Daily Return
0	100.00		100.00	
1	101.80	1.80%	99.10	−0.90%
2	99.80	−1.96%	97.90	−1.21%
3	98.10	−1.70%	96.40	−1.53%
4	100.90	2.85%	94.30	−2.18%
5	102.10	1.19%	93.50	−0.85%
6	99.50	−2.55%	95.30	1.93%
7	97.90	−1.61%	96.30	1.05%
8	99.70	1.84%	97.85	1.61%
9	102.60	2.91%	100.20	2.40%
10	99.10	−3.41%	103.00	2.79%
11	98.40	−0.71%	103.60	0.58%
12	97.60	−0.81%	104.10	0.48%
13	99.10	1.54%	105.30	1.15%
14	101.30	2.22%	106.90	1.52%
15	102.70	1.38%	107.80	0.84%
16	100.20	−2.43%	109.50	1.58%
17	99.30	−0.90%	109.10	−0.37%
18	96.70	−2.62%	108.80	−0.27%
19	99.70	3.10%	110.80	1.84%
20	102.80	3.11%	109.20	−1.44%
21	98.30	−4.38%	108.10	−1.01%
22	98.90	0.61%	108.00	−0.09%
23	101.50	2.63%	107.40	−0.56%
24	99.10	−2.36%	105.90	−1.40%
25	100.60	1.51%	106.50	0.57%
26	99.10	−1.49%	105.40	−1.03%
27	96.90	−2.22%	103.80	−1.52%
28	99.90	3.10%	101.90	−1.83%
29	102.80	2.90%	100.85	−1.03%
30	100.00	−2.72%	100.00	−0.84%

Note: Annualized standard deviation of daily returns: stock 1 = 37.55%; stock 2 = 22.11%.

The second sample compares the smallest 29 observations, or approximately 96 percent of the total observations. Again, the measures for stock 1 are greater than those for stock 2. The absolute values of 29

Table 7-3 Comparing Historic Volatility: Method 2

Stock 1		Stock 2	
22	0.61%	22	0.09%
11	0.71%	18	0.27%
12	0.81%	17	0.37%
17	0.90%	12	0.48%
5	1.19%	23	0.56%
15	1.38%	25	0.57%
26	1.49%	11	0.58%
25	1.51%	15	0.84%
13	1.54%	30	0.84%
7	1.61%	5	0.85%
3	1.70%	1	0.90%
1	1.80%	21	1.01%
8	1.84%	29	1.03%
2	1.96%	26	1.03%
27	2.22%	7	1.05%
14	2.22%	13	1.15%
24	2.36%	2	1.21%
16	2.43%	24	1.40%
6	2.55%	20	1.44%
18	2.62%	27	1.52%
23	2.63%	14	1.53%
30	2.72%	3	1.53%
4	2.85%	16	1.58%
29	2.90%	8	1.61%
9	2.91%	28	1.83%
28	3.10%	19	1.84%
19	3.10%	6	1.93%
20	3.11%	4	2.18%
10	3.41%	9	2.40%
21	4.38%	10	2.79%

Stock 1 (rows 22 through 18): 68% less than 2.63%, avg. 1.67%

Stock 1 (rows 22 through 10): 95% less than 3.42%, avg. 2.08%

Stock 2 (rows 22 through 27): 68% less than 1.53%, avg. 0.86%

Stock 2 (rows 22 through 9): 95% less than 2.41%, avg. 1.16%

changes are less than 3.42 percent for stock 1 but less than 2.41 percent for stock 2. Also, the average of these changes is 2.08 percent for stock 1 and 1.16 percent for stock 2. Statistically, stock 1 is more volatile than stock 2 during the period observed.

Another Look at Daily Returns

Figure 7-2 is a bar graph of the daily returns in chronological order for stocks 1 and 2. Although a visual comparison of these data indicates that there are more large daily returns for stock 1 than for stock 2, visual observation for larger amounts of data is both impractical and inaccurate. For this reason, mathematicians prefer to organize daily return data in the manner presented in Figure 7-3.

Figure 7-3 contains two bar graphs that show the frequency of returns for stocks 1 and 2. The *frequency* is the percent of observations that fall within a range. The tallest bar for stock 2, for example, indicates that approximately 20 percent of the outcomes are very close to

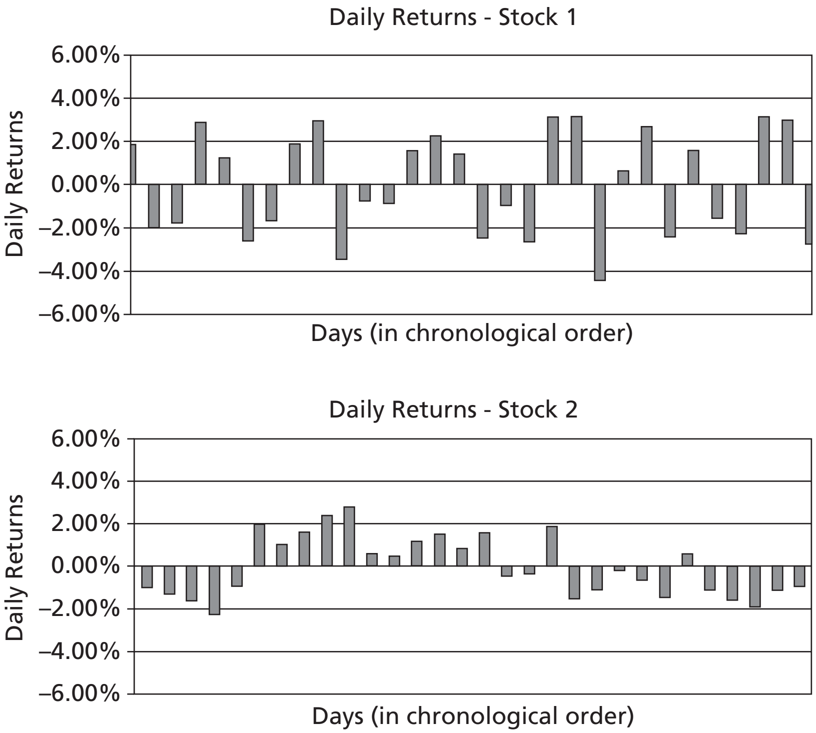


Figure 7-2 Bar Graph of Daily Returns in Chronological Order

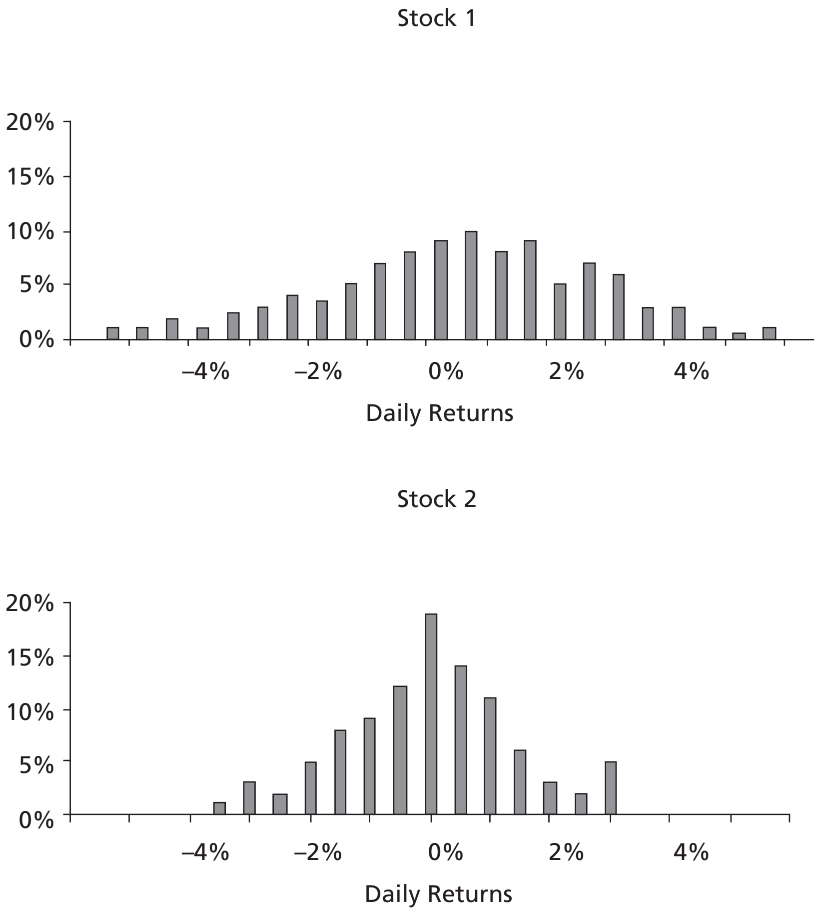


Figure 7-3 Frequency of Daily Returns

0 percent return. In both graphs, most returns are close to 0 percent, but the distributions are clearly different. The peak of the distribution for stock 1 is lower than that for stock 2, and the bars are spread out in a wider and flatter pattern for stock 1 than for stock 2. A *wider and flatter pattern* means that more daily deviations from the mean are larger for stock 1, and this is expected because it is more volatile than stock 2. If a line were drawn from the tops of the bars, that line would form an imperfect bell-shaped curve. For mathematicians, the shape

of the bell-shaped curve describes a stock's volatility: The broader the curve, the higher is the volatility; the narrower the curve, the lower is the volatility.

Figure 7-4 is a stylized graph of a normal distribution. A normal distribution means that the left and right halves of the distribution are identical in shape. When returns are normally distributed, inferences can be made about the frequency of returns occurring in the future. Therefore, if returns are normally distributed, approximately 68 percent will occur within one standard deviation of the mean, 95 percent will occur within two standard deviations, and 99 percent occur within three standard deviations.

A short, broad line at the bottom center of the diagram in Figure 7-4 indicates the mean of the distribution, and the text under the curve explains how returns will be distributed around the mean within one, two, or three standard deviations.

The concept of Figure 7-4 is expanded in Table 7-4, which lists the statistical percentages of the occurrence of events out to six standard deviations. Statistically, a stock-price change equal to six standard deviations is not impossible, just unlikely.

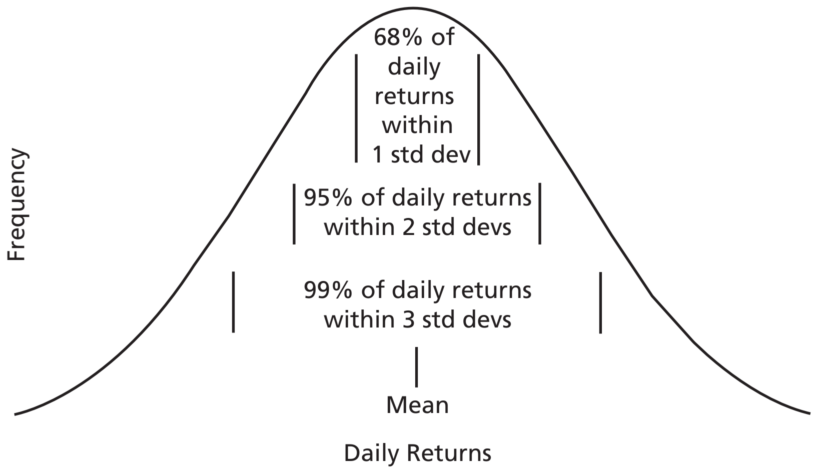


Figure 7-4 Distribution of Returns

Table 7-4 Percentage of Events by Standard Deviations

	Percentage of Events Occurring Within the Number of Standard Deviations Indicated	
1 sd	68.26894921371%	Approx. 2 out of 3
2 sd	95.44997361036%	Approx. 19 out of 20
3 sd	99.73002039367%	Approx. 369 out of 370
4 sd	99.99366575163%	Approx. 15,999 out of 16,000
5 sd	99.99994266969%	Approx 999,999 out of 1,000,000
6 sd	99.99999980268%	You get the idea!

sd = standard deviation.
Source: Wikipedia.

Summary of Historic Volatility

Historic volatility is a measure of observed stock-price changes in the past. While most price changes are small, large ones can occur. The distribution of price changes can be graphed, mathematically, by a bell-shaped, or normal, curve. A narrower curve with a higher peak indicates lower volatility, and a wider curve with a lower peak indicates higher volatility.

Realized Volatility

Realized volatility is a measure of stock-price fluctuations between today and some date in the future. If one could observe stock prices from today until that future date and calculate historic volatility using those prices, that calculation would produce the realized volatility. *Future volatility* is another name for realized volatility because it is unknown today.

The Meaning of "30 Percent Volatility"

An option's volatility is stated as a percentage based on the annualized standard deviation. Applying the percentages from Table 7-4, it follows that if a stock's volatility is 30 percent, then there is a 68 percent chance that one year from today the stock price will lie between 30 percent below today's price and 30 percent above today's price. There is also a 95 percent chance that it will lie between 60 percent below and 60 percent above today's price (two standard deviations). And there is a 99 percent chance that it will lie between 90 percent below and 90 percent above today's price (three standard deviations).

No Direction Implied

Remember, the volatility percentage does not give an indication of direction, only the range. Therefore, the volatility cannot help a trader forecast market direction. However, given a trader's forecast for direction, volatility can help to estimate a profit target.

A trader who is very bullish, for example, might forecast a two-standard-deviation price rise. For a stock currently trading at $100 and at 30 percent volatility, then a two-standard-deviation price expectation implies that the stock price will reach $160 some time in the next year (100 plus 60 percent, or two standard deviations). The bullish component of the forecast and the expectation for a two-standard-deviation price change are the trader's subjective opinion based on his or her experience and interpretation of market conditions. They are not objective calculations derived from the options market. The $160 price target, however, is an objective calculation based on the stock's current price and volatility. Because making a one-year forecast may seem impractical to many, a simple method of converting the annual price-range expectation into a shorter time period may be more useful.

Converting Annual Volatility to Different Time Periods

The one-year standard deviation of stock price range can be converted to a standard deviation for any time period using the formula presented in Table 7-5. The formula is: Annual volatility × the square root of time. This formula can be used to estimate both a price range and a probability that the price will lie within that range.

Table 7-5 Converting a Stock's Annual Volatility to Different Time Periods

The formula:

Annual volatility × square root of time = SD for time period
Annual volatility × $\sqrt{\text{days to exp./days per year}}$ = volatility for days to exp.
where volatility = standard deviation of returns.
Assumption: Volatility 35%
Standard deviation for one year: $0.35 \times \sqrt{365/365} = 0.350$
For a stock at 78.50, one standard deviation for one year is ±27.47 (78.50 × 0.35)
Standard deviation for four weeks: $0.35 \times \sqrt{28/365} = 0.097$
For a stock at 78.50, one standard deviation for four weeks is ±7.61
(78.50 × 0.097)
Standard deviation for one week: $0.35 \times \sqrt{7/365} = 0.048$
For a stock at 78.50, one standard deviation for one week is ±3.77
(78.50 × 0.048)
Standard deviation for one day: $0.35 \times \sqrt{1/365} = 0.018$
For a stock at 78.50, one standard deviation for one day is ±1.41 (78.50 × 0.018)

Table 7-5 assumes a stock price of $78.50 and a volatility of 35 percent and calculates a one-standard-deviation price range for one year, for four weeks, for one week, and for one day. Focus on the calculation for four weeks: One standard deviation equals ±7.61. Consequently, the expectation under these assumptions is that the stock price will close at the end of the period between 70.89 and 86.11 approximately two of three months (a 68 percent probability). In one of three four-week periods, the change in closing price is expected to be above or below this range but between 63.62 and 83.74 (two standard deviations). And occasionally, one of 20 four-week periods, the closing price is expected to be between two and three standard deviations from the current price.

Op-Eval Pro Calculates Distributions

To make it easy to get a standard deviation, the Distribution screen in Op-Eval Pro will perform the conversion calculation. Type in a stock price, a volatility assumption, and a number of days, and Op-Eval Pro will calculate the one-standard-deviation price range for that number of days, two times that number of days, three times that number of days, and four times that number of days.

Figure 7-5 confirms the four-week Op-Eval Pro calculation in Table 7-5. The stock price is 78.50, the volatility assumption is 35 percent, and the time period is 28 days. Op-Eval Pro calculates the one-standard-deviation price range as 70.89 to 86.11. These prices are 7.61, or one standard deviation, above or below the stock price of 78.50. The difference of 1 cent between Figure 7-5 and Table 7-5 is due to rounding.

The additional price ranges on the Distribution screen are for twice the time period, three times the time period, and four times the time period. These time periods are helpful to traders who want a quick estimate of a longer time frame. For a trader evaluating a four-week option and its implied stock price range, the information on the Distribution

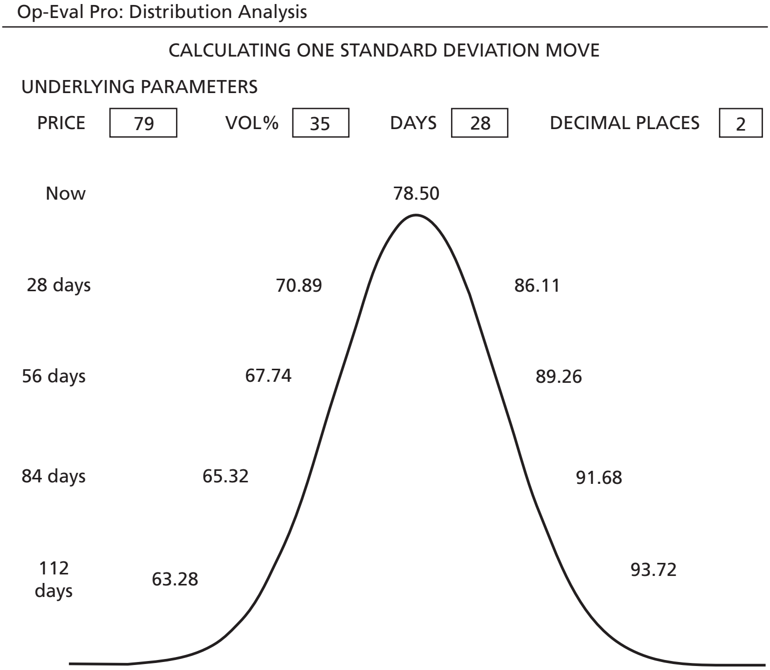


Figure 7-5 The Distribution Page from Op-Eval Pro

screen makes a comparison with 8-, 12-, and 16-week options fast and easy.

Consider a trader who is bullish on stock XYZ, currently trading at 78.50. Also assume that the trader wants to compare the purchase of the four-week XYZ 80 Call trading at 2.50 with the purchase of the eight-week XYZ 80 Call trading at 3.85. If the trader believes that XYZ will trade in a range consistent with 35 percent volatility, then Figure 7-5 indicates that the one-standard-deviation price range is ±7.61 for four weeks and ±10.76 for eight weeks. Only the trader, individually, can decide if the extra time and the wider price range provided by the eight-week call is worth the additional cost of 1.35. The implied stock price ranges, however, provide additional and helpful information.

Calendar Days versus Trading Days

The "calendar days" component in the formula in Table 7-5 is often debated. The question is, "Should the formula use calendar days or trading days?" Those in favor of trading days argue that volatility, that is, stock-price change, can only happen on trading days. Others counter that calendar days better reflect the actual amount of time until expiration. The answer is: In most cases, either can be used without much impact on the result.

The conversion formula uses square root of time in years, so the important question is whether calendar days or trading days best approximates time in years. It can be argued, generally, that it does not matter. Any percent of a full year is the same regardless of the number of days in a year. Choosing 252 (trading days) versus 365 (calendar days) for days per year for price-range estimates using volatility becomes an issue only when the time period is short. What is a "short" time period? Two examples follow that shed light on this issue.

First, consider a two-month time period in which there are 61 calendar days and 43 trading days. Also assume a stock price of 78.50 and 35 percent volatility. Calendar days are used to calculate a standard deviation for the period as follows: 61 calendar days divided by 365 calendar days in a year is 0.1671, the square root of which is 0.4087. The volatility for the period, therefore, is 14.3 percent (0.35 × 0.4087). And for a stock trading at 78.50, one standard deviation is 11.23 (78.50 × 0.143).

Trading days are used to calculate a standard deviation for the period as follows: 43 trading days divided by 252 trading days in a year is 0.1706, the square root of which is 0.4130. The volatility for the period, therefore, is 14.5 percent (0.35 × .4130). And for a stock trading at 78.50, one standard deviation is 11.38 (78.50 × 0.145).

The difference between using calendar days and trading days is 15 cents. For a stock price of 78.50 and a period of two months, this difference is not significant.

Second, consider a three-day time period, again assuming a stock price of 78.50 and volatility of 35 percent. Using calendar days, 3 divided by 365 calendar days in a year is 0.0082, the square root of which is 0.0906. The volatility for the period, therefore, is 3.2 percent (0.35 × 0.0906). And for a stock trading at 78.50, one standard deviation is 2.51 (78.50 × 0.032).

Using trading days, 3 divided by 252 trading days in a year is 0.0119, the square root of which is 0.1091. The volatility for the period, therefore, is 3.8 percent (0.35 × 0.1091). And for a stock trading at 78.50, one standard deviation is 2.98 (78.50 × 0.038).

The difference between using calendar days and trading days is 47 cents (2.51 versus 2.98). This is approximately a 17 percent difference and arguably significant.

How much of a concern should the difference between using calendar days and trading days be to traders? For a two-month time period, given a stock price of 78.50, most traders would not consider 15 cents to be significant. For the three-day period, the difference of 47 cents might be significant depending on how often a trader uses strategies targeted at three days. In general, the answer also partly depends on how accessible the necessary information is. Most traders have easy access to the number of calendar days to expiration because brokers supply it. In contrast, the number of trading days is more difficult to find and time-consuming to calculate. Many traders therefore use calendar days when converting annual volatility to shorter time periods because it is easier, and it usually does not make much difference.

The focus now will shift from volatility as it relates to stock-price movements to volatility as it relates to option prices. Remember, from Chapter 2, that volatility is one of the six components that influence option prices.

Implied Volatility

Implied volatility is the volatility percentage that justifies the market price of an option. In other words, it is the volatility percentage that returns the option's market price as the theoretical value. This concept is best explained with an example.

Consider Gary, who uses Op-Eval Pro to estimate the theoretical value of an XYZ March 70 Call. Figure 7-6 shows a Single Option Calculator screen from Op-Eval Pro with Gary's inputs: current stock price of 68.00, strike price of 70, no dividend, interest rate of 4 percent, and 75 days to expiration. Gary chose a volatility of 26 percent because that percentage was the historic volatility based on the 30 most recent daily closing stock prices (available from www.cboe.com and www.ivolatility.com). Given Gary's inputs, Op-Eval Pro calculates a value of 2.57 for the XYZ March 70 Call.

Gary now turns to check the current market and discovers that the XYZ March 70 Call is trading at 3.40! What is going on? Did Gary do something wrong? Or could the market be assuming something different from Gary? For instance, could the market be assuming a different stock price? No, the stock price is known to be $68. A different strike price or time to expiration? No, both of these are part of the contract specifications and are known. A different interest rate or dividend? A slight difference in interest rates or dividend yield might produce a change in option value of a few pennies, but not 82 cents. So, again, the answer is no.

Figure 7-6 Gary's Estimate of the March 70 Call

What, then, can account for the difference between Gary's calculation of 2.58 and the market price of 3.40? The only remaining factor is volatility. The market must be assuming a different volatility than Gary. Figure 7-7 shows the Single Option Calculator screen with the price of 3.40 entered in the "CALL" box. When the "Enter" key is pressed, Op-Eval Pro recalculates the volatility as 32.84 percent. This is the volatility percentage that justifies the market price of this XYZ March 70 Call, and thus it is the implied volatility of this option. Examples later in this and future chapters will demonstrate that implied volatility is used in several ways to compare option prices, to estimate the outcome of strategies, to enter bid and ask prices, and to make subjective judgments about the relative value of an option.

The Role of Supply and Demand

The forces of supply and demand determine option prices, just as they determine all prices in free markets. What varies from market to market, however, is the *market-determined component of price* that is used

Figure 7-7 Implied Volatility of the March 70 Call

to evaluate the instrument being priced. In the stock market, for example, the price-earnings ratio is used widely to make judgments about a stock's value.

If the stock of Company A is at $80 per share with a price-earnings ratio of 10, and if the stock of Company B trades at $35 per share with a price-earnings ratio of 15, then Company A is said to be less expensive than Company B. In this context, the term *less expensive* means the stock with the lowest price-earnings ratio, not the lowest absolute price per share. Price-earnings ratios make it possible to compare companies with different levels of sales, different number of shares outstanding, and different stock prices. Book value and price-to-sales and debt-to-equity ratios are other "common denominators" used by stock analysts.

The price-earnings ratio, however, is market-determined because it is a function of stock price. The earnings per share reported by auditors is known and is determined independently of the stock price. The stock price, however, is determined by supply and demand; so too, therefore, is the price-earnings ratio determined by supply and demand. In other words, the price-earnings ratio is market-determined.

In the options market, implied volatility is a market-determined component of option price that makes comparisons between options possible. Five of the inputs to the option-pricing formula are known: stock price, strike price, expiration date, interest rate, and dividend. Volatility between now and option expiration, however, is unknown. Nevertheless, given an option price, a trader can work the pricing formula backwards to find the volatility percentage that would produce the market price of the option as the theoretical value. This percentage is the implied volatility of the option. In other words, the volatility percentage that produces the option's market price as the theoretical value is the implied volatility. In Gary's XYZ 70 Call, 32.84 percent is the volatility that made the formula's calculated value equal the option's market price.

Just as the price-earnings ratio in the stock market is a common denominator that makes comparison of stock prices possible, implied volatility also facilitates comparisons of option prices. If the options on the stock of Company A are trading at an implied volatility of 38 percent, and if the options on the stock of Company B are trading at an implied volatility of 25 percent, then it can be said that the market believes that the price of Company A's stock will be more volatile than the price of Company B's stock. No one can guarantee that price action between now and option expiration—realized volatility—will bear this out, but it can be said with certainty that, today, this evaluation reflects the market's opinion.

Implied Volatility Changes

In addition to making comparisons between stocks feasible, implied volatility also makes it possible to evaluate changing conditions on one stock by comparing its volatility at different times. It is common parlance, for example, to describe Gary's XYZ March 70 Call as trading at 32.84 percent volatility. This call, at some previous time, may have been trading at a higher or lower implied volatility. If all other factors are equal, then an option trading at a lower implied volatility should make a relatively good purchase, and an option trading at a higher implied volatility should make a relatively better sale. Rarely, if ever, however, are all other factors equal! Therefore, the level of implied volatility cannot, in and of itself, dictate whether you should buy or sell an option. Implied volatility is, however, important information that a trader can incorporate into the subjective decision-making process.

Both Historic and Implied Volatility Change

Stock prices go through periods of high and low historic volatility. The changes may be driven by events specific to the company, such as new-product development, earnings announcements, or management turmoil, or perhaps the changes may be driven by events in the general market. Nevertheless, option traders need to be aware of the stock's current level of volatility in order to make a realistic forecast. If a stock's price has not risen or fallen $10 in any month in the last two years, such a price change will not likely occur this month. However, if a monthly $10 price change happens frequently, then forecasting such a change this month would be reasonable.

Implied volatility also rises and falls both because of company events and because of changes in the general market. And just as traders need to be aware of stock-price volatility, so too do they need to follow implied volatility.

Figure 7-8 shows how historic and implied volatility changed over a 12-month period for a well-known large-capitalization stock. The information in this figure was supplied by I-Volatility and is available for all exchange-listed stocks at www.ivolatility.com and at www.cboe.com.

The upper portion of Figure 7-8 is a line graph of the stock price from April 2007 to March 2008, and the lower portion contains line graphs for historic volatility and implied volatility. Conventional wisdom states that volatility rises when stock prices fall. Figure 7-8, however, shows that conventional wisdom is not always correct.

Figure 7-8 Stock Prices and Changing Volatilities (*Source*: ivolatility.com)

From early April through late July of 2007, the implied volatility of the options in Figure 7-8 rose from less than 20 percent to approximately 25 percent, while the stock price also rose from approximately 95 to above 115. Implied volatility did spike higher in early August when the stock price fell from approximately 117 to below 110, and it spiked higher again in October–November when the stock price declined from 115 to approximately 100. Nevertheless, traders must be careful to analyze how implied volatility is changing and not just rely on conventional wisdom.

Revisiting the Insurance Analogy

One explanation of why implied volatility changes is based on the analogy between options and insurance presented in Chapter 3. In that analogy, volatility is comparable with the risk factor in insurance. The level of risk is one component in determining the level of insurance premiums.

If an insurance company has a record of claims showing that one of 100 homes is destroyed by fire, for example, then, in theory, fire insurance would cost 1 percent of the value of a home plus a profit margin. If, however, the insurance company forecasts that fire will destroy a greater percentage of homes in the future, then it will raise its premiums. Similarly, if the company perceives that fire will cause less damage, perhaps owing to fire and smoke alarms and improved building practices, then premiums are lowered.

Insurance companies, however, live in a competitive environment, and some premiums are set to meet the competition. In some market environments, the competitive level of insurance premiums will be higher than the theoretical level calculated by an insurance company. In such an environment, the market expects more risk than the history of risk as calculated by the insurance company. In other market environments, the competitive level of insurance premiums is below the theoretical level calculated by the insurance company. In those environments, the market expects less risk than history indicates.

Historic volatility is like the insurance company's records of actual claims experience. Expected volatility is like a particular insurance company's forecast of future claims.

While it might seem desirable to sell insurance at higher premiums when the market expectation for risk is above the historic level of claims, one has to remember that markets are generally very efficient. Frequently, prices rise before most people understand why because the market perceives something that many individuals do not see. An example of the market perceiving something was the historic rise in oil prices from 2006 to 2008 to over $140 per barrel. In the early stages, when oil was hitting new all-time highs of $40 and $50 per barrel, there were several oil market analysts who said, "Oil above $40 is a temporary phenomenon," and then, "Oil above $50 is unwarranted by the fundamentals," and then, "Oil above $70 simply cannot be sustained." In retrospect, the market clearly foresaw that supply-demand conditions had changed, whereas many individuals did not.

In options, the level of implied volatility is the market's consensus estimate of future volatility. In many cases, the market perceives a rise or fall in stock price volatility that many individuals actively involved in the market do not see. Professional traders must never forget this. They must constantly ask: What is the market—through implied volatility—saying about future volatility? What might the market be seeing that I do not see? And how can I protect myself if what the market is saying turns out to be right and what I am thinking turns out to be wrong?

Implied Volatility Can Change Intraday

Implied volatility not only changes over weeks and months, Table 7-6 demonstrates how implied volatility can change within a trading day. Column 1 shows the time of day, whereas column 2 lists the stock price. The stock price fluctuates from a low of 76.25 to a high of 77.95. Columns 3 and 4 contain the bid and ask prices of the 80 Call, and columns 5 and 6 state the implied volatilities of the bid and ask prices.

At 9:30 a.m., when the market opens, for example, the stock price is 76.25, and the 80 Call has a bid price of 2.60 and an ask price of 2.80. The implied volatility is 31.0 percent for the bid and 32.6 percent for the ask. By itself, this information has little value. However, consider the situation at 12:30 p.m. when the stock price is up to 77.95, and the implied volatilities of the bid and ask prices have increased to 33.8 and 35.4 percent, respectively. Then consider the situation at 4 p.m., when the stock price is down to 77.40, and the implied volatilities have retreated to 31.1 and 32.7 percent, respectively.

A trader who looks at implied volatility only at the beginning and end of each day would notice little change. Only full-time traders who

Table 7-6 Implied Volatility Intraday

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Time	Stock Price	80 Call Bid Price	80 Call Ask Price	Imp. Vol. of Bid	Imp. Vol. of Ask
09:30	76.25	2.60	2.80	31.0%	32.6%
10:00	76.50	2.70	2.90	31.0%	32.6%
10:30	76.40	2.65	2.85	31.0%	32.6%
11:00	76.50	2.70	2.90	31.0%	32.6%
11:30	76.70	2.90	3.10	31.9%	33.5%
12:00	77.25	3.20	3.40	32.4%	34.0%
12:30	77.95	3.70	3.90	33.8%	35.4%
01:00	77.60	3.40	3.60	32.8%	34.3%
01:30	77.40	3.20	3.40	31.9%	33.5%
02:00	77.75	3.40	3.60	32.2%	33.8%
03:00	77.60	3.30	3.50	32.0%	33.6%
03.30	77.55	3.20	3.40	31.4%	33.0%
04.00	77.40	3.10	3.31	31.1%	32.7%

Assumptions: Days to expiration, 63; interest rate, 4%; dividends, none.

watch this market all day see the nearly 3 percent rise and fall in implied volatility. Of course, Table 7-6 presents only one possible pattern of implied volatility, which, like stock prices, could behave in any number of ways.

Just as in forecasting stock prices, predicting changes in implied volatility is an art, not a science. Option traders must be aware of how much implied volatility can change, and they must gauge the potential impact on their positions. This topic will be discussed more in Chapter 10.

Expected Volatility

Expected volatility is a loosely used term that describes a trader's forecast for either realized volatility or implied volatility. After a period of low historic volatility of stock prices, for example, a trader might predict that realized volatility between now and expiration will be higher. Such a forecast could lead the trader to a long volatility delta-neutral trade, as explained in Chapter 8. In this case, the expected volatility is the forecast level of realized volatility, the stock-price fluctuations in the future.

Alternatively, after analyzing recent developments in the market, a trader might conclude that the level of implied volatility in option prices is low (high) and forecast that it will rise (fall). Such a forecast could lead the trader to buy calls (or puts) rather than sell puts (or calls). As discussed in Chapter 3, option traders need a three-part forecast, which includes a stock-price target, a time period, and a level of implied volatility. In this case, the expected volatility is the trader's forecast for the level of implied volatility in the future. *Forecast volatility* is another name for expected volatility.

Many Terms for Volatility

Words in the options business are often used loosely and with contradictory meanings. Different traders sometimes use the same words differently. Here is a rough guide to some of the terms related to the many aspects of volatility. *Past volatility* is the same thing as historic volatility. *Option volatility*, or *an option's volatility*, means implied volatility. *Future volatility* is another name for realized volatility. *Expected volatility* is a prediction for either realized or implied volatility; *forecast volatility* and *predicted volatility* are other names for expected volatility.

Stock-price action in the past is historic volatility. When a trader enters a number as the volatility input of an option-pricing calculator, that is expected volatility. And the stock-price fluctuations between today and some day in the future constitute realized volatility.

Using Volatility

Traders can use the concept of volatility and the related concept of price-range distributions to plan trades and to choose strike prices. A volatility percentage, by itself, does not predict when the small-movement and big-movement days will occur, but traders who are willing to apply their own judgment can study a stock's price action and develop a feel for the size and length of small- and big-movement periods. These traders then can choose appropriate strategies for the price action they expect based on their experience with the stock and their knowledge of other events affecting the market. The risk of applying this subjective judgment, of course, is that a forecast will be wrong, and a loss will result.

One variation of this approach adds a trader's knowledge of volatility. In this strategy, the trader sells options with a strike price that is at least one standard deviation away from the current stock price. For example, consider a stock price of 78.50 and a volatility of 35 percent, as in Table 7-5 and Figure 7-5. Given a one-month one-standard-deviation stock price range of 7.61, the strike price of 70 is more than one standard deviation below 78.50. One justification for selling the one-month 70 Put is that, based on the principles of volatility, it has a 68 percent chance of expiring worthless and earning a profit for the seller.

Remember, however, that a statistical probability of earning a profit does not guarantee that a profit will be earned. Even if such an option expires worthless two of three months over several years, it might not expire worthless in the specific month that a trader sells it. Also, even if the option ultimately is out of the money and expires worthless at expiration in one month, stock-price action could cause it to be in the money at some time prior to expiration. Such stock-price action could cause the trader to cover the short option at a loss, even though the option eventually expired worthless. This frustrating series of events happens occasionally to every experienced option trader.

"Overvalued" and "Undervalued"

A discussion of volatility naturally leads to an exploration of the relationship of option prices to theoretical value. Many traders strive to buy options when they are trading below their theoretical value, so-called undervalued options. Likewise, they try to sell overvalued options.

Like the old adage, "Buy low, sell high," the goal of buying undervalued options and selling overvalued ones may prove illusive. A complete understanding of what *overvalued* and *undervalued* mean raises questions about how the goal can be achieved.

As discussed in Chapter 3, the value of an option depends on six inputs, one of which is the volatility between the current date and expiration, that is, realized volatility. Realized volatility, though, is unknown. The true theoretical value therefore is unknown. Theoretical values are actually only estimates of that value and are, in fact, based on the volatility assumption that a trader uses as an input, that is, expected volatility.

Now consider what makes an option overvalued. An *overvalued option* is an option the market price of which is higher than its theoretical value. The difference between these two prices, however, is generally the volatility assumption. The volatility component of an option's market price is implied volatility, but the volatility component of an option's theoretical value is expected volatility. The difference between market price and theoretical value, therefore, is the difference between implied volatility and expected volatility. In the case of an overvalued option, implied volatility is higher than expected volatility.

The logic for undervalued options is similar. An *undervalued option* is an option the market price of which is lower than its theoretical value. In the case of an undervalued option, implied volatility is lower than expected volatility.

The calculation of implied volatility is objective; it uses known variables, stock price, strike price, days to expiration, interest rate, dividends, and the market price of an option. Theoretical value, however, is subjective because it uses expected volatility, an unknown variable. The determination of overvalued or undervalued therefore also must be subjective. Trader A and Trader B will agree on the implied volatility of an option, but if their expectations for volatility are different, they will disagree on whether that option is overvalued or undervalued.

An Alternative Focus

Rather than focusing on whether an option is overvalued or undervalued, a trader's time is spent most productively on refining the three-part forecast—for the stock price, the time period, and the level of implied volatility.

Volatility Skews

Volatility skew is a market condition in which options with the same underlying and the same expiration but different strike prices trade at different implied volatilities. This is a common occurrence in stock-index options and options on futures contracts but less common in options on individual stocks.

Table 7-7 contains prices and implied volatilities of calls and puts with 13 strike prices. The underlying is the XSP Index, the Mini-SPX Index, which is based on the Standard & Poor's 500 Stock Index. When the data were gathered, the XSP Index was 132.00, the dividend yield

Table 7-7 Volatility Skew

Call Price	Strike Price	Put Price	Implied Volatility
12.60	120	0.27	26.25%
10.75	122	0.44	25.24%
9.00	124	0.67	24.49%
7.30	126	0.95	23.52%
5.75	128	1.40	22.89%
4.30	130	1.95	21.75%
3.05	132 A-T-M	2.70	20.83%
2.25	134	3.90	21.77%
1.45	136	5.05	20.80%
0.95	138	6.55	20.90%
0.66	140	8.25	21.70%
0.44	142	10.05	22.40%
0.05	144	11.95	24.10%

Note: Option prices indicated are the midpoint between the bid and ask.
Assumptions: XSP Index, 132.00; days to expiration, 25; dividend yield, 1.2%.

was 1.9 percent, the interest rate was 3.50 percent, and there were 25 days to expiration. As the table indicates, the implied volatility of the at-the-money 132 Call is 20.83 percent, and the implied volatilities of the other options increase as strike prices increase or decrease. The implied volatility of the 130 Call and the 130 Put, for example, is 21.75 percent.

Figure 7-9 graphs the information in Table 7-7. Note that the line above 132 is not symmetric with the line below 132 and that neither line is perfectly straight. Note also that this information is only from one time on one day. Although Table 7-7 and Figure 7-9 illustrate volatility skews in numerous index options markets, in these dynamic markets, the overall level of implied volatility and the slopes of implied volatility skew change. Option traders must be aware of this potential market condition and prepare themselves accordingly.

Why Skews Exist

There is no theoretical reason for the existence of volatility skews. However, one practical explanation may be that since option prices

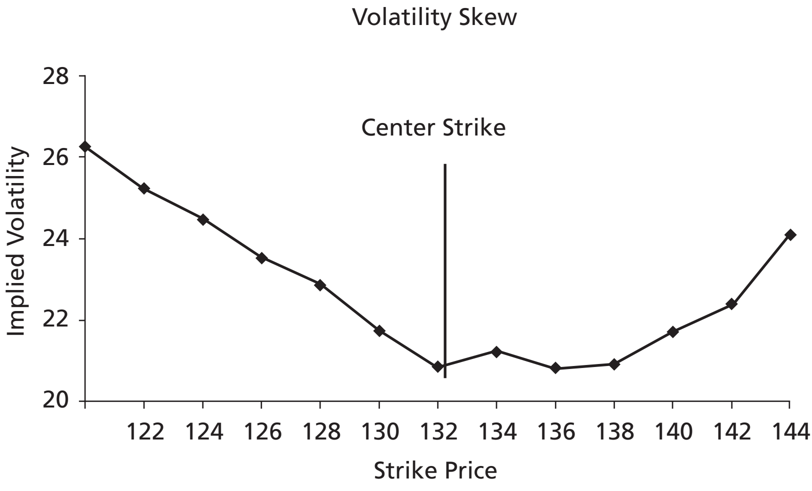


Figure 7-9 Graphical Depiction of Volatility Skew

are determined by supply and demand, different forces of supply and demand affect options with different strike prices in varying ways. Options are analogous to insurance policies, and strike prices are analogous to deductibles. Consequently, like the forces at work in the insurance industry, the varying elements of supply and demand for the different amounts of protection offered by options with different strike prices produce volatility skews.

For example, when there is more demand for cheap insurance policies—policies with a low absolute price—sellers of low-cost insurance policies require a high risk premium. In options, meeting this demand would result in high implied volatility but not a high absolute price.

Skews Affect Trading Results

Traders must consider the existence of volatility skews when making forecasts. If out-of-the-money option strike O is trading at a higher implied volatility than at-the-money option strike A, for example, then as the underlying moves from strike A to strike O, there may be a tendency for the implied volatility of the call and put with strike O, which is not at the money, to decrease and for the implied volatility of the call and put with strike A, which is now out of the money, to increase.

Consider the forecasting problem being addressed by Barb, an experienced XSP options trader. Assuming an XSP level of 132 and the option prices and market conditions in Table 7-7, Barb must first state her three-part forecast for the XSP level, for the time period, and for the implied volatility of the option she is considering buying.

Barb is considering buying an XSP 126 Put with 25 days to expiration because she is bearish on the market and predicts that XSP will decline from 132 to 126 or lower in 10 days. Barb also believes that implied volatility will remain constant. Her volatility forecast, however, raises a question.

What does *implied volatility will remain constant* mean when there is a volatility skew? What implied volatility level should Barb use when estimating the value of the 126 Put? If XSP declines to 126 in 10 days, as Barb predicts, the 126 Put will have moved from six points out of the money to at the money. If the level of implied volatility remains constant and the skew does not change, then the implied volatility of the 126 Put will decline from 23.52 to 20.83 percent. Table 7-8 shows the implications of this change.

Column 1 shows the initial market conditions: The index level is 132, there are 25 days to expiration, the implied volatility is 23.52 percent, and the price of the 126 Put is 0.95. Column 2 estimates a price of 2.30 for the 126 Put, assuming an index level of 126, 15 days to expiration, and the implied volatility of the 126 Put unchanged at 23.52 percent. Column 3 estimates a price of 2.00 for the 126 Put, assuming the same conditions as column 2 but with an implied volatility decline to 20.83 percent. This difference means that had Barb bought the put for 0.95, she would make 1.05 per option instead of 1.35 per option. Whether this difference is sufficient to dissuade Barb from making this trade is a subjective decision that only she can make. Nevertheless, even if Barb is confident of her forecasts for the index

Table 7-8 Barb Analyzes the Impact of the Volatility Skew

	Col 1	Col 2	Col 3
	Initial Inputs	Index and Days Changed, Volatility Unchanged	Index, Days, and Volatility Changed
Inputs			
Index level	132.00	→ 126.00	
Strike price	126	→	
Dividend yield	1.9%	→	
Volatility	23.52%	→ 23.52%	→ 20.83%
Interest rates	4%	→	
Days to expiration	25	→ 15	15
Outputs			
126 Put price	0.95	→ 2.30	→ 2.00
Estimated profit	–	+1.35	+1.05

level and the time period, the volatility skew could have an impact on her decision.

The conclusion from this example is that if other factors remain constant, the existence of implied volatility skew tends to be a disadvantage for buyers of out-of-the-money options. Other factors, of course, are rarely equal. There could be a change in the overall level of implied volatility, or there could be a change in the slope of the volatility skew. Changes in either or both of these market conditions could produce favorable or unfavorable results for a particular option strategy. Consequently, option traders must consider the overall level of implied volatility and the volatility skew, if any.

Summary

Volatility is a measure of price change without regard to direction. Mathematicians, option traders, and the market each view volatility somewhat differently. Mathematically, volatility is the annualized standard deviation of daily returns. A volatility percentage, such as 35 percent, is an annual standard deviation, which can be converted to another time period by multiplying it by the square root of time.

There are many terms that describe volatility. Historic volatility is a measure of stock-price fluctuations during some defined period in the past. Expected volatility is a trader's prediction of what volatility will be in the future and is used to calculate theoretical values. Realized volatility is a measure of actual stock-price fluctuations between now and some point in the future and is unknown. Implied volatility justifies the current market price of an option.

Implied volatility is the common denominator of option prices. Just as the price-earnings ratio makes possible comparisons of stock prices over a range of variables such as total earnings and number of shares outstanding, implied volatility facilitates comparisons of options on different underlying instruments and comparisons of the same option at different times.

Theoretical value of options is a statistical concept only. Traders should focus on relative value, not absolute value. The terms *overvalued* and *undervalued* describe a relationship between implied volatility and expected volatility. Two traders could differ in their opinion of the relative value of the same option if they had different market forecasts and trading styles.

Volatility skew is a market condition in which options with the same underlying and same expiration but with different strike prices trade at different levels of implied volatility. Since option prices, like all prices in free markets, are determined by the forces of supply and demand, volatility skews likely exist because there are differing levels of supply and demand for different options.

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Chapter 8

DELTA-NEUTRAL TRADING: THEORY AND REALITY

Delta-neutral trading is a nondirectional trading technique that profits, loses, or breaks even from the relationship between price fluctuations in the underlying stock and the time decay of option prices. In the language of options, this relationship is the difference between implied volatility and realized volatility. As this chapter will explain, professional market makers and professional speculators have very different motivations for using this trading technique.

This chapter begins with a definition of a delta-neutral position and some examples. Then it explains the theory of delta-neutral trading with two detailed examples, one in which options are purchased and one in which options are sold. After the theory is explained, two more examples show how and why the reality of delta-neutral trading differs from the theory. Then the chapter explores the different motivations of professional market makers and professional speculators who use delta-neutral trading. Finally, the chapter concludes by discussing the profit potential and risks assumed by market makers and speculators and the judgments that each must make.

Delta-Neutral Defined

A *delta-neutral position* is a multiple-part position that has a combined net delta of zero or approximately zero. The components of the multiple-part position can be any combination of long and short calls, puts, or stock. Tables 8-1 through 8-4 illustrate basic two-part delta-neutral positions. Table 8-5 contains a three-part example.

Tables 8-1 through 8-4 each contain two sections. The upper section describes the individual option and stock trades that create the delta-neutral position. The lower section has four columns and three rows that calculate the delta of the position. Column 1 contains an abbreviated description of each component of the position in the upper section of the table. Column 2 states the number of shares represented by the component in column 1. For a stock position, the number of shares in column 2 matches the number in column 1. For option positions, however, the number of shares in column 2 equals 100 times the number of option contracts in column 1. A directional sign, plus or minus, is not associated with the number of shares in column 2 because the directional sign in front of the delta in column 3 indicates whether the position is long or short. As explained in Chapter 4, long stock, long calls, and short puts have positive deltas, and short stock, short calls, and long puts have negative deltas. The number in column 4 represents the market exposure, or delta, in shares of each component. The number is the product of the numbers in columns 2 and 3.

Delta Neutral with Long Calls and Short Stock

Table 8-1 shows a two-part position of long calls and short stock resulting in a net delta of zero. As the upper section of the table indicates, the position is created by buying 20 XYZ 90 Calls at 2.75 each and selling short 900 shares of XYZ stock at 89.05 each.

In the lower section of Table 8-1, row 1, column 1 contains only an abbreviated description of the option position, "Long 20 90 Calls," because calculation of delta does not require the option price or the name of the underlying stock. The "2,000" in column 2 indicates that

Table 8-1 A Delta-Neutral Position with Long Calls and Short Stock

Creating the position:

The option trade: Buy 20 XYZ 90 Calls @ 2.75

The stock trade: Short 900 XYZ shares @ 89.05

Calculation of position delta:

	Col 1	Col 2		Col 3		Col 4
	Position	Number of Shares Represented	×	Delta per Share	=	Market Exposure in Shares
Row 1	Long 20 90 Calls	2,000	×	+0.45	=	+900
Row 2	Short 900 shares	900	×	−1.00	=	−900
Row 3				Position net delta:		-0-

Assumptions: Stock price, 89.05; days to expiration, 43; interest rate, 5%; no dividend; volatility, 28%.

the option position in column 1 represents 2,000 shares of the underlying stock. Remember, a directional sign, plus or minus, is not associated with the number of shares in column 2 because long or short is specified by the directional sign in front of the delta in column 3. In column 3, the delta of "+0.45" has two meanings. First, the "+" means that the position in column 2 represents positive exposure to the market, that is, long shares. Second, the "0.45" is the delta per share of each call in column 1. As described in Chapters 3 and 4, delta is the per-share market exposure of an option. The "+900" in column 4 is the product of the shares in column 2 and the delta in column 3 (2,000 × +0.45 = +900). The "+900" means that the option position described in column 1 will behave the same as long 900 shares of the underlying stock.

Row 2 in the lower section of Table 8-1 describes the stock component of the delta-neutral position. "Short 900 shares" in column 1 describes the position without the price or name. Column 2 contains the number of shares, "900," without indicating whether they are long or short. For a stock position, the number of shares in column 2 matches the number of shares in column 1 because shares of stock do not have a multiplier, as options do. The delta in column 3, row 2,

"−1.00," has two meanings. First, the "−" means that the position represents negative exposure to the market, that is, short shares. Second, the "1.00" is the delta of each share. Stock always has a per-share delta of 1.00, +1.00 for long stock and −1.00 for short stock. The number "−900" in column 4, row 2, is the product of the "900" in column 2 and the "−1.00" in column 3 and indicates that the market exposure is short 900 shares.

Row 3, column 4 of Table 8-1 contains the net delta of the position, "–0–," which is the sum of the deltas of the components in column 4. A position delta of zero indicates that, in fact, this is a delta-neutral position.

More Delta-Neutral Stock and Option Combinations

Tables 8-2 through 8-4 illustrate that delta-neutral positions also can be created with short calls and long stock (Table 8-2), with long puts and long stock (Table 8-3), and with short puts and short stock (Table 8-4). The explanations of these tables follow closely the explanation of Table 8-1; reviewing each table in depth, therefore, is not necessary.

Table 8-2 A Delta-Neutral Position with Short Calls and Long Stock

Creating the position:

The option trade: Sell 40 QRS 35 Calls @ 4.25

The stock trade: Buy 3,000 QRS shares @ 38.00

Calculation of position delta:

	Col 1	Col 2		Col 3		Col 4
	Position	Number of Shares Represented	×	Delta per Share	=	Market Exposure in Shares
Row 1	Short 40 35 Calls	4,000	×	−0.75	=	−3,000
Row 2	Long 3,000 shares	3,000	×	+1.00	=	+3,000
Row 3				Position net delta:		-0-

Assumptions: Stock price, 38.00; days to expiration, 70; interest rate, 5%; no dividend; volatility, 35%.

Table 8-3 A Delta-Neutral Position with Long Puts and Long Stock

Creating the position:

The option trade: Buy 40 MNO 17.50 Puts @ 1.10

The stock trade: Buy 1,600 MNO shares @ 17.80

Calculation of position delta:

	Col 1	Col 2		Col 3		Col 4
	Position	Number of Shares Represented	×	Delta per Share	=	Market Exposure in Shares
Row 1	Long 40 17.50 Puts	4,000	×	−0.40	=	−1,600
Row 2	Long 1,600 shares	1,600	×	+1.00	=	+1,600
Row 3				Position net delta:		-0-

Assumptions: Stock price, 17.80; days to expiration, 55; interest rate, 5%; no dividend; volatility, 31%.

Table 8-4 A Delta-Neutral Position with Short Puts and Short Stock

Creating the position:

The option trade: Sell 50 FGH 45 Puts @ 1.20

The stock trade: Short 1,500 FGH shares @ 47.50

Calculation of position delta:

	Col 1	Col 2		Col 3		Col 4
	Position	Number of Shares Represented	×	Delta per Share	=	Market Exposure in Shares
Row 1	Short 50 45 Puts	5,000	×	+0.30	=	+1,500
Row 2	Short 1,500 shares	1,500	×	−1.00	=	−1,500
Row 3				Position net delta:		-0-

Assumptions: Stock price, 47.50: days to expiration, 28; interest rate, 5%; no dividend; volatility 45%

Consistency of Units

When creating delta-neutral positions, traders must be careful to keep shares of stock and options in equivalent units. Inconsistencies will cause the delta calculation of a multiple-part position to be incorrect.

The relationship between stock and stock options is generally 100 shares per option. However, infrequent events such as splits, mergers, and special distributions can change this relationship. Between futures contracts and options on those contracts, the relationship is generally one futures contract per option, but sometimes that ratio also can vary. Consequently, keeping track of the multiplier between options and their underlying is essential for delta-neutral traders.

Multiple-Part Delta-Neutral Positions

Table 8-5 differs slightly from Tables 8-1 through 8-4 because it describes a three-part position. The three components are short 40 MNO 22.50 Puts, long 40 MNO 25.00 Puts, and long 1,000 shares of MNO stock. The process for calculating the net delta follows that for a simple delta-neutral trade except that there are more than two components. The message is simple: Delta-neutral positions come in many shapes and sizes. What a trader needs to know is how to make money from them, and that is discussed later in this chapter.

Table 8-5 A Three-Part Delta-Neutral Position

Creating the position:

Option trade 1:	Sell 40 MNO 22.50 Puts @ 0.20
Option trade 2:	Buy 40 MNO 25.00 Puts @ 0.90
The stock trade:	Buy 1,000 MNO shares @ 25.75

Calculation of position delta:

	Col 1	Col 2		Col 3		Col 4
	Position	Number of Shares Represented	×	Delta per Share	=	Market Exposure in Shares
Row 1	Short 40 22.50 Puts	4,000	×	+0.12	=	+ 480
Row 2	Long 40 25.00 Puts	4,000	×	−0.37	=	−1,480
Row 3	Long 1,000 shares	1,000	×	+1.00	=	+1,000
Row 4				Position net delta:		-0-

Assumptions: Stock price, 25.75; days to expiration, 55; interest rate, 4%; no dividend; volatility, 32%.

The Theory of Delta-Neutral Trading

Delta-neutral trading involves three steps. First, a trader establishes a delta-neutral position. Second, as the underlying stock price changes and as the net delta of the total position changes away from zero, the trader makes adjusting stock trades according to predetermined rules. Third, the trader closes the entire position, hopefully for a net profit.

An *adjusting stock trade* is the purchase or sale of a specific number of shares of stock that returns the net delta of the total position to zero or approximately zero. The *predetermined rules* dictating when stock trades are made can be based on time or stock-price movement. For example, adjusting stock trades based on time might consist of making trades every day at noon or every day shortly before the market closes. Adjusting trades being based on stock-price movement might require making trades whenever the stock price rises or falls $2.00 or when the stock price rises or falls one standard deviation, as explained in Chapter 7. Adjusting stock trades also can be based on the net position delta.

The theory of delta-neutral trading can be illustrated best with two examples, one involving purchased calls and the second involving sold calls. In each example, a trader named Tom will practice delta-neutral trading, which will be explained in five steps. First, Tom will establish a delta-neutral position. The implied volatility of the options that Tom buys or sells will be assumed and identified. Second, Tom will make adjusting stock trades at the close of each trading day. Closing stock prices for each day are chosen for the sake of the examples, but the deltas and theoretical values of the options that appear in the tables are actual calculations based on those stock prices using the Op-Eval Pro software that accompanies this text. Third, on the fifth day of trading, Tom will close the position. Fourth, Tom will calculate his profit or loss. Fifth, the conclusion will explain why the example is important, what concepts it illustrates, and what factors in the real world might differ from the example. The reasons that professional market makers and professional speculators might use this strategy will be discussed later in this chapter.

Delta-Neutral Trading—Long Volatility Example

This first example uses the theoretical values presented in Table 8-6A, the trades presented in Table 8-6B, and the profit-and-loss calculations presented in Table 8-6C. Table 8-6A contains theoretical values and deltas of a 90 Call over five days in the columns and over a range of stock prices in the rows. The left-most column contains stock prices, and the other columns contain option theoretical values and deltas. In the first column to the right of a stock price of 91.00, for example, "5.71/0.58" appears. The "5.71" is the option's theoretical value, and the "0.58" is the option's delta. Six circles appear in Table 8-6A for ease of identification. These circles indicate when trades are made. As noted earlier, the daily price action is created for the sake of the example. In the real world, of course, the market will determine price action.

Table 8-6A Delta-Neutral Trading—Long Volatility: 90 Call Theoretical Values and Deltas (Volatility 30%, Interest Rate 3%, No Dividends, 75–71 Days)

	Monday	Tuesday	Wednesday	Thursday	Friday
Stock Price	75 Days T.V./Delta	74 Days T.V./Delta	73 Days T.V./Delta	72 Days T.V./Delta	71 Days T.V./Delta
92.20	6.42/0.61	6.39/0.61	6.35/0.61	6.31/0.61	6.28/0.61
92.00	6.30/0.60	6.26/0.60	6.23/0.60	6.19/0.60	6.15/0.60
91.80	6.18/0.60	6.14/0.60	6.11/0.60	6.07/0.60	6.03/0.60
91.60	6.06/0.59	6.02/0.59	6.99/0.59	5.95/0.59	5.91/0.59
91.40	5.94/0.59	5.90/0.59	5.87/0.59	5.83/0.59	5.79/0.59
91.20	5.82/0.59	5.79/0.59	5.75/0.59	5.71/0.59	5.68/0.59
91.00	5.71/0.58	5.67/0.58	5.63/0.58	5.60/0.58	5.56/0.58
90.80	5.60/0.58	5.55/0.58	5.52/0.58	5.48/0.58	5.45/0.58
90.60	5.48/0.57	5.44/0.57	5.40/0.57	5.37/0.57	5.33/0.57
90.40	5.37/0.56	5.33/0.56	5.29/0.56	5.26/0.56	5.22/0.56
90.20	5.26/0.56	5.22/0.56	5.18/0.56	5.15/0.56	5.11/0.56
90.00	5.15/0.54	5.11/0.54	5.07/0.54	5.04/0.54	5.00/0.54
89.80	5.04/0.54	5.00/0.54	4.96/0.54	4.93/0.54	4.89/0.54
89.60	4.93/0.52	4.89/0.52	4.85/.52	4.82/0.52	4.78/0.52

Table 8-6B contains the essential details of all of Tom's trades in this first example. Column 1 indicates the day of the week. Tom makes two trades on Monday and then one trade on each day from Tuesday through Friday. Column 2 indicates the stock price when a trade is made. Column 3 contains the delta of the 90 Call given the day in column 1 and the stock price in column 2. Note that the deltas in column 3 of Table 8-6B are the same as the deltas in Table 8-6A in the corresponding column (day) and row (stock price). For example, on Monday, with a stock price of 90.80, the delta of the 90 Call is +0.58 in both tables. Column 4 contains the necessary information about each trade. Column 5 explains briefly the motivation for the trade, and column 6 indicates the ending stock position after the trade is made.

Long Volatility—Overview

Long volatility means that a position has a positive vega, as defined in Chapter 4. Long calls and long puts have positive vega. The position in the upcoming exercise is long volatility because the calls are long; that is, they are owned.

Table 8-6B Delta-Neutral Trading—Long Volatility: The Trades

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Day	Stock Price	Option Delta	Trade	Explanation	Stock Position
Mon	90.80	+0.58	Buy 100 90 Calls @ 5.60 Short 5,800 shares @ 90.80	Opening trade Delta-neutral	−5,800
Mon	92.00	+0.60	Short 200 shares @ 92.00	Adjusting trade to get delta-neutral	−6,000
Tue	90.20	+0.56	Buy 400 shares @ 90.20	Adjusting trade to get delta-neutral	−5,600
Wed	91.40	+0.59	Short 300 shares @ 91.40	Adjusting trade to get delta-neutral	−5,900
Thu	89.60	+0.52	Buy 700 shares @ 89.60	Adjusting trade to get delta-neutral	−5,200
Fri	90.80	+0.58	Sell 100 90 Calls @ 5.45 Buy 5,200 shares @ 90.80	Closing trade	–0–

Before each trade is explained in detail, here is an overview. Tom's first trade occurs on Monday when he establishes the delta-neutral position. He subsequently makes adjusting stock trades each day at the end of the day. Finally, he closes the entire position on Friday. There are six trades in Table 8-6B, each of which will be explained next. Transaction costs are not included for the sake of simplicity.

Long Volatility Step 1—Opening the Position

Tom's first trade in Table 8-6B creates a delta-neutral position. He establishes the position some time on Monday in a two-part trade. With a stock price of $90.80, Tom buys 100 of the 90 Calls at 5.60 each and simultaneously sells 5,800 shares of stock short. As indicated in Table 8-6A, the volatility assumption is 30 percent. Tom will use this information later. Tom calculated how many shares to sell short using the process presented in Tables 8-1 through 8-5. He first figured out the share-equivalent position and then traded that number of shares in a way to bring the net delta of the total position to zero. In this example, the delta of a 90 Call is +0.58, and Tom purchased 100 Calls, so his option position is equivalent to long 5,800 shares (100 options × 100 shares/option × 0.58 = 5,800). He therefore sells short 5,800 shares at $90.80 to create a delta-neutral position.

Long Volatility Step 2—The Adjusting Trades

Tom makes a second trade on Monday, but this time at the end of the day just before the market closes. Between the time of Tom's opening trade and the end of the trading day, the stock price rises to 92.00. Because of the change in stock price, the delta of the option has changed. The change in delta is explained by the concept of gamma, which is discussed in Chapter 4.

Table 8-6A indicates that with a stock price of 92.00 and 75 days to expiration (Monday), the delta of the 90 Call is +0.60. Long 100 of the 90 Calls with a delta of +0.60 each represents a share-equivalent position of long 6,000 shares. Thus the two-part position that Tom established in his first trade is no longer delta-neutral. To reestablish delta-neutrality, Tom must sell short 200 more shares of stock. This trade is described in the second row of Table 8-6B, "Short 200 shares @ 92.00." In column 5 the explanation is "adjusting trade to get delta-neutral." And in column 6, Tom's new stock position, "−6,000," appears. He now has a position of short 6,000 shares.

Tom makes his third trade on Tuesday. The 90 Calls do not trade on this day, and the stock price closes at 90.20, down 1.80 on the day. Just as in the second trade, the change in stock price changes the delta of the 90 Call. This time the delta dropped to +0.56, and once again, Tom's previously delta-neutral position is no longer delta-neutral. Consequently, he must make an adjusting stock trade to bring the delta back to zero. Now, with a delta of +0.56, the long call position is equivalent to long 5,600 shares of stock. Since Tom's stock position after the second trade was short 6,000 shares, he must buy, or cover, 400 shares. By buying 400 shares Tom reduces his stock position to short 5,600 shares, or "−5,600," as indicated in column 6. The resulting position, long 100 of the 90 Calls and short 5,600 shares at 90.20, is delta-neutral. Again, the explanation in column 5 is "adjusting trade to get delta-neutral."

The fourth and fifth trades on Wednesday and Thursday, respectively, are also adjusting trades. For the fourth trade, the stock price rises to 91.40, making the delta of the 90 Call +0.59. Tom therefore must sell 300 shares short to increase his stock position to short 5,900 shares. When the stock price falls to 89.60 and the delta of the 90 Call is +0.52, the delta-equivalent number of shares becomes 5,200. Tom must purchase 700 shares to make the total position delta-neutral. After the fifth trade, Tom's stock position is short 5,200 shares.

Long Volatility Step 3—Closing the Remaining Position

Tom's last trade in Table 8-6B, the sixth trade, occurs during the day on Friday when the stock price reaches 90.80, and Tom makes a two-part trade to close his entire remaining position. After the fifth trade, Tom's position consisted of long 100 Calls and short 5,200 shares. Therefore, in his closing trade, Tom sells all 100 of the calls at 5.45 and buys 5,200 shares at 90.80.

There are two noteworthy aspects of Tom's final trade. First, the implied volatility of the 90 Calls is 30 percent, the same level as when the original position was opened on Monday. Second, the delta of the option was not used in determining the number of shares to trade because this trade closed the entire position.

Tom's six trades comprise a complete delta-neutral trade. First, he opened a delta-neutral position. Second, he made adjusting stock trades on each day, and third, he closed the remaining position. It is now reasonable to ask, "Did Tom make or lose money?" The profit-and-loss calculation is presented next.

Long Volatility Step 4—Calculation of Profit and Loss

Table 8-6C contains two parts that calculate profit and loss. Part one accounts for the option trades, and part two accounts for the stock trades. Column 1 indicates the day on which a transaction is made. Column 2 states the action—buy, sell, or short—and the quantity of shares or options traded. Columns 3 and 4 state the purchase price and sale price, respectively. Column 5 indicates the profit or loss per share, and column 6 indicates the total dollar profit or loss.

In part 1 of Table 8-6C, Tom calculates his loss from the option trades. In column 1, he lists both Monday and Friday because those were the days when he bought and sold options. Similarly, in column 2, he indicates "buy and sell." In columns 3 and 4, Tom writes down that the purchase price and sale price were 5.60 and 5.45, respectively. Note that these are per-share prices. Column 5 indicates a per-share loss of 0.15, or 15 cents. Tom reaches this the result by subtracting the purchase price of 5.60 in column 3 from the sale price of 5.45 in column 4 (sale price − purchase price = profit or loss). Tom's total dollar loss of −\$1,500 in column 6 is the product of three numbers: the per-share loss in column 5, the number of options in column 2, and the option multiplier of 100 (−\$0.15 per share × 100 options × 100 shares/option = −\$1,500).

Table 8-6C Delta-Neutral Trading—Long Volatility: Calculation of Profit and Loss

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
	Action & Quantity	Purchase Price	Sale Price	P/(L) per Share	Total P/(L) in Dollars
Part 1: Option Trade					
Mon & Fri	Buy/sell 100	5.60	5.45	(0.15)	($1,500)
Part 2: Stock Trades					
Row 1 Mon	Short 5,800	—	90.80	—	—
Row 2 Mon	Short 200	—	92.00	—	—
Row 3 Tue	Buy 400	90.20	92.00 (200)	+1.80	+$ 360
Row 4		—	90.80 (200)	+0.60	+$ 120
Row 5 Wed	Short 300	—	91.40	—	—
Row 6 Thu	Buy 700	89.60	91.40 (300)	+1.80	+$ 540
Row 7		—	90.80 (400)	+1.20	+$ 480
Row 8 Fri	Buy 5,200	90.80	90.80	0.00	0
Row 9			Profit from stock trading		+$1,500
Row 10			Combined P/(L) stock and options		-0-

In part 2 of Table 8-6C, Tom calculates the profit or loss from his stock trades and concludes with the net dollar profit from all the trades. Row 1 shows Tom's first stock trade, which was part of his initial delta-neutral position. He made this trade on Monday, as indicated in column 1, by selling short 5,800 shares, as indicated in column 2. Tom reflects the short sale price of 90.80 in column 4. Column 3 has no price because this transaction did not involve a purchase. Tom also leaves columns 5 and 6 blank in row 1 because an opening trade will not involve a profit or loss.

Starting with row 2, Tom enters his adjusting stock trades. He made the first before the close on Monday by selling 200 shares short at a price of 92.00 per share. Like the columns left blank for the opening trade in row 1, Tom leaves columns 3, 5, and 6 of row 2 blank because there was no purchase transaction in this trade and therefore no profit or loss.

Tom lists his first closing stock trade in rows 3 and 4 and, as a result, makes his first profit/loss calculation. In this example, profit-and-loss calculations are made on a last-in, first-out (LIFO) basis. Tom indicates in column 1, row 3 that he made this trade on Tuesday by purchasing 400 shares at 90.20 per share (columns 2 and 3). Column 4, rows 3 and 4 contain the prices and numbers of short shares from rows 1 and 2. Since Tom purchased 400 shares in row 3, he must match them with shares previously sold short in order to calculate profit or loss. Only 200 shares were sold short in row 2, so Tom must take a second 200-share block from row 1 in order to reach a total of 400 shares. He reflects these matches in column 4. Row 3 indicates that 200 shares sold short at 92.00 are matched with the first 200 shares purchased at 90.20. This 200-share purchase and sale results in 1.80 profit per share and $360 total profit, as shown in row 3 in columns 5 and 6. Tom calculates profit/loss for the second 200-share block in row 4. Column 4, row 4 indicates a price of 90.80 and a quantity of 200 shares, and column 5 indicates a profit per share of 0.60. Tom concludes in column 6 that he made a total dollar profit of $120 on these 200 shares.

Tom shows in row 5 his adjusting trade of shorting 300 shares at a price of 91.40 per share on Wednesday. Since this is another opening short trade, he leaves columns 3, 5, and 6 blank because he has no information about a purchase price, profit per share, or total profit.

Rows 6 and 7 show Tom's profit/loss calculation for the adjusting trade he made on Thursday. In this trade, he purchased 700 shares (row 6, column 2), at 89.60 per share (column 3). To calculate his profit or loss, Tom must match this purchase with two different short sales. In row 6, Tom applies LIFO and matches the 300 shares he sold short on Wednesday at 91.40 per share with his purchase, resulting in a per-share profit and total profit of 1.80 and $540, respectively. Tom then matches 400 shares (row 7, column 4) that were part of his initial trade made on Monday (row 1) at 90.80 per share with his purchase. His per-share profit and total profit from these shares equal 1.20 and $480, respectively.

Tom accounts for his final stock trade in row 8. The 5,200 shares he purchased on Friday are part of the two-part trade that closed the entire position. He matches these shares with the remaining short shares from Monday. Since the purchase price of these shares of 90.80 (row 8, column 3) matches the sale price on Monday, there is no profit or loss, and "–0–" appears in column 6, row 8.

Row 9, column 6 contains the sum of all the profits from Tom's stock trading, which is $1,500.

Tom now completes part 2 of Table 8-6C with row 10, which combines the profit or loss from option trading and from stock trading. Since the option loss of $1,500 exactly offsets the profit of $1,500 from stock trading, Tom records a "–0–" in column 6, row 10.

Long Volatility Step 5—Recapping the Trades

Tom established a delta-neutral position by buying calls—at 30 percent implied volatility—and shorting shares of the underlying stock. He made adjusting stock trades daily until he closed the remaining position by selling calls—at 30 percent implied volatility—and buying shares. His accounting for profit and loss revealed that the owned options incurred a loss from time decay and that the profits from trading stock exactly offset that loss.

It may seem like Tom went to a lot of trouble to just break even, but this exercise illustrated the concept of delta-neutral trading. In theory, when buying options delta-neutral, implied volatility stays constant, and the adjusting stock trades offset the time decay of options. The theory, therefore, is that implied volatility equals realized volatility and that delta-neutral trading breaks even.

What is different in reality? First, implied volatility can—and does—change. Second, realized volatility can—and does—differ from implied volatility. New information is constantly hitting the market, and investor psychology changes. Both these factors cause unforeseen changes in the relative level of option prices—implied volatility—and in the fluctuation of stock prices—realized volatility.

The next exercise illustrates the theory of delta-neutral trading with short volatility.

Delta-Neutral Trading—Short Volatility Example

This example of delta-neutral trading by our hypothetical trader, Tom, uses the theoretical values presented in Table 8-7A, the trades presented in Table 8-7B, and the profit-and-loss calculations presented in Table 8-7C. Table 8-7A contains theoretical values and

Table 8-7A Delta-Neutral Trading—Short Volatility: 35 Call Theoretical Values (Volatility 40%, Interest Rate 5%, No Dividends, 43–37 Days)

	Thursday	Friday	Monday	Tuesday	Wednesday
Stock Price	43 Days T.V./Delta	42 Days T.V./Delta	39 Days T.V./Delta	38 Days T.V./Delta	37 Days T.V./Delta
35.40	2.24/+0.59	2.21/+0.59	2.13/+0.58	2.11/+0.58	2.08/+0.58
35.30	2.18/+0.58	2.15/+0.57	2.08/+0.57	2.05/+0.57	2.03/+0.57
35.20	2.12/+0.57	2.10/+0.57	2.02/+0.56	2.00/+0.56	1.97/+0.55
35.10	2.07/+0.56	2.04/+0.55	1.97/+0.54	1.94/+0.54	1.91/+0.54
35.00	2.01/+0.55	1.99/+0.54	1.91/+0.54	1.89/+0.53	1.86/+0.53
34.90	1.96/+0.54	1.93/+0.54	1.86/+0.53	1.83/+0.53	1.81/+0.53
34.80	1.90/+0.53	1.88/+0.53	1.80/+0.53	1.78/+0.53	1.75/+0.52
34.70	1.85/+0.52	1.83/+0.52	1.75/+0.52	1.73/+0.52	1.70/+0.51
34.60	1.80/+0.51	1.78/+0.51	1.70/+0.51	1.68/+0.51	1.65/+0.51
34.50	1.75/+0.50	1.73/+0.50	1.65/+0.50	1.63/+0.50	1.60/+0.50
34.40	1.70/+0.49	1.68/+0.49	1.60/+0.49	1.58/+0.49	1.55/+0.49
34.30	1.65/+0.48	1.63/+0.48	1.55/+0.48	1.53/+0.48	1.50/+0.48
34.20	1.60/+0.47	1.58/+0.47	1.51/+0.47	1.48/+0.47	1.46/+0.47
34.10	1.56/+0.47	1.53/+0.47	1.46/+0.46	1.43/+0.46	1.41/+0.46
34.00	1.51/+0.46	1.48/+0.46	1.41/+0.45	1.39/+0.45	1.36/+0.45

deltas of a 35 Call over five trading days, from a Thursday to the next Wednesday, in the columns and over a range of stock prices in the rows. As in the long volatility exercise, six circles appear in Table 8-7A for ease of identifying when trades are made. Also as in the preceding example, the daily stock-price action is created for the purposes of the exercise.

Short Volatility—Overview

The difference between long volatility and short volatility is simply the difference between buying and selling options. *Short volatility* means that a position has a negative vega, as defined in Chapter 4. The position created by Tom's first trade in Table 8-7B is short volatility because the calls are short.

Table 8-7B contains the essential details of all of Tom's trades in this example. On Thursday, Tom's first trade consists of selling 100 of the 35 Calls delta-neutral; that is, he sells calls and buys shares. As in the preceding example, transaction costs are not included for the sake

Table 8-7B Delta-Neutral Trading—Short Volatility: The Trades

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Day	Stock Price	Option Delta	Trade	Explanation	Stock Position
Thu	34.80	+0.53	Sell 100 35 Calls @ 1.90 Buy 5,300 shares @ 34.80	Opening trade	+5,300
Thu	35.30	+0.58	Buy 500 shares @ 35.30	Adjusting trade to get delta-neutral	+5,800
Fri	34.10	+0.47	Sell 1,100 shares @ 34.10	Adjusting trade to get delta-neutral	+4,700
Mon	35.10	+0.54	Buy 700 shares @ 35.10	Adjusting trade to get delta-neutral	+5,400
Tue	34.20	+0.47	Sell 700 shares @ 34.20	Adjusting trade to get delta-neutral	+4,700
Wed	34.30	+0.48	Buy 100 35 Calls @ 1.50 Sell 4,700 shares @ 34.30	Closing trade	-0-

of simplicity. After the first trade, Tom makes adjusting stock trades each day at the end of the day. Finally, he closes the entire position on Wednesday. Tom's six trades in Table 8-7B will be explained next.

Short Volatility Step 1—Opening the Position

Tom establishes his delta-neutral position in Table 8-7B some time on Thursday when the stock price is 34.80. He sells 100 of the 35 Calls at 1.90 each and simultaneously buys 5,300 shares of stock at 34.80. As indicated in Table 8-7A, the volatility assumption is 40 percent. Tom decides on the quantity of shares to purchase, 5,300, by multiplying the option's delta, +0.53, by the number of options, 100, times the multiplier, also 100 ($+0.53 \times 100 \times 100 = +5{,}300$).

Short Volatility Step 2—The Adjusting Trades

Tom makes his second trade also on Thursday, but this time at the end of the day just before the market closes. In this example, between the time of the opening trade and the end of the trading day, the stock price rose to 35.30. The change in stock price causes the delta of the option to increase to +0.58, as indicated in Table 8-7A. Consequently, Tom's two-part position is no longer delta-neutral. To reestablish delta-neutrality, he must purchase 500 more shares of stock. This trade is described in the second row of Table 8-7B, "Buy 500 shares @ 35.30." In column 5, the explanation for Tom's trade is "adjusting trade to get delta-neutral." And in column 6, his new stock position, "+5,800," appears. This indicates Tom's position of long 5,800 shares.

Tom's third trade in Table 8-7B occurs on Friday. The 35 Calls do not trade on this day, and the stock price closes at 34.10. Once again, the delta has changed, this time to +0.47. Consequently, Tom must make an adjusting stock trade that brings the delta back to zero. Now, with a delta of +0.47, the short call position is equivalent to short 4,700 shares of stock. Since Tom's stock position after trade two is long 5,800 shares, he must sell 1,100 shares. Selling 1,100 shares reduces the stock position to long 4,700 shares, or "+4,700," as indicated in column 6.

Tom also makes adjusting trades on Monday and Tuesday, respectively. On Monday, the stock price rises to 35.10, and the delta of the 35 Call rises to +0.54. Therefore, Tom must purchase 700 shares to increase the stock position to long 5,400 shares, or "+5,400." On Tuesday, the stock price falls to 34.20, and the delta of the 35 Call decreases to +0.47, making the delta-equivalent number of shares long 4,700. To return to a delta-neutral position, Tom must sell the 700 shares he purchased the day before. Therefore, after the fifth trade, Tom's stock position is long 4,700 shares.

Short Volatility Step 3—Closing the Remaining Position

The final trade in Table 8-7B is a two-part trade in which Tom closes his remaining position. After the fifth trade, Tom's position consists of short 100 Calls and long 4,700 shares. Therefore, in his closing trade, he buys all 100 of the calls at 1.50 and sells the 4,700 shares at 34.30.

As with the long volatility example presented earlier, it is noteworthy that the implied volatility of the 35 Calls, 40 percent, was the same for both the opening and closing trades. The stock price when the position was closed on Wednesday, 34.30, however, was not the same as when it was opened on Thursday, 34.80. Tom's profit-and-loss calculation is presented next.

Short Volatility Step 4—Calculation of Profit and Loss

Part 1 of Table 8-7C accounts for Tom's option trades. Column 1 lists both Thursday and Wednesday because Tom made trades on those days. Similarly, column 2 notes that he executed both buy and sell transactions. Columns 3 and 4 indicate that the purchase price and sale price were 1.50 and 1.90, respectively. Column 5 indicates a per-share profit of 0.40, or 40 cents. Tom's total dollar profit of +\$4,000 in column 6 is the product of three numbers: the per-share profit in column 5, the number of options in column 2, and the option multiplier of 100 ($+\$0.40$ per share $\times$ 100 options $\times$ 100 shares per option $= +\$4,000$).

Table 8-7C Delta-Neutral Trading—Short Volatility: Calculation of Profit and Loss

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
	Action & Quantity	Purchase Price	Sale Price	P/(L) per Share	Total P/(L) in Dollars
Part 1: Option Trade					
Thu & Wed	Buy/sell 100	1.50	1.90	+0.40	+$4,000
Part 2: Stock Trades					
Row 1 Thu	Buy 5,300	34.80	—	—	—
Row 2 Thu	Buy 500	35.30	—	—	—
Row 3 Fri	Sell 1,100	35.30 (500)	34.10	(1.20)	($ 600)
Row 4		34.80 (600)	—	(0.70)	($ 420)
Row 5 Mon	Buy 700	35.10	—	—	—
Row 6 Tue	Sell 700	35.10	34.20 (700)	(0.90)	($ 630)
Row 7 Wed	Sell 4,700	34.80	34.30	(0.50)	($2,350)
Row 8			Loss from stock trading		($4,000)
Row 9			Combined P/(L) stock and options		-0-

Part 2 of Table 8-7C has nine rows that describe each stock trade and calculate Tom's net dollar loss from all the stock trades. Row 1 of shows his first stock trade, in which he established part of his initial delta-neutral position. On Thursday, he purchased 5,300 shares at 34.80, as indicated in columns 1, 2, and 3, respectively. Column 4 is blank because this transaction did not involve a sale. Columns 5 and 6 are also blank in row 1 because an opening trade produces no profit or loss.

Row 2 contains Tom's adjusting stock trade made before the close on Thursday, in which he purchased 500 additional shares at a price of 35.30 per share. Like the columns left blank for the opening trade, columns 4, 5, and 6 of row 2 are also left blank because there was no sale transaction in this trade and therefore no profit or loss.

Rows 3 and 4 reflect Tom's first closing stock trade and, as a result, his first profit/loss calculation. As in the first example, profit-and-loss calculations are made on a LIFO basis. Column 1, row 3 indicates that Tom made this trade on Friday by selling 1,100 shares (column 2) at 34.10 per share (column 4). Rows 3 and 4 of column 3 contain the prices and numbers of purchased shares from rows 1 and 2. The 1,100 shares Tom sold in row 3 must be matched with shares previously purchased in order to calculate profit or loss. Under LIFO principles, the 500 shares purchased in Tom's adjusting stock trade (row 2) must be matched first, and then an additional 600-share block must be taken from the initial purchase (row 1) in order to get to a total of 1,100 shares. Column 3, row 3 indicates that 500 shares purchased at 35.30 are matched with the first 500 sold at 34.10. Thus this 500-share purchase and sale result in a loss of 1.20 per share and a total loss for Tom of $600, as shown in row 3 of columns 5 and 6. The profit/loss calculation for the additional 600-share block is shown in row 4. Column 3, row 4 indicates a price of 34.80 for a quantity of 600 shares, resulting in a per-share loss of 0.70, noted in column 5. Column 6 then shows Tom's total dollar loss of $420 on these 600 shares.

Row 5 in Table 8-7C reflects Tom's next adjusting trade on Monday. He bought 700 shares at a price of 35.10 per share. Since this was another opening trade, columns 4, 5, and 6 are blank because there is no information about a sale price, profit per share, or total profit.

Row 6 shows Tom's profit/loss calculation for the adjusting trade he made on Tuesday, when he sold 700 shares at 34.20. This profit/loss calculation is easy because 700 is the same number of shares purchased the day before and is easily matched under LIFO to that purchase. Row 6 reflects Tom's Tuesday sale at 34.20 of the 700 shares purchased on Monday at 35.10 per share for a loss of 0.90 per share (column 5) and a total loss of $630 (column 6).

Row 7 accounts for Tom's final stock trade in Table 8-7C. Tom closed his position on Wednesday by selling 4,700 shares. That sale is matched with the remaining shares purchased on Thursday. The purchase price on Thursday of 34.80 (row 1, column 3) and the sale price of 34.30 on Wednesday results in a loss of 50 cents per share (row 7, column 5) and a total loss for Tom of $2,350 (column 6).

Row 8, column 6 contains the sum of all the losses from Tom's stock trading, which amount to $4,000.

Row 9 completes part 2 of Table 8-7C by combining the profit from option trading and the loss from stock trading. Since Tom's option profit in part 1 exactly offsets the loss from stock trading in part 2, the net result of "–0–" appears in column 6, row 9.

Short Volatility Step 5—Recapping the Trades

Tom established a delta-neutral position by selling calls and buying stock. He made adjusting stock trades daily until he closed the remaining position. The accounting for profit and loss revealed that he realized a profit on the short options from time decay and that his losses from trading stock exactly offset that profit.

As with the long volatility delta-neutral exercise presented first, the implied volatility in this second exercise was unchanged at 40 percent during the period involved. What changed in this example was the stock price, which was 34.80 on Thursday when Tom made his first trade and was 34.30 on Wednesday when he made the closing trade. Despite the change in stock price, the result was still break-even.

Also like the long volatility example, this short volatility example might seem like a lot of work to just break even, but that is the concept of delta-neutral trading. In theory, when selling options delta-neutral, implied volatility will stay constant, and the losses from adjusting stock trades will offset the profit from time decay of the options—even when the stock price changes over time. In the language of options, if implied volatility equals realized volatility, then delta-neutral trading will break even. How traders use delta-neutral trading and attempt to profit from it is discussed after the next two examples that address some of the real-world issues of delta-neutral trading.

Simulated "Real" Delta-Neutral Trade 1

This exercise uses the theoretical values presented in Table 8-8A, the trades presented in Table 8-8B, and the profit-and-loss calculations presented in Table 8-8C. It also employs a hypothetical trader named Susan.

Table 8-8A is an abbreviated version of Tables 8-6A and 8-7A. It contains only the stock prices with the option theoretical values and deltas necessary for the trades in Table 8-8B and the profit-and-loss calculations in Table 8-8C.

Like Tom's previous two delta-neutral trading exercises, Table 8-8B contains the essential details of Susan's trades. Susan establishes a delta-neutral position on Tuesday when the stock price is 86.50. She purchases 100 of the 85 Puts at 2.66. Because the delta of the 85 Put is −0.40, she buys 4,000 shares of stock. This is a long volatility position because options are purchased, and as indicated in Table 8-8A, the volatility assumption is 35 percent.

Susan's second trade also occurs on Tuesday, but just before the market closes. With the stock price at 87.40, the delta of the 85 Put changes to −0.36. Therefore, Susan sells 400 shares of stock to reestablish delta-neutrality. This trade is described in column 4, row 2 and is explained as "adjusting trade to get delta=neutral" in column 5. Susan's new stock position is shown in column 6 as "+3,600," or long 3,600 shares.

Table 8-8A Delta-Neutral Trading—Simulated "Real" Example 1: 85 Put Theoretical Values and Deltas (Volatility 35%; Interest Rate 4%; No Dividends, 31–28 Days)

	Tuesday	Wednesday	Thursday	Friday
Stock Price	31 Days T.V./Delta	30 Days T.V./Delta	29 Days T.V./Delta	28 Days T.V./Delta
87.40	2.32/−0.36		2.21/−0.36	
86.50	2.66/−0.40			
84.65				3.32/−0.49
83.10		4.23/−0.56		

Table 8-8B Delta-Neutral Trading—Simulated "Real" Example 1: The Trades

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Day	Stock Price	Option Delta	Trade	Explanation	Stock Position
Tues	86.50	−0.40	Buy 100 85 Puts @ 2.66 Buy 4,000 shares @ 86.50	Opening trade	+4,000
Tues	87.40	−0.36	Sell 400 shares @ 87.40	Adjusting trade to get delta -neutral	+3,600
Wed	83.10	−0.56	Buy 2,000 shares @ 83.10	Adjusting trade to get delta -neutral	+5,600
Thu	87.40	−0.36	Sell 2,000 shares @ 87.40	Adjusting trade to get delta -neutral	+3,600
Fri	84.65	−0.49	Sell 100 85 Puts @ 3.32 Sell 3,600 shares @ 84.65	Closing trade	-0-

Susan makes another adjusting trade on Wednesday after the stock price falls to 83.10. The change in stock price moves the delta of the 85 Put to −0.56. Therefore, Susan buys 2,000 shares and increases her stock position to long 5,600 shares (column 6). She makes another trade on Thursday by selling 2,000 shares at 87.40.

Susan's lat last trade in Table 8-8B closes her position on Friday. She sells all 100 of the 85 Puts at 3.32 and the remaining 3,600 shares at 84.65.

Table 8-8C calculates Susan's profit and loss in two parts. In part 1, the profit from Susan's option trades is +$6,600. Part 2 calculates the profit from her stock trades as +$1,940 for a combined profit of +$8,540.

Recapping Simulated "Real" Trade 1

Susan established a delta-neutral position by buying puts and buying stock. She made adjusting stock trades daily until she closed her remaining position. The profit-and-loss calculation showed that both

Table 8-8C Delta-Neutral Trading—Simulated "Real" Example 1: Calculation of Profit and Loss

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
	Action & Quantity	Purchase Price	Sale Price	P/(L) per Share	Total P/(L) in Dollars
Part 1: Option Trade					
Tue & Fri	Buy/sell 100	2.66	3.32	+0.66	+$6,600
Part 2: Stock Trades					
Row 1 Tue	Buy 4,000	86.50	—	—	—
Row 2 Tue	Sell 400	86.50	87.40	+0.90	+$ 360
Row 3 Wed	Buy 2,000	83.10	—	—	—
Row 4 Thu	Sell 2,000	83.10	87.40	+4.30	+$8,600
Row 5 Fri	Sell 3,600	86.50	84.65	(1.95)	($7,020)
Row 7			Profit from stock trading		+$1,940
Row 8			Combined P/(L) stock and options		+$8,540

the option trades and the stock trades earned a profit. This is the ideal situation! However, if Susan was trading delta-neutral, how did she make a profit? The following three observations and the Distribution screen in Op-Eval Pro explain what happened.

The first observation is that implied volatility did not change. According to Table 8-8A, implied volatility was 35 percent on each of the four days. The second observation is that there was a net stock-price decline during the four days from 87.40 to 84.65. Third, the stock-price action seemed very volatile. There was a stock-price drop of 4.30 from Tuesday's close to Wednesday's close and then a rise of the same amount from Wednesday's close to Thursday's close. Those two moves were followed by a drop of 2.85 on Friday before Susan closed the position.

To get an estimate of what the realized volatility was during the four-day period in this example, the Distribution screen of Op-Eval Pro is useful. By setting the "PRICE" to 87.40 and the "DAYS" to 1, it is possible to estimate the "Volatility %" by trial and error. The goal is to find the volatility percentage that has a one-day standard deviation of 4.30. This percentage is found by raising the volatility until the range in "1 days" is 83.10 to 91.70, or a range of 4.30 up or down from 87.40. The volatility percentage that achieves this result is 94. This number means that the price action of the stock in simulated "real" trade 1 is consistent with 94 percent volatility.

Susan's combined profit of $8,540 in Table 8-8C resulted from the realized volatility of 94 percent being greater than the implied volatility of 35 percent. In other words, the actual fluctuation of the stock price (realized volatility) was much higher than the fluctuation estimated by the price of the 85 Put (implied volatility). Remember, if realized volatility and implied volatility are equal, then delta-neutral trading breaks even because the profit (or loss) from stock trading offsets the loss (or profit) from option time decay. If realized volatility is greater than implied volatility, however, then the stock-price swings will more than offset the option decay. If a long volatility delta-neutral position is maintained in this environment, then profits will result from the relatively large stock-price swings.

Susan's profit from the put resulted from the price decline of the stock. From Tuesday to Friday, the stock price fell from 87.40 to 84.65, for a net decline of 2.85. Undoubtedly, there was some time decay of the 85 Put, but the delta component was greater than the theta component.

In fact, simulated "real" trade 1 represents the ideal long volatility situation. Delta-neutral traders, when trading long volatility, want situations when the realized volatility is higher than implied volatility—and the higher, the better! They also want large stock-price changes in a short period of time. In this example, there were three large stock-price changes in four days. They were large because they were consistent with 94 percent volatility, which is much higher than the implied volatility of the purchased 85 Put of 35 percent. Unfortunately, as the next example shows, not all delta-neutral trades work out this way.

Simulated "Real" Delta-Neutral Trade 2

This exercise is different from the previous three because it explores the issue of changing implied volatility. Table 8-9A is another abbreviated version of Tables 8-6A and 8-7A. It contains only the stock prices, option values, and deltas needed to explain the activities of hypothetical trader Susan. The implied volatility assumptions are indicated in the heading of each column. On Thursday, for example, the implied volatility assumption is 28 percent ("I.V. 28 percent"). On Friday, the assumption is 30 percent, and it is 32, 34, and 24 percent on Monday, Tuesday, and Wednesday, respectively.

As in the preceding delta-neutral trading exercises, Table 8-9B contains the essential details of all of Susan's trades. Her initial trade occurs on Thursday. With a stock price of $61.00, she buys 50 of the 60 Puts at 1.86 and simultaneously buys 2,000 shares of stock to establish a delta-neutral position because the delta of the 60 Put is −0.40.

Table 8-9A Delta-Neutral Trading—Simulated "Real" Example 2:60 Put Theoretical Values and Deltas (Volatility Varies, Interest Rate 4%, No Dividends, 49–45 Days)

	Thursday	Friday	Monday	Tuesday	Wednesday
Stock Price	49 Days I.V. 28% T.V./Delta	48 Days I.V. 30% T.V./Delta	45 Days I.V. 32% T.V./Delta	44 Days I.V. 34% T.V./Delta	43 Days I.V. 24% T.V./Delta
61.00	1.86/−0.40			2.24/−0.42	
60.50			2.31/−0.44		
60.00		2.44/−0.46			
59.80	2.56/−0.48				
59.50					2.23/−0.50

Table 8-9B Delta-Neutral Trading—Simulated "Real" Example 2: The Trades

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Day	Stock Price	Option Delta	Trade	Explanation	Stock Delta Position
Thu	61.00	−0.40	Buy 50 60 puts @ 1.86 Buy 2,000 shares @ 61.00	Opening trade	+2,000
Thu	59.80	−0.48	Buy 400 shares @ 59.80	Adjusting trade to get delta -neutral	+2,400
Fri	60.00	−0.46	Sell 100 shares @ 60.00	Adjusting trade to get delta -neutral	+2,300
Mon	60.50	−0.44	Sell 100 shares @ 60.50	Adjusting trade to get delta -neutral	+2,200
Tue	61.00	−0.42	Sell 100 shares @ 61.00	Adjusting trade to get delta -neutral	+2,100
Wed	59.50	−0.50	Sell 50 60 calls @ 2.23 Sell 2,100 shares @ 59.50	Closing trade	-0-

Susan makes a second trade on Thursday just before the market closes after the stock price falls to 59.80. She buys 400 shares because the delta of the 60 Put is now −0.48. On Friday, Susan sells 100 shares when the stock price rises to 60. In Table 8-9A, the column heading for Friday ("48 Days") notes that the implied volatility has risen to 30 percent. The change in the volatility assumption has a slight impact on the delta, but the impact of a 2 percent change is probably too small to notice.

On Monday, Susan sells 100 shares at 60.50. Again, the implied volatility has increased, this time to 32 percent. Susan's fifth trade, on Tuesday, consists of selling still another 100 shares, this time at 61.00. And again, implied volatility has increased 2 percent to 34 percent.

Susan closes the position on Wednesday when the stock price is 59.50 and when implied volatility has dropped—sharply—to 24 percent.

Perhaps this decline in implied volatility is the result of an earnings report, other anticipated news, or simply a sudden change in investor psychology. Nevertheless, Susan sells all 50 of the 60 Puts at 2.23 and the remaining 2,100 shares at 59.50.

Part 1 of Table 8-9C calculates Susan's profit from the option trades at $1,850, and part 2 calculates the loss from stock trades at $2,820 for a combined *loss* of $970.

Recapping Simulated "Real" Trade 2

Susan established a delta-neutral position by buying puts and buying stock. She made adjusting stock trades daily until she closed the remaining position. The net result, however, was a *loss*. What happened?

Table 8-9C Delta-Neutral Trading—Simulated "Real" Example 2: Outcome 1—Calculation of Profit and Loss

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
	Action and Quantity	Purchase Price	Sale Price	P /(L) per Share	Total P/(L) in Dollars
Part 1: Option Trade					
Thu & Wed	Buy/sell 50	1.86	2.23	+0.37	+$1,850
Part 2: Stock Trades					
Row 1 Thu	Buy 2,000	61.00	—	—	—
Row 2 Thu	Buy 400	59.80	—	—	—
Row 3 Fri	Sell 100	59.80	60.00	+0.20	+$ 20
Row 4 Mon	Sell 100	59.80	60.50	+0.70	+$ 70
Row 5 Tue	Sell 100	59.80	61.00	+1.20	+$ 120
Row 6 Wed	Sell 100	59.80	59.50	(0.30)	($ 30)
Row 7	Sell 2,000	61.00	59.50	(1.50)	($3,000)
Row 8			Loss from stock trading		($2,820)
Row 9			Combined P/(L) stock and options		($ 970)

The first observation is that implied volatility dropped sharply from 34 to 26 percent from Tuesday to Wednesday. The second observation is that the stock-price action seemed very calm because three of the daily stock-price changes were 50 cents or less. The price rose 20 cents from Thursday's close to Friday's close, then 50 cents to Monday's close, and then 50 cents to Tuesday's close. The stock-price change from Tuesday's market close to closing the position on Wednesday was 1.50.

Susan's combined loss of $970 in Table 8-9C is made up of one positive component and two negative ones. The sharp down move in the stock price from Tuesday to Wednesday was a positive component because it caused the price of Susan's puts to rise, but time decay and decreasing implied volatility were negative components. Ultimately, the negative impacts of vega and theta were greater than the positive impact of delta.

Considering Another Outcome for Simulated "Real" Trade 2

Would Susan's outcome change if she had closed her position one day earlier when implied volatility was 34 percent? Table 8-9D answers this question.

Table 8-9D shows that had Susan closed her position on Tuesday, rather than on Wednesday, she would have realized a *profit* of $2,230 instead of a *loss* of $970. With the stock price at 61.00 on Tuesday and implied volatility at 34 percent, the 60 Put was trading at 2.24. On Wednesday, however, with the stock price at 59.50 and implied volatility at 24 percent, the 60 Put was trading 1 cent lower at 2.23. Even though the stock price declined by 1.50, the price of the 60 Put, which had a delta of −0.42, *declined* by 1 cent. You can see the significance of this decrease in implied volatility!

Table 8-9D shows that selling 2,200 shares at 61.00 on Tuesday (rows 5 and 6 in Table 8-9D) improves the stock trading result by $3,150 compared with selling at 59.50 on Wednesday (rows 6 and 7

Table 8-9D Delta-Neutral Trading—Simulated "Real" Example 2: Outcome 2—Calculation of Profit and Loss (if Position Had Been Closed on Tuesday)

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
	Action and Quantity	Purchase Price	Sale Price	P/(L) per Share	Total P/(L) in Dollar
Part 1: Option Trade					
Thu & Wed	Buy/sell 50	1.86	2.24	+0.38	+$ 1,900
Part 2: Stock Trades					
Row 1 Thu	Buy 2,000	61.00	—	—	—
Row 2 Thu	Buy 400	59.80	—	—	—
Row 3 Fri	Sell 100	59.80	60.00	+0.20	+$ 20
Row 4 Mon	Sell 100	59.80	60.50	+0.70	+$ 70
Row 5 Tue	Sell 200	59.80	61.00	+1.20	+$ 240
Row 6	Sell 2,000	61.00	61.00	-0-	-0-
Row 7			Profit from stock trading		+$ 330
Row 8			Combined P/(L) stock and options		+$ 2,230

in Table 8-9C), converting a loss of $2,820 to a profit of $330. The 34 percent level of implied volatility on Tuesday also allowed Susan to sell the 60 Puts at 2.24 with the stock price at 61.00 and improve her combined profit to $2,230.

Note that had implied volatility been 24 percent on Tuesday, the price of the 60 Put would have been 1.59. This price is calculated with the Op-Eval Pro software using the assumptions other than volatility in Table 8-9C. A selling price of 1.59 for the 60 Puts would have changed the options profit of $1,900 in Table 8-9D to a *loss* of $1,350, a negative swing of $3,250.

The conclusion is obvious: The drop in implied volatility from 34 to 24 percent from Tuesday to Wednesday caused the delta-neutral position in simulated "real" trade 2 to lose money. This is one of the risks facing delta-neutral traders. A trader must constantly ask, "Should I exit today, or should I wait until tomorrow?" The answer depends on the forecast for implied volatility, and it is a decision that can only be made by traders individually.

Delta-Neutral Trading—Opportunities and Risks for Speculators

Speculators attempt to profit by forecasting direction. A speculator buys stock, buys calls, or sells puts because the forecast is bullish. In the case of delta-neutral trading, speculators must forecast the direction of implied volatility, the direction of realized volatility, and the relationship between the two. If implied volatility is deemed to be low, and if realized volatility is forecast to rise, then a speculator might attempt to profit from this forecast by buying options delta-neutral, as explained in the long volatility example discussed earlier. Alternatively, if implied volatility is deemed to be high, and if realized volatility is forecast to fall, then a speculator might attempt to profit from this forecast by selling options delta-neutral, as explained in the short volatility example.

In an effort to make a profit from delta-neutral trading, speculators assume risk over a period of time that is several trading days at minimum and several weeks at maximum. Hypothetical trader Tom's delta-neutral trading exercise (1) involved five trading days, with a break-even result, not including transaction costs. While Tom closed his position after five days, in a real situation, a speculator would have nearly daily decisions to make. Should the position be closed at break-even, as it was in the example? Or should the position be kept open? The answer to this question is a subjective one that traders must make individually. Just as trading market direction is an art, based on one's instinct to enter trades and to take profits and losses, so too is delta-neutral trading more of an art than a science.

Speculative Risks of Long Volatility

Speculators engaged in delta-neutral trading carry limited but substantial risk in the case of long volatility. For example, consider a delta-neutral position created by buying 50 call options and shorting 2,000 shares of stock. If each option's vega is 0.12, or 12 cents, a one percentage point change in implied volatility would cause the option price to rise or fall by 12 cents, or $12 for each option. Thus, if implied volatility were to drop by five percentage points without the underlying stock moving, then each option in this example would lose 60 cents per share, or $60 per option (5 percent volatility × $0.12 per share per 1 percent of volatility × 100 shares per option = $60). For a long 50-option position, the loss would total $3,000 ($60 per option × 50 options = $3,000), not including any loss from time decay. And the loss would increase if implied volatility declined further. The maximum possible loss of a long volatility delta-neutral position occurs if the position is held to expiration and if the stock price equals the strike price of the options at expiration, in which case the options expire worthless.

Speculative Risks of Short Volatility

The risk of delta-neutral trading borne by speculators is unlimited in the case of short volatility. Delta-neutral positions with short options carry two risks. The first risk stems from rising implied volatility. If a speculator sells 100 Call options delta-neutral, and if each call has a vega of 0.09, or 9 cents per share, then the speculator will suffer a loss of $900 for each one percentage point rise in implied volatility.

The second risk of delta-neutral positions with short options arises from a big move in the underlying stock. Table 8-10 shows how a sudden price rise from $42 to $49 in the underlying stock can cause a large loss for a delta-neutral position involving short options. An announcement after the close of trading can cause a stock to open sharply higher or lower on the next day. Such price action at the start of trading is known as a *gap opening* and occurs frequently after earnings announcements. However, gaps in stock prices also can occur during the trading day. Traders with short option positions always must be on alert for such events.

In Table 8-10, column 1 describes the initial position, and column 2 contains the initial prices. The position is short 100 of the 45 Calls at 1.00 and long 3,000 shares of stock at $42.00. The name of the stock is omitted because it is unimportant. Row 3, column 2 indicates that the initial position is delta-neutral because the delta of each short call is −0.30.

Column 3 reflects prices after the big move. The stock price has risen to $49.00, and the call price has risen to 4.90. Column 4 contains the per-share loss of 3.90 for each option (row 1) and the per-share profit of $7.00 for the stock (row 2). Column 5 calculates the loss for the 100 Calls and the profit for the 3,000 shares. For the two-part position, the net *loss* is $18,000.

The message of Table 8-10 is that having a delta-neutral position is not necessarily protection against losses. As explained earlier, delta-neutral positions with long options profit from large stock-price swings, or high volatility, and lose from little or no stock-price changes, or low volatility. In contrast, delta-neutral positions with short options profit from low volatility and lose from high volatility. What constitutes *low* and *high* varies from stock to stock, from index to index, and from futures contract to futures contract.

Table 8-10 Risk of a Big Move with Short Options, Delta-Neutral

	Col 1	Col 2	Col 3	Col 4	Col 5
Row	Position	Initial Prices	Prices after Big Move	Profit/Loss per Share	Position Loss
1	Short 100 45 Calls	1.00	4.90	(3.90)	(39,000)†
2	Long 3,000 shares	42.00	49.00	7.00	21,000‡
3	Position delta*	-0-	−5,000	Total loss:	(18,000)

* With stock price 42.00, the delta of the short 45 Call is −0.30.

† Option position loss = ($390) per option × 100 options = ($39,000).

‡ Stock position profit = $7 per share × 3,000 shares = $21,000.

Option traders who employ delta-neutral trading must be familiar with the historic volatility and implied volatility of the underlying instrument they are trading (see Chapter 7), and they must make judgments about what is low and what is high. Delta-neutral trading is not a quick road to riches for speculators; it is a difficult enterprise involving judgment and discipline. It has its risks and potential rewards, as does any trading endeavor.

Trading Delta-Neutral—Opportunities and Risks for Market Makers

Market makers, in contrast to speculators, attempt to profit by buying at the bid price and selling at the ask price. Delta-neutral trading for market makers therefore is the first step in a two-step process that hopefully lasts only minutes or no more than a few hours.

As will be discussed in Chapter 8 with several examples, step one for a market maker is to buy an option at the bid price (or sell at the ask price) and then to create a delta-neutral position with the underlying stock. Step two is to sell the option at the ask price (or buy at the bid price) and then close the stock position. The market maker hopes that when both the stock and option positions are closed, a profit will result. The risk, of course, is that the market maker will instead suffer a loss.

When market makers buy at the bid price and immediately create a delta-neutral position by trading stock, the stock trade is known as a *hedge*. A *hedging trade* or, simply, a *hedge* is establishing a position that offsets the short-term market risk of another position. Consider the delta-neutral positions in Tables 8-1 through 8-4. Market makers could have created each of these positions after buying (or selling) the options at the bid (or ask) price.

A market maker in XYZ options, call him Market Maker A, might have created the position in Table 8-1 as follows: After reviewing the historic volatility of XYZ stock and the implied volatility of its options, and after evaluating several bids and offers in XYZ options, the market maker decides that XYZ options at 28 percent volatility would be a good buy and that at 30 percent volatility those options would be a good sell. Market Maker A also decides that he is willing to buy or sell 50 contracts at these levels. He then programs his computer to make trades at these levels. When the price of XYZ stock is at $89.05, Market Maker A's computer automatically bids 2.75 for 50 XYZ 90 Calls and offers 50 at 2.85.

At this instant, with XYZ trading at $89.05, assume that another trader, call her Trader B, decides to sell 20 XYZ 90 Calls at "the market." A *market order* is an instruction to a broker to make a trade at the best price currently available. Trader B could be a nonprofessional individual trader or a professional trader at a mutual fund, or she could be another market maker. The seller's identity does not matter. All that matters is that Market Maker A, who is bidding for XZY 90 Calls, has just purchased 20 of them at a price of 2.75. Trader B is the seller.

At this point, with XYZ stock at $89.05, Market Maker A now holds 20 calls with a delta of +0.45 each, creating is an exposure of +900 deltas that he wants reduced to zero. The quickest and surest way of bringing the delta to zero is to short 900 shares of XYZ stock, so Market Maker A's computer automatically executes this trade. As a result, Market Maker A has the delta-neutral position described in Table 8-1 of long 20 XYZ 90 Calls at 2.75 and short 900 shares of XYZ stock at 89.05.

How Market Maker A decides what to do next is more complicated and is discussed in Chapter 10. In brief, however, market makers strive not only to be delta-neutral, but they also try to be volatility-neutral. Consequently, as long as Market Maker A senses that implied volatility is staying the same or rising, he will maintain his long call and short stock position and hope that still another trader will purchase the calls at the ask price. If, however, it appears that implied volatility is beginning to decline, then Market Maker A will sell another option to hedge the volatility risk of the long 90 Calls.

In theory, the risk borne by market makers is the same risk borne by speculators. Buying options delta-neutral poses substantial risk, whereas selling options delta-neutral caries unlimited risk regardless of the trader. In practice, however, speculators enter delta-neutral positions with the intention of holding them for several days or longer, whereas market makers hope to limit their exposure to much shorter periods of time, which decreases their risk exposure.

Speculators who engage in delta-neutral trading strategies hope to profit from predicted changes in implied and realized volatility. They risk losing money if their forecasts are wrong. For market makers, a delta-neutral position does not involve a forecast. It is a hedge, or risk-reducing tactic, until they make "step two" of a trade.

Summary

Delta-neutral trading is a nondirectional trading technique that profits, loses, or breaks even from the relationship between implied volatility and realized volatility. A delta-neutral position is one whose delta is at or near zero. Professional market makers and professional speculators have very different motivations for using delta-neutral trading.

Long volatility describes delta-neutral positions in which options are owned, such as long calls and short stock or long puts and long stock. Short volatility describes delta-neutral positions with short options, such as short calls and long stock or short puts and short stock. Delta-neutral positions can have more than two components.

The process of delta-neutral trading involves, first, establishing a delta-neutral position; second, making adjusting stock trades over several days according to predetermined rules; and third, closing the remaining position. The theory behind delta-neutral trading is that the profit or loss from option trades will exactly offset the loss or profit from stock trades. In the language of options, the theory is that implied volatility equals realized volatility.

The reality of delta-neutral trading is different from the theory. Implied volatility and realized volatility both change because both are subject to market forces. Consequently, there is no assurance that they will be equal. Traders who use delta-neutral trading therefore must assume some risk.

Speculators use a forecast for the direction of implied volatility and realized volatility and the relationship of the two, and they assume the risk that their forecast is wrong. Market makers use delta-neutral trading as a short-term hedging technique with a goal of closing a position by buying at the bid price or selling at the ask price in a short period of time before implied volatility changes adversely.

Chapter 9

SETTING BID-ASK PRICES

Market makers must feel comfortable with the prices at which they buy and sell options. They therefore must have a system to establish these prices to their advantage. At a minimum, the prices must be set in such a way that traders believe that they have a slight theoretical advantage. This chapter will discuss four important concepts related to how traders establish bid and ask prices. The first concept explained is the theory of the bid-ask spread, how it works, and why it is so important to market makers. Second, the chapter explores how market makers attempt to earn the bid-ask spread by trading delta-neutral. Setting bid and ask prices based on implied volatility will be discussed next, and finally, the fourth concept, how market makers use implied volatility to keep track of bid and ask prices as stock prices change, will be explained. The discussion concludes with four exercises that illustrate how buying options on the bid, selling at the ask, and trading delta-neutral can help to establish butterfly spreads, reverse conversions, and box spreads at profitable prices.

This chapter assumes that you are familiar with "the market" being a combination of a bid price, an ask price, and a quantity for both. If you need a refresher on these concepts, please review Chapter 1 before proceeding through the following material.

The Theory of the Bid-Ask Spread

Tables 9-1 and 9-2 illustrate how market makers attempt to make money by buying on the bid, selling at the ask, and hedging delta-neutral. Each table has an opening trade, a closing trade, and a profit/loss calculation. The hypothetical market maker engaging in the trades in these examples is called Alex.

Alex makes his first trade in Table 9-1 at 10:00 a.m. when the stock has bid and ask prices of 53.99 and 54.01, respectively, and the 55 Call has a bid price of 1.80, an ask price of 1.85, and a delta of +0.40. For simplicity, this example assumes that the necessary number of shares and options can be traded at the prices indicated, so the quantities of shares and options bid for and offered are not mentioned.

Trade 1 in Table 9-1 has two parts. Alex sells 10 of the 55 Calls at the ask price of 1.85 per share and purchases 400 shares of stock at the ask price of 54.01 to hedge the option position. A *hedging stock trade* is the purchase or sale of the specific number of shares that offsets the total delta of an option position. The calculation of total position delta is shown after the trade 1 description. Alex purchases stock at the ask price because a market maker must act quickly after making an option trade. If he fails to act quickly, the stock price could move the wrong way, which would make the hedging stock trade ineffective.

Alex's next trade in Table 9-1 occurs at 11:00 a.m. after the stock price rallies $1.00 and the bid and ask prices for the 55 Call increase by 40 cents. For simplicity, these changes in option prices are exactly as predicted by the delta. In the real world, gamma or vega or both, as explained in Chapter 4, would cause the option price to change differently than indicated by the delta. Trade 2 closes both parts of the position established in trade 1. Alex buys the short options at the bid price of 2.20 and sells the stock at the bid price of 54.99.

Profit and loss are calculated at the bottom of Table 9-1. Alex sold 10 of the 55 Calls at 1.85 per share and repurchased them for 2.20 for a loss of 35 cents per share, or $35 per option or $350 total for 10 options. He bought 400 shares of stock at 54.01 and sold them at 54.99

Table 9-1 Theory of the Bid-Ask Spread Part 1

		Bid	Ask
10:00 a.m.	Stock quote:	53.99	54.01
	55 Call quote:	1.80	1.85
	55 Call delta:	+0.40	

Trade 1: Sell 10 55 Calls at the ask price and hedge delta-neutral with stock

		±Number of Shares	×	Delta	=	Position Delta
Sell 10 55 Calls	1.85	−1,000	×	+0.40	=	−400
Buy 400 shares	54.01	+400	×	+1.00	=	+400
		Total position delta			=	−0−

		Bid	Ask
11:00 a.m.	Stock quote:	54.99	55.01
	55 Call quote:	2.20	2.25

Trade 2: Buy 10 55 Calls on the bid, and close the stock position

	±Number of Shares	×	Delta	=	Position Delta
Buy 10 55 Calls	2.20		(Closes position from Trade 1)		
Sell 400 shares	54.99		(Closes position from Trade 1)		

Calculation of profit or loss

	Stock Trade	Option Trade	Net Profit/Loss
Sell price	+54.99	+ 1.85	
Buy price	−54.01	− 2.20	
P/L per share	+ 0.98	− 0.35	
× Number of shares	× 400	× 1,000	
Profit or loss	+ 392	−350	+ 42

for a profit of 98 cents per share, or $392 total. The net result is a profit of $42, not including transaction costs.

The message of Table 9-1 seems to be that buying options on the bid and selling them at the ask yields profits for market makers, even if they have to give up the bid-ask spread on the underlying stock. But is Table 9-1 conclusive? Suppose that the stock price declines instead of rallies. What would the result be? Table 9-2 addresses this question.

Table 9-2 is similar to Table 9-1 with one major difference: The stock price declines by $1.00 rather than rises. Alex's first trade in Table 9-2 is the same as trade 1 in Table 9-1. He sells 10 of the 55 Calls at the ask price of 1.85 and purchases 400 shares at 54.01 to hedge the options.

Table 9-2 Theory of the Bid-Ask Spread Part 2

		Bid	Ask
10:00 a.m.	Stock quote:	53.99	54.01
	55 Call quote:	1.80	1.85
	55 Call delta:	+0.40	

Trade 1: Sell 10 55 Calls at the ask price and hedge delta-neutral with stock:

		±Number of Shares	×	Delta	=	Position Delta
Sell 10 55 Calls	1.85	−1,000	×	+0.40	=	−400
Buy 400 shares	54.01	+ 400	×	+1.00	=	+400
				Position delta	=	−0−

		Bid	Ask
11:00 a.m.	Stock quote:	52.99	53.01
	55 Call quote:	1.40	1.45

Trade 2: Buy 10 55 Calls on the bid and close the stock position:

	Buy 10 55 Calls	1.40	(Closes position from Trade 1)
	Sell 400 shares	52.99	(Closes position from Trade 1)

Calculation of profit or loss:

	Stock Trade	Option Trade	Net Profit/Loss
Sell price	+52.99	+1.85	
Buy price	−54.01	−1.40	
P/L per share	−1.02	+0.45	
× number of shares	× 400	× 1,000	
Profit or loss	−408	+450	+42

Trade 2 in Table 9-2 occurs at 11:00 a.m. after the stock price declines $1.00 and the bid and ask prices for the 55 Call decline by 40 cents. In trade 2, Alex purchases the short options at the bid price of 1.40 and sells the stock at the bid price of 52.99.

Profit and loss are calculated at the bottom of Table 9-2. Alex sold 10 of the 55 Calls at 1.85 per share and repurchased them for 1.40 for a profit of 45 cents per share, or $45 per option or $450 total for 10 options. He bought 400 shares of stock at 54.01 and sold them at 52.99 for a loss of 1.02 per share, or $408 total. The net result is a profit of $42, not including transaction costs. This is exactly the same result as in Table 9-1. A stock-price decline therefore yields the same result as a stock-price rally.

Real-World Factors

The exercises in Tables 9-1 and 9-2 show, conceptually, that buying options on the bid, selling them at the ask, and trading delta-neutral can yield profits for market makers regardless of which way the stock price changes and even if they have to give up the bid-ask spread in the underlying stock. In the real world, of course, there are several complicating factors. First, traders must pay transaction costs. Even if they are very low for professional market makers, transaction costs can have an impact on trading results and must be included when planning trades. Second, the size of the bid-ask spread in the underlying stock is significant. In these two examples, the stock's bid-ask spread was 40 percent of the bid-ask spread in the options: 2 cents per share for the stock versus 5 cents for the options. There is clearly a point at which the bid-ask spread in the stock requires an adjustment to the bid-ask spread in the options. Third, since stock prices fluctuate, market makers must learn to adjust their bid and ask prices for options in a manner consistent with stock-price changes. Using the delta is one tool of the market maker is this regard, but as will be shown below, there are other tools that are more important.

The Need to Adjust Bid and Ask Prices

Option prices do not always change exactly as the delta and gamma predict they will because the level of implied volatility can change. The impact of implied volatility was illustrated in Table 7-6. For this reason, market makers must respond in two ways. They must set risk limits, and they must scale into and out of positions.

A limit on risk can be stated in dollars, in exposure to volatility, or in the number of option contracts. For the following example, the market maker, whose name is Anna, will set a risk limit of 100 contracts, long or short. Also, in this example, Anna will buy or sell a maximum of 20 contracts before adjusting the bid and ask prices.

Scaling in means buying at successively lower prices or selling at successively higher prices so that the average price of a large position is more favorable than the initial price. The concept is that if a series of buy orders or sell orders comes into the market, one right after another, then a market maker can scale in, or average in, up to the predetermined maximum contract position. In the following example, the market maker, Anna, sells 20 contracts at the initial price, then 20 more at a higher price, then 20 more at a still higher price, and so on until the maximum of 100 contracts is reached or she is able to buy and close some of the short contracts.

By adjusting bid and ask prices in this manner, Anna accomplishes two things. First, she manages her position by getting a better price (higher in this case) with each sale. Second, the higher bid might entice sellers into the marketplace. Remember, a market maker's goal is to buy on the bid price and sell at the ask price, make a profit, and eliminate risk by closing the position.

In real trading, a trader applies personal judgment in this process. Why 20 contracts at each level and not 10 contracts or 25? How much should the price be adjusted after each purchase or sale? Should bid and ask prices be raised or lowered by one tick, two ticks, or more? And when should the size of the adjustment be changed—when a position reaches 40 contracts, 60 contracts, or some other number?

There are no scientifically "right" answers to these questions. Every market maker must make an individual determination based on experience and willingness to accept risk.

The Process of Adjusting Bid and Ask Prices

Market maker Anna makes four trades in the following example. As three successive 20-contract buy orders enter the market followed by a 60-contract sell order, Anna sells to the buy orders and then buys from the sell order. After each sale, she raises the bid and ask prices. For the sake of simplicity, the example assumes that the stock price does not change. The issue of changing stock prices will be discussed in later exercises.

Table 9-3 starts with the essential information. The stock has a bid price of 80.40 and an ask price of 80.42. The 80 Call has a bid price of 4.50, an ask price of 4.60, and a delta of +0.60. It is assumed that the necessary number of shares and options can be traded at the prices indicated.

In step 1 in Table 9-3, Anna sells 20 of the 80 Calls at the ask price of 4.60 and purchases 1,200 shares of stock at 80.42 to hedge the option position. Given the call delta of +0.60, Anna calculates the number of shares as follows: The underlying for 20 short calls is 2,000 short shares, but given the delta, the market exposure is equivalent to short 1,200 shares ($-2{,}000 \times 0.60 = -1{,}200$). To be delta-neutral and offset this short market exposure, Anna immediately buys 1,200 shares at the ask price of 80.42.

Since Anna's position now has 20 short calls, she must adjust the bid and ask prices in compliance with her predetermined rule to manage risk. In step 2, therefore, she raises the bid and ask prices by 2 cents each, changing the market for the 80 Call to 4.52 bid and 4.62 ask. In step 3, Anna sells 20 more of the 80 Calls at the new ask price of 4.62 and purchases 1,200 more shares of stock at 80.42 to hedge the newly sold calls.

Table 9-3 Adjusting Bid and Ask Prices

	Bid	Ask
Stock quote:	80.40	80.42
80 Call quote:	4.50	4.60
80 Call delta:	+0.60	

Step 1: Sell 20 80 Calls at the ask price and hedge delta-neutral with stock:

			±Number of Shares	×	Delta	=	Position Delta
Trade 1:	Sell 20 80 Calls	4.60	−2,000	×	+0.60	=	−1,200
	Buy 1,200 shares	80.42	+1,200	×	+1.00	=	+1,200
					Total delta	=	−0−

Step 2: Raise the call bid and ask prices by 2 cents: bid, 4.52; ask, 4.62.
Step 3: Sell 20 80 Calls at the ask price and hedge delta-neutral with stock:

			±Number of Shares	×	Delta	=	Position Delta
Trade 2:	Sell 20 80 Calls	4.62	−2,000	×	+0.60	=	−1,200
	Buy 1,200 shares	80.42	+1,200	×	+1.00	=	+1,200
					Total delta	=	−0−

Step 4: Raise the call bid and ask prices by 2 cents: bid, 4.54; ask, 4.64.
Step 5: Sell 20 80 Calls at the ask price and hedge delta-neutral with stock:

			±Number of Shares	×	Delta	=	Position Delta
Trade 3:	Sell 20 80 Calls	4.64	−2,000	×	+0.60	=	1,200
	Buy 1,200 shares	80.42	+1,200	×	+1.00	=	+1,200
					Total delta	=	−0−

Step 6: Raise the call bid and ask prices by 2 cents: bid, 4.56; ask, 4.66.
Step 7: Buy 60 80 Calls on the bid price and close the stock position:

Trade 4:	Buy 60 80 Calls	4.56	(Closes position)
	Sell 3,600 shares	80.40	(Closes position)

Step 8: Profit or loss:

	Stock Trade	Option Trade 1	Option Trade 2	Option Trade 3	Combined Profit/Loss
Sell price	80.40	4.60	4.62	4.64	
Buy price	80.42	4.56	4.56	4.56	
P/L per share	−0.02	+0.04	+0.06	+0.08	
× number of shares	3,600	2,000	2,000	2,000	
Profit or loss	−72	+80	+120	+160	+288

After step 3 in Table 9-3, Anna's position has increased to 40 short calls, the next 20-contract increment. The bid and ask prices therefore have to be raised again in step 4, when she raises the bid and ask prices by another 2 cents each, this time to 4.54 bid and 4.64 ask. In step 5, Anna sells 20 more of the 80 Calls at the new ask price of 4.64 and again buys 1,200 more shares of stock at 80.42 to hedge the newly sold options.

With Anna's position now at the next 20-contract increment of 60, Anna again raises the bid and ask prices to 4.56 bid and 4.66 ask, another 2-cent increase shown in step 6. Finally, in step 7, a sell order of 60 contracts enters the market. As a market maker, Anna buys all 60 of the 80 Calls at the bid price of 4.56 and simultaneously sells all 3,600 shares at the bid price of 80.40.

Calculating Profit and Loss

Step 8 in Table 9-3 calculates Anna's profit and loss. In this example, Anna bought all 3,600 shares of stock at 80.42 and sold them all at 80.40. This loss of 2 cents per share amounts to a total loss of $72, not including transaction costs.

Turning to the option profit/loss calculation, Anna purchased all options at the same price of 4.56 but sold them at three different prices, 4.60, 4.62, and 4.64. As indicated under option trade 1, option trade 2, and option trade 3, the profits on these trades were $80, $120, and $160, respectively. Combining the loss on the stock trades with the profits on the option trades yields Anna a net profit of $288.

The eight steps in Table 9-3 show that scaling into positions is a technique that market makers can use to avoid taking on a large position all at one price. Also, by adjusting the bid and ask prices, the profitability of a position can be maintained. The exercise, however, raises two questions.

First, how many times can the bid and ask be raised before a profitable trade becomes a losing one, and second, how are bid and ask prices monitored and adjusted in the face of fluctuating stock prices? These questions will be addressed with some examples.

The Limit on Adjusting Bid and Ask Prices

Table 9-4 calculates the maximum number of times that a bid-ask spread can be adjusted (raised or lowered) so that a break-even result still can be achieved on the last adjustment. It is assumed that the same number of contracts are purchased or sold at each price.

Table 9-4 contains six columns. Column 1 indicates the number of times that the bid-ask spread is raised. The bid and ask prices are in columns 2 and 3, respectively, and column 4 describes each trade and its price. Each row of column 5 indicates the average sale price of all

Table 9-4 The Limit on Adjusting Bid and Ask Prices

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Times Raised	Bid	Ask	Trade	Avg. Sale Price	No. of Short Contracts
	1.75	1.80	Sell 1 at 1.80	1.800	1
1	1.76	1.81	Sell 1 at 1.81	1.805	2
2	1.77	1.82	Sell 1 at 1.82	1.810	3
3	1.78	1.83	Sell 1 at 1.83	1.815	4
4	1.79	1.84	Sell 1 at 1.84	1.820	5
5	1.80	1.85	Sell 1 at 1.85	1.825	6
6	1.81	1.86	Sell 1 at 1.86	1.830	7
7	1.82	1.87	Sell 1 at 1.87	1.835	8
8	1.83	1.88	Sell 1 at 1.88	1.840	9
9	1.84	1.89	Buy 9 at 1.84		0
				Result = −0− (break even)	

Conclusion: If the initial bid-ask spread is 5 cents, and if bid and ask prices are raised by 1 cent after each sale transaction, then prices can be raised nine times before buying on the bid causes a net break-even for all the trades up to that point. The ninth sale would create a situation where buying on the next bid would cause a loss.

General formula: The break-even point is equal to two times the bid-ask spread minus one divided by the increment of increase/decrease. This is the number of times the bid-ask spread can be adjusted (raised or lowered) until closing the total position at the current bid or ask would result in breaking even.

the contracts sold up to that point. Column 6 keeps a running total after each trade of contracts sold up to that point.

In the first row of Table 9-4, for example, column 1 is blank because 1.75 in column 2 and 1.80 in column 3 are the initial bid and ask prices. Column 4 contains the trade description, "Sell 1 at 1.80," and column 5 contains the average sale price of 1.80. Since only one contract has been sold at 1.80 at this point, this is the average price. Column 6 indicates that up to this point there is one short contract in the total position.

In the second row of Table 9-4, there is a 1 in column 1 because this is the first time that the bid and ask prices are raised. The bid price is now 1.76 (column 2), and the ask price is now 1.81 (column 3). The trade description in column 4 is, "Sell 1 at 1.81." Therefore, the average sale price in column 5 is 1.805 because this is the average of 1.80 and 1.81, the sale prices of the contracts sold in the first and second rows, respectively. Column 6 indicates that there are now a total of two short contracts in the position.

The process is repeated in the next seven rows, in which the bid and ask prices are raised by 1 cent after another contract is sold.

The last row of Table 9-4 is the ninth time that the bid and ask prices have been raised (column 1), and as indicated in column 2, the bid price of 1.84 equals the average sale price in column 5 of the previous row. The trade in the last row (column 4) is buying nine at the bid price of 1.84. Nine is the total number of short contracts in the position, as indicated in the previous row in column 6, and buying them at 1.84 results in zero net profit or loss for all contracts, not including transaction costs.

The conclusion drawn from the exercise in Table 9-4 is that in this example, a market maker can raise the bid and ask prices nine times and still break even if all the contracts are purchased and closed on the ninth, or last, time. There are two constant factors in this example. First, the bid-ask spread is 5 cents, and second, the bid and ask prices increase by 1 cent after each sale. Although these factors could be different in real trading situations, a general conclusion can be drawn from this specific example.

Drawing a General Conclusion

The concept presented in Table 9-4 can be applied to other trading situations. Generally, the number of times that a bid-ask spread can be adjusted equals two times the bid-ask spread minus one divided by the increment of change. The *increment of change* is the amount that bid and ask prices are raised or lowered in each adjustment.

In Table 9-4, the bid-ask spread is 5 cents, and the increment of change is 1 cent. Therefore, two times the bid-ask spread minus one equals nine ($2 \times 5 - 1 = 9$). This number divided by the change is also nine ($9 \div 1 = 9$). This simple formula tells a market maker how many times a delta-neutral position can be increased before there is a risk of incurring a loss.

The exercises in Tables 9-1 through 9-4 omit the real-world factors of changing stock prices and changing implied volatility. When the stock price is static, it is easy to see that an option price of 1.81 is higher than a price of 1.80. It gets more difficult, however, when the stock price changes. When the stock price is 53.75, is a 55 Call price of 2.20 relatively higher, lower, or the same as a price of 2.80 when the stock price was 54.60? How can a similar judgment be made when stock prices fluctuate? Market makers need is a simple method of evaluating option prices as market conditions change. The method requires two skills that are shown in Tables 9-5 and 9-6 and are discussed next.

Estimating Option Prices as Volatility Changes

Table 9-5 demonstrates the first skill, which is the ability to quickly estimate a new option price when the implied volatility changes. The formula that accomplishes this estimation is stated at the top of the table. It starts with an initial theoretical value of the option, the volatility assumption of which is known. The option's vega or a fraction

Table 9-5 From Option Price to Implied Volatility

Theoretical option value at known implied volatility + fraction of vega = theoretical option value at new implied volatility

	Stock Price = 81.50			
	80 Call	85 Call	90 Call	
Theoretical value	4.00	1.75	0.65	
Volatility	30%	30%	30%	
Vega	0.10	0.08	0.06	
	Change Volatility Assumption			
New volatility	31%	31.5%	32%	
Estimated price	4.10	1.87	0.77	
80 Call:	Theor value at 30% imp. vol.			4.00
	plus 1.0 × vega (0.10)			+0.10
	= 80 Call value at 31% imp. vol.			4.10
85 Call:	Theor. value at 30% imp. vol.			1.75
	plus 1.5 × vega (0.08)			+0.12
	= 85 Call value at 31.5% imp. vol.			1.87
90 Call:	Theor. value at 30% imp. vol.			0.65
	plus 2.0 × vega (0.06)			+0.12
	= 90 Call value at 32% imp. vol.			0.77

thereof is then added to or subtracted from the initial theoretical value. The result is a new theoretical value with a new volatility assumption. The vega, remember, is the change in option theoretical value for a one percentage point change in volatility. For a refresher on vega, refer to Chapter 4.

After the formula, Table 9-5 lists the theoretical values of three calls, their vegas, and the volatility assumptions. The 80 Call, the 85 Call, and the 90 Call have theoretical values of 4.00, 1.75, and 0.65, respectively. The volatility assumption is 30 percent, and the stock price is 81.50.

The row below the vega lists a new level of volatility. For the 80 Call, the new level of volatility is 31 percent. For the 85 Call, it is 31.5 percent, and for the 90 call, it is 32 percent. The next row contains the estimated new option prices under the new volatility assumptions.

The 80 Call, for example, increases from 4.00 to 4.10. The 85 Call increases from 1.75 to 1.87, and the 90 Call increases to 0.77.

The bottom section of Table 9-5 shows that the estimated prices are calculated in two steps. First, the percentage change in volatility is related to the vega. If volatility changes by 1 percent, for example, the option theoretical value changes by one vega. This is what happened to the 80 Call. The increase in volatility of one percentage point from 30 to 31 percent caused the option theoretical value to rise by one vega from 4.00 to 4.10.

The increase in volatility for the 85 Call, however, is one and a half percentage points. Its value therefore rises by one and a half vegas. The vega of the 85 Call is 0.08, so the increase in volatility from 30 to 31.5 percent causes the theoretical value to increase by 0.12 (0.08 vega × 1.5) from 1.75 to 1.87. Finally, the two percentage point increase in volatility for the 90 Call causes its theoretical value to rise by 0.12 from 0.65 to 0.77 (twice its vega of 0.06).

Expressing Bid and Ask Prices in Volatility Terms

The second skill needed to quickly evaluate option prices as stock prices change is the ability to state the market for an option in volatility terms, which is shown in Table 9-6.

Table 9-6 The Market in Volatility Terms

		Stock Price = 81.50	
	80 Call	85 Call	90 Call
Theoretical value	4.00	1.75	0.65
Volatility	30%	30%	30%
Vega	0.10	0.08	0.06
		Market Quotes	
Bid-ask	3.90–4.10	1.75–1.83	0.68–0.77
Market stated in volatility terms:	29–31%	30–31%	30.5–32%

Table 9-6 starts with the same three calls and their theoretical values and vegas from Table 9-5. The next line in Table 9-6 states bid and ask prices for each of the calls. For the 80 Call, for example, the bid price is 3.90, and the ask price is 4.10. For the 85 and 90 Calls, the bid-ask prices are 1.75 and 1.83 and 0.68 and 0.77, respectively.

The last row in Table 9-6 states the bid and ask prices in volatility terms. For the 80 Call, this is 29 percent bid and 31 percent ask. These percentages are calculated the same way that prices with a new volatility assumption were calculated in Table 9-5. The vega or a fraction of it is added to or subtracted from the initial theoretical value with the known volatility.

Consider the bid and ask prices for the 80 Call. Given the theoretical value of 4.00, the volatility of 30 percent, and the vega of 0.10, a price of 3.90 is one vega less than 4.00, which is an implied volatility level of 29 percent. Similarly, a price of 4.10 for the 80 Call is one vega greater than a price of 4.00, so its implied volatility is 31 percent. Consequently, bid-ask prices of 3.90 and 4.10, respectively, for the 80 Call can be stated in volatility terms as 29 percent bid and 31 percent ask.

The 85 Call has a bid price of 1.75 and an ask price of 1.83. The top of Table 9-6 indicates that 1.75 is the theoretical value, assuming 30 percent volatility. Adding the vega of 0.08 to this price yields a new price of 1.83, which is 1 percent higher in volatility terms, or 31 percent. The bid and ask for the 85 Call therefore can be stated in volatility terms as 30 percent bid and 31 percent ask.

Finally, assuming 30 percent volatility for the 90 Call, its theoretical value of 0.65 and its vega of 0.06 mean that its bid and ask prices of 0.68 and 0.77 can be stated in volatility terms as 30.5 percent bid and 32 percent ask. The price of 0.68 is one-half a vega greater than 0.65, and 0.77 is two vegas greater.

Using vega to estimate new option prices if volatility changes and stating bid and ask prices in volatility terms are essential skills for professional traders to master because trading decisions often must be made quickly. The following exercises in this chapter and those in the next chapter illustrate that these skills are also valuable in creating and closing positions, in managing positions, and in managing risk.

Trading Exercises Introduced

The four exercises that follow demonstrate three trading techniques that market makers use. First, they trade delta-neutral to avoid the risk of market direction. Second they use implied volatility to set and adjust bid and ask prices. Third, market makers can be indifferent about which options they buy or sell because buying on the bid and selling at the ask can lead to profitable conversions, reverse conversions, butterfly spreads, and box spreads. The following exercises give only a glimpse of the many trades this technique makes possible.

All four trading exercises use the theoretical values, deltas, and vegas in Table 9-7. The stock price range is from 83.60 to 85.00, the volatility assumption is 32 percent, and the days to expiration, interest rates, and dividends are as stated at the bottom of the table.

Each exercise has its own assumptions about the width of the bid-ask spread and about the number of bid-ask price adjustments, if any. These variations are consistent with the real world in that different options markets have different characteristics, one of which is the width of bid-ask spreads. Such differences might be the result of stock-price volatility, of volume of trading in the underlying stock or in the options themselves, or of a specific company event, such as a pending earnings announcement.

Each exercise uses three tables that explain the activities of hypothetical trader, Ross. The first table, labeled "Instructions," is an overview of the steps of the exercise. In the first step, Ross makes a market in one or more options, which involves stating bid and ask prices given levels of volatility. In the second step, Ross makes a trade at one of those prices. Subsequently, in the third step, the stock price changes,

Table 9-7 Theoretical Values, Deltas and Vegas Calls and Puts: 80 Strike, 85 Strike, 90 Strike

Stock Price	80 Call T.V. 32%	80 Put T.V. 32%	85 Call T.V. 32%	85 Put T.V. 32%	90 Call T.V. 32%	90 Put T.V. 32%
85.00	7.42	1.94	4.50	3.98	2.50	6.96
Delta	0.72	−0.28	0.54	−0.46	0.38	−0.62
Vega	0.08	0.08	0.10	0.10	0.09	0.09
84.80	7.28	2.00	4.40	4.08	2.42	7.08
Delta	0.72	−0.28	0.54	−0.46	0.36	−0.64
Vega	0.08	0.08	0.10	0.10	0.08	0.08
84.60	7.12	2.06	4.28	4.16	2.34	7.20
Delta	0.70	−0.30	0.52	−0.48	0.34	−0.66
Vega	0.08	0.08	0.10	0.10	0.08	0.08
84.40	7.00	2.10	4.18	4.26	2.28	7.32
Delta	0.70	−0.30	0.52	−0.48	0.34	−0.66
Vega	0.08	0.08	0.10	0.10	0.08	0.08
84.20	6.86	2.18	4.08	4.36	2.20	7.46
Delta	0.70	−0.30	0.50	−0.50	0.34	−0.66
Vega	0.08	0.08	0.10	0.10	0.08	0.08
84.00	6.72	2.24	3.98	4.46	2.12	7.60
Delta	0.70	−0.30	0.50	−0.50	0.32	−0.68
Vega	0.09	0.09	0.10	0.10	0.08	0.08
83.80	6.58	2.30	3.88	4.56	2.08	7.74
Delta	0.68	−0.32	0.50	−0.50	0.32	−0.68
Vega	0.09	0.09	0.10	0.10	0.08	0.08
83.60	6.44	2.36	3.78	4.66	2.02	7.88
Delta	0.68	−0.32	0.49	−0.51	0.30	−0.70
Vega	0.09	0.09	0.10	0.10	0.08	0.08

Days to Expiration, 56; Interest Rates, 4%; Dividends, none

and Ross establishes new bid and ask prices and makes more trades. He closes the position in the fourth step. The second table contains a step-by-step explanation of how Ross implements the instructions in the first table, and the third table summarizes the exercise. Profit and loss are calculated by comparing the price at which a position is established to its theoretical value. A conclusion is stated at the end of the third table that summarizes the essential point of the exercise.

Exercise 1: Buying Calls Delta-Neutral

Table 9-8A presents an overview of the two trades in this example. Ross is instructed first to set bid and ask prices for the 85 Call at stated levels of volatility and second to make an opening delta-neutral trade. The third instruction is to adjust the bid and ask prices, and the fourth is to close out the whole position.

Steps 1 through 4 in Table 9-8B detail how Ross follows each instruction. In step 1, he sets bid and ask prices for the 85 Call at volatility levels of 32.0 and 33.0 percent, respectively, with the stock price 84.60. Given a theoretical value of 4.28, and assuming 32.0 percent volatility and a vega of 0.10, Ross sets the bid price at 4.28 (32.0 percent) and the ask price at 4.38 (33.0 percent). Note that the ask price is 0.10 or one vega greater than the bid price.

Table 9-8A Buying Calls Delta-Neutral: Instructions

Step 1	Stock price 84.60. Make a market for the 85 Call at volatility levels of 32.0% bid and 32.5% ask.
Step 2	Buy 10 85 Calls on the bid delta-neutral.
Step 3	Stock price 83.80. Make a market for the 85 Call at volatility levels of 31.8% bid and 32.3% ask.
Step 4	Sell (to close) the 10 85 Calls at the ask, and close the stock position.

Table 9-8B Buying Calls Delta-Neutral: Step-by-Step Explanation of Trades

Step 1:	85 Call	*Bid*	*Ask*	Stock price = 84.60
	Price	4.28	4.38	85 Call = 4.28 (32.0%)
	Implied vol.	32.0%	33.0%	Delta = 0.52; vega = 0.10
Step 2:	Buy 10 85 Calls	4.28		(Implied vol. = 32.0%)
	Short 520 shares	84.60		
Step 3:	85 Call	*Bid*	*Ask*	Stock price = 83.80
	Price	3.86	3.96	85 Call = 3.88 (32.0%)
	Implied vol.	31.8%	32.8%	Delta = 0.50; vega = 0.10
Step 4:	Sell 10 85 Calls	3.96		(Implied vol. = 32.8%)
	Buy 520 shares	83.80		

In step 2, Ross buys 10 of the 85 Calls on the bid and sells stock short to hedge the options delta-neutral. Since the 85 Call has a delta of +0.52 with the stock at 84.60, buying 10 of these calls requires that Ross sell 520 shares short.

Step 3 reflects how Ross adjusts the bid and ask prices to volatility levels of 31.8 percent bid and 32.8 percent ask. Given the new stock price of 83.80, a theoretical value of 3.88, and a vega of 0.10, the new market for the 85 Call is 3.86 bid (31.8 percent) and 3.96 ask (32.8 percent). The volatility is adjusted down for two reasons. First, if another sell order comes into the market that Ross might have to buy, then a lower bid price makes it possible for him to scale into a bigger position of 85 Calls at a lower average level of volatility. Second, the lower volatility hopefully will entice buyers into the market. The specific adjustment of two-tenths of a percent volatility is the result of Ross's personal judgment. Each trader makes such a decision individually based on knowledge and experience.

In step 4, Ross closes the position by selling the 10 calls at the ask price of 3.96 and purchases, or covers, the short shares at 83.80.

Exercise 1 concludes with the profit-and-loss calculations presented in Table 9-8C. The 10 calls Ross purchased at 4.28 each and sold at 3.96 each resulted in a loss of $320 [(4.28 − 3.96) × $100], not including commissions. The 520 shares he sold short at 84.60 and covered (bought) at 83.80 resulted in a profit of $416 [($84.60 − $83.80) × 520], not including commissions. The net result, therefore, was a profit of $96 before costs.

As in the exercises in Tables 9-1 and 9-2, the conclusion from this exercise is that buying on the bid, selling at the ask, and trading delta-neutral can earn profits. There are two differences, however, between this exercise and the one in Tables 9-1 and 9-2. First, in this exercise, the stock price changed between the two trades. Second, the bid and ask prices were expressed in volatility terms.

Table 9-8C Buying Calls Delta-Neutral: Calculation of Profit or Loss

Sell price of call × $100	$ 396
Minus buy price of call × $100	−428
P/(L) per call	$ (32)
× number of calls	× 10
= P/(L) from calls	($320)
Sell price of stock per share	$84.60
Minus buy price of stock per share	−83.80
P/(L) per share	+$ 0.80
× number of shares	× 520
= P/(L) from stock	+$416
Net profit/loss	+$ 96

Conclusion: Buying options on the bid, selling at the ask, and trading delta-neutral makes it possible to trade profitably regardless of the direction of stock-price change. Some complicating factors not discussed in this example are time decay and changing volatility.

Exercise 2: Creating a Butterfly Spread in Three Trades

Tables 9-9A, 9-9B, and 9-9C show how Ross creates a long call butterfly spread below its theoretical value with three trades of buying options on the bid and selling at the ask and trading delta-neutral. A *long call butterfly spread* is a three-part strategy involving one long call at the lowest strike price, two short calls at the middle strike price, and one long call at the highest strike price. The strike prices are equidistant, and the calls have the same underlying and same expiration date. Figure 1-11 is a graph of a long call butterfly spread.

Table 9-9A gives an overview of Ross's three trades in this exercise. Pursuant to the first instruction, Ross sets bid and ask prices for the 85 Call at stated levels of implied volatility. He then makes an opening delta-neutral trade. The third instruction tells Ross to adjust the implied volatility levels and to set bid and ask prices for the 80 Call, and the fourth step requires him to make an opening delta-neutral trade with the 80 Calls. The fifth and six instructions for Ross are to adjust the implied volatility levels a second time, to set bid and ask

Table 9-9A Creating a Butterfly Spread in Three Trades: Instructions

Step 1	Stock price 84.00. Make a market for the 85 Call at volatility levels of 32.0% bid and 32.5% ask.
Step 2	Sell 50 85 Calls at the ask delta-neutral.
Step 3	Stock price 84.60. Make a market for the 80 Call at volatility levels of 32.2% bid and 32.7% ask.
Step 4	Buy 25 80 Calls on the bid delta-neutral.
Step 5	Stock price 83.60. Make a market for the 90 Call at volatility levels of 32.0% bid and 32.5% ask.
Step 6	Buy 25 90 Calls on the bid delta-neutral.

prices for the 90 Call, and to make an opening delta-neutral trade with the 90 Calls.

Steps 1 through 6 in Table 9-9B show in detail how Ross completes each instruction. Step 1 tells Ross to set bid and ask prices for the 85 Call at implied volatility levels of 32.0 and 32.5 percent, respectively,

Table 9-9B Creating a Butterfly Spread in Three Trades: Step-by-Step Explanation of Trades

Step 1:	85 Call	*Bid*	*Ask*	Stock price = 84.00
	Price	3.98	4.03	85 Call = 3.98 (32.0%)
	Implied vol.	32.0%	32.5%	Delta = 0.50; vega = 0.10
Step 2:	Sell 50 85 Calls	4.03		(Implied vol. = 32.5%)
	Buy 2,500 shares	84.00		
Step 3:	80 Call	*Bid*	*Ask*	Stock price = 84.60
	Price	7.14	7.18	80 Call = 7.12 (32.0%)
	Implied vol.	32.25%	32.75%	Delta = 0.70; vega = 0.08
Step 4:	Buy 25 80 Calls	7.14		(Implied vol. = 32.25%)
	Sell 1,750 shares	84.60		
Step 5:	90 Call	*Bid*	*Ask*	Stock price = 83.60
	Price	2.02	2.06	90 Call = 2.02 (32%)
	Implied vol.	32.0%	32.5%	Delta = 0.30; vega = 0.08
Step 6:	Buy 25 90 Calls	2.02		(Implied vol. = 32.0%)
	Sell 750 shares	83.60		

with the stock price 84.00. Note that the bid-ask spread, in volatility terms, is narrower in this exercise than in the preceding one. This variation is consistent with different markets in the real world having different characteristics. Given the 85 Call's theoretical value of 3.98, assuming 32.0 percent volatility and a vega of 0.10, Ross sets the bid price at 3.98 (32.0 percent) and the ask price at 4.03 (32.5 percent).

In step 2, Ross sells 50 of the 85 Calls at the ask price of 4.03 and buys stock to hedge the options delta-neutral. Since the 85 Call has a delta of +0.50 with the stock at 84.00, selling 50 of these calls requires that Ross buy 2,500 shares.

In step 3, Ross sets bid and ask prices for the 80 Call after adjusting volatility to levels of 32.25 and 32.75 percent, respectively. He adjusts the volatility up because the previous trade was a sale of options. The higher ask price—in volatility terms—will make it possible for Ross to scale into a larger position of short calls if another buy order comes into the market. Also, he hopes the higher level of volatility will entice sellers into the market. Again, the specific volatility adjustment of up one-quarter of 1 percent is a result of Ross's individual judgment.

Given the new stock price of 84.60, a theoretical value of 7.12, and assuming 32.0 percent volatility and a vega of 0.08, the market for the 80 Call is 7.14 bid (32.25 percent) and 7.18 ask (32.75 percent).

In step 4, Ross buys 25 of the 80 Calls at the bid price of 7.14 and sells stock to hedge the options delta-neutral. Since the 80 Call has a delta of +0.70 with the stock at 84.60, buying 25 of these calls requires that Ross sell 1,750 shares. However, because Ross owned 2,500 shares as a result of his trade in step 2, this trade reduces his long stock position to 750 shares.

Step 5 involves adjusting the bid and ask prices again, this time back down to volatility levels of 32.0 and 32.5 percent, respectively, and then setting bid and ask prices for the 90 Call. Ross adjusts the implied volatility down this time because the previous trade was a purchase of options. Given the new stock price of 83.60, a theoretical value of 2.02, assuming 32.0 percent volatility and a vega of 0.08, the market for the 90 Call is 2.02 bid (32.0 percent) and 2.06 ask (32.5 percent).

In step 6, Ross buys 25 of the 90 Calls on the bid price of 2.02 and sells stock to hedge the options delta-neutral. Since the 90 Call has a delta of +0.30 with the stock at 83.60, buying 25 of these calls requires Ross to sell 750 shares, which closes his stock position. His only positions left are long 25 of the 80 Calls, short 50 of the 85 Calls, and long 25 of the 90 Calls. As described earlier and in Chapter 1, this three-part position is 25 long call butterfly spreads. The question now is, "Were these butterfly spreads established at a good price?" Table 9-9C answers this question.

Table 9-9C **Creating a Butterfly Spread in Three Trades: Calculation of Cost and Theoretical Value**

Section 1: Option Trading

Col 1 Qty	Col 2	Col 3 Price	Col 4 Debit/ Credit	Col 5 Theor. Price*	Col 6 Debit/ Credit
+1	80 Call	7.14	(7.14)	6.72	(6.72)
−2	85 Call	4.03	8.06	3.98	7.96
+1	90 Call	2.02	(2.02)	2.12	(2.12)
	Spread		(1.10)		(0.88)
	Costs†	0.04	(0.04)		(0.04)
	Gross cost per spread		(1.14)	T.V. per spread	(0.92)

Section 2: Stock Trading

1,750 × (84.60 − 84.00)	= +1,050
750 × (83.60 − 84.00)	= − 300
Net stock profit	= + 750
Stock profit per spread	= + 30 (750 profit ÷ 25 spreads)
Stock profit per share per spread	= + 0.30

Section 3: Net Cost per Butterfly Spread

Gross cost per spread − stock profit per spread = 0.84 (1.14 − 0.30)

Conclusion: With a bid-ask spread of 0.5% volatility, the butterfly spread in this example is purchased for 84 cents, or 8 cents below theoretical value.

* Theoretical prices assume a stock price of 84.00. Note that the theoretical value of the butterfly spread is between 0.88 and 0.92 when the stock price is between 83.60 and 85.00, the stock price range in Table 9-7.

† Costs are 1 cent per share or $1 per option.

Columns 1 through 4 of section 1 in Table 9-9C show that the gross cost of each butterfly spread is 1.14, including 4 cents for transaction costs. Ross purchased each 80 Call for 7.14. He sold twice as many 85 Calls for 4.03 each and purchased each 90 Call for 2.02. Columns 5 and 6 conclude that the theoretical price of this butterfly spread is 92 cents, including 4 cents for transactions costs.

Section 2 of Table 9-9C calculates that Ross's three stock trades resulted in a net profit of $750, or $30 per spread, or 30 cents per share per spread. In the first stock trade, from step 2 of Table 9-9B, Ross purchased 2,500 shares at 84.00. Subsequently, in steps 4 and 6, he sold 1,750 and 750 shares at 84.60 and 83.60, respectively. The net stock trading profit of $750 is divided by 25 (the number of Ross's long call butterfly spreads) to get $30 per spread. This per-spread profit is divided by $100 to get 30 cents per share per spread.

Section 3 of Table 9-9C shows that the net cost per butterfly spread is 84, which is 8 cents below the theoretical value of 92 cents. The net cost of 84 cents is the difference between the gross cost of 1.14 and the stock profit of 30 cents per share. The conclusion, therefore, is that with a bid-ask spread of one-half percent volatility, a long butterfly spread can be established for 8 cents below its theoretical value. The specifics of this particular example will not apply to all situations in the real world, of course, but the concept is valid. Buying on the bid price and selling at the ask price and staying delta-neutral make it possible to establish positions at advantageous prices.

Exercise 3: Creating a Reverse Conversion in Two Trades

Tables 9-10A, 9-10B, and 9-10C show how two trades of buying options on the bid, selling at the ask, and trading delta-neutral can create a profitable reverse-conversion position. Reverse conversions are discussed in detail in Chapter 6. You may want to review that chapter before reading this section.

As in the preceding two exercises, Table 9-10A contains a list of instructions to hypothetical trader Ross and an overview of the events that set bid and ask prices, make trades, and create a position. The next two tables show how Ross follows the instructions and how to evaluate his position.

Steps 1 through 4 in Table 9-10B detail how Ross's actions carry out the instructions. In step 1, Ross sets bid and ask prices for the 80 Call at implied volatility levels of 32.0 and 33.0 percent, respectively, with the stock price at 84.60. Given a theoretical value of 7.12 and assuming 32.0 percent volatility and a vega of 0.08, the bid price is 7.12 (32.0 percent), and the ask price is 7.20 (33.0 percent).

Table 9-10A **Creating a Reverse Conversion in Two Trades: Instructions**

Step 1	Stock price 84.60. Make a market for the 80 Call at volatility levels of 32.0% bid and 33.0% ask.
Step 2	Buy 10 80 Calls on the bid delta-neutral.
Step 3	Stock price 84.00. Make a market for the 80 Put at volatility levels of 32.0% bid and 33.0% ask.
Step 4	Sell 10 80 Puts at the ask delta-neutral.

Table 9-10B **Creating a Reverse Conversion in Two Trades: Step-by-Step Explanation of Trades**

Step 1:	80 Call	*Bid*	*Ask*	Stock price = 84.60
	Price	7.12	7.20	80 Call = 7.12 (32.0%)
	Implied vol.	32.0%	33.0%	Delta = 0.70; vega = 0.08
Step 2:	Buy 10 80 Calls	7.12		(Implied vol. = 32.0%)
	Sell short 700 shares	84.60		
Step 3:	80 Put	*Bid*	*Ask*	Stock price = 84.00
	Price	2.24	2.33	80 Put = 2.24 (32.0%)
	Implied vol.	32.0%	33.0%	Delta = 0.30; vega = 0.09
Step 4:	Sell 10 80 Puts	2.33		(Implied vol. = 33.0%)
	Sell short 300 shares	84.00		

In step 2, Ross buys 10 of the 80 Calls on the bid price of 7.12 and sells stock short to hedge the options delta-neutral. Since the 80 Call has a delta of +0.70 with the stock at 84.60, buying 10 of these calls requires Ross to sell 700 shares short.

In step 3, Ross sets bid and ask prices for the 80 Put after the stock price has declined to 84.00. The level of volatility is not adjusted in this step because the purchase of 10 Calls was not large enough, in the Ross's opinion, to warrant a change. Given the new stock price of 84.00, the put's theoretical value of 2.24, assuming 32.0 percent volatility and a vega of 0.09, the market for the 80 Put is 2.24 bid (32.0 percent) and 2.33 ask (33.0 percent).

In step 4, Ross sells 10 of the 80 Puts at the ask price and sells stock short to hedge delta-neutral. With the stock at 84.00, the 80 Put has a delta of −0.30. Selling 10 of these puts therefore requires that Ross sell 300 shares short. Since Ross shorted 700 shares previously, this trade increases his stock position to short 1,000 shares.

After step 4 in Table 9-10B, Ross's total position consists of three parts: long 10 of the 80 Calls, short 10 of the 80 Puts, and short 1,000 shares of stock. This position is a reverse conversion, as described in Chapter 6. The question now is, "Did Ross establish this reverse conversion at a good price?" Table 9-10C answers this question.

Section 1 of Table 9-10C lists the option trades, and section 2 shows that Ross sold 1,000 shares of stock short at an average price of 84.42. Section 3 calculates the net credit required for a reverse conversion at a strike price of 80, with an interest rate of 4 percent, 60 days to expiration, and total costs of 4 cents per share. As stated in Chapter 6, the net credit required is the amount that makes the reverse-conversion position profitable. Step 1 calculates the DPV of the strike price, which is 79.51 in this example, and step 2 adds the costs of 4 cents per share and the target profit of 5 cents per share. The net credit required therefore is 79.60 per share.

Table 9-10C concludes with section 4, which calculates the actual net credit per share by the trades in this exercise. The stock sold short brought in 84.42 per share. The purchased 80 Calls each cost 7.14,

Table 9-10C Creating a Reverse Conversion in Two Trades Calculation of Cost and Theoretical Value

Section 1: Option Trading

±Qty	Option	Price
+10	80 Call	7.14
−10	80 Puts	2.33

Section 2: Stock Trading

±Qty	×	Price	=	Weighted Price
−700	×	84.60	=	59.22
−300	×	84.00	=	25.20
Average weighted price			=	84.42

Section 3: Calculating the Net Credit Required (NC)

Step 1: Calculate discounted present value (DPV) of strike
= 80 ÷ (1 + 0.04 × 56/365) = 79.51

Step 2: Calculate the net credit
= DPV of strike + costs + profit = NC
= 79.51 + 0.04 + 0.05 = 79.60 NC

Section 4: Calculation of Actual Net Credit (per Share)

Stock sold short	84.42	Credit
80 Calls purchased	(7.14)	Debit
80 Puts sold	2.33	Credit
Net	79.61	Credit (>79.60 NC)

Conclusion: With a bid-ask spread of 1.0% volatility in this example, a profitable reverse-conversion position can be established.

and the sold 80 Puts each brought in 2.33. The net amount brought in, or net credit, therefore is 79.61, an amount higher than the net credit required to achieve the target profit of 79.60.

The conclusion stated at the bottom of Table 9-10C is that with a bid-ask spread of 1 percent in volatility terms, a trader may establish a profitable reverse conversion position, which is just what Ross accomplished. As stated earlier, the specifics of this example will not apply to all situations in the real world, but the concept is valid.

Exercise 4: Creating a Long Box Spread in Two Trades

Tables 9-11A, 9-11B, and 9-11C show how buying a call spread delta-neutral and then buying a put spread delta-neutral can create a profitable long box spread. Box spreads are discussed in detail in Chapter 6.

As in the preceding exercises, Table 9-11A contains a list of instructions for Ross, the hypothetical trader in this example. The instructions also give an overview of the events that set bid and ask prices, make trades, and create a position. The next two tables show how Ross follows the instructions and how to evaluate the position.

Steps 1 through 4 in Table 9-11B explain how Ross implements each instruction. Step 1 in Table 9-11B sets bid and ask prices for the 85 and 90 Calls at implied volatility levels of 32.0 and 33.5 percent, respectively, with the stock price at 84.80. Note that this is the widest bid-ask spread in volatility terms so far. This wide spread is consistent with the real world in that different options markets have bid-ask spreads of varying widths. As stated earlier, such differences might be attributed to stock-price volatility, stock or option volume, or a special company-related event.

Following the instruction in step 1, Ross sets the bid and ask prices for the 85 and 90 Calls at 4.40 and 4.55 and 2.42 and 2.54, respectively. In step 2, Ross buys 10 of the 85–90 call spreads and hedges them delta-neutral. Ross establishes the call spreads by buying the 85 Calls on the

Table 9-11A Creating a Long Box Spread in Two Trades: Instructions

Step 1	Stock price 84.80. Make markets for the 85 and 90 Calls at volatility levels of 32.0% bid and 33.5% ask.
Step 2	Buy 10 85–90 call spreads delta-neutral. (Buy the 85 Calls on the bid; split the bid-ask for the 90 Call.)
Step 3	Stock price 83.80. Make markets for the 85 and 90 Puts at volatility levels of 32.0% bid and 33.5% ask.
Step 4	Buy 10 90–85 put spreads delta-neutral. (Buy the 90 Puts on the bid; split the bid-ask for the 85 Put.)

Table 9-11B Creating a Long Box Spread in Two Trades Step-by-Step Explanation of Trades

Step 1:			
85 Call	*Bid*	*Ask*	Stock price = 84.80
Price	4.40	4.55	85 Call = 4.40 (32.0%)
Implied vol.	32.0%	33.5%	Delta = 0.54; vega = 0.10
90 Call	*Bid*	*Ask*	Stock price = 84.80
Price	2.42	2.54	90 Call = 2.42 (32.0%)
Implied vol.	32.0%	33.5%	Delta = 0.36; vega = 0.08
Step 2:			
Buy 10 85–90 call spreads		1.92	85 Call = 4.40; 90 Call = 2.48
Sell short 180 shares		84.80	Spread net delta = +0.18
Step 3:			
85 Put	*Bid*	*Ask*	Stock price = 83.80
Price	4.56	4.71	85 Put = 4.56 (32.0%)
Implied vol.	32.0%	33.5%	Delta = −0.50; vega = 0.10
90 Put	*Bid*	*Ask*	Stock price = 83.80
Price	7.74	7.86	90 put = 7.74 (32.0%)
Implied vol.	32.0%	33.5%	Delta = −0.68; vega = 0.08
Step 4:			
Buy 10 90–85 put spreads		3.11	90 put = 7.74; 85 put = 4.63
Buy 180 shares		83.80	Spread net delta = −0.18

bid and selling the 90 Calls at the midpoint of the bid-ask spread. It is common practice to trade one-to-one vertical spreads this way for the following reason: Bid-ask spreads for vertical spreads should not be wider than bid-ask spreads for individual options because vertical spread positions have less risk than individual option positions. Vertical spreads also have lower deltas, lower gammas, lower vegas, and lower thetas (absolute value) than single-option positions. They therefore are less sensitive to changes in stock price, volatility, and time.

Following the instruction in step 2, therefore, Ross buys 10 of the 85–90 call spreads at a net debit of 1.92 each because the purchase price of the 85 Calls is 4.40 and the selling price of the 90 Calls is

2.48. Ross determines the hedging stock trade as follows: The 85 Calls have a delta of +0.54, and the 90 Calls have a delta of +0.36. The net delta of the 85–90 call spread therefore is +0.18, so the purchase of 10 spreads requires that Ross sell 180 shares short at the current price of 84.80.

In step 3, Ross sets bid and ask prices for the 85 and 90 Puts at volatility levels of 32.0 and 33.5 percent, respectively, with the stock price at 83.80. He does not adjust implied volatility in this case because vertical spreads have both long and short options, which means that exposure to changing volatility is very low.

In step 4, Ross buys 10 of the 90–85 Put spreads by buying the 90 Puts on the bid and selling the 85 Puts at the midpoint of the bid-ask spread. The purchase price of the 90 Puts therefore is 7.74, and the sale price of the 85 Puts is 4.63, which is approximately halfway between the bid of 4.56 and the ask of 4.71. Ross purchases the 90–85 put spread, therefore, for 3.11.

Ross hedges the 10 put spreads by buying 180 shares of stock. The 90 Puts have a delta of −0.68, and the 85 Puts have a delta of −0.50. The net delta of the spread therefore is −0.18. The purchase of 10 spreads requires Ross to purchase 180 shares at the current price of 83.80. Since he sold 180 shares short as part of the previous trade, Ross's purchase in this trade closes his stock position.

After step 4, the total position consists of long 10 of the 85 Calls, short 10 of the 90 Calls, long 10 of the 90 Puts, and short 10 of the 85 Puts. This position is a long box spread. The question now is, "Did Ross establish this long box spread at a good price?" Table 9-11C answers this question.

Section 1 of Table 9-11C shows the option trades on a per-share basis. Ross bought 10 of the 85–90 call spreads for 1.92 each and 10 of the 90–85 put spreads for 3.11 each, for a total gross cost of 5.03 for each long box spread.

Section 2 of the table shows that Ross sold 180 shares short at 84.80 and covered at 83.80, resulting in a profit of $180, or $18 per spread

Table 9-11C Creating a Long Box Spread in Two Trades Calculation of Cost and Theoretical Value

Section 1: Option Trading	
	Price
+10 85–90 call spreads	1.92
+10 90–85 put spreads	3.11
Gross cost of box spread	5.03
Section 2: Stock Trading	
Sold short 180 shares	84.80
Purchased 180 shares	83.80
Profit per share	1.00
Profit on 180 shares	$180
Profit per share per spread	−0.18
Net cost per share per spread	4.85

Section 3: Theoretical Value

DPV of spread minus the sum of transaction costs plus target profit

$5.00 \div (1 + 0.05 \times 56/365) - (0.06 + 0.05) = 4.85$

where borrowing rate = 5%

transactions costs = 0.06

target profit = 0.05

Conclusion: With a bid-ask spread of 1.5% volatility in this example, a profitable long box spread can be established.

or 18 cents per share per spread. Subtracting 0.18 from the gross cost of 5.03 yields a net cost per share per box spread of 4.85, which equals the theoretical value as calculated in section 3.

The theoretical value of the 85–90 long box spread is equal to the DPV of the $5.00 difference between the strike prices minus the sum of transaction costs plus target rpofit, and this is 4.85, as shown in section 3 of Table 9-11C. The conclusion, therefore, is that with the bid-ask spread of 1.5 percent volatility in this example, a trader can establish profitable long box spread by buying a call spread delta-neutral and then buying a put spread delta-neutral.

Summary

Making markets in options has three parts: buy on the bid, sell at the ask, and trade delta-neutral. The goals are to earn the bid-ask spread and to trade profitably regardless of market direction. Accomplishing these goals requires three essential skills.

The first skill is expressing bid and ask prices in volatility terms. Starting with an option's theoretical value at a known level of volatility, the vega is used to calculate the volatility level of a higher or lower price.

The second skill is understanding how to create arbitrage strategies and low-risk spreads in a few steps. This chapter demonstrated buying calls delta-neutral, creating a butterfly spread in three delta-neutral trades, creating a reverse conversion in two delta-neutral trades, and creating a box spread in two delta-neutral trades. There are many other low-risk positions that can be created in just a few steps.

The third skill is adjusting bid and ask prices. Deciding when to adjust prices and how much to adjust them involves judgment that comes from experience and varies by underlying stock and market conditions. Nevertheless, by adjusting bid and ask prices when risk limits are reached, traders can scale into and out of positions at better average levels of volatility. There is a limit, however, on the number of times that bid and ask prices can be raised or lowered before a position becomes unprofitable.

Chapter 10

MANAGING POSITION RISK

There are many types of option positions. Outright long and short options, one-to-one spreads, and stock-and-option spreads are perhaps most common for speculators. But there are also ratio spreads, time spreads, butterfly spreads, condor spreads, and complex delta-neutral strategies. Each of these positions has unique potential profits and risks. If a trader can understand the potentials—both good and bad—then the chances of earning profits are increased. Traders therefore must identify and quantify the risks and know alternative strategies for reducing risk. Only then can a trader choose the appropriate risks to monitor based on individual trading style.

Managing risk requires an understanding of how the Greeks change, as discussed in Chapter 4. It is essential to have a thorough understanding of that material before delving into this chapter. This chapter focuses on the risks associated with delta, gamma, vega, and theta. The risk of changing interest rates, rho, is not discussed because small changes in short-term interest rates do not have a significant impact on short-term option positions.

This chapter will first illustrate how position risk is calculated. It then will demonstrate how delta might be used to manage directional risk. Next, a case study analyzes the changing risks of vertical spreads.

The fourth topic, neutralizing position risk, asks—and answers—this question, "Which Greek is best to neutralize?" The chapter then concludes with a discussion of setting risk limits.

Calculating Position Risks

Quantifying the delta, gamma, vega, and theta risks of option positions is a straightforward task. Table 10-1 has five columns and five rows that calculate the Greeks of 20 long 70 Calls that were purchased for 2.82 per share each. Assumptions about the current stock price, days to expiration, volatility, interest rate, and dividends are listed at the bottom of the table.

Column 1 in Table 10-1 lists five risk factors—price and four Greeks—and column 2 quantifies them on a per-share basis. Since the underlying is 100 shares for each option, column 3 has the number 100 in every row. Similarly, every row in column 4 has the number 20 because that is the number of options in the position. Column 5 contains the risk factor of the entire position, which is the product of the three numbers in columns 2, 3, and 4.

The risk factor "Price" appears in column 1 of the first row of Table 10-1, and the per-share price of 2.82 is listed in column 2. The

Table 10-1 Position Risks of 20 Long 70 Calls

	Col 1	Col 2	Col 3	Col 4		Col 5
Row	Risk Factor	Individual Option	× Multiplier	× Quantity	=	Position
1	Price	$2.82	×100	×20	=	$5,640
2	Delta	+0.535	×100	×20	=	+1,070
3	Gamma	+0.059	×100	×20	=	+118
4	Vega	+0.087	×100	×20	=	+174
5	Theta	−0.310	×100	×20	=	−620

Assumptions: Stock price, 70.00; strike price, 70; days to expiration, 35; volatility, 31%; interest rates, 4%, dividends, none; 7-day theta.

multiplier in column 3 and the number of options in column 4 are 100 and 20, respectively. The price risk of the 20-contract position therefore is $5,640 (2.82 × 100 × 20), as shown in column 5.

The position Greeks in column 5, rows 2 through 5, are calculated in a similar manner to the price of the position, but the risks are stated differently depending on the Greek. The position delta of +1,070, for example, indicates that this position of 20 long 70 Calls will behave like 1,070 shares of long stock over small stock-price changes. If the stock price rises by $1.00, this position will profit by approximately $1,070, and if the stock price declines by $1.00, this position will lose approximately this same amount.

The position gamma of +118 in row 3 of Table 10-1 indicates that a $1.00 move in stock price will change the position delta by 118 shares in the same direction as the change in stock price. If the stock price rises by $1.00, for example, the position delta will increase by 118 from +1,070 to +1,188. Similarly, if the stock price falls by $1.00, the position delta will decrease by 118 from +1,070 to +952.

The position vega of +174 in row 4 of Table 10-1 indicates that a one percentage point change in volatility will change the position value by $174. If volatility rises from 31 to 32 percent and other factors remain constant, the price of one option will rise by 8.7 cents (0.087 in column 2), which would raise the value of the 20-option position by $174 from $5,640 to $5,814. Similarly, if volatility declines by 1 percent, the position value would decrease by $174 from $5,640 to $5,466.

The position theta in Table 10-1 estimates the impact of "one unit" of time decay. In this example, "one unit" is seven days. The position theta of –620 indicates that the passing of seven days will cause the position value to decrease by $620 if other factors remain constant.

A trader can use the information in Table 10-1 to ask—and answer—several questions about risk. First, can I withstand a $1,070 loss if the stock price declines $1.00? What about a $2.00 or $3.00 stock-price decline? Where will I take my loss if the stock price declines? These are questions that traders must answer individually.

One comment needs to be made on volatility risk. The position vega in Table 10-1 tells a trader that a one percentage point change in implied volatility will change the position value by $174. The vega, however, does not estimate the likelihood of implied volatility changing or by how much it might change. Historical data, such as that provided at www.cboe.com or at www.ivolatility.com (see Figure 7-7), can assist, but forecasting volatility is an art, not a science.

In contrast to vega, the position theta provides a much firmer estimate of the risk of time decay. In Table 10-1, if the stock price and other factors are unchanged in seven days, this position will lose $620. A trader can use this estimate with a dollar risk limit to determine how long a position will be held before a loss is taken.

Risks of Short Options

Although the Greeks of long and short options are opposite, the risks of short options are *not* simply opposite the risks of long options. Positions with uncovered short options have unlimited risk in the case of short calls and substantial risk in the case of short puts. An *uncovered short option* is a short option that has no offsetting stock or option position that truly limits risk. Although, in practice, stock-price changes are never really unlimited, they can be very large. As experienced traders know, unexpected events can cause prices to change by 30 percent, 50 percent, or more overnight or in very short periods of time. The risk of short option positions, therefore, must be considered differently than the known maximum price risk of long options. Unfortunately, there is no uniform method of determining the suitability of short option risk. Are 50 short options too many? Can I be short 200 options that are 10 percent out of the money? These are questions that traders must answer individually.

Managing Directional Risk with Delta

Table 10-2 demonstrates how a trader might use delta to manage a long option position to both increase profit and decrease risk. This technique is based on the behavior of stock prices, which generally do not make large price changes in a straight line; rather, stock prices typically rise for a few days and then fall back before resuming an up trend. The goal of this managing technique, therefore, is to benefit from normal up-and-down stock-price action by maintaining a relatively constant delta. Since long options have positive gamma, the delta of a long call will increase as the stock price rises and decrease as the stock price falls. This technique therefore involves selling a portion of owned calls when a stock rallies and buying them back when the stock declines. In the example that follows, a hypothetical trader named Grace implements this trading technique.

The top section of Table 10-2 lists the rules that Grace created to govern when to purchase and sell 70 Calls. Grace's initial position of

Table 10-2 Managing Directional Risk by Delta

Managing rules:
Initial position delta = +1,100.
When delta is at or above +1,500, sell Calls to lower position delta to +1,100.
When delta is at or below +900, buy Calls to raise position delta to +1,100.

Row		Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
1	Stock price	70.00	76.00	72.00	77.00	73.00	78.00
2	Days to exp.	35	32	28	24	21	19
3	70 Call	2.82	6.88	3.70	7.49	4.07	8.27
4	Call delta	+0.53	+0.84	+0.66	+0.90	+0.74	+0.95
5	Beg. position	None	Long 20	Long 13	Long 17	Long 12	Long 15
6	Beg. total delta	0	+1,680	+ 858	+1,530	+888	+1,425
7	Beg. position value	0	13,760	4,810	12,733	4,884	12,405
8	Action/quantity	Buy 20	Sell 7	Buy 4	Sell 5	Buy 3	Sell 15
9	End position	Long 20	Long 13	Long 17	Long 12	Long 15	None
10	End total delta	+1,060	+1,092	+1,122	+1,080	+1,110	0
11	End total value	5,640	8,944	6,290	8,988	6,105	0
12	Cash flow	(5,640)	4,816	(1,480)	3,745	(1,221)	12,405
13	Final profit (total of cash flows)						+12,625

Profit from buy and hold: Buy 20 @ 2.82 = (5,640)
Sell 20 @ 8.27 = 16,540
Net profit 10,900

Assumptions: Volatility, 31%; interest rate, 4%.

long 20 of the 70 Calls has a delta of approximately +1,100 (actually, +1,060). Her goal is to approximately maintain this delta as the stock price rises and falls, and she has chosen two triggers for action, deltas of +1,500 and +900. Consequently, when the position delta rises above +1,500, Grace will sell a sufficient number of 70 Calls so that the position delta is reduced to approximately +1,100. Conversely, when the position delta falls below +900, Grace will buy a sufficient number of 70 Calls so that she increases the position delta. Using +1,100 and +900 as triggers for buying and selling is a subjective decision. Traders can use Op-Eval Pro to experiment with stock-price scenarios and levels of delta based on the number of contracts traded.

The middle section of Table 10-2 has six columns and 13 rows that detail how Grace implements her strategy over a 16-day period from 35 days to expiration to 19 days to expiration. Rows 1 and 2 list stock prices and days to expiration. In column 1, for example, the stock price is 70.00 at 35 days to expiration. Row 3 lists the price of the 70 Call, row 4 lists its delta, and row 5 lists the initial position ("Beg. position"). Rows 6 and 7 hold the total delta and total value of the initial position, respectively. Row 8 indicates the action, buy or sell, and the quantity of calls, and the ending position is listed in row 9. Row 10 indicates the delta of the ending position, which should be approximately +1,100, and row 11 indicates the value of the ending position. Row 12 lists the cash flow from the trade in row 8, which is the product of quantity of calls in row 8 and the price in row 3 and the multiplier, which is 100 and assumed. After Grace makes the final trade and closes the position, the "Final profit" is listed in column 6, row 13. The final profit is the total of positive and negative cash flows in row 12.

This exercise starts in column 1 of Table 10-2 when the stock price is 70.00 (row 1), the price of the 70 Call is 2.82 (row 2), and its delta is +0.53 (row 4). There is no beginning position (row 5), so there is no beginning delta or value (rows 6 and 7). When Grace buys 20 of these calls (row 8), she creates a position with a total delta of +1,060 (row 10) and a value of $5,640 (row 11). The purchase is a negative cash flow (line 12). Parentheses indicate option purchases, which are negative cash flows. Cash inflows, from option sales, are numbers without parentheses.

In column 2 of Table 10-2, the stock price has risen to 76.00 (row 1) at 32 days to expiration (row 2). The price of the 70 Call has increased to 6.88 (row 3), and its delta is +0.84. Grace's position of 20 long calls (row 5) therefore has a total delta of +1,680 (row 6), which exceeds Grace's trigger limit and spurs her to act. She sells seven calls (row 8) in order to reduce the delta to approximately +1,100. Grace calculated this quantity by subtracting the desired delta from the beginning delta and dividing the quotient by the delta of the call in row 4; that is, $(1{,}680 - 1{,}100) \div (0.84 \times 100) = 6.90 \approx 7$. The actual ending delta is +1,092 (row 10). Selling seven calls resulted in a positive cash flow of $4,816 (row 12).

This trading exercise continues in column 3 of Table 10-2 when the stock price falls to 72.00 at 28 days (rows 1 and 2). As a result, the position delta falls to +858 (row 6). To raise the delta to approximately +1,100, Grace must buy four of the 70 Calls (row 8). She calculates this quantity by subtracting the beginning delta from the desired delta and dividing the quotient by the delta of the call; that is, $(1{,}100 - 858) \div (0.66 \times 100) = 3.7 \approx 4$. The actual ending delta on this day is +1,122.

In columns 4 and 5 in Table 10-2, the stock price rises to 77.00 at 24 days and falls to 73.00 at 21 days, respectively. To adjust the delta to the desired level, Grace sells five of the 70 Calls in column 4 and buys three in column 5. When the stock price is 78.00 at 19 days to expiration in column 6, Grace sells the remaining 15 calls at 8.27 each to close the position.

Row 13 in Table 10-2 indicates that the profit from the trades in columns 1 through 6 amounts to $12,625, not including trading costs.

The bottom section of Table 10-2 calculates the alternative outcome of a buy-and-hold strategy. Had Grace held the original position of 20 long 70 Calls for the entire time period and sold them all at 8.27, then her profit would have been $10,900, not including trading costs.

The conclusion is that given the stock-price action in Table 10-2, the technique of managing delta increased Grace's profits by $1,725 ($12,625 versus $10,900). Different stock-price action, of course, would lead to a different result. It is possible that a loss could exceed the initial investment. Had the stock price declined shortly after Grace purchased the initial 20 calls, the delta could have declined below +900. The rules then would have required Grace to purchase additional calls. If the original calls plus the additional calls then all expired worthless, Grace's loss would have exceeded $5,640.

Despite the potential for negative outcomes, the exercise in Table 10-2 demonstrates that profits of long option positions potentially can be increased by managing delta. This technique tends to increase profits when prices are trending in a volatile manner, and it tends to underperform the buy-and-hold approach when prices trend with below-average volatility.

Tracking Changes in Position Risk

Table 10-3 calculates the risks of 20 long 70–75 Call vertical spreads. A long vertical call spread, also known as a *bull call spread*, involves the purchase of one call and the sale of another call with the same underlying and same expiration date but with a higher strike price. Figure 1-9 is a graph of a long call vertical spread. There are also short vertical call spreads, known as *bear call spreads*, and long and short vertical put spreads. A comparison of Table 10-3 with Table 10-1 reveals that the risks of vertical spreads are very different from the risks of outright long options.

Table 10-3 is similar to Table 10-1 in that the position risks listed in the right-most column are the product of the individual risk component, the multiplier, and the number of contracts. Table 10-3, however, has seven columns instead of five because there are two option positions, 20 long 70 Calls and 20 short 75 Calls. The second option requires an additional column, and the spread value also adds

Table 10-3 Position Risks of 20 Bull Call Spreads 1

Stock price, 70, equals strike of long call.
Position: Long 20 70 Calls @ 2.82.
Short 20 75 Calls @ 1.02.

	Col 1	Col 2		Col 3	Col 4	Col 5	Col 6	Col 7
Row	Risk Factor	Long 20 70 Calls		Short 20 75 Calls	Spread Value	Multiplier	Quantity	=Position
1	Price	$2.82	−	$1.02	= $1.80	×100	×20	= $3,600
2	Delta	+0.535	−	0.262	= +0.273	×100	×20	= +546
3	Gamma	+0.059	−	0.049	= +0.010	×100	×20	= +20
4	Vega	+0.087	−	0.066	= +0.021	×100	×20	= +42
5	Theta	−0.310	−	(−0.225)	= −0.085	×100	×20	= −170

Assumptions: Stock price, 70; days to expiration, 35; volatility, 31%; interest rate, 4%, dividends, none; 7-day theta.

another column. Note that the assumptions about stock price, days to expiration, volatility, etc. are the same in Tables 10-1 and 10-3. Comparison of the position risks in the two tables therefore is valid.

If you compare column 7 in Table 10-3 with column 5 in Table 10-1, you can see that the 20 long call spreads have lower risks in every respect than the outright long calls. Whereas the 20 long 70 Calls have a position price of $5,640 (Table 10-1, row 1, column 5), the 20 long 70–75 call spreads have a position price of $3,600 (Table 10-3, row 1, column 7). The position delta of the long call spreads is +546, significantly less than the delta of +1,070 for the long calls. Also, the position gamma of +20 indicates that the delta of the long call spreads is less sensitive to stock-price change than the delta of the long calls, which have a gamma of +118.

The sensitivity to volatility, as measured by the vega, is also less for the call spreads, +42 versus +174, and finally, a comparison of the thetas indicates that the call spread position is less sensitive to time erosion than the outright long calls. The call spreads will lose $170 in one week from time decay, whereas the long calls will lose $620 in one week.

The conclusion is that vertical spreads are less sensitive to all Greeks than outright long option positions. How can traders use this information? Consider the trading example presented next.

Vertical Spreads versus Outright Long Options

Table 10-4 compares two bullish strategies in two market scenarios. The first strategy is long one 70 Call, and the second is long one 70–75 call vertical spread. Rows 1, 2, and 3 contain the assumptions about the stock price, the days to expiration, and the level of implied volatility, and rows 4 and 5 contain the prices of the 70 Call and the 70–75 call spread. The price of the 70–75 call spread is calculated by subtracting the price of the 75 Call from the price of the 70 Call. To avoid confusion, the price of the 75 Call is not shown. Column 1 contains the initial market assumptions and the initial prices. The initial stock price is $70.00, there are 35 days to expiration, and the implied volatility is 31 percent.

Table 10-4 Strategy Comparison: Long Calls versus Long Vertical Call Spreads

Strategy 1: Long 70 Call @ 2.82.
Strategy 2: Long 70–75 call spread @ 1.80.

			Scenario 1		Scenario 2	
Row		Col 1	Col 2	Col 3	Col 4	Col 5
1	Stock price	70.00	73.50		73.50	
2	Days to exp.	35	14		14	
3	Implied volatility	31%	31%		24%	
				Profit (Loss)		Profit (Loss)
4	Price of 70 Call	2.82	4.11	1.29	3.85	1.03
5	70–75 call spread	1.80	2.92	1.12	3.05	1.25

Assumptions: Interest rate, 4%, dividends, none.
Conclusion: Vertical spreads are less susceptible to changes in implied volatility and perform better than outright long options in certain market scenarios.

Columns 2 and 3 in Table 10-4 show the estimated option prices and profit of the first scenario in which the stock price rises to 73.50 (row 1), three weeks pass, leaving 14 days remaining to expiration (row 2), but the implied volatility remains unchanged at 31 percent (row 3). In this scenario, the 70 Call rises in price to 4.11 for a profit of 1.29 (row 4), and the 70–75 call spread rises to 2.92 for a profit of 1.12 (row 5).

In the second scenario, the stock price (73.50) and time to expiration (14 days) are the same as in scenario 1, but the implied volatility has declined to 24 percent. This scenario is presented in columns 4 and 5 of Table 10-4. The 70 Call rises in price to 3.85 for a profit of 1.03, and the 70–75 call spread rises to 3.05 for a profit of 1.25. In this scenario, the profit from the 70–75 call spread increases by 0.13, whereas the profit of the 70 Call declines by 0.26. Profits from these two strategies change because implied volatility decreases—this is the only difference between the two scenarios. Table 10-4 demonstrates that vertical spreads sometimes can perform better in an environment of declining implied volatility than outright long options.

Vertical Spreads—How the Risks Change

Any calculation of position risks is only a snapshot that catches the situation at one stock price and at one point in time. Position risks change if stock price, time, or implied volatility change, as they inevitably will. In Table 10-3, the stock price is 70, so the 70 Call is at the money, and the 75 Call is out of the money. The Greeks of the 70 Call therefore are larger, in absolute terms, than the Greeks of the 75 Call.

Table 10-5 calculates position risks of the 20 long 70–75 call vertical spreads assuming a stock price of 75, at which point the 70 Call is in the money and the 75 Call is at the money.

A comparison of Table 10-5 with Table 10-3 reveals how—and by how much—the Greeks change when the stock price is 75 versus 70. With the stock price at 70, the 20 long 70–75 call vertical spreads have a position delta of +546, a positive gamma, a positive vega, and a

Table 10-5 Position Risks of 20 Bull Call Spreads 2

Stock price, 75, equals strike price of short call.
Position: Long 20 70 Calls @ 6.16.
Short 20 75 Calls @ 3.03.

Col 1	Col 2		Col 3	Col 4	Col 5	Col 6		Col 7
Risk Factor	Long 20 70 Calls		Short 20 75 Calls	Spread Value	Multiplier	Quantity	=	Position
Price	$6.16	−	$3.03	= $3.13	×100	×20	=	$6,260
Delta	+0.791	−	0.535	= +0.256	×100	×20	=	+512
Gamma	+0.040	−	0.055	= −0.015	×100	×20	=	−30
Vega	+0.062	−	0.093	= −0.031	×100	×20	=	−62
Theta (7-day)	−0.242	−	(−0.332)	= +0.090	×100	×20	=	+180

Assumptions: Stock price, 75; days to expiration, 35; volatility, 31%; interest rate, 4%, dividends, none.

negative theta. With a stock price of 75, the position delta is +512, which is lower than with the stock price at 70. The gamma is now negative, and the vega also has changed from positive to negative. The theta, however, is now positive rather than negative.

The message of Table 10-5 is that a stock price rise of $5.00 causes the position risks to reverse completely. The position delta now will change in the *opposite* direction from the change in price of the underlying stock. The position now will be *hurt* if implied volatility rises and helped if it declines. Finally, the passing of time now will help this position.

The difference in position Greeks caused by the rise in stock price from 70 to 75 means that the strategy's primary source of profit has changed. When the stock price is 70 (see Table 10-3), a bull call spread is a bullish strategy that profits primarily from a stock-price rise and is hurt by the passing of time. When the stock price is 75 (see Table 10-5), however, a bull call spread is more of a neutral strategy; it still has a positive delta, but now the position will profit from time decay.

The change in position risks from Table 10-3 to Table 10-5 is only one example of how position risks change. Given the interaction of the changing Greeks of long and short options, it is not always easy to anticipate how position risks will change as market conditions change. Traders must continuously update their risk analysis of positions because those risks can change in unanticipated ways.

Changing Risks Graphed

The position risks of 20 of the 70–75 bull call spreads are illustrated in Figures 10-1 through 10-5. In all these figures, the straight line graphs risk at expiration, and the curved lines represent the risk at 35 and 17 days to expiration. It can be difficult determining which curved line is 35 days and which is 17 days because they cross, so attention to detail is important.

Figure 10-1 graphs position value against stock price (underlying). The value of a bull call spread is small when the stock price is below the lower strike price and rises to its maximum value as the stock price rises above the upper strike price. The curved line that is upper on the left and lower on the right depicts the strategy value at 35 days to

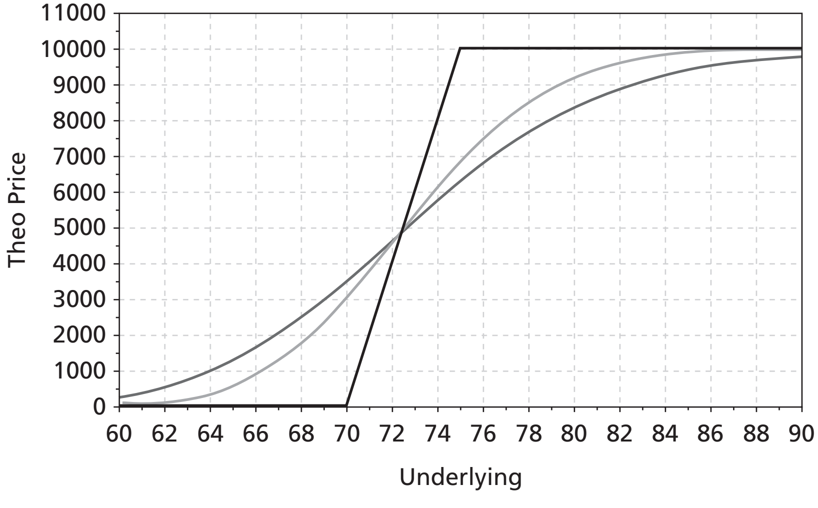

Figure 10-1 Value of 20 Long 70-75 Call Vertical Spreads

expiration. The curved line in the middle on both sides of the graph represents the strategy value at 17 days to expiration. A comparison of the curved lines shows how the strategy value moves to the value at expiration—the straight line—as time passes.

Figure 10-2 graphs the position delta of the bull call spreads as the stock price changes. The curved lines show that delta is highest when the stock price is between the strike prices and falls to zero when the stock price falls below 70 or rises above 75. The straight line shows that delta is zero at expiration if the stock price is below 70 or above 75. With the stock price between 70 and 75 at expiration, the delta is +2,000 because the 20 long 70 Calls are exercised, and the position becomes long 2,000 shares of stock.

Gamma is the focus of Figure 10-3. Gammas are biggest when an option is at the money, so a bull call spread has a positive gamma when the stock price is below or near the lower strike price (long call). As explained in Chapter 4, positive gamma means that the delta of the position changes in the same direction as the change in price of the underlying. The position gamma turns negative, however, when

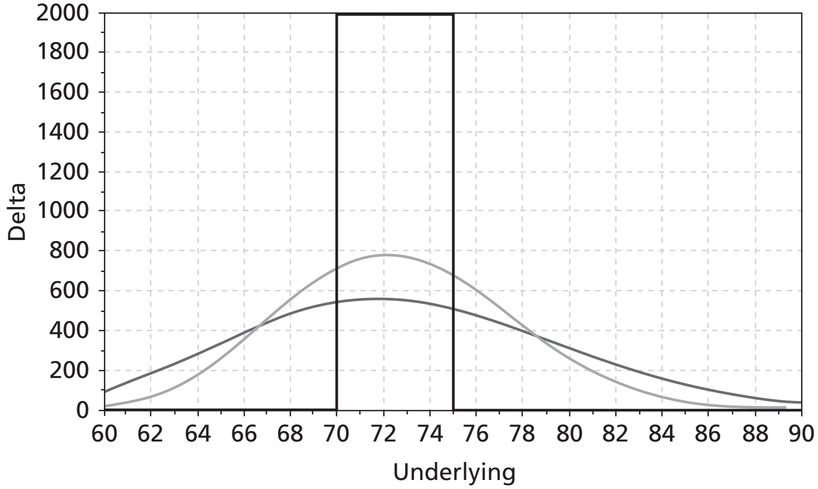

Figure 10-2 Delta of 20 Long 70-75 Call Vertical Spreads

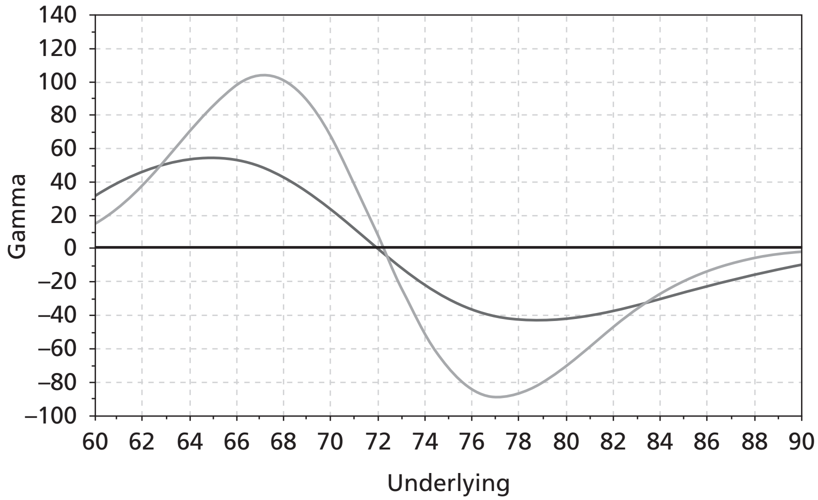

Figure 10-3 Gamma of 20 Long 70-75 Call Vertical Spreads

the stock price equals the strike price of the short call. Negative gamma means that the delta changes in the opposite direction from the change in price of the underlying.

The graph of vega in Figure 10-4 is similar to the graph of gamma in Figure 10-3 because both vegas and gammas are biggest when options are at the money. The proximity of the curved lines, however, is quite different. The gamma lines in Figure 10-3 are farther apart when the stock price is 70 or 75 because gammas of at-the-money options increase as expiration approaches, whereas gammas of out-of-the-money options decrease. The difference between the 35- and 17-day gamma lines therefore changes noticeably in Figure 10-3.

In Figure 10-4, however, the curved vega lines are closer together because vegas of both at-the-money options and out-of-the-money options decrease as expiration approaches. As a result, the difference between the 35-day line and 17-day line remains fairly constant as time passes to expiration.

The graph of position theta in Figure 10-5 is nearly the mirror image of the gamma and vega graphs because the sign of a position's theta is

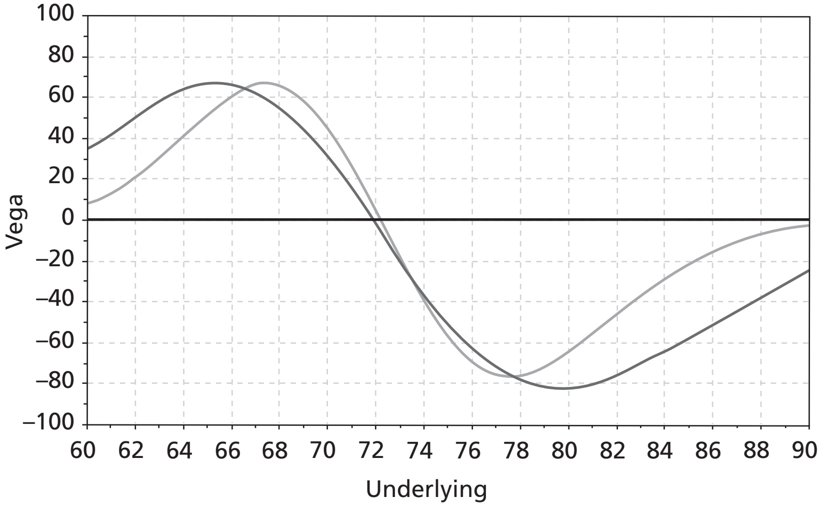

Figure 10-4 Vega of 20 Long 70-75 Call Vertical Spreads

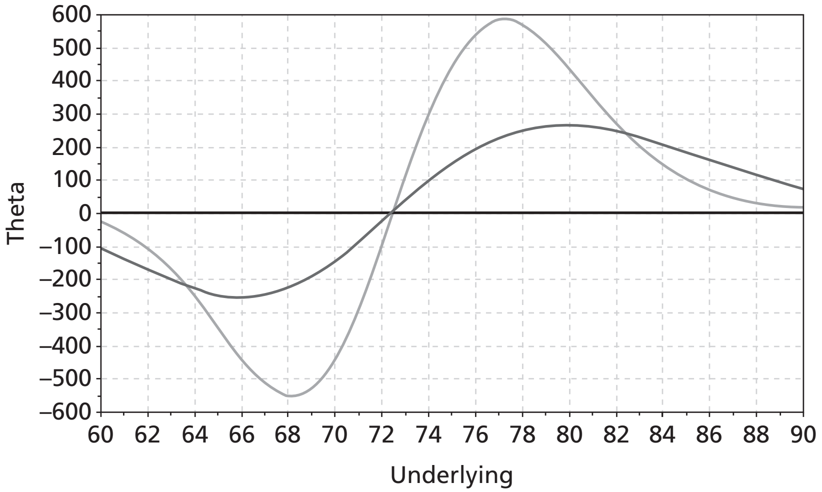

Figure 10-5 Theta of 20 Long 70-75 Call Vertical Spreads

opposite that of a position's gamma and vega. Thetas are negative numbers with the largest absolute values when options are at the money. Consequently, when the stock price equals the strike price of the long call in a bull call spread, the position theta is negative, which indicates that the position will lose money as time passes. When the stock price equals the strike price of a short call, however, the position theta is positive, which indicates that the position will make money as time passes.

Graphs of position Greeks such as Figures 10-1 through 10-5 are valuable tools in estimating how changing market conditions will change the risks of positions. Traders should familiarize themselves with this feature of Op-Eval Pro and use it regularly to analyze position risks. Keeping on top of the Greeks is key to good risk management. If you do not know how your risks have changed, you cannot react to changing market conditions within your preestablished limits.

Greeks Of Delta-Neutral Positions

Table 10-6 and Figure 10-6 take the position of 20 long call vertical spreads analyzed in Table 10-3 and make it delta-neutral by adding 546 short shares. Three important observations can be made about this new position and its risk characteristics.

Table 10-6 The Greeks of a Delta-Neutral Position

20 long call spreads delta-neutral.
Position: Short 546 shares @ 70.00.
Long 20 70 Calls @ 2.82.
Short 20 75 Calls @ 1.02.

	Col 1	Col 2		Col 3		Col 4		Col 5
Row	Risk Factor	Short 409 Shares		Spread Total	×	Multiplier × Quantity		Position
1	Price	−70.00	+	($1.80	×	100 ×20)	=	−$34,620
2	Delta	(+1 × −546)	+	(+0.273	×	100 ×20)	=	−0−
3	Gamma	−0−	+	(+0.010	×	100 ×20)	=	+20
4	Vega	−0−	+	(+0.021	×	100 ×20)	=	+42
5	Theta	−0−	+	(−0.085	×	100 ×20)	=	−170

Assumptions: Stock price, 70; days to expiration, 35; volatility, 31%; interest rate, 4%, dividends, none; 7-day theta.

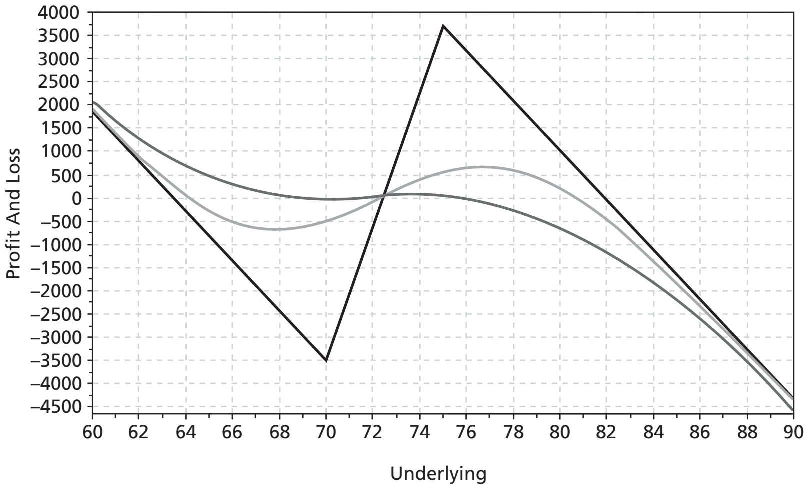

Figure 10-6 **Value of Delta-Neutral 20 Long 70-75 Call Vertical Spreads**

First, the indicated "Price" of the position is –$34,620 (column 7 of Table 10-6). This figure represents the credit from the stock short sale less the net debit paid for the options. This figure, however, is *not* an accurate measure of the maximum risk of the position because the short shares have unlimited risk. A trader therefore must estimate potential risk by considering other factors such as pending news and the possibility of a sharp stock-price rise. Such considerations are subjective.

The second observation is about the benefits and risks of being delta-neutral. Table 10-6 calculates that the position delta is zero at 35 days to expiration. In Figure 10-6, the 35-day line is the upper line on the left and the lower line on the right. This line shows that the position approximately breaks even between stock prices of 68 and 76. The position, however, begins to profit below 68 and to lose above 76. A delta-neutral position therefore is safe from stock-price fluctuations over a finite range, not an infinite one. Figure 10-6 clearly illustrates the potential for loss if the stock price rises sharply.

Third, the position gamma, vega, and theta in Table 10-6 are the same as those risks in Table 10-3. The gamma in both tables is

+20, the vega in both is +42, and the theta in both is –170. A delta-neutral position, therefore, is *not* immune from the risks of changing delta, changing volatility, or changing time. What a trader might do to manage these risks is discussed next.

Neutralizing Position Greeks

Neutralizing position Greeks is explained with two examples that analyze multiple-part positions. The first example assumes that interest rates are zero, and the second assumes that they are positive. The zero-interest-rate example is instructive because it demonstrates clearly the "equal and opposite" relationship that exists between some of the Greeks. Also, this example applies generally to options on futures. Positive interest rates apply to options on stocks, where cost of carry is a concern. Cost of carry is discussed in Chapter 6.

The first example analyzes the action of a hypothetical trader named Matthew who wants to neutralize his position risk. In Table 10-7A, the gamma, vega, and theta of Matthew's initial position are not neutral (≠0). His position is listed at the top of the table and consists of 35 short 80 Puts, 60 short 85 Calls, 120 long 90 Calls, and 2,060 short shares. Prices are shown, but they are not necessary to analyze position Greeks. The bottom portion of the table lists the Greeks of the individual options.

A position Greek in Table 10-7A is the product of the quantity of shares represented by the option position and the option's individual Greek. The delta of the 80 Put position of +885 in row 1, for example, is calculated by multiplying –3,500 and –0.253. The numbers in the tables that follow were calculated in the Spread Positions screen in Op-Eval Pro. *Slight differences are due to rounding.*

The total Greeks in row 5 are simply the sums of the position Greeks in columns 3 through 6. Matthew's position, as illustrated in Table 10-7A, has a total delta of 0, a total gamma of +104, a total vega of +358, and a total theta of –780. These Greeks indicate that this position will profit if there is big stock-price change (positive gamma) and if implied volatility rises (positive vega). It will lose if time passes

Table 10-7A Neutralizing Position Risk—Interest Rate Zero: The Initial Position

Position: Short 35 80 Puts @ 1.70.
Short 60 85 Calls @ 4.73.
Long 120 90 Calls @ 2.61.
Short 2,060 shares @ 86.10.

		Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Row	Option/ Stock	Price	±Qty	Delta	Gamma	Vega	Theta*
1	80 put	1.70	−35	+885	−107	−368	+793
2	85 call	4.73	−60	−3,397	−225	−775	+1,694
3	90 call	2.61	+120	+4,572	+436	+1,501	−3,268
4	Stock	86.10	−2,060	−2,060	0	0	0
5	Totals			−0−	+104	+358	−780

Individual Greeks

	Delta	Gamma	Vega	Theta*
80 Put	−0.253	+3.05	+10.50	−22.68
85 Call	+0.566	+3.75	+12.91	−28.24
90 Call	+0.381	+3.63	+12.50	−27.23

Assumptions: Stock price, 86.10; days to expiration, 53; volatility, 32%; interest rate, 0%; dividends, none.
*7-day theta.

(negative theta). Small stock-price changes will have a nearly zero impact on profit (zero delta).

If Matthew is concerned that the underlying price will trade in a narrow range, which would expose the position to losses from time decay, or if he is concerned that implied volatility will fall, then he must act to reduce these risks. Which Greek, however, should be the focus of Mathew's risk-management effort?

Table 10-7B demonstrates three alternatives that neutralize Matthew's position risk. The purpose of examining three alternatives is to determine the impact on the other Greeks when one is neutralized. Each alternative starts with the position in Table 10-7A and makes a trade that neutralizes one Greek. Alternative 1 neutralizes the position gamma. Alternative 2 reduces the position vega to zero, and Alternative 3 focuses on the position theta. All three approaches use the 85 Calls to neutralize the targeted Greek. However, Matthew could choose any option.

Matthew first looks at the position gamma of +104 (Table 10-7A, row 5, column 4). He knows that he must sell some quantity of 85 Calls to reduce it to zero. Short calls, remember, have negative gamma, so selling calls reduces the gamma of the position. The quantity of options that neutralizes a position Greek is calculated by dividing the position Greek by the Greek of the individual option. In this case, the position gamma of +104 divided by the gamma of the 85 Call of 3.75 yields 28. Selling 28 of the 85 Calls therefore reduces the position gamma to zero. However, simply selling 28 of the 85 Calls will add negative delta to the total position, and Matthew wants his

Table 10-7B Neutralizing Position Risk—Interest Rate Zero: Selling 85 Calls to Neutralize the Greeks

Alternative 1: Neutralizing Gamma by Selling 85 Calls				
Position gamma	÷	gamma of 85 Call	=	quantity of 85 Calls
+104	÷	+3.75	=	27.7 ≈28
The position gamma is positive, so 85 Calls must be sold.				
The delta-neutral trade: Sell 28 85 Calls (delta is +0.566).				
Buy 1,585 shares (2,800 × 0.57 = 1,585).				
Alternative 2: Neutralizing Vega by Selling 85 Calls				
Position vega	÷	vega of 85 Call	=	quantity of 85 Calls
+358	÷	+12.91	=	27.7 ≈28
The position vega is positive, so 85 Calls must be sold.				
The delta-neutral trade: Sell 28 85 Calls (delta is +0.566).				
Buy 1,585 shares (2,800 × 0.57 = 1,585).				
Alternative 3: Neutralizing Theta by Selling 85 Calls				
Position theta	÷	theta of 85 Call	=	quantity of 85 Calls
−780	÷	−28.24	=	27.6 ≈28
The position theta is negative, so 85 Calls must be sold.				
The delta-neutral trade: Sell 28 85 Calls (delta is +0.566).				
Buy 1,585 shares (2,800 × 0.57 = 1,585)				

position to remain delta-neutral. In addition to selling 28 calls, therefore, Matthew must buy 1,585 shares of stock because the delta of the short 85 Call is –0.566 (28 × 100 × 0.566 = 1,585).

Alternative 2 in Table 10-7B illustrates a second approach to neutralizing risk by focusing on the position vega. Since the position vega is +358, Matthew must sell options to bring it to zero. Dividing the position vega of +358 by the vega of the 85 Call of 12.91 yields 28. Selling 28 of the 85 Calls therefore reduces the position vega to zero. Again, however, Matthew wants to keep his position delta at or near zero, so he buys 1,585 shares of stock. Thus, bringing the position vega to zero required Matthew to make the same delta-neutral trade as in Alternative 1 that neutralized gamma.

Neutralizing a negative theta also requires selling options. In this third alternative, dividing the position theta of –780 by the theta of the 85 Call of –28.24 yields 28, the same number of 85 Calls as in the preceding two trades. The two parts of the delta-neutral trade that neutralize theta therefore are the same as Alternatives 1 and 2. Matthew sells 28 of the 85 Calls and buys 1,585 shares of stock.

Matthew's next step is performed in Table 10-7C. He adds 28 short 85 Calls and 1,585 long shares to his initial position and calculates the new Greeks. The new position has 88 short 85 Calls (short 28 plus short 60) and 475 short shares (short 2,060 plus long 1,585). Row 5 of Table 10-7C presents the Greeks of the new position.

As row 5 in Table 10-7C indicates, the new delta is +1, the new gamma is –1, the new vega is –3, and the new theta is +11. None of the Greeks is exactly zero owing to rounding, but they are all close to zero. One of the many decisions that market makers must make is how close is close enough? Based on his own experience, judgment, and comfort level, Matthew is satisfied with these Greeks.

The conclusion of Tables 10-7A through 10-7C is that when interest rates are zero, a trade that neutralizes either gamma, vega, or theta also neutralizes the other two. Traders therefore do not have to worry about which Greek to neutralize! When interest rates are positive, however, the situation is different.

Table 10-7C Neutralizing Position Risk—Interest Rate Zero: The Neutralized Position

Position: Short 35 80 Puts @ 1.70.
Short 88 85 Calls @ 4.73.
Long 120 90 Calls @ 2.61.
Short 475 shares @ 86.10.

	Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7
Row	Option or Stock	Price	±Qty	Delta	Gamma	Vega	Theta*
1	80 Put	1.70	−35	+885	−107	−368	+793
2	85 Call	4.73	−88	−4,981	−330	−1,136	+2,485
3	90 Call	2.61	+120	+4,572	+436	+1,501	−3,268
4	Stock	86.10	−475	−475	0	0	0
5	Totals			+1	−1	−3	+11

Individual Greeks

	Delta	Gamma	Vega	Theta*
80 Put	−0.253	+3.05	+10.50	−22.68
85 Call	+0.566	+3.75	+12.91	−28.24
90 Call	+0.381	+3.63	+12.50	−27.23

Assumptions: Stock price, 86.10; days to expiration, 53; volatility, 32%; interest rate, 0%; dividends, none.
*7-day theta.
Conclusion: When interest rates are zero, if one Greek is neutralized, then all Greeks are neutralized.

Neutralizing Greeks when Interest Rates Are Positive

Tables 10-8A through 10-8C present a three-part example similar to Tables 10-7A through 10-7C, except that the short-term interest rate is 5 percent. Table 10-8A presents an initial delta-neutral position (delta = –2), with a gamma of –92, a vega of –143, and a theta of +326.

Hypothetical trader Matthew again confronts three possible approaches to neutralizing the Greeks in his initial position. The three alternatives in Table 10-8B all involve buying the 60 Puts, but each trade targets a different Greek. In Alternative 1, Matthew neutralizes the gamma by buying 15 of the 60 Puts (92 ÷ 5.97 ≈ 15). He also buys

Table 10-8A Neutralizing Position Risk—Interest Rate Positive: The Initial Position

Position: Short 25 55 Puts @ 1.18.
Long 30 60 Puts @ 3.48.
Short 35 65 Calls @ 0.60.
Long 1,700 shares @ 58.00.

		Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Row	Option or Stock	Price	±Qty	Delta	Gamma	Vega	Theta*
1	55 Put	1.18	−25	+688	−127	−106	+288
2	60 Put	3.48	+30	−1,702	+179	+277	−361
3	65 Call	0.66	−35	−668	+145	−224	−399
4	Stock	58.00	+1,700	+1,700	0	0	0
5	Totals			−2	−92	−143	+326

Individual Greeks

	Delta	Gamma	Vega	Theta*
55 Put	−0.275	+5.07	+ 7.85	−11.51
60 Put	−0.567	+5.97	+ 9.25	−12.02
65 Call	+0.191	+4.13	+ 6.40	−11.40

Assumptions: Stock price, 58.00; says to exp., 60; volatility, 28%; interest rate, 5%; dividends, none.
*7-day theta.

800 shares of stock so that his ending position remains delta-neutral. In Alternative 2, he buys 15 of the 60 Puts, which neutralizes the position vega (143 ÷ 9.25 ≈ 15) and he buys 800 shares to maintain delta-neutrality. Alternative 2 is the same as Alternative 1.

Alternative 3 in Table 10-8B, which targets theta, however, is different. Bringing the position theta of +326 to 0 requires Matthew to buy 27 of the 60 Puts (326 ÷ 12.02 ≈ 27). The question then is, "Why the difference?"

Table 10-8C has three parts that answer this question. The upper part of the table illustrates Matthew's new position after he buys 15 of the 60 Puts and 800 shares of stock. His four-part position now consists of 25 short 55 Puts, 45 long 60 Puts (up from 30), 35 short

Table 10-8B Neutralizing Position Risk—Interest Rate Positive: Buying 60 Puts to Neutralize the Greeks

Alternative 1: Neutralizing Gamma by Buying 60 Puts				
Position gamma	÷	gamma of 60 Put	=	quantity of 60 Puts
−92	÷	+ 5.97	=	15.4 ≈15
The position gamma is negative, so 60 Puts must be purchased.				
The delta-neutral trade: Buy 15 60 Puts (delta is −0.55).				
Buy 800 shares (1,500 × 0.567 = 850)				
Alternative 2: Neutralizing Vega by Buying 60 Puts				
Position vega	÷	vega of 60 Put	=	quantity of 60 Puts
−143	÷	+9.25	=	15.4 ≈15
The position vega is negative, so 60 Puts must be purchased.				
The delta-neutral trade: Buy 15 60 Puts (delta is −0.567).				
Buy 800 shares (1,500 × 0.567 = 850)				
Alternative 3: Neutralizing Theta by Buying 60 Puts				
Position theta	÷	theta of 60 Put	=	quantity of 60 Puts
+326	÷	−12.02	=	27.1 ≈27
The position theta is positive, so 60 puts must be purchased.				
The delta-neutral trade: Buy 27 60 Puts (delta is −0.55).				
Buy 1,485 shares (2,700 × 0.55 = 1,485)				

Note: When interest rates are positive, neutralizing theta requires a different number of contracts than when neutralizing gamma and vega.

65 Calls, and long 2,500 shares (up from long 1,700). The position delta (–3), the position gamma (–3), and the position vega (–4) are all nearly zero, but the position theta is not. At +146, the position theta estimates that $146 will be made in one week if the other factors remain constant. The middle and lower parts of Table 10-8C explain why the position theta is +146.

The middle part of the table calculates the value of the position as a net debit of $158,300. *Debit* means that establishing a position requires a net payment. Funding the position therefore requires Matthew to pay interest on borrowed funds or to forego interest on his own equity capital that could be invested elsewhere.

The lower part of Table 10-8C calculates the amount of interest required to finance the position. At 5 percent, interest for one week

Table 10-8C Neutralizing Position Risk—Interest Rate Positive: The Neutralized Position

Position: Short 25 55 Puts @ 1.18.
Long 45 60 Puts @ 3.48.
Short 35 65 Calls @ 0.60.
Long 2,550 shares @ 58.00.

		Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Row	Option or Stock	Price	±Qty	Delta	Gamma	Vega	Theta*
1	55 Put	1.18	−25	+668	−127	−206	+188
2	60 Put	3.48	+45	−2,553	+269	+416	−541
3	65 Call	0.66	−35	−668	+145	−224	−399
4	Stock	58.00	+2,550	+2,550	0	0	0
5	Totals			−3	−3	−4	+146

	±Qty	×	Price	=	Value
Value of 55 Put position	−25	×	1.18	=	2,950 credit
Value of 60 Put position	+45	×	3.48	=	15,660 debit
Value of 65 Call position	−35	×	0.66	=	2,310 credit
Value of stock position	+2,550	×	58.00	=	147,900 debit
Value of total Position				=	158,300 debit

Interest for one week at 5% on value of total position =
158,300 × 0.05 ÷ 52 = 152 ≈ 146 (+146 = position theta)

Conclusion: When interest rates are positive, if either gamma or vega is neutralized, then the other is also neutralized. The position theta, which is not neutral, offsets the impact of interest. If theta is positive, it offsets the interest cost. If theta is negative, it offsets the interest income.
*7-day theta.

on $158,300 is $152, which is approximately the weekly amount earned from time decay, as indicated by the position theta of +146. *The difference of $6 between the calculated interest and the theta is due to rounding.*

The conclusion, therefore, from Tables 10-8A through 10-8C has two parts. First, when interest rates are positive, if either gamma or vega is neutralized, then the other is also neutralized. Second, the position theta, which is not neutral, will offset the impact of interest on the position. If the theta is positive, as in this case, it offsets the interest expense of carrying a debit position. If theta is negative, it offsets the interest income from the invested cash from a credit position. The addition of interest rates therefore means that Matthew must neutralize either gamma or vega, which will neutralize the other, whereas theta will remain nonneutral and offset the interest factor.

The conclusions about theta and a position's interest factor from Tables 10-8A through 10-8C apply only when there is a significant stock position. As discussed below, theta cannot be related to interest when there is no stock component in a position. In such positions, theta risk must be viewed differently.

Establishing Risk Limits

The preceding exercises calculated position risks, tracked how they change, and explained how they can be neutralized. The exercises do not, however, address how much risk is acceptable. While there are no scientific answers to questions about acceptable risk, there are some guidelines that traders can use to determine their own limits.

Fluctuation in position value is inevitable. Therefore, traders must decide, first, how much of an adverse fluctuation is tolerable. "Can I withstand a $500 swing or a $5,000 swing in my account equity and still be able to trade rationally?" Some traders focus on risk limits in dollar amounts, and some prefer percentages. Either way, this subjective and personal decision is fundamental to good risk management. It forms the basis for every risk limit. After a trader establishes this limit, then position size—quantities of stocks and options—naturally follows and can be determined using the Greeks.

Three types of positions and appropriate risk limits are discussed next: delta-neutral positions with a stock component, delta-neutral positions without a stock component, and directional positions.

Delta-Neutral Positions with a Stock Component

When analyzing delta-neutral positions with a stock component, one can infer from the exercise in Tables 10-8A through 10-8C that concerns about risk should focus on either gamma or vega. This inference stems from two observations. First, since reducing either gamma or vega also reduces the other, there is no need to focus on both. Second, theta seems to take care of itself because it is related to the interest component of a position, at least when there is a stock position involved.

Position Greeks provide concrete estimates of the profit or loss that will result from a one-unit change in the related component. Traders therefore should study both the historic and implied volatilities of the underlying and make a subjective decision about "normal ranges."

Does the implied volatility "normally" change by three percentage points in a few days or by eight percentage points? A subjective answer to this question leads to a risk limit based on vega. In Table 10-8A, the vega of –143, for example, estimates that $143 will be lost if implied volatility rises by 1 percent. If a trader predicts that implied volatility "normally" changes less than 3 percentage points in a few days, then the position in Table 10-8A has a normal risk of three times $143, or $429. For a trader with a chosen risk limit of $1,000, this position seems "acceptable" because a sudden loss of $1,000 requires a 7 percent rise in implied volatility, a change that lies outside the range considered "normal."

The $1,000 risk limit and the belief that a 3 percentage point change in implied volatility is "normal" leads to a vega limit of ±333. If a position has vega of +333, then a decrease in implied volatility of 3 percent would cause a $1,000 loss, and a rise of 3 percent would cause the same loss for a position with a vega of –333. Consequently, a trader with this limit would calculate the vega daily and act accordingly to keep the position within the limit.

Delta-Neutral Positions without a Stock Component

When a position does not include stock, the position theta cannot be related to interest, as in Table 10-8C. However, the position theta can be related to the position vega and gamma because they have opposite signs. Assuming the same expiration for all options, a position with positive vega and positive gamma will have negative theta, and vice versa. The setting of risk limits therefore requires a choice. A trader must ask, "Do I hope to profit from time decay at the risk of losing from rising implied volatility or from a big stock-price change?" or "Do I hope to profit from rising implied volatility or from a big stock-price change at the risk of losing from time decay?" In other words, "Do I want to be net long or net short options?" Once a trader decides this issue, then limits on vega or theta can be established and monitored.

Directional Positions

A *directional position* is a position that intentionally has stock-price risk, and the main risk of such a position, of course, is its delta. The first determination therefore is, "How much delta can I take on?" Again, there is no scientific answer to this question. While the maximum risk of a long option is the total price paid plus commissions, traders practicing good risk management generally set predetermined limits, known as *stop-loss points*, at which they close a position and take a loss that is less than the possible maximum loss. Stop-loss points can be stated in a dollar amount, the price of an option, or the price of the underlying stock. Regardless of how they are expressed, traders set stop-loss points individually. It is a subjective decision.

In the case of short options, the position delta does not fully state the risk because a stock-price change against the position will cause the position delta to increase adversely, generating a loss that grows at an increasing rate. This effect is known as *negative gamma*. Stop-loss points therefore are especially important for short option positions, which also must be monitored continuously.

The gamma, vega, and theta risks of directional trades can be adjusted, but the general impact of such adjustments is to also adjust the delta. The comparison at the beginning of this chapter illustrated that the call spreads in Table 10-3 had lower Greeks than the outright long calls in Table 10-1. A trader who sells calls with a higher strike price in an effort to reduce the vega risk of some existing long calls also reduces the delta. Since delta is almost always the bigger risk, reducing vega may have little value.

Another strategy that reduces the theta risk of long calls is selling puts with a lower strike price. The positive theta of the short puts reduces the time-decay risk of the long calls, but short puts also increase the position delta, and the increased delta increases position risk. Again, the value of reducing theta risk while increasing delta and position risk is questionable. Ultimately, directional positions must focus on delta risk, and the amount of delta risk to assume is a subjective decision.

Summary

There are both quantitative and subjective elements in managing risk. Every strategy from outright long options to vertical spreads and ratio spreads has unique tradeoffs of profits versus risks. Managing those risks requires an understanding of how the risks of individual options change and how they interact with each other as market conditions change. The task of managing risk is also different for directional traders and delta-neutral traders.

When trading with a directional forecast with long options, it is sometimes possible to increase profits and decrease risk at the same time by managing a position's delta.

Calculating the Greeks of multiple-option positions is straightforward. First, the Greeks of individual options are multiplied by the number of contracts. Second, the Greeks of the total position are the sum of the Greeks of the individual option positions. It is not always easy to anticipate how position Greeks will change because the Greeks of individual options change at varying rates as time passes, as volatility rises or falls, and as the stock price fluctuates above and below the strike price.

When interest rates are zero, neutralizing either gamma, vega, or theta also neutralizes the other two. When interest rates are positive, however, neutralizing gamma or vega will neutralize the other, but the theta will remain nonneutral. With a stock position as part of a delta-neutral position, the position theta is related to the interest component, either the cost of carry or the interest income.

Although position risk can be quantified, only traders can choose a risk limit, which can be stated in dollar terms or in terms of one of the Greeks. If a trader understands the potentials—both good and bad—and combines that knowledge with the stock-price ranges estimated by historic and implied volatility, then the chances of earning profits are improved.

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EPILOGUE

This book has discussed several topics that both market makers and advanced individual traders need to master. Computers assist market makers in trade execution, adjusting prices, and monitoring position risk, and they greatly increase efficiency. Computers, however, do not make decisions, and they do not replace the human element in making markets. Option market makers still need to be well versed in options price behavior, volatility, synthetic relationships and arbitrage, delta-neutral trading, setting bid-ask prices, and managing position risk.

For individual traders, the goal of learning how market makers think is to improve your skills in entering orders and in anticipating strategy performance. Knowing that market makers are in a unique business, not in competition with investors or speculators; knowing that they are only one participant in the market, not the market; knowing that they face tough decisions, just as you do; and knowing that they make or lose money by assuming risk should give you confidence in trading with them.

While market forecasting remains an art, an increased understanding of volatility should help you in estimating stock-price ranges, picking price targets, and anticipating how option strategies will perform. Traders of all stripes must be guided by objectivity rather than by emotion. They also must have the discipline to implement a trading technique consistently.

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