Chapter 6
Foreign Currency Options

Global View

French Bank Stages Mock Options Market on Super Bowl to Teach Businesses How to Hedge Their Risks

'Skins Up by 10? You Make the Call: Punt or Put?

Move over, Jimmy the Greek. Make way for Société Generale. The French bank is throwing a Super Bowl party today at which 80 top corporate executives will speculate continuously on the game's outcome in a mock, Wall Street trading pit—complete with computer monitors, hustling clerks and big TV screens to watch the game in progress.

The bank hopes that the exercise will cast light on the real-life options market, a fast-growing but little-known corner of the financial markets in which corporations, investors and speculators trade the rights to buy everything from Japanese yen and IBM stock to gold.

After every big plunge on Wall Street, public critics charge that the options market, centered in this country mainly at the Chicago Board Options Exchange, is nothing but a den of gamblers and speculators. The impression may not exactly be dispelled by Société Generale's football bash. But supporters say the options market is an invaluable aid to banks and businesses seeking to "hedge," or limit, their risks in a highly volatile, interconnected global economy. And like a real options market, there will be the usual "calls" and "puts"—the two basic types of options that represent the right to buy and to sell, respectively.

Given the risks, some say that the most speculative thing an international company such as International Business Machines Corp. can do is not to buy and sell options, since it is then completely exposed to the fluctuations of currencies.

Although Société Generale would prefer the public to focus only on worthy causes such as foreign currency hedging, it and other banks with large options operations are among the biggest speculators in options. Such speculation, while not strictly gambling, can lead to very big profits or very big losses, depending on whether one correctly anticipates the direction of foreign exchange or interest rates.

Source: Adapted from Robert J. McCartney, "Skins Up by 10?," *The Washington Post*, 1/26/92, H1, H5.

Foreign currency options are instruments that have assumed increasing importance in the marketplace in recent years. They can be used to hedge the foreign exchange risk that results from commercial transactions, and they can be used for speculative purposes. Use of foreign currency options to hedge commercial transactions is covered in Chapter 7.

This chapter is presented in two parts. The first half provides a basic description of currency options, of the markets in which they are traded, and of their use for investment or speculation purposes. The second half of the chapter provides a deeper look into the forces determining option values (pricing), and how option values change with these forces.

Vocabulary

- A *foreign currency option* is a contract giving the option purchaser (the buyer) the right, but not the obligation, to buy or sell a given amount of foreign exchange at a fixed price per unit for a specified time period (until the expiration date). In many ways buying an option is like buying a ticket to a Rolling Stones concert. The buyer has the right to attend the concert, but does not have to (after all, Mick Jagger is over 50 years old). The buyer of the concert ticket risks nothing more than what was paid for the ticket. Similarly, the buyer of an option cannot lose anything more than what was paid for the option. If the buyer of the ticket decides later not to attend the concert, prior to the day of the concert, the ticket can be sold to someone else who does wish to go (someone interested in the music of aging rock stars).
- There are two basic types of options: calls and puts. A *call* is an option to buy foreign currency, and a *put* is an option to sell foreign currency.
- The buyer of an option is termed the *holder;* the seller of an option is referred to as the *writer* or *grantor.*
- Every option has three different price elements: (1) the exercise or strike price, the exchange rate at which the foreign currency can be purchased (call) or sold (put); (2) the premium, the cost, price, or value of the option itself; and (3) the underlying or actual spot exchange rate in the market.

- An *American option* gives the buyer the right to exercise the option at any time between the date of writing and the expiration or maturity date. *European options* can be exercised only on their expiration date, not before.
- The premium or option price is the cost of the option, usually paid in advance by the buyer to the seller. In the over-the-counter market (options offered by banks), premiums are quoted as a percentage of the transaction amount. Premiums on exchange-traded options are quoted as a domestic currency amount per unit of foreign currency.
- An option whose exercise price is the same as the spot price of the underlying currency is said to be *at-the-money (ATM)*. An option that would be profitable (ignoring the premium) if exercised immediately is said to be *in-the-money (ITM)*. An option that would not be profitable if exercised immediately is referred to as *out-of-the-money (OTM)*.

Foreign Currency Options Markets

In the past decade the use of foreign currency options as a hedging tool and for speculative purposes has blossomed into a major foreign exchange activity. A number of banks in the United States and other capital markets offer flexible foreign currency options on transactions of $1 million or more. The bank market, or over-the-counter market as it is called, offers custom-tailored options on all major trading currencies for any time period up to several years. These provide a useful alternative to forward and futures contracts (discussed in chapter 4) for firms interested in hedging foreign exchange risk on commercial transactions.

In December 1982, the Philadelphia Stock Exchange introduced trading in standardized foreign currency option contracts in the United States. The Chicago Mercantile Exchange and other exchanges in the United States and abroad have followed suit. Exchange-traded contracts are particularly appealing to speculators and individuals who do not normally have access to the over-the-counter market. Banks also trade on the exchanges because this is one of several ways they can offset the risk of options they have transacted with clients or other banks.

Increased use of foreign currency options is a reflection of the explosive growth in the use of other kinds of options and the resultant improvements in option pricing models. The original option pricing model was developed by Black and Scholes in 1973.[1] It has been extended by others to apply to foreign currency options.[2] Several commercial programs are available for option writers and traders to utilize.

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[1] Fisher Black and Myron Scholes, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy*, May/June 1973, pp. 637–659.

[2] Mark Garman and Steven Kohlhagen, "Foreign Currency Option Values," *Journal of International Money and Finance*, December 1983, pp. 231–237; J. Orlin Grabbe, "The Pricing of Call and Put Options on Foreign Exchange," *Journal of International Money and Finance*, December 1983, pp. 239–253; and Nahum Biger and John Hull, "The Valuation of Currency Options," *Financial Management*, Spring 1983, pp. 24–28.

Options on the Over-the-Counter Market

Over-the-counter (OTC) options are most frequently written by banks for U.S. dollars against British pounds, German marks, Swiss francs, Japanese yen, and Canadian dollars. They are usually written in round lots of $5 to $10 million in New York and $2 to $3 million in London.

The main advantage of over-the-counter options is that they are tailored to the specific needs of the firm. Financial institutions are willing to write or buy options that vary by amount (notional principal), strike price, and maturity. Although the over-the-counter markets were relatively illiquid in the early years, the market has grown to such proportions that liquidity is now considered quite good. On the other hand, the buyer must assess the writing bank's ability to fulfill the option contract. Termed *counterparty risk,* the financial risk associated with the counterparty is an increasing issue in international markets as a result of recent failures, such as the Bank of New England and Drexel-Burnham Lambert, and legal risks associated with certain semi-sovereign parties in the United Kingdom (Chapter 14 provides an expanded discussion of counterparty risk). However, firms buying and selling currency options as part of their risk management program (as detailed in Chapter 7), do so primarily in the over-the-counter market. Exchange-traded options are more the territory of the financial institutions themselves.

A firm wishing to purchase an option in the over-the-counter market normally places a call to the currency option desk of a major money center bank, specifies the currencies, maturity, strike rate(s), and asks for an *indication,* a bid-offer quote. The bank normally takes a few minutes to a few hours to price the option and return the call.

Options on Organized Exchanges

Options on the physical (underlying) currency are traded on a number of organized exchanges worldwide, one of which is the Philadelphia Stock Exchange. Exchange-traded options are settled through a clearinghouse. Buyers do not deal directly with sellers. The clearinghouse is the counterparty to every option contract and it guarantees fulfillment. Clearinghouse obligations are in turn the obligation of all members of the exchange, including a large number of banks.

Foreign currency options on seven major currencies are traded on the Philadelphia Stock Exchange (each against the U.S. dollar): Australian dollar, British pound, Canadian dollar, Deutschemark, French franc, Japanese yen, and Swiss franc. It also trades the European Currency Unit (ECU). The Philadelphia Stock Exchange has recently introduced cross-currency options (STG/DEM, DEM/YEN)[3] and end-of-month contract maturities in addition to the current mid-month maturity. Both American and European options are available for each of the currencies, except for European Currency Units (ECUs), which trade only an American option. Options on exchanges are traded in standardized amounts per option contract. For example, on the Philadelphia Stock Exchange each option on Deutschemarks is for DM62,500. If a

[3]Note that the Philadelphia Stock Exchange uses the three-letter computer symbols for the British pound sterling, STG, and the Deutschemark, DEM, rather than the traditional symbols utilized throughout this book of £ and DM, respectively.

company wishes to buy options on DM1,000,000, the company would purchase 16 contracts, because DM1,000,000/ DM62,500 per contract = 16 contracts.

Each foreign currency option is introduced for trading with one, two, three, six, nine, and twelve months to run until expiration. Expiration months are March, June, September, and December, with trading also available in two additional near-term consecutive months. Thus in November, trading would occur in November, December, January, March, June, and September maturities. Finally, each mid-month option contract expires at 11:59 P.M. on the Friday preceding the third Wednesday of the expiration month. All end-of-month (EOM) options expire at 11:59 P.M. on the last Friday of the expiration month.[4]

Currency Option Quotations and Prices

Quotes in the *Wall Street Journal* for options on German marks are shown in Exhibit 6.1. The *Journal's* quotes refer to transactions completed on the Philadelphia Stock Exchange on the previous day. Quotations are usually available for more combinations of strike prices and expiration dates than were actually traded and thus reported in the newspaper.

Exhibit 6.1 illustrates the three different prices that characterize any foreign currency option. The three prices that characterize an "August 58 1/2 call option" (highlighted in Exhibit 6.1) are the following:[5]

1. **Spot rate.** In Exhibit 6.1, "option and underlying" means that 58.51 cents, or $0.5851, is the spot dollar price of one German mark at the close of trading on the preceding day. This spot rate is sometimes omitted from the *Wall Street Journal* quotations.
2. **Exercise price.** The exercise price, or "strike price" listed in Exhibit 6.1, means the price per mark that must be paid if the option is exercised. The August call option on marks of 58 1/2 means $0.5850/DM. Exhibit 6.1 lists nine different strike prices, ranging from $0.5600/DM to $0.6000/DM, although more were available on that date than listed here.[6]
3. **Premium.** The premium is the cost or price of the option. The price of the August 58 1/2 call option on German marks is 0.50 U.S. cents per mark, or $0.0050/DM. There was no trading of the September and December 58 1/2 call on that day. The premium is the market value of the option, and therefore the

[4]Expiration dates on the Philadelphia Stock Exchange were traditionally the Saturday following the third Wednesday of the expiration month, not Friday. The change to Friday was made effective on June 13, 1993, in an attempt to better accommodate trading in a 24-hour marketplace.

[5]Currency option strike prices and premiums on the U.S. dollar are quoted throughout this chapter as direct quotations ($/DM, $/¥, etc.) as opposed to the more common usage of indirect quotations used throughout the rest of the book. This is standard practice with option prices as quoted on major option exchanges like the Philadelphia Stock Exchange.

[6]Options are available at fixed strike prices, the prices reflecting current market prices of the underlying currency at the time that option was first offered.

Exhibit 6.1 Foreign Currency Option Quotations (Philadelphia Stock Exchange)

Option and Underlying	*Strike price*	*Calls—Last*			*Puts—Last*		
		Aug.	*Sept.*	*Dec.*	*Aug.*	*Sept.*	*Dec.*
62,500 German marks-cents per unit.							
58.51	56	—	—	2.76	0.04	0.22	1.16
58.51	56 1/2	—	—	—	0.06	0.30	—
58.51	57	1.13	—	1.74	0.10	0.38	1.27
58.51	57 1/2	0.75	—	—	0.17	0.55	—
58.51	58	0.71	1.05	1.28	0.27	0.89	1.81
58.51	58 1/2	0.50	—	—	0.50	0.99	—
58.51	59	0.30	0.66	1.21	0.90	1.36	—
58.51	59 1/2	0.15	0.40	—	2.32	—	—
58.51	60	—	0.31	—	2.32	2.62	3.30

Source: Adapted from *The Wall Street Journal*, Tuesday, August 3, 1993; quotes are for close of Monday, August 2, 1993.

terms *premium, cost, price,* and *value* are all interchangeable when referring to an option.[7]

The August 58 1/2 call option premium is 0.50 cents per mark, and in this case, the August 58 1/2 put's premium is also 0.50 cents per mark. Since one option contract on the Philadelphia Stock Exchange consists of 62,500 marks, the total cost of one option contract for the call (or put in this case) is DM62,500 × \$0.0050/DM = \$312.50.

Foreign Currency Speculation

Speculation is an attempt to profit by trading on expectations about prices in the future. In the foreign exchange markets, one speculates by taking an open (unhedged) position in a foreign currency and then closing that position after the exchange rate has moved—one hopes—in the expected direction. In the following section we analyze the way speculation is undertaken in spot, forward, and options markets. It is important to understand this phenomenon because it has a major impact on our inability to accurately forecast future exchange rates.

Speculating in the Spot Market

Willem Koopmans is a currency speculator in Amsterdam. He is willing to risk money on his own opinion about future currency prices. Willem Koopmans may speculate in

[7]All option premiums are expressed in cents per unit of foreign currency on the Philadelphia Stock Exchange except for the French franc, which is expressed in tenths of a cent per franc, and the Japanese yen, which is expressed in hundredths of a cent per yen.

the spot, forward, or options markets. To illustrate, assume the German mark is currently quoted as follows:

Spot rate:	\$0.5851/DM
Six-month forward rate:	\$0.5760/DM

Willem Koopmans has \$100,000 with which to speculate, and he believes in six months the spot rate for the mark will be \$0.6000/DM. Speculation in the spot market requires only that the speculator believe the foreign currency will appreciate in value. He should take the following steps:

1. Today use the \$100,000 to buy DM170,910.96 spot at \$0.5851/DM.
2. Hold the DM170,910.96 indefinitely. Although the mark is expected to rise to the target value in six months, the speculator is not committed to that time horizon.
3. When the target exchange rate is reached, sell DM170,910.96 at the new spot rate of \$0.6000/DM, receiving DM170,910.96 × \$0.6000/DM = \$102,546.57.
4. Profit = \$2,546.57, or 2.5% on the \$100,000 committed for six months (5.0% per annum). This ignores interest income on the Deutschemarks and opportunity cost on the dollars for the moment.

The potential maximum gain is unlimited; the maximum loss will be \$100,000 if the marks purchased in step 1 drop in value to zero. Having initially undertaken a spot market speculation for six months, Koopmans is nevertheless not bound by that target date. He may sell the marks earlier or later if he wishes.

Speculating in the Forward Market

Forward market speculation occurs when the speculator believes the spot price at some future date will differ from today's forward price for that same date. Success does not depend on the direction of movement of the spot rate, but on the relative position of the future spot rate and the current forward rate. Given the data and expectations just described, Willem Koopmans should take the following steps:

1. Today buy DM173,611.11 forward six months at the forward quote of \$0.5760/DM. Note that this step requires no outlay of cash.
2. In six months, fulfill the forward contract, receiving DM173,611.11 at \$0.5760/DM for a cost of \$100,000.
3. Simultaneously sell the DM173,611.11 in the spot market, receiving DM173,611.11 × \$0.6000/DM = \$104,166.67.
4. Profit: \$4,166.67.

The profit of \$4,166.67 cannot be related to an investment base to calculate a return on investment because the dollar funds were never needed. On the six-month anniversary Willem Koopmans simply crosses the payment obligation of \$100,000 with receipts of \$104,166.67, and accepts a net \$4,166.67. Nevertheless, some financial institutions might require him to deposit collateral as margin to assure his ability to complete the trade.

In this particular forward speculation, the maximum loss is $100,000, the amount needed to buy marks via the forward contract. This loss would be incurred only if the value of the spot mark in six months were zero. The maximum gain is unlimited, since marks acquired in the forward market can in theory rise to an infinite dollar value.

Forward market speculation cannot be extended beyond the maturity date of the forward contract. However, if the speculator wants to close out the speculative operation before maturity, that speculator may buy an offsetting contract. In our example, after, say, four months, Willem Koopmans could sell DM173,611.11 forward two months at whatever forward price then existed. Two months after that he would close the matured six-month contract to purchase marks against the matured two-month contract to sell marks, pocketing any profit or paying up any loss. The amount of profit or loss would be fixed by the price at which Willem Koopmans sold forward two months.

The example just presented is only one of several possible types of forward speculations. Note that the examples given in this discussion have ignored any interest earned. In a spot speculation, the speculator can invest the principal amount in the foreign money market to earn interest. In the various forward speculations, a speculator who is holding cash against the risk of loss can invest those funds in the home money market. Thus relative profitability will be influenced by interest differentials.

Speculating in Option Markets

Options differ from all other types of financial instruments in the patterns of risk they produce. The option owner has the choice of exercising the option or allowing it to expire unused. The owner will exercise it only when exercising is profitable, which means only when the option is in the money. In the case of a call option, as the spot price of the underlying currency moves up, the holder has the possibility of unlimited profit. On the down side, however, the holder can abandon the option and walk away with a loss never greater than the premium paid.

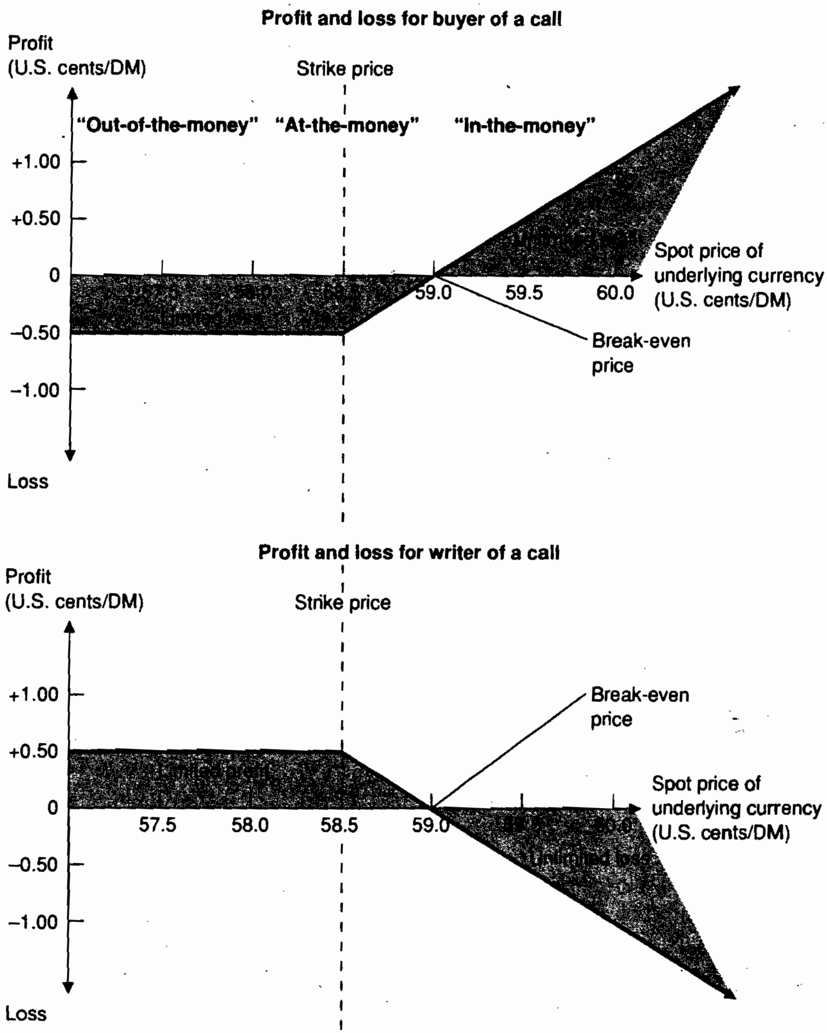
Buyer of a Call

The position of Willem Koopmans as a buyer of a call is illustrated in the upper half of Exhibit 6.2. Assume that Koopmans purchases the August call option on German marks described previously, the one with a strike price of 58 1/2 ($0.5850/DM) and a premium of $0.005/DM. The vertical axis measures profit or loss for the option buyer, at each of several different spot prices for the mark up to the time of maturity.

At all spot rates *below* the strike price of $0.585, Koopmans would choose not to exercise his option. This is obvious, since at a spot rate of $0.585, for example, Koopmans would prefer to buy a German mark for $0.580 on the spot market rather than exercising his option to buy a mark at $0.585. If the spot rate remains below $0.580 until August when the option expired, Koopmans would not exercise the option. His total loss would be limited to only what he paid for the option, the $0.005/DM purchase price. At any lower price for the mark, his loss would similarly be limited to the original $0.005/DM cost.

Alternatively, at all spot rates *above* the strike price of $0.585, Koopmans would exercise the option, paying only the strike price for each German mark. For example, if the spot rate were $0.595 cents per mark at maturity, Koopmans would exercise his call

Exhibit 6.2 Profit and Loss Position for the Buyer and Writer of a Call Option on German Marks with a Premium of $0.005/DM



option, buying German marks for \$0.585 each instead of purchasing them on the spot market at \$0.595 each. The German marks could be sold immediately in the spot market for \$0.595 each, pocketing a gross profit of \$0.010/DM, or a net profit of \$0.005/DM after deducting the original cost of the option of \$0.005/DM. The profit to Koopmans, if the spot rate is greater than the strike price, with strike price \$0.585, a premium of \$0.005, and a spot rate of \$0.595, is:

$$\begin{aligned}\text{Profit} &= \text{Spot Rate} - (\text{Strike Price} + \text{Premium})\\ &= \$0.595/\text{DM} - (\$0.585/\text{DM} + \$0.005/\text{DM})\\ &= \$0.005/\text{DM}.\end{aligned}$$

More likely, Koopmans would realize the profit through executing an offsetting contract on the options exchange rather than taking delivery of the currency. Because the dollar price of a mark could rise to an infinite level (off the upper right-hand side of the page in Exhibit 6.2), maximum profit is unlimited. The buyer of a call option thus possesses an attractive combination of outcomes: limited loss and unlimited profit potential.

The *break-even price* of \$0.590/DM is the price at which Koopmans neither gains nor loses on exercise of the option. The premium cost of \$0.005, combined with the cost of exercising the option of \$0.585, is exactly equal to the proceeds from selling the marks in the spot market at \$0.590. Note that Koopmans will still exercise the call option at the break-even price. This is because by exercising it Koopmans at least recoups (pardon the pun) the premium paid for the option. At any spot price above the exercise price but below the break-even price, the gross profit earned on exercising the option and selling the underlying currency covers part (but not all) of the premium cost.

Writer of a Call

The position of the writer (seller) of the same call option is illustrated in the bottom half of Exhibit 6.2. If the option expires when the spot price of the underlying currency is below the exercise price of \$0.585, the option holder does not exercise. What the holder loses, the writer gains. The writer keeps as profit the entire premium paid of \$0.005/DM. Above the exercise price of \$0.585, the writer of the call must deliver the underlying currency for \$0.585/DM at a time when the value of the mark is above \$0.585. If the writer wrote the option naked, that is, without owning the currency, that writer will now have to buy the currency at spot and take the loss. The amount of such a loss is unlimited and increases as the price of the underlying currency rises. Once again, what the holder gains, the writer loses, and vice versa. Even if the writer already owns the currency, the writer will experience an opportunity loss, surrendering against the option the same currency that could have been sold for more in the open market.

For example, the profit to the writer of a call option of strike price \$0.585, premium \$0.005, a spot rate of \$0.595/DM is:

$$\begin{aligned}\text{Profit} &= \text{Premium} - (\text{Spot Rate} - \text{Strike Price})\\ &= \$0.005/\text{DM} - (\$0.595/\text{DM} - \$0.585/\text{DM})\\ &= -\ \$0.005/\text{DM}\end{aligned}$$

but **only** if the spot rate is greater than or equal to the strike rate. At spot rates less than the strike price, the option will expire worthless and the writer of the call option will keep the premium earned. The maximum profit the writer of the call option can make is limited to the premium. The writer of a call option would have a rather unattractive combination of potential outcomes: limited profit potential and unlimited loss potential, but there are ways to limit such losses through other techniques.

Buyer of a Put

The position of Koopmans as buyer of a put is illustrated in Exhibit 6.3. The basic terms of this put are similar to those we just used to illustrate a call. The buyer of a put option, however, wants to be able to sell the underlying currency at the exercise price when the market price of that currency drops (not rises as in the case of a call option). If the spot price of a mark drops to, say, \$0.575/DM, Koopmans will deliver marks to the writer and receive \$0.585/DM. The marks can now be purchased on the spot market for \$0.575 each and the cost of the option was \$0.005/DM, so he will have a net gain of \$0.005/DM.

Explicitly, the profit to the holder of a put option if the spot rate is less than the strike price, with a strike price \$0.585/DM and premium of \$0.005/DM, and a spot rate of \$0.575/DM is:

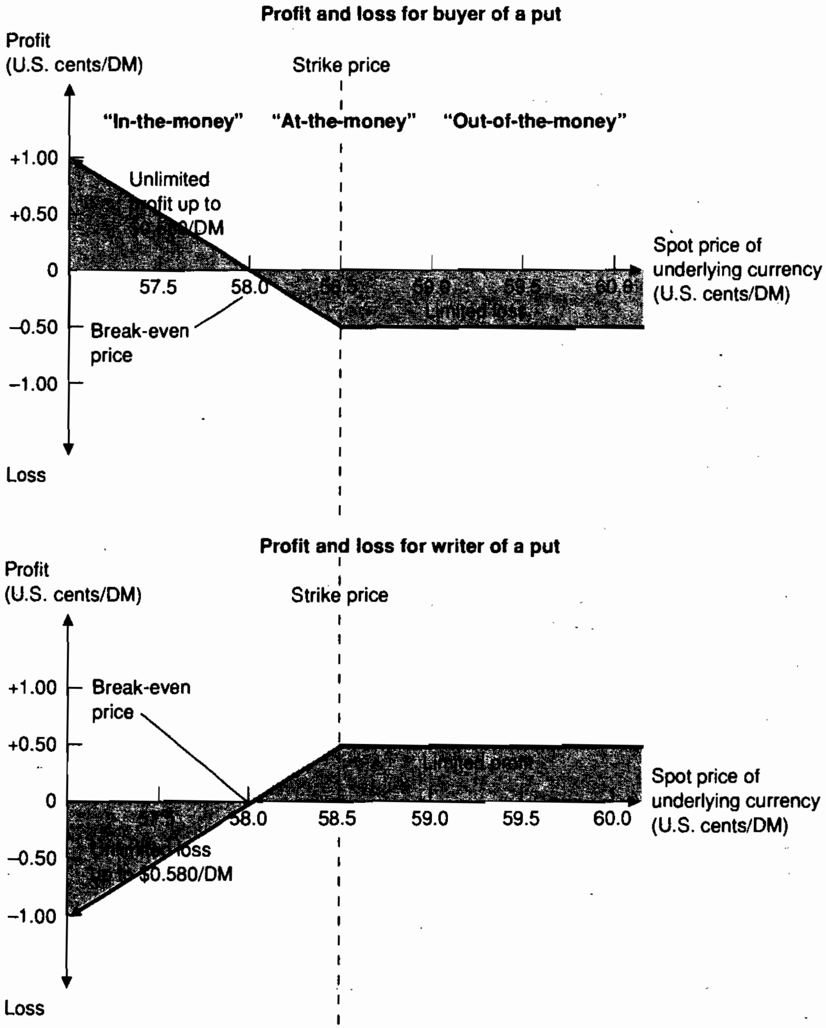
$$\begin{aligned} \text{Profit} &= \text{Strike Price} - (\text{Spot Rate} + \text{Premium}) \\ &= \$0.585/\text{DM} - (\$0.575/\text{DM} + \$0.005/\text{DM}) \\ &= \$0.005/\text{DM}. \end{aligned}$$

The break-even price for the put option is the strike price less the premium, or \$0.580/DM in this case. As the spot rate falls further and further below the strike price, the profit potential would continually increase, and Koopmans' profit could be unlimited (up to a maximum of \$0.580/DM, when the price of a DM would be zero). At any exchange rate above the strike price of \$0.585, Koopmans would not exercise the option, and so would lose only the \$0.005/DM premium paid for the put option. The buyer of a put option has an almost unlimited profit potential with a limited loss potential. Like the buyer of a call, the buyer of a put can never lose more than the premium paid up front.

Writer of a Put

The position of the writer of the put sold to Koopmans is shown in the lower half of Exhibit 6.3. Note the symmetry of profit/loss, strike price, and break-even prices between the buyer and the writer of the put as was the case of the call option. If the spot price of marks drops below \$0.585 per mark, the option will be exercised by Koopmans. Below a price of \$0.585 per mark, the writer will lose more than the premium received from writing the option (\$0.005/DM), falling below break even. Between \$0.580/DM and \$0.585/DM the writer will lose part, but not all, of the premium received. If the spot price is above \$0.585/DM, the option will not be exercised, and the option writer

Exhibit 6.3 Profit and Loss Position for the Buyer and Writer of a Put Option on German Marks with a Premium of $0.005/DM



pockets the entire premium of \$0.005/DM. The profit earned by the writer of a \$0.585 strike price put, premium \$0.005, at a spot rate of \$0.575, is:

$$\begin{aligned}\text{Profit} &= \text{Premium} - (\text{Strike Price} - \text{Spot Rate})\\ &= \$0.005/\text{DM} - (\$0.585/\text{DM} - \$0.575/\text{DM})\\ &= -\$0.005/\text{DM},\end{aligned}$$

but **only** for spot rates that are less than or equal to the strike price. At spot rates that are greater than the strike price, the option expires out-of-the-money and the writer keeps the premium earned up front. The writer of the put option has the same basic combination of outcomes available to the writer of a call: limited profit potential and unlimited loss potential.

Option Pricing and Valuation

Exhibit 6.4 illustrates the profit/loss profile of a European-style call option on British pounds. The call option allows the holder to buy British pounds (£) at a strike price of \$1.70/£. The value of this call option is actually the sum of two components:

$$\text{Total Value (premium)} = \text{Intrinsic Value} + \text{Time Value}.$$

Intrinsic value is the financial gain if the option is exercised immediately. It is shown by the solid line in Exhibit 6.4, which is zero until reaching the strike price, then rises linearly 1 cent for each 1 cent increase in the spot rate. Intrinsic value will be zero when the option is out-of-the-money, that is, when the strike price is above the market price, since no gain can be derived from exercising the option. When the spot price rises above the strike price, the intrinsic value becomes positive because the option is always worth at least this value if exercised.

In Exhibit 6.4, when the spot rate is \$1.72/£ the option has an *intrinsic value* of \$1.72 less \$1.70/£, or 2 cents per pound. At a spot rate below \$1.70/£, the option is out-of-the-money and has no intrinsic value (and only a fool would exercise it instead of buying pounds more cheaply on the spot market).

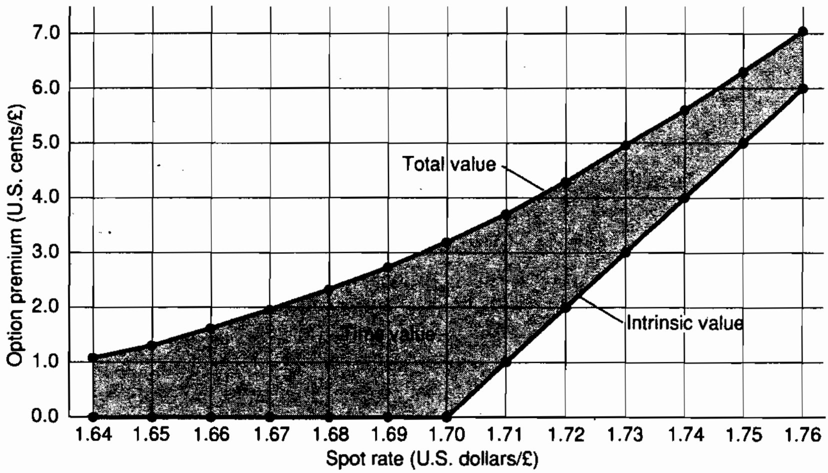
The *time value* of an option exists because the price of the underlying currency, the spot rate, can potentially move further and further in-the-money between the present time and the option's expiration date. Time value is shown in Exhibit 6.4 as the area between the total value of the option and its intrinsic value. At a spot rate of \$1.72/£, the option's total value is composed of the 2 cents per pound intrinsic value and 2.39 cents per pound in time value, for a total value of 4.39 cents per pound.

An investor will pay something today for an out-of-the-money option (i.e., zero intrinsic value) on the chance the spot rate will move far enough before maturity to move the option in-the-money. Consequently, the price of an option is always somewhat greater than its intrinsic value, since there is always some chance the intrinsic value will rise between the present and the expiration date.

Components of Option Pricing

The total value of an option is the sum of its intrinsic value, which is easy to calculate, and its time value, which depends on the market's expectations about the likelihood the

Exhibit 6.4 Intrinsic Value, Time Value, and Total Value of a Call Option on British pounds



Spot ($/£)	1.64	1.65	1.66	1.67	1.68	1.69	1.70	1.71	1.72	1.73	1.74	1.75	1.76
						Premium Components (cents/£)							
Intrinsic Value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	2.00	3.00	4.00	5.00	6.00
Time Value	1.12	1.37	1.67	2.01	2.39	2.82	3.30	2.82	2.39	2.01	1.67	1.37	1.12
Total Value	1.12	1.37	1.67	2.01	2.39	2.82	3.30	3.82	4.39	5.01	5.67	6.37	7.12
Delta	0.27	0.28	0.32	0.36	0.41	0.45	0.50	0.55	0.59	0.63	0.68	0.71	0.75

underlying currency will rise in value (for a call option) prior to maturity. On the date of maturity an option will have a value equal to its intrinsic value (zero time remaining means zero time value).

The pricing of a currency option combines six elements. For example, the European style call option on British pounds depicted in Exhibit 6.4 has a premium of $0.033/£ at a spot rate of $1.70/£. This premium is based on the following assumptions:

1. present spot rate, $1.70/£;
2. time to maturity, 90 days;
3. forward rate for matching maturity (90 days), $1.70/£;
4. U.S. dollar interest rate, 8.00% per annum;

5. British pound sterling interest rate, 8.00% per annum;
6. volatility, the standard deviation of daily spot price movement, 10.00% per annum.

These assumptions are all that are needed to calculate the option premium. This base case numerical example, which we continue to use through the remainder of the chapter, assumes both currency interest rates are the same. This means the forward rate equals the spot rate. In the following section we demonstrate how the value of the option—the option premium—changes as these six components change. This chapter's appendix describes the theoretical specification of currency option pricing and demonstrates the numerical calculation of the call option just described.

Currency Option Pricing Sensitivity

If currency options are to be used effectively, either for the purposes of speculation or risk management (covered in the coming chapters), the individual trader needs to know how option values—premiums—react to their various components. The following section analyzes these six basic sensitivities:

1. the impact of changing forward rates;
2. the impact of changing spot rates;
3. the impact of time to maturity;
4. the impact of changing volatility;
5. the impact of changing interest differentials;
6. the impact of alternative option strike prices.

1. Forward Rate Sensitivity

Although rarely noted, standard foreign currency options are priced around the forward rate. This is because the current spot rate and both the domestic and foreign interest rates (home currency and foreign currency rates) are included in the option premium calculation.[8] Regardless of the specific strike rate chosen and priced, the forward rate is central to valuation. The option-pricing formula calculates a subjective probability distribution centered on the forward rate. This does not mean the market expects the forward rate to be equal to the future spot rate, it is simply a result of the arbitrage-pricing structure of options.

[8]Recall from Chapter 4 that the forward rate is calculated from the current spot rate and the two subject currency interest rates for the desired maturity. For example, the 90-day forward rate for the call option on British pounds just described is calculated as follows:

$$F_{90} = \$1.70/£ \times \left[\frac{1 + .08\left(\frac{90}{360}\right)}{1 + .08\left(\frac{90}{360}\right)} \right] = \$1.70/£.$$

The forward rate focus also provides helpful information for the trader managing a position. When the market prices a foreign currency option, it does so without any bullish or bearish sentiment on the direction of the foreign currency's value relative to the domestic currency. If the trader has specific expectations about the future spot rate's direction, those expectations can be put to work. A trader will not be inherently betting against the market. In a following section we also describe how a change in the interest differential between currencies, the theoretical foundation of forward rates, also alters the value of the option.

2. Spot Rate Sensitivity (Delta)

The call option on British pounds depicted in Exhibit 6.4 possesses a premium that exceeds the intrinsic value of the option over the entire range of spot rates surrounding the strike rate. As long as the option has time remaining before expiration, the option will possess this time value element. This is one of the primary reasons why an American-style option, which can be exercised on any day up to and including the expiration date, is seldom actually exercised prior to expiration. If the option holder wishes to liquidate it for its value, it would normally be sold, not exercised, so any remaining time value can also be captured by the holder. If the current spot rate falls on that side of the option's strike price which would induce the option holder to exercise the option upon expiration, the option also has an intrinsic value. The call option illustrated in Exhibit 6.4 is in-the-money (ITM) at spot rates to the right of the strike rate of \$1.70/£, at-the-money (ATM) at \$1.70/£, and out-of-the-money (OTM) at spot rates less than \$1.70/£.

The vertical distance between the market value and the intrinsic value of a call option on pounds is greatest at a spot rate of \$1.70/£. At \$1.70/£ the spot rate equals the strike price (at-the-money). This premium of 3.30 cents per pound consists entirely of time value.[9] The further the option's strike price is out-of-the-money, the lower the value or premium of the option. This is because the market believes the probability of this option actually moving into the exercise range prior to expiration is significantly less than one that is already at-the-money. If the spot rate were to fall to \$1.68/£, the option premium falls to 2.39 cents/£, again, entirely time value. If the spot rate were to rise above the strike rate to \$1.72/£, the premium rises to 4.39 cents/£. In this case the premium represents an intrinsic value of 2.00 cents (\$1.72/£ − \$1.70/£) plus a time value element of 2.39 cents. Note the symmetry of time value premiums (2.39 cents) to the left and to the right of the strike rate.

The symmetry of option valuation about the strike rate is seen by decomposing the option premia into their respective intrinsic and time values. Exhibit 6.5 illustrates how varying the current spot rate by ± \$0.05 about the strike rate of \$1.70/£ alters each option's intrinsic and time values.

The sensitivity of the option premium to a small change in the spot exchange rate is called the *delta*. For example, the delta of the \$1.70/£ call option, when the spot rate

[9] In fact, the value of any option that is currently out-of-the-money (OTM) is made up entirely of time value.

Exhibit 6.5 Decomposing Call Option Premiums: Intrinsic Value and Time Value

Strike Rate ($/£)	*Spot Rate ($/£)*	*Money*	*Call Premium (cents/£)*	=	*Intrinsic Value (cents/£)*	+	*Time Value (cents/£)*	*Delta (0 to 1)*
1.70	1.75	ITM	6.37		5.00		1.37	.71
1.70	1.70	ATM	3.30		0.00		3.30	.50
1.70	1.65	OTM	1.37		0.00		1.37	.28

changes from $1.70/£ to $1.71/£, is simply the change in the premium divided by the change in the spot rate:

$$\text{delta} = \frac{\Delta\ \text{Premium}}{\Delta\ \text{Spot Rate}} = \frac{\$0.038/£ - \$0.033/£}{\$1.71/£ - \$1.70/£} = 0.5.$$

If the delta of the specific option is known, it is easy to determine how the option's value will change as the spot rate changes. If the spot rate changes by one cent ($0.01/£), given a delta of 0.5, the option premium would change by 0.5 × $0.01, or $0.005. If the initial premium was $0.033/£, and the spot rate increased by 1 cent (from $1.70/£ to $1.71/£), the new option premium would be $0.033 + $0.005 = $0.038/£. Delta varies between +1 and 0 for a call option, and −1 and 0 for a put option.

Traders in options categorize individual options by their delta rather than in-the-money, at-the-money, or out-of-the-money.[10] As an option moves further in-the-money, like the in-the-money option in Exhibit 6.5, delta rises toward 1.0 (in this case to .71). As an option moves further out-of-the-money, delta falls toward zero. Note that the out-of-the-money option in Exhibit 6.5 has a delta of only .28.[11]

Rule of Thumb: The higher the delta (deltas of .7 or .8 and up are considered high) the greater the probability of the option expiring in-the-money.

3. Time to Maturity: Value and Deterioration (Theta)

Option values increase with the length of time to maturity. The expected change in the option premium from a small change in the time to expiration is termed *theta*.

Theta is calculated as the change in the option premium over the change in time. If the $1.70/£ call option were to age one day from its initial 90-day maturity, the theta of

[10]The full range of delta values at the bottom of Exhibit 6.4 illustrate how a call option's delta changes as the spot rate moves from out-of-the-money to far in-the-money.

[11]The expected change in the option's delta resulting from a small change in the spot rate is termed *gamma*. It is often used as a measure of the stability of a specific option's delta. Gamma is utilized in the construction of more sophisticated hedging strategies that focus on deltas (delta-neutral strategies).

the call option would be the difference in the two premiums, 3.30 cents/£ and 3.28 cents/£ (assuming a spot rate of \$1.70/£):

$$\text{Theta} = \frac{\Delta\ \text{premium}}{\Delta\ \text{time}} = \frac{\text{cents } 3.30/£ - \text{cents } 3.28/£}{90 - 89} = .02.$$

Theta is based not on a linear relationship with time, but rather the square root of time. Exhibit 6.6 illustrates the time value deterioration for our same \$1.70/£ call option on pounds. The at-the-money strike rate is \$1.70/£, and the out-of-the-money and in-the-money spot rates are \$1.67/£ and \$1.73/£, respectively. Option premiums deteriorate at an increasing rate as they approach expiration. In fact, the majority of the option premium—depending on the individual option—is lost in the final 30 days prior to expiration.

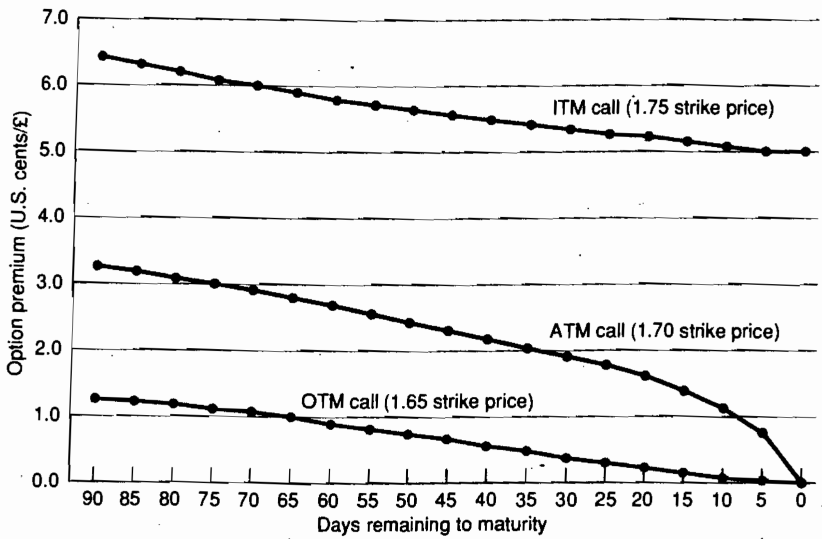
This exponential relationship between option premium and time is seen in the ratio of option values between the three-month and the one-month at-the-money maturities. The ratio for the at-the-money call option is not 3 to 1 (holding all other components constant), but rather

$$\frac{\text{Premium of 90 day ATM call}}{\text{Premium of 30 day ATM call}} = \frac{\text{cents } 3.30/£}{\text{cents } 1.93/£} = 1.71.$$

The three-month option's price is only 1.71 times that of the one month, not 3 times the price.

The rapid deterioration of option values in the last days prior to expiration is seen by

Exhibit 6.6 Theta: Option Premium Time Value Deterioration



once again calculating the theta of the \$1.70/£ call option, but now as its remaining maturity moves from 15 days to 14 days:

$$\text{Theta} = \frac{\Delta \text{ premium}}{\Delta \text{ time}} = \frac{\text{cents } 1.37/£ - \text{cents } 1.32/£}{15 - 14} = .05.$$

A decrease of one day in the time to maturity now reduces the option premium by .05 cents/£, rather than only .02 cents/£ as it did when the maturity was 90 days.

Exhibit 6.6 also illustrates the basic spot rate-option premium relations noted previously. The out-of-the-money call option's premium is logically smaller than the at-the-money option throughout its life, but deteriorates at a slower rate due to having an initially smaller level to fall from. The in-the-money option is of greater value throughout its time-life relative to the at-the-money, falling toward its intrinsic value (5 cents/£) at expiration. The at-the-money option, however, falls particularly quickly in the final periods prior to expiration. As any specific option ages, moving continually toward expiration, the time value will constantly decrease (assuming nothing else has changed). This would be illustrated by the total value line of the call option initially shown in Exhibit 6.4 collapsing inward toward the strike price of \$1.70.

The implications of time value deterioration for traders are quite significant. A trader purchasing an option with only one or two months until expiration will see the option's value deteriorate rapidly. If the trader were then to sell the option, it would have a significantly smaller market value in the periods immediately following its purchase.

At the same time, however, a trader who is buying options of longer maturities will pay more, but not proportionately more, for the longer maturity option. A 6-month option's premium is approximately 2.45 times more expensive than the one month; the 12-month option would be only 3.46 times more expensive than the one month. This implies that two 3-month options do not equal one 6-month option.[12]

Rule of Thumb: A trader will normally find longer maturity options better values, giving the trader the ability to alter an option position without suffering significant time value deterioration.

4. Sensitivity to Volatility (Vega)

There are few words in the financial field that are more used and abused than *volatility*. *Option volatility* is defined as the standard deviation of daily percentage changes in the underlying exchange rate. Volatility is important to option value because of an exchange rate's perceived likelihood to move either into or out of the range in which the option would be exercised. If the exchange rate's volatility is rising, and therefore the risk of the option being exercised increasing, the option premium would be increasing.

[12] A common error among beginning option traders is to purchase short-dated options that are then continually replaced with expiration to maintain their portfolio positions. The purchase of a longer dated option, for example a six-month or even twelve-month option, is significantly cheaper for the basic option position.

Volatility is stated in percent per annum. For example, an option may be described as having a 12.6% annual volatility. The percentage change for a single day can be found as follows:

$$\frac{12.6\%}{\sqrt{365}} = \frac{12.6\%}{19.105} = 0.66\% \text{ daily volatility.}$$

The sensitivity of the option premium to a unit change in volatility is termed *vega* (also termed *kappa*). For our \$1.70/£ call option, an increase in annual volatility of 1 percentage point, for example from 10.0% to 11.0%, will increase the option premium from \$0.033/£ to \$0.036/£.

$$\text{Vega} = \frac{\Delta \text{ premium}}{\Delta \text{ volatility}} = \frac{\$0.036/£ - \$0.033/£}{.11 - .10} = 0.30.$$

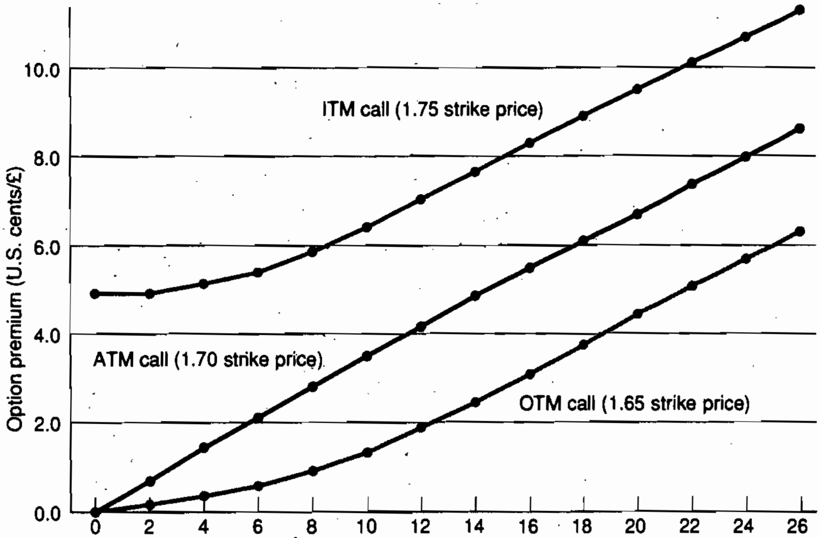
The primary problem with volatility is that it is *unobservable;* it is the only input into the option pricing formula that is judgmentally based by the trader pricing the option. There is no single correct method for its calculation. The problem is one of forecasting; the historical volatility is not necessarily an accurate predictor of the future volatility of the exchange rate's movement, yet there is little to go on except historical data.

Volatility is viewed three ways: *historic,* where the volatility is drawn from a recent period of time; *forward looking,* where the historic volatility is altered to reflect expectations about the future period over which the option will exist; and *implied,* where the volatility is backed out of the market price of the option itself.

Historic volatility is normally measured as the percentage movement in the spot rate on a daily, 6, or 12-hour basis over the previous 10, 30, or even 90 days. If option traders believe the immediate future will be the same as the recent past, the historic volatility will equal the forward-looking volatility. If, however, the future period is expected to experience greater or lesser volatility, the historic measure must be altered for option pricing. Implied volatility is equivalent to having the answers to the test; implied volatilities are calculated by being backed out of the market option premium values traded. Since volatility is the only unobservable element of the option premium price, after all other components are accounted for, the residual value of volatility that is *implied* by the price is used.

Option premia are highly sensitive to volatility. As illustrated in Exhibit 6.7, the at-the-money call premium on the British pound rises linearly with currency volatility. That is, a doubling of volatility translates into a doubling of the option value. The out-of-the-money call option also gains value rapidly with rising volatility. Even though the out-of-the-money option may possess no intrinsic value at this point in time, the higher the volatility the greater the chance the spot rate could move enough to move the option in-the-money. The in-the-money call option on pounds, although possessing a positive premium even at 0% volatility due to its intrinsic value, also rises in value with increased volatility due to the potential for further movements of the spot rate in-the-money.

Exhibit 6.7 Vega: Option Premium Sensitivity to Volatility



Like all futures markets, option volatilities react instantaneously and negatively to unsettling economic and political events (or rumor). Most currency option traders focus their activities on predicting movements of currency volatility in the short run, for they will move price the most. For example, option volatilities rose significantly in the months preceding the Persian Gulf War of 1991, in September 1992 when the European Monetary System was in crisis, and in July 1993 when the EMS once again was in crisis and was eventually restructured. In all instances option volatilities for major cross-currency combinations such as the DM/$ rose to nearly 20% for extended periods.

Sample implied volatilities for a number of currency pairs in February 1993 are listed in Exhibit 6.8. Volatilities are the only judgmental component that the option writer contributes, and yet they play a critical role in the pricing of options. Volatilities are typically expressed in bid/offer form, reflecting whether the trader wishes to buy or sell (write) the specific option. Note also that the implied volatilities do vary over maturity (3, 6, or 12 months in Exhibit 6.8). All currency pairs have historical series that contribute to the formation of the expectations of option writers. There is a noticeable difference in relative implied volatilities, with the SFR/DM at 3 months at 5.5%/6.0% at the low end, and the $/£ at 3 months at 13.3%/13.5% at the high end.

Rule of Thumb: Traders who believe volatilities will fall significantly in the near term will sell (write) options now, hoping to buy them back for a profit immediately after volatilities fall causing option premia to fall.

Exhibit 6.8 Implied Volatilities in February 1993 (percent per annum)

Cross	*3 months*	*6 months*	*12 months*
DM/$	12.3/12.5	12.3/12.5	12.4/12.6
¥/$	10.2/10.45	10.2/10.35	10.1/10.3
SFR/$	13.5/13.7	13.5/13.7	13.6/13.8
$/£	13.3/13.5	13.3/13.5	13.4/13.6
C$/$	5.3/5.8	5.8/6.3	5.8/6.3
US$/A$	9.4/9.8	9.0/9.4	8.4/8.7
DM/¥	11.3/11.55	11.2/11.45	11.1/11.3
SFR/DM	5.5/6.0	5.5/6.0	5.6/6.1
£/DM	7.5/8.0	7.6/8.1	7.6/8.1

Source: *Finance & Treasury Risk Advisor*, Economic Intelligence Unit, June 21, 1993, p.7.

5. Sensitivity to Changing Interest Rate Differentials (Rho and Phi)

At the start of this section we pointed out that currency option prices and values are focused on the forward rate. The forward rate is in turn based on the theory of interest rate parity discussed in Chapter 5. According to option-pricing theory, the premium on an option (European style) must be greater than or equal to the difference between the strike rate and the forward rate:[13]

$$\text{Premium} \geq (\text{Strike rate} - \text{Forward rate}).$$

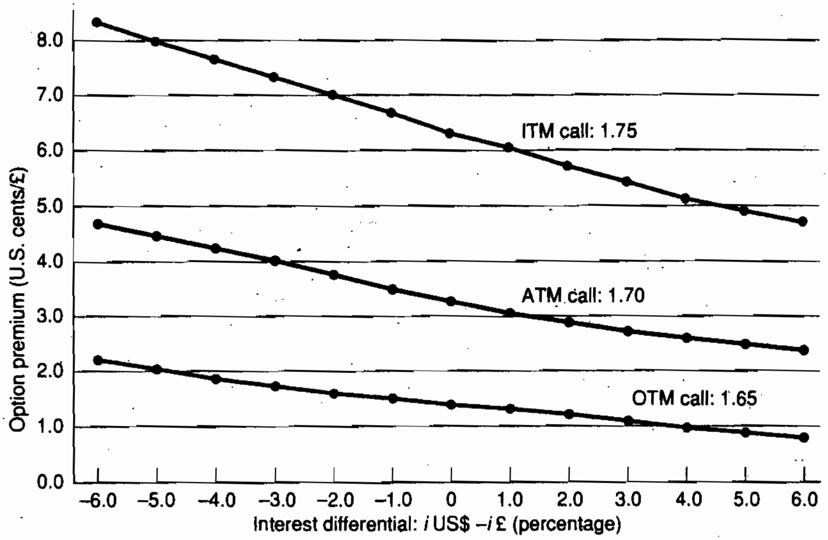
Interest rate changes in either currency will alter the forward rate, which in turn will alter the option's premium or value. The expected change in the option premium from a small change in the domestic interest rate (home currency) is termed *rho*. The expected change in the option premium from a small change in the foreign interest rate (foreign currency) is termed *phi*.

For example, throughout the early 1990s U.S. dollar (domestic currency) interest rates were substantially lower than other currency (foreign currency) interest rates. This meant foreign currencies consistently sold forward at a discount versus the U.S. dollar. If these interest differentials were to widen (either from U.S. interest rates falling or foreign currency interest rates rising, or some combination of both), the foreign currency would sell forward at a larger discount. An increase in the forward discount is the same as a decrease in the forward rate (in U.S. dollars per unit of foreign currency). The option premium condition just described states that the premium must increase as interest rate differentials increase (assuming spot rates remain unchanged).

Exhibit 6.9 demonstrates how European call option premiums change with interest differentials. Using the same option value assumptions as before, an increase in U.S.

[13]For American-style options, which may be exercised on any date up to and including the expiration date, the condition is slightly different: If the difference between the strike rate and forward rate is greater than the difference between the strike rate and spot rate, the premium will be the larger difference. The premium must, however, be at least the difference between the strike rate and spot rate.

Exhibit 6.9 Rho and Phi: Interest Differentials and Option Premiums



dollar interest rates relative to British pound interest rates results in a decline in call option premia.

For the option trader, an expectation on the differential between interest rates can obviously help in the evaluation of where the option value is headed. For example, when foreign interest rates are higher than domestic interest rates, the pound sells forward at a discount. This results in relatively higher call option premia (and lower put option premia).

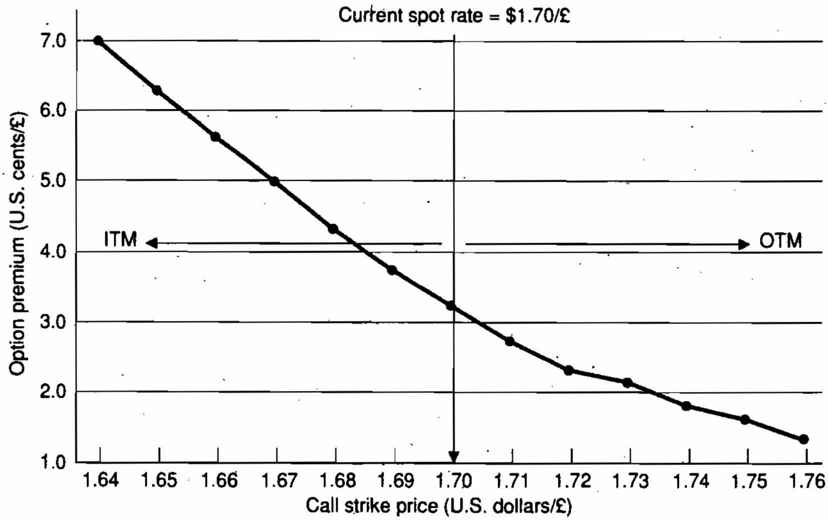
> **Rule of Thumb:** A trader who is purchasing a call option on foreign currency should do so before the foreign interest rate rises or the domestic interest rate falls. This allows the trader to purchase the option before its price rises.

6. Alternative Strike Prices and Option Premiums

The sixth and final element that is important in option valuation (but thankfully has no Greek alias) is the selection of the actual strike price. Although we have conducted all of our sensitivity analysis using the strike price of $1.70/£ (a forward at-the-money strike rate), a firm purchasing an option in the over-the-counter market may choose its own strike rate. The question is how to choose?

Exhibit 6.10 illustrates call option premiums required for a series of alternative strike rates above and below the forward at-the-money strike rate of $1.70/£ using

Exhibit 6.10 Option Premiums for Alternative Strike Rates



our benchmark example. The option premium for the call option used throughout, the \$1.70/£, is 3.3 cents/£. Call options written with strike prices less than \$1.70/£, when the present spot rate is \$1.70/£, are already profitable or in-the-money. For example, a call option with a strike rate of \$1.65/£ would have an intrinsic value of 5.0 cents/£ (\$1.70/£−\$1.65/£), which the option premium must cover. The call option premium for the \$1.65/£ strike rate is 6.3 cents/£, which is higher than the benchmark.

Similarly, call options on pounds at strike rates above \$1.70/£ are increasingly cheap because the underlying spot rate, which is presently \$1.70/£, will have to move further to make them profitable. At present they have no intrinsic value. For example, a call option on pounds with a strike rate of \$1.75/£ possesses a premium of only 1.5 cents/£ because the option is at present very much out-of-the-money. The option has no intrinsic value but time value only.

Exhibit 6.11 briefly summarizes the various "Greek" elements and impacts discussed in the previous sections. The option premium is one of the most complex concepts in financial theory, and the application of option pricing to exchange rates does not make it any simpler. Only with a considerable amount of time and effort can you expect to attain a "second sense" in the management of currency option positions.

Exhibit 6.11 Summary of Option Premium Components

Greek	*Definition*	*Interpretation*
Delta	Expected change in the option premium for a small change in the ***spot rate***	Higher the delta the more likely the option will move in-the-money
Theta	Expected change in the option premium for a small change in ***time to expiration***	Premiums are relatively insensitive until the final 30 or so days
Vega	Expected change in the option premium for a small change in ***volatility***	Premiums rise with increases in volatility
Rho	Expected change in the option premium for a small change in the ***domestic interest rate***	Increases in domestic interest rates cause falling call option premiums
Phi	Expected change in the option premium for a small change in the ***foreign interest rate***	Increases in foreign interest rates cause increasing call option premiums

Summary

- Foreign currency options are financial contracts that give the holder the right, but not the obligation, to buy (in the case of calls) or sell (in the case of puts) a specified amount of foreign exchange at a predetermined price on or before a specified maturity date.

- The use of a currency option as a speculative device for the buyer of an option arises from the fact that an option gains in value as the underlying currency rises (for calls) or falls (for puts). Yet the amount of loss when the underlying currency moves opposite to the desired direction is limited to the cost of the option.

- The use of a currency option as a speculative device for the writer (seller) of an option arises from receiving an option premium at the start. If the option, either a put or call, expires out-of-the-money (valueless), the writer of the option has earned the premium.

- Speculation is an attempt to profit by trading on expectations about prices in the future. In the foreign exchange market, one speculates by taking a position in a foreign currency and then closing that position after the exchange rate has moved; a profit results only if the rate moves in the direction that the speculator expected.

- Currency option valuation, the determination of the option's premium, is a complex calculation based on the current spot rate, the specific strike rate, the forward rate (which itself is dependent on the current spot rate and interest differentials), currency volatility, and time to maturity.

Questions

1. Currency Option Premiums and Alternative Strike Prices
Use Exhibit 6.1 to answer the following questions.

- **a.** If the current spot rate is 58.51 (cents/DM) and the first option strike price listed is a "56," is the Aug 56 put in- or out-of-the-money?
- **b.** As the strike price of the put option rises from 56 upward to 60, how does the Aug maturity put option premium change? Why?
- **c.** What is the break-even rate for the Sep maturity put option with a strike price of 59 1/2?

2. Willem Koopmans and Call Option Speculation (C06A.WK1)
Willem Koopmans is considering a different call option on German marks than what he bought previously (see Exhibit 6.2). He can also buy an August call option with a strike price of 59.0 cents per Deutschemark. The premium for this call option is 0.30 cents per Deutschemark.

- **a.** Diagram the profit and loss potential for this call option as seen by Willem Koopmans.
- **b.** What is the break-even price for Koopmans?
- **c.** What would Koopmans expect as the profit or loss on this call option if by August the spot exchange rate is $0.6000/DM?

3. Willem Koopmans and Put Option Speculation (C06B.WK1)
Willem Koopmans is considering a different put option on German marks than what he bought previously (see Exhibit 6.3). He can also buy a September put option with a strike price of 58.5 cents per Deutschemark. The premium for this option is much higher, 0.99 cents per Deutschemark.

- **a.** Diagram the profit and loss potential for this put option as seen by Willem Koopmans.
- **b.** What is the break-even price for Koopmans?
- **c.** What would Koopmans expect as the profit or loss on this put option if by December the spot exchange rate is $0.5700/DM?

4. Pricing Your Own Options: Calls on British pounds (OPTION.WK1)
The set of assumptions used throughout the second half of this chapter assumed a spot rate of $1.70/£, a 90-day period, U.S. dollar and British pound 90-day interest rates of 8.00% per annum, and a $/£ volatility for 90 days of 10.0%.

Using these assumptions and the OPTION.WK1 spreadsheet, answer the following questions after plugging in the values as shown to make sure your results (option prices and Greeks) are consistent with what is shown here. Note that the exchange rates of $1.70/£ are entered as "170.00 cents/£". Use only the European option prices and Greeks in all questions.

Simple Options Valuation Program

		AMERICAN MODEL	
PARAMETERS	*INPUT*	Price	3.289
		Delta	0.5030
Current Spot Rate	170.0000	Gamma	0.0481
Foreign Interest Rate (5% as .05)	8.000%	Theta	6.6954
Domestic Interest Rate (10% as .1)	8.000%		
Option (1, CALL, −1 PUT)	1	*EUROPEAN MODEL*	
Strike Rate	170.0000	Price	3.302
Days to Maturity	90	Delta	0.4999
Annual Volatility (10% as .1)	10.00%	Gamma	0.0463
		Theta	6.4294

Source: Professor James N. Bodurtha, Jr., The University of Michigan. Reprinted with permission.

a. If the spot rate suddenly changed, the pound falling to \$1.65/£, what would be the new 90-day call option premium?

b. If the British government responded to the falling pound by raising British interest rates to 8.50% per annum, what would the value of the call option be?

c. As a result of the falling pound and the policy decision to raise interest rates, the British prime minister is thought to be about to lose his support. The volatility rises to 12.0%. What is the new 90 day call option premium?

5. Pricing Your Own Options: Puts on Deutschemarks (OPTION.WK1)

You now consider a put option on Deutschemarks, with an initial volatility of 12.0%, Euro-\$ deposit interest rate of 4.2500%, Euro-DM deposit interest rate of 9.6500%, and maturity of 90 days. The strike price of the put is \$0.6000/DM.

a. Calculate the premium and record the option delta for the following spot rates:

Spot (\$/DM):	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.64
P_m (\$/DM):	____	____	____	____	____	____	____	____	____	____
Delta:	____	____	____	____	____	____	____	____	____	____

b. Using the data derived in part a, graph the premiums and spot rates, separating out time value from intrinsic value similar to that of Exhibit 6.4.

6. Option Volatilities and Premiums

Using the volatilities listed in Exhibit 6.8, answer the following questions:

a. Which of the currency crosses is the most volatile at any maturity?

b. Which of the currency crosses is the least volatile at any maturity?

c. Do the volatilities per currency cross generally increase or decrease as maturity lengthens?

7. Option Volatilities and Trader's Expectations

As discussed in the chapter, many option traders who believe option volatilities are about to fall will write (sell) options now, expecting to be able to close out their position (buy their option back) in a matter of days at a substantial profit.

a. Calculate the price of a 90-day call option on Swiss francs (put option on U.S. dollars) with a strike price of SF1.4823/$, if the spot rate is currently SF1.4796, the 90-day Euro-$ and Euro-SF interest rates are 3.1250% and 3.9375%, and the SF/$ 90-day volatility is 13.6%.

b. If this same call option was repriced the following day, and everything had remained the same except the volatility had fallen to 12.5%, what would be the new price?

c. If a currency trader sold SF5,000,000 in notional principal of these call options on the first day, and bought them back on the second day at the lower volatility (and one-day shorter maturity), what would be the net profit in U.S. dollars?

8. Speculating on the Movement of the Dutch Guilder

The current spot rate for Dutch guilders is: NGL 1.9200/$.
The three-month forward quote is: NGL 1.9000/$.

You believe that the spot Dutch guilder in three months will be NGL 1.8800/$, and you have $100,000 with which to speculate for three months. Any bank with which you conduct a forward market transaction will want 100% initial margin; that is, you will be required to deposit the amount of any transaction in a certificate of deposit.

Illustrate two different ways of speculating, and calculate the dollar profit to be made by each method. Assume the three-month rate of interest for deposits or lending in guilders is 4% per annum and in U.S. dollars is 8% per annum. For each way of speculating, explain the risks involved.

9. Allied-Lyons: Option Hedging Run Amok

Allied-Lyons (A-L), the British conglomerate that owns a number of American fast-food chains including Roy Rogers, Dunkin Donuts, and Hardees, had a relatively profitable treasury as a result of its aggressive management of currency exposures and its willingness to write options and predict market movements. In the first quarter of 1991, however, A-L reported a loss of £150 million (approximately $268 million) on foreign exchange transactions.

A-L's finance director, Clifford Hatch Jr., and his chief financial strategist, Michael Bartlett, had actively pursued a number of currency option speculation strategies. The strategy employed by Allied-Lyons in the early months of 1991 was not in any fashion simplistic. The strategies combined both *rate views*, expectations regarding the direction of a specific exchange rate, and *volatility views*, expectations regarding the size of the daily movements of the exchange rate. A combination of rate views and volatility views could work as follows:

- First, if A-L believed in January 1991 that the U.S. dollar had risen as far as likely against the British pound sterling, it could write call options.

- Second, if A-L believed option volatilities were as high as they were going to go, they should sell options now and buy them back (if necessary) after volatilities had dropped substantially (or not at all if it looked like their first assumption was correct).
  - **a.** What would be the premium earnings by A-L if they sold 30-day call options on 10 million U.S. dollars on Friday January 11, when the spot rate was \$1.9000/£, option volatilities were about 14.5%, and 30 day Euro-\$ and Euro-£ interest rates were 6.00% and 8.00%, respectively?
  - **b.** What would be the losses incurred by A-L on these options 21 days later (February 1) if the spot rate were now \$1.9755/£, and volatilities were 16.0% and climbing?

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Chapter 6 Appendix A

Currency Option Pricing Theory

The foreign currency option model presented here, the European-style option, is the result of the work of Black and Scholes (1972), Cox and Ross (1976), Cox, Ross, and Rubinstein (1979), Garman and Kohlhagen (1983), and Bodurtha and Courtadon (1987). Although we do not explain the theoretical derivation of the following option-pricing model, the original model derived by Black and Scholes is based on the formation of a riskless hedged portfolio composed of a long position in the security, asset, or currency, and a European call option. The solution to this model's expected return yields the option premium.

The basic theoretical model for the pricing of a European call option is:

$$C = e^{-r_f T} S N(d1) - E e^{-r_d T} N(d2)$$

where

C	premium on a European call
e	continuous time discounting
S	spot exchange rate ($/fc)
E	exercise or strike rate
T	time to expiration
N	cumulative normal distribution function
r_f	foreign interest rate
r_d	domestic interest rate
σ	standard deviation of asset price (volatility)
ln	natural logarithm

The two density functions, $d1$ and $d2$, are defined:

$$d1 = \frac{\ln\left(\frac{S}{E}\right) + \left(r_d - r_f + \frac{\sigma^2}{2}\right) T}{\sigma\sqrt{T}},$$

and

$$d2 = d1 - \sigma\sqrt{T}$$

This can be rearranged so the premium on a European call option is written in terms of forward rates:

$$C = e^{r_f T} F N(d1) - e^{r_d T} E N(d2),$$

where the spot rate and foreign interest rate have been replaced with the forward rate, F, and both the first and second terms are discounted over continuous time, e. If we now slightly simplify, we find the option premium is the present value of the difference between two cumulative normal density functions:

$$C = [FN(d1) - EN(d2)]\, e^{rdT}.$$

The two density functions are now defined:

$$d1 = \frac{\ln\left(\frac{F}{E}\right) + \left(\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}},$$

and

$$d2 = d1 - \sigma\sqrt{T}.$$

Solving each of these equations for d1 and d2 allows the determination of the European call option premium. The premium for a European put option, P, is similarly derived:

$$P = [F(N(d1) - 1) - E(N(d2) - 1)]\, e^{rdT}.$$

The European Call Option: Numerical Example

The actual calculation of the option premium is not as complex as it appears from the preceding set of equations. Assuming the following basic exchange rate and interest rate values, computation of the option premium is relatively straightforward:

Spot rate	= \$1.7000/£
90-day forward	= \$1.7000/£
Strike rate	= \$1.7000/£
U.S. dollar interest rate	= 8.00% (per annum)
Pound sterling interest rate	= 8.00% (per annum)
Time (days)	= 90
Standard deviation (volatility)	= 10.00 %
e (infinite discounting)	= 2.71828

The value of the two density functions are first derived:

$$d1 = \frac{\ln\left(\frac{F}{E}\right) + \left(\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = \frac{\ln\left(\frac{1.7000}{1.7000}\right) + \left(\frac{.1000^2}{2}\right)\frac{90}{365}}{.1000\sqrt{\frac{90}{365}}} = .025,$$

and

$$d2 = .025 - .1000\sqrt{\frac{90}{365}} = -.025.$$

The values of d1 and d2 are then found in the cumulative normal probability table (see Appendix 6B),

$$N(d1) = N(.025) = .51; \quad N(d2) = N(-.025) = .49.$$

The premium of the European call with a "forward at-the-money" strike rate is

$$C = [(1.7000)(.51) - (1.7000)(.49)]\, 2.71828^{-.08(90/.365)} = \$0.033/£.$$

This is the call option premium shown in Exhibit 6.4 and used throughout the second half of the chapter in the sensitivity analyses.

Chapter 6 Appendix B
Cumulative Normal Probability Tables

The probability that a drawing from a unit normal distribution will produce a value less than the constant d is

$$\text{Prob}(\tilde{z} < d) = \int_{-\infty}^{d} \frac{1}{\sqrt{2\pi}} e^{-z^2/2} dz = N(d).$$

Range of d: $-2.49 \leq d \leq 0.00$

d	−0.00	−0.01	−0.02	−0.03	−0.04	−0.05	−0.06	−0.07	−0.08	−0.09
−2.40	0.00820	0.00798	0.00776	0.00755	0.00734	0.00714	0.00695	0.00676	0.00657	0.00639
−2.30	0.01072	0.01044	0.01017	0.00990	0.00964	0.00939	0.00914	0.00889	0.00866	0.00842
−2.20	0.01390	0.01355	0.01321	0.01287	0.01255	0.01222	0.01191	0.01160	0.01130	0.01101
−2.10	0.01786	0.01743	0.01700	0.01659	0.01618	0.01578	0.01539	0.01500	0.01463	0.01426
−2.00	0.02275	0.02222	0.02169	0.02118	0.02068	0.02018	0.01970	0.01923	0.01876	0.01831
−1.90	0.02872	0.02807	0.02743	0.02680	0.02619	0.02559	0.02500	0.02442	0.02385	0.02330
−1.80	0.03593	0.03515	0.03438	0.03362	0.03288	0.03216	0.03144	0.03074	0.03005	0.02938
−1.70	0.04457	0.04363	0.04272	0.04182	0.04093	0.04006	0.03920	0.03836	0.03754	0.03673
−1.60	0.05480	0.05370	0.05262	0.05155	0.05050	0.04947	0.04846	0.04746	0.04648	0.04551
−1.50	0.06681	0.06552	0.06426	0.06301	0.06178	0.06057	0.05938	0.05821	0.05705	0.05592
−1.40	0.08076	0.07927	0.07780	0.07636	0.07493	0.07353	0.07215	0.07078	0.06944	0.06811
−1.30	0.09680	0.09510	0.09342	0.09176	0.09012	0.08851	0.08691	0.08534	0.08379	0.08226
−1.20	0.11507	0.11314	0.11123	0.10935	0.10749	0.10565	0.10383	0.10204	0.10027	0.09853
−1.10	0.13567	0.13350	0.13136	0.12924	0.12714	0.12507	0.12302	0.12100	0.11900	0.11702
−1.00	0.15866	0.15625	0.15386	0.15150	0.14917	0.14686	0.14457	0.14231	0.14007	0.13786
−0.90	0.18406	0.18141	0.17879	0.17619	0.17361	0.17106	0.16853	0.16602	0.16354	0.16109
−0.80	0.21186	0.20897	0.20611	0.20327	0.20045	0.19766	0.19489	0.19215	0.18943	0.18673
−0.70	0.24196	0.23885	0.23576	0.23270	0.22965	0.22663	0.22363	0.22065	0.21770	0.21476
−0.60	0.27425	0.27093	0.26763	0.26435	0.26109	0.25785	0.25463	0.25143	0.24825	0.24510
−0.50	0.30854	0.30503	0.30153	0.29806	0.29460	0.29116	0.28774	0.28434	0.28096	0.27760
−0.40	0.34458	0.34090	0.33724	0.33360	0.32997	0.32636	0.32276	0.31918	0.31561	0.31207
−0.30	0.38209	0.37828	0.37448	0.37070	0.36693	0.36317	0.35942	0.35569	0.35197	0.34827
−0.20	0.42074	0.41683	0.41294	0.40905	0.40517	0.40129	0.39743	0.39358	0.38974	0.38591
−0.10	0.46017	0.45620	0.45224	0.44828	0.44433	0.44038	0.43644	0.43251	0.42858	0.42465
0.00	0.50000	0.49601	0.49202	0.48803	0.48405	0.48006	0.47608	0.47210	0.46812	0.46414

Range of d: $0.00 \leq d \leq 2.49$

d	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.00	0.50000	0.50399	0.50798	0.51197	0.51595	0.51994	0.52392	0.52790	0.53188	0.53586
0.01	0.53983	0.54380	0.54776	0.55172	0.55567	0.55962	0.56356	0.56749	0.57142	0.57535
0.20	0.57926	0.58317	0.58706	0.59095	0.59483	0.59871	0.60257	0.60642	0.61026	0.61409
0.30	0.61791	0.62172	0.62552	0.62930	0.63307	0.63683	0.64058	0.64431	0.64803	0.65173
0.40	0.65542	0.65910	0.66276	0.66640	0.67003	0.67364	0.67724	0.68082	0.68439	0.68793
0.50	0.69146	0.69497	0.69847	0.70194	0.70540	0.70884	0.71226	0.71566	0.71904	0.72240
0.60	0.72575	0.72907	0.73237	0.73565	0.73891	0.74215	0.74537	0.74857	0.75175	0.75490
0.70	0.75804	0.76115	0.76424	0.76730	0.77035	0.77337	0.77637	0.77935	0.78230	0.78524
0.80	0.78814	0.79103	0.79389	0.79673	0.79955	0.80234	0.80511	0.80785	0.81057	0.81327
0.90	0.81594	0.81859	0.82121	0.82381	0.82639	0.82894	0.83147	0.83398	0.83646	0.83891
1.00	0.84134	0.84375	0.84614	0.84850	0.85083	0.85314	0.85543	0.85769	0.85993	0.86214
1.10	0.86433	0.86650	0.86864	0.87076	0.87286	0.87493	0.87698	0.87900	0.88100	0.88298
1.20	0.88493	0.88686	0.88877	0.89065	0.89251	0.89435	0.89617	0.89796	0.89973	0.90147
1.30	0.90320	0.90490	0.90658	0.90824	0.90988	0.91149	0.91309	0.91466	0.91621	0.91774
1.40	0.91924	0.92073	0.92220	0.92364	0.92507	0.92647	0.92785	0.92922	0.93056	0.93189
1.50	0.93319	0.93448	0.93574	0.93699	0.93822	0.93943	0.94062	0.94179	0.94295	0.94408
1.60	0.94520	0.94630	0.94738	0.94845	0.94950	0.95053	0.95154	0.95254	0.95352	0.95449
1.70	0.95543	0.95637	0.95728	0.95818	0.95907	0.95994	0.96080	0.96164	0.96246	0.96327
1.80	0.96407	0.96485	0.96562	0.96637	0.96712	0.96784	0.96856	0.96926	0.96995	0.97062
1.90	0.97128	0.97193	0.97257	0.97320	0.97381	0.97441	0.97500	0.97558	0.97615	0.97670
2.00	0.97725	0.97778	0.97831	0.97882	0.97932	0.97982	0.98030	0.98077	0.98124	0.98169
2.10	0.98214	0.98257	0.98300	0.98341	0.98382	0.98422	0.98461	0.98500	0.98537	0.98574
2.20	0.98610	0.98645	0.98679	0.98713	0.98745	0.98778	0.98809	0.98840	0.98870	0.98899
2.30	0.98928	0.98956	0.98983	0.99010	0.99036	0.99061	0.99086	0.99111	0.99134	0.99158
2.40	0.99180	0.99202	0.99224	0.99245	0.99266	0.99286	0.99305	0.99324	0.99343	0.99361

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