OPTIONS ON SHORT-TERM INTEREST RATE FUTURES*

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Options are contracts that give their owners the right, but not the obligation, to buy or sell a specified item at a set price on or before a specified date. An active over-the-counter market in stock options has existed in the United States for about a century. Options began to be traded on organized exchanges in 1973 when the Chicago Board Options Exchange (CBOE) was organized and began listing standardized stock options. Soon after the start of trading on the CBOE, the American, Pacific, and Philadephia stock exchanges also began listing standardized stock options. As interest in options trading among institutional investors and other financial market participants became evident the number of exchange-traded options grew rapidly. Today several different types of standardized options trade on virtually all major futures and stock exchanges, including stock options, other financial options such as foreign currency options, commodity options, and futures options.

Futures options are options on futures contracts. Currently traded money market futures options include options on three-month Treasury bill and three-month Eurodollar time deposit futures. The most active trading in both Treasury bill and Eurodollar time deposit futures options takes place at the International Monetary Market (IMM) division of the Chicago Mercantile Exchange (CME), although Eurodollar futures options also trade on the London International Financial Futures Exchange (LIFFE). Options on actual three-month Treasury bills are listed for trading by the American Stock Exchange (ASE), but this market is not active.

TERMINOLOGY AND DEFINITIONS

A ***call option*** gives the buyer the right, but not the obligation, to buy a specified item at a stipulated price called the exercise or ***strike*** price. The ***underlying*** instrument, or item specified by the option contract, can be a security such as a common stock or a Treasury bond, a specified amount of a commodity, or a futures contract. Call options are bought and sold for a market-determined price termed the ***premium*** or call price. In exchange for the premium, the seller (or ***writer)*** of a call option obligates himself to sell the underlying instrument at the strike price at the option of the buyer. When the buyer (or holder) of the option chooses to purchase the underlying instrument he is said to ***exercise*** the option.

A call option is said to be ***in-the-money*** when the market price of the underlying instrument is above the strike price and out-of-the-money when the market price of the underlying instrument falls below the strike price. When a call option is in-the-money the buyer has the right to purchase the underlying instrument at a price below the market price. The holder of an in-the-money ***American*** option can exercise it at any time before expiration date. In contrast, a ***European*** option can only be exercised on the expiration date.

Before the expiration date, out-of-the-money options will typically sell at a positive premium because of the possibility that the price of the underlying instrument will rise before expiration. At expiration the buyer will exercise the option if it is in-the-money or let it expire unexercised if it is out-of-the-money. An out-of-the-money call option has no value at expiration, since buyers will not purchase the underlying instrument at a price above the current market price. The value of an in-the-money call option at expiration is the current market price of the underlying instrument minus the strike price.

The buyer (holder) of a ***put option*** receives the right to sell a specified security at the strike or exercise price stipulated by the contract. In exchange for a cash premium ***(put*** price), the seller (writer) of a put option becomes contractually obliged to buy the underlying security at the strike price at the option of the holder. A put option is in-the-money when the market price of the underlying instrument is below the strike price and out-

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of-the-money when the market price is above the strike price.

Exchange-traded or ***standardized*** options, like futures contracts, are standardized contracts traded on organized exchanges. An option contract is completely specified by the description of the underlying instrument, strike price, and the expiration date. An exchange-traded option always specifies a uniform underlying instrument, one of a limited number of strike prices, and one of a limited number of expiration dates. Strike price intervals and expiration dates for traded contracts are determined by the exchange. Contract performance for exchange-traded options, as with futures contracts, is guaranteed by a clearing corporation that interposes itself as a third party to each option contract. The clearing corporation becomes the seller to each buyer and the buyer to each seller, thereby removing the risk that the seller of an option might fail to meet contract obligations.

Contract standardization together with the clearing corporation guarantee facilitates options trading. A holder or seller of an exchange-traded option can always liquidate an open position in an option before expiration by making an offsetting transaction. For example, a holder of a Treasury bill futures call option can offset his position by selling a T-bill futures call with the same strike price and expiration date; the net profit or loss from such a transaction is determined by the difference between the premium originally paid for the call and the price received when it is sold. Similarly, the holder of a put option can liquidate his position by selling a put with the same strike price and expiration date. As with futures contracts, most positions in standardized options are liquidated before the expiration date with an offsetting transaction rather than being held for the purpose of selling or buying the underlying instrument.

Unlike futures contracts, buyers of put and call options are not required to deposit funds in a margin account because their risk of loss is limited to the premium paid for the option. Sellers of put and call options are required to maintain margin accounts, however, since they face a considerable risk of loss, as will become evident when the payoffs to different option positions are examined below.

Finally, ***over-the-counter*** (OTC) options are custom-tailored agreements for which option specifications (the underlying instrument, amount, strike price, exercise rights, and expiration date) are all negotiated by the two parties to the contract. OTC options are usually sold directly rather than through an exchange. Major commercial and investment banks often write custom-tailored interest rate options for their commercial customers. A bank, for example, might write a cap, or series of interest rate put options, for a commercial customer to fix a maximum interest rate on a floating-rate loan tied to short-term interest rates.

OPTIONS ON SHORT-TERM INTEREST RATE FUTURES

Put and call options on Treasury bill and Eurodollar futures are actively traded at the IMM in trading areas, or ***trading pits*** as they are called, located next to the trading pits for the underlying futures contracts.[1] Exercising a futures option results in either a long or short futures position. When a holder exercises a futures call option he buys the underlying futures contract at the strike price, or takes on a ***long futures position.*** To completely liquidate his resulting futures position, the buyer must undertake an offsetting futures transaction. The writer of a call option must in turn sell, or take on a ***short futures position,*** in the underlying futures contract when it is exercised. When a futures put option is exercised the holder takes on a short futures position and the writer a long position.

The primary advantage of futures options over options for actual securities stems from the liquidity of futures contracts. Because futures markets tend to be more liquid than underlying cash markets, offsetting a position resulting from the exercise of an option is usually easier with futures options than with options on actual securities. This can be especially important to put and call writers, who usually enter into options agreements to earn fee income rather than with the ultimate goal of buying or selling the underlying instrument.

IMM money market futures options are American options. ASE Treasury bill options, in contrast, are European-type options for actual Treasury bills. LIFFE Eurodollar futures options are American options specifying LIFFE Eurodollar time deposit futures contracts as the underlying instrument.

At present trading activity in IMM Treasury bill futures options is relatively light but greatly surpasses trading in ASE bill options, which is almost nonexistent. IMM Eurodollar futures options are very actively traded while volume in LIFFE Eurodollar futures options, although significant, is considerably smaller. Contract specifications for IMM money market futures, options are described in the enclosed box on the following page.

PAYOFF DIAGRAMS

The difference between options and the underlying futures contracts becomes evident once the payoff

[1] Kuprianov [1986] contains a detailed description of IMM short-term interest rate futures contracts.

CONTRACT SPECIFICATIONS FOR OPTIONS ON IMM MONEY MARKET FUTURES

Options on Treasury Bill Futures

IMM Treasury bill futures options were first listed for trading in April of 1986. The underlying instrument for these options is the IMM three-month Treasury bill futures contract. Expiration dates for traded contracts fall approximately three to four weeks before the underlying futures contract matures.1 IMM futures options can be exercised any time up to the expiration date.

Strike Price Internals Strike price intervals are 25 basis points for IMM index prices above 91.00 and 50 basis points for index prices below 91.00. Strike prices are typically quoted in terms of basis points. Thus, the strike prices for traded Treasury bill futures options can be 90.50 or 92.25, but not 90.25 or 92.10.

Price Quotation Premium quotations for Treasury bill futures options are based on the IMM index price of the underlying futures contract. As with the underlying futures contract, the minimum price fluctuation is one basis point and each basis point is worth $25. Thus, a quote of 0.35 represents an options premium of $875 (35 basis points x $25). The minimum price fluctuation for put and call premiums is one basis point. There is no upper limit on daily price fluctuations.

[1] The precise rule used to determine IMM Treasury bill futures options expiration dates is as follows. The expiration date is the business day nearest the underlying futures contract month that satisfies the following two conditions. First, the expiration date must fall on the last business day of the week. Second, the last day of trading must precede the first day of the futures contract month by at least six business days.

Options on Eurodollar Futures

IMM options on Eurodollar futures began trading in March, 1985. Eurodollar options expire at the end of the last day of trading in the underlying Eurodollar futures contract. Since the Eurodollar futures contract is cash settled the final settlement for Eurodollar futures options follows the cash settlement procedure adopted for the underlying Eurodollar futures contracts.

To illustrate, suppose the strike price for a bought Eurodollar futures call option is 91.00 and the final settlement price for Eurodollar futures is 91.50. Exercising the call option at expiration gives the holder the right, in principle, to place $1,000,000 in a three-month Eurodollar deposit paying an add-on rate of nine percent. But since the contract is settled in cash, the holder receives $1250 (50 basis points x $25) in lieu of the right to place the Eurodollar deposit paying nine percent.

Strike Price Intervals for Eurodollar futures options are the same as Treasury bill strike price intervals.

Price Quotation Premium quotations for Eurodollar options are based on the IMM index price of the underlying Eurodollar futures contract. As with the underlying futures contract, the minimum price fluctuation is one basis point and each basis point is worth $25.

diagrams for each contract are compared. The payoff diagrams depicted in Figures 1 through 3 show how profits and losses from different futures and options positions held to expiration vary as underlying futures prices change.

Futures Contracts

Figure 1 displays payoff diagrams for unhedged long and short futures positions. The horizontal axis in these diagrams measures the price, **F,** of the futures contract while the vertical axis measures any profits or losses stemming from changes in futures prices. To simplify the analysis, transaction costs, such as brokerage fees, are ignored in drawing these diagrams. The buyer of a futures contract earns or loses one dollar for each dollar the price of the contract rises or falls. Thus, the payoff can be depicted by a 45 degree line showing a zero profit at the original purchase price, denoted by the point F_0 in Figure 1a. A trader with an unhedged short position is in the opposite position, profiting when futures prices fall and losing money when prices rise.

Futures Call Options

Figure 2a shows the payoff diagram for an unhedged, or ***naked,*** bought call option held to expiration. In return for the payment of the call premium, C, the

Figure 1

PAYOFFS FOR UNHEDGED FUTURES CONTRACTS

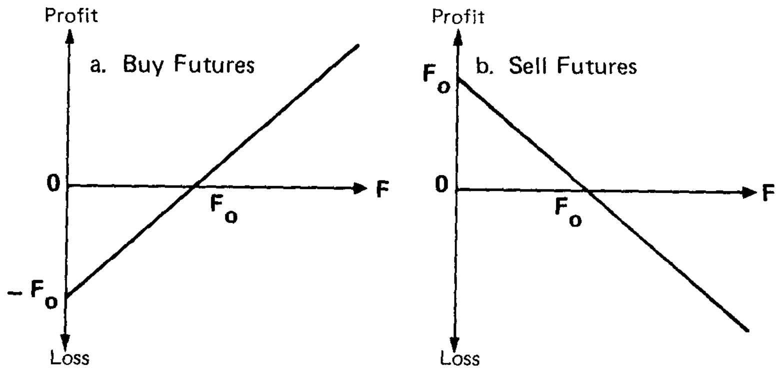


Figure 2

PAYOFFS FOR UNHEDGED CALL OPTIONS

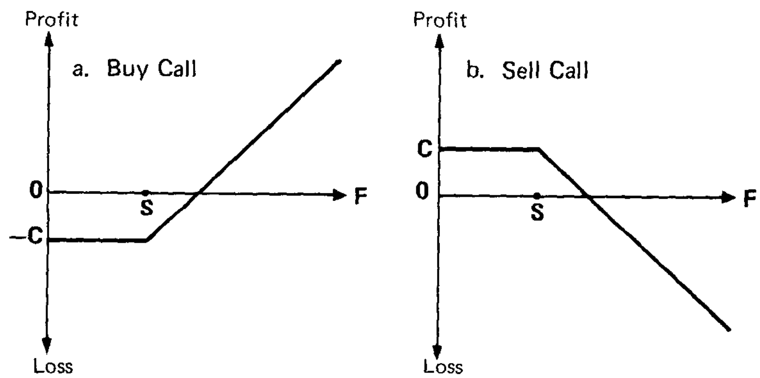
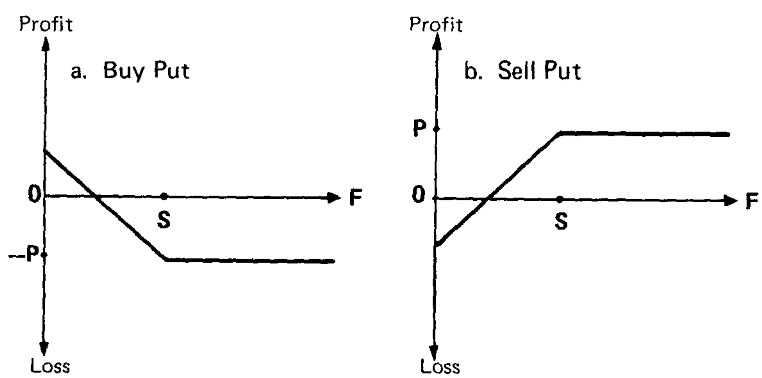


Figure 3

PAYOFFS FOR UNHEDGED PUT OPTIONS



buyer receives the right to buy the underlying futures contract at the strike price S. At expiration an out-of-the-money option has no value. A buyer holding an out-of-the-money call option will allow the option to expire unexercised, earning a total net profit of -C; that is, he loses the call premium paid at the time the option was purchased. When the price of the underlying futures contract is above the strike price the buyer can exercise the option, buy the underlying futures contract at the strike price, and liquidate his futures position at a profit. The buyer's net profit in this second case is the difference between the market price of the futures contract,, **F,** and the strike price, S, less the premium paid for the call, C.

To take an example, suppose that a buyer pays a premium of $800 for a December 1986 Treasury bill futures call option with a strike price of 94.50 (IMM index price).[2] This option is in-the-money when December Treasury bill futures prices rise above 94.50. If the price of a Treasury bill futures contract is 95.00, the buyer can exercise the option and immediately liquidate his futures position at a $1,250 (50 basis points x $25) profit. His net profit is $450 ($1,250-$800).

Figure 2b shows the payoff at expiration earned by the seller of a call option. His profit will be the full amount of the call premium C if the option is not exercised, that is, if the price of the underlying futures contract on the expiration date is below the strike price. If the price of the underlying futures contract is above the strike price, however, the option will be exercised and the writer will be required to sell the underlying futures contract at the strike price S. Liquidating the resulting futures position requires buying the contract back at the higher market price **F.** Thus, the writer's net profit if the option is exercised is the call premium C minus the difference **(F-S).** The net profit is negative if the premium C is less than the loss **(F-S)** incurred from selling the underlying futures contract at the strike price.

Futures Put Options

Figure 3a shows the payoff diagram for a bought put option held to expiration. The buyer pays a put premium **P** in exchange for the right to sell the underlying futures contract at the strike price S. He will allow the option to expire unexercised if the price of the underlying futures contract is above the strike price. In this case, he loses the put premium. When the underlying futures price is below the strike price the put holder can exercise the option, sell the underlying futures contract, and liquidate the resulting futures position at a profit. The put holder's net profit in this second case is the amount by which the strike price S exceeds the market price **F** of the underlying futures contract, minus the put premium.

As an example, suppose that a buyer pays a premium of $525 for a put option on December Treasury bill futures with a strike price of 95.00. If the price of the underlying futures contract is 94.90 the put holder can earn $250 (10 basis points x $25) by exercising the option, selling Treasury bill futures at 95.00, and then liquidating his position through an offsetting purchase at 94.90. His net profit (loss in this case) is $250-$525 = -$275.

Finally, Figure 3b shows the payoff at expiration earned by the seller of a put option. If the option is out-of-the-money (that is, if the market price of the underlying futures contract is above the strike price) at expiration, the seller earns a profit equal to the full put premium, **P.** Otherwise, the option will be exercised and the writer will be forced to buy the underlying futures contract at a price above the market price. Liquidating the resulting futures position results in a loss, which may more than offset the premium earned from writing the option.

As the payoff diagrams in Figures 2 and 3 make clear, buying a put does not offset a long call position. Instead, the holder of a call option can liquidate his position only by selling a call with the same expiration date and strike price. Similarly, the holder of a put can liquidate his position by selling a put with the same contract specification.

HEDGING WITH INTEREST RATE FUTURES OPTIONS

An option hedge combines an option with a cash position in the underlying instrument in such a way that either the underlying instrument protects the option against loss or the option protects the underlying instrument against loss. Buying a put option, for example, protects against a large loss resulting from a long position in the underlying instrument. Options on futures can be used to hedge cash market positions because futures prices tend to be highly correlated with prices of the deliverable securities. Some futures options, such as the IMM Eurodollar futures option, expire on the same day the underlying futures contract matures. Exercising a futures option on the maturity date of the underlying contract amounts to exercising an option on the actual cash instrument.

The Difference Between a Futures and an Options Hedge

The basic difference between hedging with options and hedging with futures is that options enable hedgers

[2] The *IMM* index mice for Treasury bill futures is 100 minus the futures discount yield to be paid on the deliverable bill. Each one basis point change in the index price corresponds to a $25 change in the price of the deliverable bill.

to limit losses from adverse price movements while leaving open the opportunity to profit from favorable price changes. A futures hedge, in contrast, just fixes the price at which a planned future transaction takes place-the hedger is protected from the risk of loss if the value of his cash market holdings falls, but loses the opportunity to profit if those holdings appreciate.

Thus, options can be thought of as providing a form of price insurance. Like any other form of insurance, however, buyers are required to pay a premium for protection against loss, which means that although they have the opportunity to profit if the value of their underlying cash position rises the returns to a position hedged with options will be smaller on average than the returns to an unhedged position.

Over-the-counter put and call options on short-term interest rates are sometimes called ***caps*** and floors, terms that derive from descriptions of the basic hedging strategies each type of option can be used to structure. Buying an interest rate put option caps or establishes a maximum borrowing rate on a floating-rate loan tied to short-term interest rates. Buying a call option sets a floor or minimum yield on a future investment.

Interest rate caps and floors can also be created using options on interest rate futures, as is illustrated by the following two examples.

Creating Interest Rate Floors

A futures call option establishes a maximum purchase price for the underlying instrument. Since the price of an interest-bearing security varies inversely with market interest rates, establishing a maximum purchase price on an interest-bearing security amounts to fixing a minimum yield on the anticipated investment. The following example illustrates the mechanics of an options hedge undertaken to fix an investment floor.

On August 15 a corporate treasurer learns that his firm will receive a cash inflow of $1 million in three months. Such funds are typically invested in three-month Treasury bills. The treasurer can fix a minimum yield on the anticipated investment either by buying a Treasury bill futures contract or by buying a Treasury bill futures call option. Call options on December Treasury bill futures expire on November 14, which turns out to coincide exactly with the date the hedger in this example anticipates receiving the cash inflow.

IMM Treasury bill futures can be bought at a price of 94.71 on August 15, implying a futures discount yield of 5.29 percent. Treasury bill futures call options with a strike price of 94.75 (implying a discount yield of 5.25 percent) sell for a premium of 21 basis points, or $525. The results of a futures and an options hedge are compared below under two different assumptions about market rates of return prevailing on the date of the planned investment.

Results of the Futures Hedge First, consider the rate of return fixed by a futures hedge. If the corporate treasurer could buy a Treasury bill futures contract maturing on November 14, when he plans to invest in T-bills, the hedge would be perfect and the rate of return fixed by the futures hedging strategy would be known with certainty. However, the nearest maturity date for a Treasury bill futures contract falls in December. Uncertainty about the exact relationship between futures and spot Treasury bill prices on the date of the anticipated cash inflow introduces the risk, known as basis ***risk,*** that the yield produced by the hedge may differ from the expected yield.[3] For the sake of simplicity this source of risk will be ignored in this example; specifically, it will be assumed that the futures discount yield always equals the actual yield on a thirteen-week Treasury bill on November 14. Under this assumption the futures hedge will always result in an effective discount yield of 5.29 percent on the planned investment. Although this convenient relationship could not be expected to hold in reality, the error this assumption introduces is unimportant for purposes of this simple example.

Calculating the Investment Floor Suppose that interest rates fall after August 15 and the discount yield on Treasury bill futures contracts declines from 5.29 percent to 5.00 percent on the November 14 expiration date. Since the resulting price of the underlying futures contract, 95.00, is above the strike price of 94.75, the option can be exercised and the resulting futures position liquidated at a profit of 25 basis points, or $625. This profit is partially offset by the 21 basis point call premium, reducing the net profit to 4 basis points. Again assuming no basis risk so that the discount yield on thirteen-week Treasury bills is 5.00 percent, the effective hedged discount yield in this case is 5.04 percent. This outcome produces a discount yield 4 basis points higher than the unhedged yield, but 25 basis points lower than the 5.29 percent yield that could have been fixed by the futures hedge.

Notice that in this example 5.04 percent is the minimum discount yield the hedger would face, no matter how low interest rates turn out to be on the expiration date. This is because-in the absence of basis risk-any additional decline in the Treasury bill discount yield below 5.00 percent would be exactly

[3] See Kuprianov [1986] for a more detailed discussion of futures hedging and basis risk.

offset by additional profit from the hedge. In actual practice basis risk would make the calculation of an absolute floor impossible, although an expected floor could be estimated.

Results of the* Options *Hedge When Interest Rates Rise Now consider the rate of return produced by the option hedging strategy if interest rates rise before the planned investment date. Suppose that on November 14 the price of an IMM Treasury bill futures contract falls to 94.45, implying a discount yield of 5.55 percent. In this case the price of the underlying futures contract is below the strike price of 94.75, so the option will be permitted to expire unexercised. Assuming once more that the spot price equals the futures price, the discount yield for a thirteen-week Treasury bill bought in the spot market is 5.55 percent. For the hedger, the net effective yield is 5.34 percent (5.55 percent minus the 21 basis point call premium), which is 5 basis points higher than the yield that would have been earned using a futures hedge.

This second case illustrates the potential advantage an options hedging strategy has over a futures hedge. While the interest rate floor established by the options hedge is lower than the rate fixed by the futures hedge, the options hedge permits the hedger to earn a higher yield if interest rates rise by enough to offset the cost of the call premium.

Interest Rate Caps

Buying a put option on an interest rate futures contract sets a minimum price the cash security can be sold for at a future date. Fixing a minimum price on an interest-bearing security is equivalent to fixing a maximum interest rate, however, so that an interest rate futures put option can be used to fix a maximum borrowing rate, or cap. If interest rates fall before the loan is taken out, the hedger loses part or all of the put premium, but can borrow at the lower market rate.

To take a specific example, suppose that on October 15 a large corporation makes plans to take out a three-month, $1 million loan in two months. The firm's bank typically charges 100 basis points over the three-month LIBOR for such loans. The firm can protect itself against the risk of a rise in interest rates before the loan is taken out either by selling Eurodollar futures or by buying a Eurodollar futures put option.

For purposes of this example assume that options on Eurodollar futures expire on December 15, the exact date the planned loan is to be taken out. As of October 15, December Eurodollar time deposit futures trade at a price of 93.99 on the IMM, implying a futures LIBOR of 6.01 percent. A put option on December Eurodollar futures with a strike price of 93.75 sells for a premium of 6 basis points. The results of a futures hedge and a hedge structured using the put option are compared below.

Result of a Futures Hedge IMM Eurodollar futures mature on the same day options on those contracts expire. Thus, the firm in this example can put together a perfect futures hedge. Such a hedge would lock-in a borrowing rate of 7.01 percent (6.01 percent fixed by the sale of the futures contract plus the 100 basis point markup charged by the lending bank).

Calculating the Interest Rate Cap Now consider the result of the option hedge when interest rates rise before the loan is taken out. Suppose that the three-month LIBOR is 6.30 on the expiration date, so that the final settlement price for Eurodollar futures is 93.70. The underlying futures contract price is 5 basis points below the 93.75 strike price, so the option can be exercised and the underlying position settled in cash to earn a $125 profit. Since IMM Eurodollar futures options expire on the same day the underlying futures contract matures and that contract is cash settled, this profit is paid directly to the hedger. The profit from exercising the option is more than offset by the 6 basis point put premium, however. The net loss from the hedge is thus 1 basis point. The resulting effective borrowing rate is 7.31 percent (6.30 market LIBOR, plus the 1 basis point net hedging cost, plus the 100 basis point markup), 30 basis points higher than the effective borrowing rate that could have been fixed with a futures hedge and 1 basis point higher than the unhedged borrowing rate.

The interest rate cap of 7.31 percent is attained whenever the underlying contract settlement price hits the strike price. Notice that no matter how high interest rates were to rise, effective borrowing costs would never go above this level because any further increase in market rates would be exactly offset by the additional profits gained from exercising the put option.

Result of the Options Hedge When Interest Rates Full Finally, consider the effective borrowing cost resulting from the option hedge if the three-month LIBOR were to fall to 6.00 percent on the expiration date. If LIBOR is 6.00 percent the settlement price for December Eurodollar futures will be 94.00, which means that a put option with a strike price of 93.75 is out-of-the-money. The interest rate paid on the loan in this case is 7.00 percent, but the net effective cost is 7.06 percent because of the loss of the put premium.

Notice that in both of the cases considered above the

SELECTED EURODOLLAR FUTURES CALL OPTION PREMIUMS

Expiration Month	Strike Price	Premium	Futures Price	Intrinsic Value	Time Value
December	93.50	0.53	94.02	0.52	0.01
March	93.50	0.62	94.02	0.52	0.10
June	93.50	0.60	93.85	0.35	0.25

borrowing rate produced by the options hedge was higher than either the unhedged borrowing rate or the rate that could have been fixed with a futures hedge. This points to an important characteristic of options hedges. The premium paid on an option protects the hedger from heavy losses due to large price fluctuations while permitting gains in the form of lower borrowing costs or higher investment rates in cases where favorable price movements occur. When only small price movements occur, however, any benefit from holding the option may be more than offset by the cost of the option premium. Thus, unless large price movements are realized, an options hedge can easily prove to be more costly than a futures hedge.

Although options on interest rate futures have only been actively traded for a short time, a large number of interest rate option hedging strategies have been developed. At present, the heaviest commercial users of money market futures options are commercial and investment banks that write caps and floors for their customers and then hedge their resulting net over-the-counter positions with standardized interest rate futures options. [4]

PRICE RELATIONSHIPS BETWEEN FUTURES OPTIONS AND FUTURES CONTRACTS

As noted earlier, an out-of-the-money option will typically have value before the expiration date because of the possibility that the option could go in-the-money before it expires. The difference between the strike price and the market price of the underlying instrument is called ***the intrinsic value*** of the option. An option's intrinsic value, is the gain that could be realized if it were exercised. Any excess of the option premium above its intrinsic value is called the ***time value*** of the contract. The time value of an option is greater the longer the time to expiration because an option with a longer life has a greater chance of going deeper in-the-money before it expires. As the expiration date draws nearer time value declines; once the expiration date arrives, the time value of an option is zero and the only value the option has is its intrinsic value.

To illustrate, the table above presents call prices, underlying futures prices, and time values for IMM Eurodollar futures options with different expiration dates as of the end of trading on November 6, 1986. The first row in the table gives data for options on December Eurodollar futures. As of the end of trading on November 6, a Eurodollar call option on a December 1986 futures contract with a strike price of 93.50 sold for a premium of 53 basis points. The price of the underlying futures contract at the end of the same trading session was 94.02, so this option was in-the-money. The intrinsic value of the December option was 52 basis points; thus, the difference between the call premium and its intrinsic value is one basis point, or $25. As noted above, the time value of the options for successively distant expiration dates grows larger.

A comprehensive discussion of factors determining options prices is beyond the scope of this article. However, two concluding observations are in order. First, the deeper an option is in-the-money, the greater the proportion of the option premium is due to intrinsic value and therefore the more closely price movements in the underlying futures contracts are reflected by changes in the option premium. Thus, in-the-money options provide hedgers with greater risk reduction than out-of-the-money options. Second, all other things equal, the time value of an option is greater the more volatile are underlying futures prices. This is because more volatile underlying futures prices make it more likely an option will go deeper in-the-money before it expires.

Readers interested in a formal theoretical development of the pricing formula for options on futures contracts are referred to Black [1976]. Less technically oriented readers will find Koppenhaver's [1986] introductory exposition useful. Emanuel [1985] shows how to apply the Black formula to the pricing of Eurodollar futures options.

[4] For a more detailed description of the development of interest rate options markets see Bank for International Settlements [1986, chapter 3].

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