Exchange-Traded Options on Common Stock

No financial instrument has aroused the enthusiasm of speculators, hedgers, and arbitrageurs—and the concern of regulatory authorities—as quickly and completely as exchange-traded stock options following their introduction in 1973 by the Chicago Board Options Exchange (CBOE). Market participants and informed observers have argued variously that options offer opportunities for speculative profits and for hedging or reducing risk, that options provide strong incentives for the manipulation of stock prices and the defrauding of investors, and that options may ultimately be the cause of a collapse comparable in magnitude to the great crash of 1929.

The explosive popularity of stock options is evident from the growth in trading volume from under 6 million call option contracts in 1974 to almost 39 million contracts in the first nine months of 1978.[1] When the CBOE first opened for business, it sponsored trading in call options on sixteen common stock issues. By the fall of 1978, four additional exchanges were sponsoring trading in options, including the American Stock Exchange, the Philadelphia Stock Exchange, the Midwest Stock Exchange, and the Pacific Stock Exchange.[2] The five options exchanges presently sponsor trading in call options on about 220 stock issues and put options on twenty-five of those issues.

The concern of regulatory authorities with this remarkable growth became evident during the summer of 1977, when the Securities and Exchange Commission (SEC) declared an informal moratorium on additions to the list of stocks on which exchange-traded option contracts may be written.[3] In the fall of 1977, the SEC formalized that moratorium and began an extensive study of the options market.[4] Among the major questions being examined in that study are the adequacy of self-regulation by the options exchanges, the financial integrity of the options markets, practices in selling options to individual investors, and the relation between trading in stocks and options on those stocks.[5]

Contractual aspects of stock options

A stock option is a contract, granting to the holder specified rights which can be exercised against the writer of the contract. There are two basic types of option contracts: puts and calls. Under the most common form of call option, the holder can purchase from the writer of the option some number of shares of a specified stock (called the *underlying stock*) at a des-

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[1] Exchange-traded options are traded as contracts for the purchase or sale of one round lot of stock, which is typically 100 shares

[2] An Amsterdam exchange also sponsors trading in options on common stock issued by American corporations.

[3] Securities Exchange Act Release No. 13760 (July 18, 1977). The regulatory power of the SEC over the market for options derives from Section 9(b) of the Securities Exchange Act of 1934.

[4] Securities Exchange Act Release No. 14056 (October 17, 1977).

[5] In June 1978 the SEC requested public comment on a wide variety of issues related specifically to the structure of markets in stock and options. See Securities Exchange Act Release No 14854 (June 15, 1978). Some of these market structure issues are discussed in the box on page 28.

ignated *strike price* on or before an *expiration date.* Thus, an investor may hold a call option for the purchase of 100 shares of International Business Machines (IBM) stock at a strike price of $260 per share which can be exercised on or before April 21, 1979.[6]

Should the holder of a call option choose to exercise his contract rights, he tenders to the option writer funds sufficient to complete the purchase. If an option holder does not exercise his right to purchase on or before the expiration date, all obligations of the writer terminate and the option *expires.*

A put option is a right to sell stock. Under the most common form of put option, a holder can sell a specified number of shares of some underlying stock to the writer of the put contract, on or before an expiration date, at a designated strike price. If an option holder decides to exercise his put option, he tenders to the option writer the shares he is entitled to sell. The right to sell the stock terminates after the expiration date.

Why an option has value

An option will have value if a holder can profit by exercising immediately his contract rights, or if he thinks he might be able to profit by exercising his rights at some future date on or before the expiration of the option.[7] If IBM stock is trading at, say, $293.50 a share, then an option to purchase IBM at a price of $240 per share is clearly a valuable right. An option to purchase IBM at $300 per share is also valuable if there is a possibility that the price of IBM stock will go over $300 before the expiration date of the option.

Tables 1 and 2 show an array of values on twelve different IBM put and call options as reflected in the closing prices on the CBOE on Friday, September 1, 1978. Table 1 shows that the price of a call option decreases as the strike price of the option increases. An option to purchase IBM at a price of $260 per share, for example, is more valuable than a call option with the same expiration date and a strike price of $280. Table 1 also shows that the price of an option increases with the futurity of the option. An option to purchase IBM stock on or before April 21, 1979 confers on the holder more rights than an option which expires on January 20, 1979. It follows that call options with more distant expiration dates will have higher prices, everything else being the same. Table 2 shows that the value of a put option increases with the strike price (since puts are rights to sell, a higher strike price implies a more valuable option) and increases with the futurity of the expiration date of the option.

Exchange markets for stock options

Until 1973, stock options were bought and sold in the over-the-counter (OTC) market. In practice, a secondary market sale of an unexpired OTC option was rare. Most of the business consisted of buying options and holding them to expiration, at which time they were either exercised or allowed to expire. The strike price on an OTC option was generally set at the contemporaneous price of the underlying stock, and the expiration date was most often set at one, two, three, or six months in the future. At any point in time there typically existed a wide variety of options on a given stock, with little uniformity of either strike prices or expiration dates among different options.

The innovation in 1973 by the CBOE of an organized market for options revolutionized trading in those securities. Perhaps the single most important CBOE innovation was the standardization of option strike prices and expiration dates.

Looking again at Table 1, note that there were only twelve call option contracts in IBM available for trading on the CBOE on September 1, 1978. There are only four potential expiration dates for IBM options each year: the Saturday following the third Friday in January, April, July, and October.[8] Only the three nearest dates are open for trading at any one time.

Strike prices on exchange-traded options are initially selected to bracket the price of the underlying stock. Strike prices are set in intervals of $5 for stocks priced below $50, in intervals of $10 for stocks priced between $50 and $200, and in intervals of $20 for stocks priced over $200. Trading in a new strike price will be opened if the price of the underlying stock moves at least halfway through the interval bounded by the new strike price. For example, if there are options with

[6] The concepts discussed in this article are illustrated with options on IBM common stock. IBM stock is widely owned and familiar to many investors, and both the stock and the options are actively traded. On December 19, 1978, IBM announced a four-for-one stock split, to take effect on or after May 10, 1979. Following the effective date of the split, each previously outstanding exchange-traded option contract for 100 shares of IBM stock will become four contracts for 100 shares each, with strike prices equal to one quarter of the original strike prices. For example, the holder of one call option contract for 100 shares at $260 per share will become the holder of four call option contracts for 100 shares each at $65 per share. The stock split will have no impact on the economic position of either writers or holders of IBM options. The stock split will also not affect any of the illustrative examples given below, since all of those examples involve options which expire on or before April 21, 1979.

[7] It is noted in an appendix to this article that, under one theory of option pricing, the price of an option is equal to the discounted present value of the price the option is expected to have on its expiration date.

[8] This is called the January-April-July-October expiration cycle. Other options may have the same expiration cycle, or may have a February-May-August-November cycle or a March-June-September-December cycle

Market Structure

At the present time, trading in an option occurs on an exchange different from the primary exchange for transactions in the underlying stock. In mid-1977, however, proposals submitted to the Securities and Exchange Commission (SEC) by the New York Stock Exchange (NYSE) and the Chicago Board Options Exchange (CBOE) raised several novel questions about the structure of trading in stock and options. The NYSE proposal was a request to trade options, most of which would be on stocks already traded on that exchange. (The NYSE proposed, however, to separate physically trading in options from trading in underlying stocks.) In reaction to the NYSE proposal, the CBOE proposed to begin trading stocks for the first time. More importantly, the CBOE proposal would not segregate stock and options trading and would permit "dual market making" where floor members could make markets in both securities simultaneously.

On the basis of the NYSE and CBOE proposals, the SEC requested public comment on alternatives to the current geographic separation of stock and option trading.* One such alternative is the dual market making system advanced by the CBOE. A less radical alternative is "contiguous market making", in which options and underlying stocks would be traded at the same location but floor members would be prohibited from making a market in both securities simultaneously. These alternative market structures could have important consequences for efficient securities pricing.

Pricing efficiencies of an integrated market

At the present time, information on the price and size of stock transactions first becomes known to option market participants through publicly available price interrogation systems. Were the floor markets in stock and options physically integrated, transaction price information from one market would reach the other market much more rapidly. In consequence, market makers would be able to adjust their purchase and sale quotations to reflect that information on a more timely basis.

Integrated stock and options markets would also permit the simultaneous observation of order flow in both markets. At the present time, an options market participant does not learn of orders for the purchase and sale of an underlying stock until after they have been executed and reported. A stock market participant may know of pending orders in the stock, but not of orders in options on that stock. Thus, neither the quotations of a stock specialist nor those of an options market maker or options specialist fully reflect the aggregate order flow.

Off-floor arbitrageurs now devote time and resources to searching for discrepancies between option prices and stock prices, implying that the current fragmentation of the markets is not insignificant. If the markets were physically integrated, the increased and accelerated availability of information would lead to transactions by floor members to eliminate price discrepancies even before they became known to off-floor participants. The consolidated market would then appear to be in relative equilibrium continuously because an off-floor participant would never see an unusual profit opportunity.

Front running

A major deterrent to the physical integration of stock and options markets is the fear that an integrated market could facilitate practices like *front running*. Front running is the purchase or sale of options on the basis of knowledge of impending transactions in the underlying stock. In an integrated market, an options trader could have substantially greater access to information on order flow in underlying stocks. If he learned that a stockbroker was executing a large stock purchase order through a series of small trades, he would have an incentive to buy call options on that stock in anticipation of a subsequent price increase. His purchases might push up the prices of the call options, leading on-floor arbitrageurs to sell the options and to buy the stock. Any resulting stock price increase would deprive the original stock buyer of his right to "best execution" of his purchase order.

The issues

The fundamental issues in the integration of stock and option trading are (1) deciding who should be able to use information which has not yet become widely available and hence has not yet been reflected in securities prices and (2) deciding how notions like best execution are to be balanced against the desire for efficient securities pricing. If the markets are integrated, the advantage in trading will go to floor participants. Their efforts to profit from information not yet available off an exchange floor will result in prices which more rapidly reflect that information. Opportunities for stock/option arbitrage may then exist only for floor participants. If the markets remain segregated, off-floor participants will be at a smaller disadvantage, but prices in one market will not adjust as rapidly to the arrival of new information in the other market.

* Securities Exchange Act Release No. 14854 (June 15, 1978).

strike prices of $80 and $90, the underlying stock must trade at or above $95 a share before trading is opened in options with a $100 strike price.

The standardization of contract terms and the limitation of the number of different contracts available for trading is a deliberate policy decision of the options exchanges. Standardization of the terms of put and call options means that trading is concentrated in a small number of contracts rather than spread out over tens or hundreds of different contracts, as was the case prior to 1973. This has resulted in more liquid markets and has facilitated trading in options.

Purchase and sale of exchange-traded options

Most investors are familiar with the mechanics of trading stock on an exchange like the New York Stock Exchange (NYSE). Brokers representing the buyer and seller meet on the Exchange's floor and agree to a mutually acceptable transaction price.[9] The seller delivers his stock to his broker, who redelivers the stock to the buyer's broker, who in turn sends it to the ultimate buyer. Payment for the stock follows the reverse path. Transactions in exchange-traded options *do not* occur the same way.

Suppose one investor wants to sell a single IBM April 280 call option contract, *i.e.,* a call option on 100 shares of IBM stock with a strike price of $280 per share and an expiration date of April 21, 1979, and a second investor wants to buy the same option. As in the case of stock trading, brokers representing the two investors will meet on the floor of the CBOE and agree to a mutually acceptable transaction price. The transaction will not, however, be completed by the delivery of a call option contract written by the seller to the buyer.

Transactions in exchange-traded stock options result in the establishment of a series of contractual relationships. Following the agreement of the two brokers in the example to a transaction price on the IBM April 280 calls, the broker representing the *seller* will give a call option contract to an organization known as The Options Clearing Corporation (OCC), agreeing to deliver 100 shares of IBM stock upon payment of $280 per share before the April expiration date. The OCC in turn gives an identical call option contract to the broker representing the *buyer* of the option. The buyer has a right to demand 100 shares of IBM stock from his broker upon payment of the strike price, and the seller's broker has a similar right to demand stock from the seller. Funds from the ultimate buyer reach the ultimate seller through the OCC and the transactors' brokers.

The significance of these contractual relations is that the option contract does not run directly from the seller's broker to the buyer's broker, but rather runs *through* the OCC. The OCC is a contractual intermediary in all exchange-traded stock options.[10]

The importance of the OCC stems from the homogeneity of risk which it imparts to exchange-traded options. In the OTC options market that existed before 1973, an investor had to be careful not to buy an option from a financially unreliable writer. A holder certainly wanted to have confidence that the writer would deliver stock if his call was exercised, or would deliver cash if his put was exercised.[11] A buyer of exchange-traded options does not need to know or pass judgment upon the creditworthiness of either a seller or a seller's broker, since he never enters into a contract with either one. His contract is with the OCC, and the integrity of that contract rests solely on the creditworthiness of the OCC.

The Options Clearing Corporation

The OCC is a corporation owned by the five exchanges that sponsor trading in options. Legally, it is an *issuer* of option contracts to brokerage firms. It does not, however, act like an ordinary corporation selling securities. The OCC issues an option only when a buyer and seller have agreed, through brokers on an exchange floor, to a transaction in that option. The OCC then issues an option contract to the buyer's broker and acquires an option contract from the seller's broker. In this way, the OCC maintains a balanced book in option contracts: it writes exactly the same type and number of contracts that it holds. The number of contracts in a particular option which the OCC has written is called the *open interest* in that option.

The holder of an OCC option can sell his option by locating, through his broker, an agreeable buyer on an exchange floor. Technically, however, the sale of an option contract by an existing holder is actually a repurchase by the OCC of one of its outstanding contracts and, unless the buyer had previously written an

[9] The mechanics of trading stock on an exchange is discussed more completely in William Melton, "Corporate Equities and the National Market System", this *Review*, box on pages 14-15.

[10] The OCC deals only with brokers who are members of one of the five options exchanges and who have sufficient financial resources. Such brokers are called "clearing members" of the OCC. Any participant in the options market who is not a clearing member of the OCC must have purchases and sales booked through a clearing member. This includes other brokers and traders active on the floors of the options exchanges.

[11] Writers of OTC options usually had their option contracts endorsed or guaranteed by a member of the NYSE to improve the creditworthiness of those contracts. The endorser charged a fee for this service.

identical contract to the OCC, the reissuance of that contract to the new buyer. Had the buyer previously written an identical contract to the OCC, his purchase would close out that earlier position. That is, his purchase would eliminate his contractual obligation to the OCC. The difference between the two sales is that in the first case the open interest in the option is unchanged while in the second case the open interest is reduced by one contract.

Exercising OCC options

When a holder decides to exercise a call option he informs his broker, which in turn informs the OCC that it is exercising an option which it holds on that corporation. To complete the exercise, the OCC randomly selects a broker on whom it holds an identical option. That broker will then select one of its customers who have written call options to deliver stock according to his or her contract. The broker can select the customer randomly, or by any other reasonable method. The stock obtained from the exercise of a call option moves from the ultimate writer to the ultimate holder through their respective brokers. Put options are exercised in a similar way.

A broker who has written an option to the OCC is contractually obligated to make good on his option regardless of whether or not his customers can deliver stock (on calls) or cash (on puts). To ensure that brokers can meet their obligations, the OCC requires brokers representing option writers to maintain deposits of cash, United States Government securities, or bank letters of credit or, in the case of writers of call options, deposits of the underlying stock. In practice, the bulk of the deposits held by the OCC is in the form of letters of credit, which amounted to over $780 million on June 30, 1978. The OCC, of course, remains liable for the options that it has written to brokerage firms representing option holders.

If the price per share of some stock is greater than the strike price of a call option on that stock, the option clearly has positive value. When such an option approaches expiration, a holder will usually either sell or exercise the option, since its value will fall to zero following the expiration date. Experience with exchange-traded options has shown that most (but not all) holders of such valuable option contracts never exercise those contracts. Instead, they close out their positions by selling to other investors who are short to the OCC. If the strike price of a call option exceeds the price of the underlying stock, a holder may allow his option simply to expire.

How much is a call option worth?

Call options have positive value because they impose obligations only on the writer and not on the holder. As Table 1 shows, however, the value of an option depends on its strike price and expiration date. The characteristics of this dependence illuminate the nature of a call option.[12]

The intrinsic value of a call option

Consider, in Table 1, the October 280 call option in IBM. Since IBM was trading at $293.50 a share at the close of the markets on September 1, 1978, an investor holding that option could profitably exercise his right to buy IBM stock at a price of $280 a share. His net revenue would be the difference between the market price of the stock and the strike price of his call option, or $13.50 per share. This price difference is called the *intrinsic value* of the option.

The intrinsic value of a call option measures the value of the option to an investor who would buy and exercise the option immediately. If the stock price is greater than the option strike price, an option exercise, followed by a sale of the stock, produces a profit. Hence, the option has a positive intrinsic value, and is said to be *in-the-money.* If the stock price is less than the strike price, an exercise would not generate any revenues (it would, in fact, cause a loss), so the option has zero intrinsic value and is *out-of-the-money.* The IBM October 300 call option shown in Table 1 was out-of-the-money and had zero intrinsic value on September 1, 1978.

The price of an unexpired option must always be greater than, or equal to, its intrinsic value. If the option price is less than intrinsic value, arbitrageurs[13] will buy and exercise the option and simultaneously sell the underlying stock at a price greater than the cost of the option and its strike price. They will use the shares obtained from the exercise to deliver against the stock sale. Such riskless arbitrage will keep the option price from falling below the intrinsic value of the option. Table 3 shows the intrinsic values of the twelve call option contracts exhibited in Table 1. All of the option prices exceed the corresponding intrinsic values.

[12] Because trading in call options is far more important at present than trading in put options, this section on option valuation, and the two following sections on hedging and speculating, discuss only the former.

[13] Arbitrage is the purchase of undervalued securities, and the sale of overvalued securities. In an intrinsic value arbitrage, the purchase of the option and simultaneous sale of the stock will yield a profit at no risk and hence is called riskless arbitrage. Other arbitrage activities may involve risk, but are nevertheless undertaken if their anticipated profits far outweigh their risks.

Table 1

Closing Prices of IBM Call Options on September 1, 1978*

In dollars; per share optioned

Strike price	Expiration date: October 21 1978	January 20 1979	April 21 1979
240	56.00	58.75	62.00
260	38.00	41.00	45.75
280	20.63	26.75	32.38
300	8.63	15.13	20.00

* International Business Machines stock closed at $293.50 a share on the New York Stock Exchange on September 1, 1978.

Table 2

Closing Prices of IBM Put Options on September 1, 1978*

In dollars; per share optioned

Strike price	Expiration date: October 21 1978	January 20 1979	April 21 1979
240	.07	1.19	2.88
260	.56	3.75	6.50
280	3.63	9.00	11.63
300	11.63	17.00	20.25

* International Business Machines stock closed at $293.50 a share on the New York Stock Exchange on September 1, 1978.

Table 3

Intrinsic Values of IBM Call Options on September 1, 1978*

In dollars; per share optioned

Strike price	Expiration date: October 21 1978	January 20 1979	April 21 1979
240	53.50	53.50	53.50
260	33.50	33.50	33.50
280	13.50	13.50	13.50
300	0	0	0

* Computed as the greater of (a) zero and (b) the difference between the closing stock price of $293.50 and the strike price of the option.

Table 4

Time Values of IBM Call Options on September 1, 1978*

In dollars; per share optioned

Strike price	Expiration date: October 21 1978	January 20 1979	April 21 1979
240	2.50	5.25	8.50
260	4.50	7.50	12.25
280	7.13	13.25	18.88
300	8.63	15.13	20.00

* Computed as the difference between the closing option price in Table 1 and the intrinsic value of the option in Table 3.

Table 5

Estimated Hedge Ratios for IBM Call Options on September 1, 1978*

Change in dollar price of an option on one share per $1.00 change in the stock price

Strike price	Expiration date: October 21 1978	January 20 1979	April 21 1979
240	1.00	.98	.96
260	.97	.91	.88
280	.81	.77	.77
300	.46	.56	.61

* See appendix for method of estimation.

Table 6

Estimated Elasticities of IBM Call Options on September 1, 1978*

Percentage change in dollar price of an option per 1 percent change in the stock price.

Strike price	Expiration date: October 21 1978	January 20 1979	April 21 1979
240	5.21	4.66	4.21
260	7.76	6.16	5.24
280	12.37	8.14	6.48
300	19.24	10.54	7.91

* See appendix for method of estimation.

The time value of a call option

Market participants will value an option at a premium over the revenue they can get from an immediate exercise if they believe they may be able to make even more money by exercising the option at some future date. When the price of an option exceeds its intrinsic value, the option is said to have a positive *time value.*

That options should have a positive time value is most easily seen by considering out-of-the-money options with zero intrinsic value. Such options are clearly not worthless because there is always the chance that the stock price will move above the option strike price before the expiration date. In Table 1, an IBM October 300 call option was worth $8.63 on September 1, 1978, even though the underlying stock was then trading at less than $300 a share. Investors knew it was not impossible that the stock price could exceed $300 some time during the fifty days before the October 21 expiration date.

Table 4 shows the time values of the twelve IBM call option contracts. Observe that the time values of options with a common strike price increase as the futurity of the expiration date increases. This shows that "time" really is a valuable aspect of an option.

The total value of a call option

Chart 1 shows the relation between call option prices and stock prices (both expressed as a percentage of the option strike price) for IBM options with three different expiration dates. On its expiration date, an option will have a price which lies on one of the two intrinsic value line segments. Prior to that date, the value of an option will vary with the price of the underlying stock approximately as shown in the chart. The option/stock price curve will shift closer to the intrinsic value line segments as the expiration date approaches. This downward shifting shows why market participants sometimes refer to an option as a *wasting asset.* As the time remaining to expiration declines, so does the value of an option when the price of the underlying stock remains unchanged.

The option/stock price curves shown in Chart 1 were computed from a theoretical model of option pricing derived by Fischer Black and Myron Scholes. (Their model is described in the appendix.) That model has come into general use among participants in the options markets and is available through several electronic information systems.

How option/stock price relationships are maintained

Chart 1 also locates the values of the twelve IBM call option contracts shown in Table 1. Although the option/stock price curves exhibited in Chart 1 are based on a theoretical model, the proximity of the actual IBM option prices to their predicted values suggests the model is reasonably accurate. This is the result of arbitrage activity by market participants.

Suppose, for example, that the price of IBM common stock increases in trading on the NYSE but that IBM option prices remain unchanged on the CBOE. The option/stock price curves imply that the options have become "undervalued", *i.e.,* priced below their theoretical values derived from the now higher price of the underlying stock. This may lead some market participants to buy the options and, if they want to hedge their risk, sell the stock. (Exactly how they hedge their risk is explained in the next section.) Their transactions drive up the price of the options relative to the stock price. Such arbitrage activity will continue until the predicted option/stock price relationships are reestablished.[14]

Information on the price at which an underlying stock is trading is a critically important piece of information to the market in options on that stock. Under normal circumstances, stock price information reaches the options exchanges via ticker tapes and price interrogation systems. Although these systems usually report the price of a stock trade within a minute or two after it has occurred, market participants have a substantial incentive to get even faster information. In the summer of 1976, the NYSE found some of its members were relaying information on IBM stock price changes to colleagues at the CBOE over open telephone lines. Their colleagues then bought or sold IBM options in arbitrage activities like that described above. This practice, known as *tape racing,* ended when the NYSE upgraded the speed of reporting transactions in IBM. The incident is noteworthy because it illustrates the value to the options markets of information on stock transactions and the lengths to which market participants will go to obtain and use such valuable information.[15]

It should not be assumed that causality runs only in the direction of stock price changes affecting option

[14] Since clearing charges and other transactions costs are incurred in trading both stock and options, an option/stock price discrepancy must be large enough to permit an arbitrageur to make a profit net of those costs. Thus, there is a region around the "equilibrium" option value within which the actual option price can fluctuate freely without inducing arbitrage activity.

[15] A related, but different, type of activity, called *front running,* involves the purchase or sale of options on the basis of *future* stock transactions. For example, if a market participant learns of the impending sale of a large block of stock, he may anticipate a price decline and hasten to sell options on that stock. Tape racing involves the use of information on transactions which occurred in the *past,* but which have not yet been reported to the options markets. See also the box on page 28.

prices The converse, whereby changes in option prices are reflected in subsequent stock price changes, can also occur Indeed, since call options give an investor substantial leverage of his capital, it may sometimes make more sense to buy options instead of stock, especially if the buyer has access to favorable information about a stock issuer which has not yet been fully reflected in securities prices [16] Any resulting increase in option prices relative to stock prices would lead arbitrageurs to sell options and, as a hedge, buy the underlying stock Their efforts to restore equilibrium between the stock and options markets will push up the stock price, an increase which would appear as a sympathetic response of stock prices to the original increase in option prices

The option/stock price curves of Chart 1 illustrate a price *level* equilibrium between the stock and options markets That chart does not, however, give any hint as to whether price *changes* will first appear in the stock market or in the options market

Spreading

Arbitrage keeps stock prices and option prices approximately at their relative equilibrium values A similar activity, called *spreading*, maintains the relative values of different option contracts Suppose, for example, an influx of retail purchase orders on the floor of the CBOE was to drive up the price of IBM January 280 call options Market professionals would quickly observe that those options had become overpriced relative to other IBM option contracts They would then sell January 280 calls at what they perceive as a premium price and, to hedge their exposure to risk, buy other IBM call options

Spreading, or the simultaneous purchase and sale of different option contracts, is an arbitrage of relative values between two options rather than between an option and the underlying stock It is usually undertaken by floor traders on an options exchange, because their access to trading in options is quicker than the access of off-floor arbitrageurs

Spreading is important to options markets, because it increases the liquidity of contracts which trade infrequently In the absence of spreading, a relatively small public purchase or sale order in a thinly traded option could cause a large price change in that contract Because of the opportunity to spread, however, market professionals are willing to take the other side of a public trade, thereby dampening price fluctuations, since they know they can hedge their risk in more actively traded contracts Even though they may have to hold a position in the infrequently traded option for some time, their spread hedging removes much of their exposure to market risk

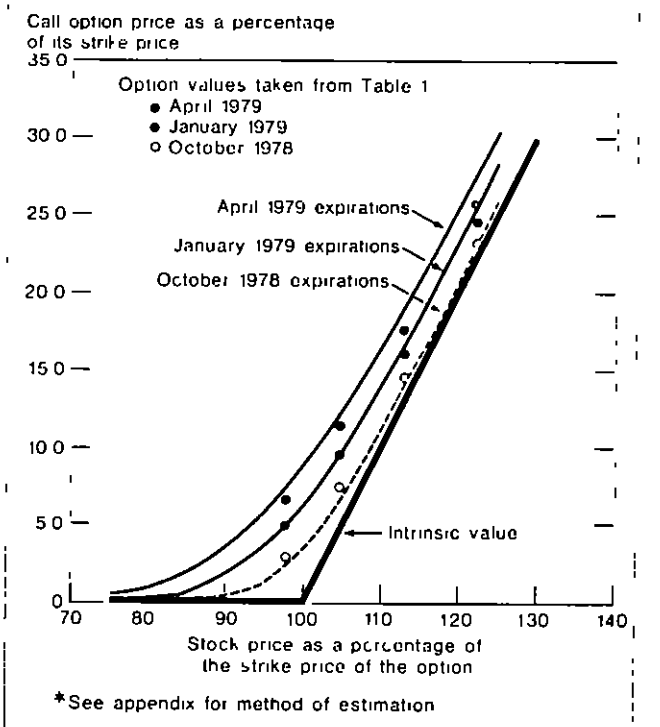
Hedging risk by writing call options

When an investor owns common stock, he is exposed to the risk of unanticipated changes in the value of his stock One way to avoid that risk is, of course, to sell the stock Another, and increasingly popular, way to reduce or to eliminate risk on equity investments is to write call options

Chart 1 shows that call option prices move in the same direction as stock prices If the price of a stock declines, an investor who earlier wrote call options on his stock can recover part of the losses on that stock by buying back the same options at their new, lower,

Chart 1

Estimated Values of IBM Call Options as a Function of the Stock Price on September 1, 1978*

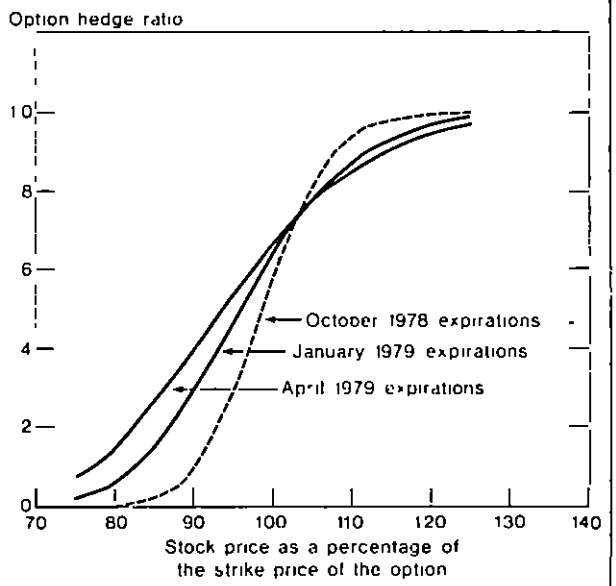


*See appendix for method of estimation

[16] Such undisseminated information typically involves future earnings prospects of the issuer, but also includes information about the value of the issuer's securities which is not directly related to future earnings Examples of such information called *market facts* include tender offers and block transactions See Arthur Fleischer Robert Manchem and John Murphy An Initial Inquiry into the Responsibility to Disclose Market Information *University of Pennsylvania Law Review* 121 (1973), pages 798-850 and Marvin Lipton Market information *Institute on Securities Regulation* 5th (1973) pages 287-301

Chart 2

Estimated Hedge Ratios of IBM Call Options as a Function of the Stock Price on September 1, 1978 *



* See appendix for method of estimation

price This method of hedging risk depends on the relation between changes in option prices and changes in stock prices, a relation known as the *hedge ratio*

The hedge ratio

The hedge ratio of an option is defined as the dollar change in option value which accompanies a one-dollar change in the price of the underlying stock [17] This ratio must lie somewhere in the interval between zero and unity It will be zero if the option is far out-of-the-money, so that changes in the stock price hardly affect the value of the option The hedge ratio will be unity if the option is deep-in-the-money, for the option is then tantamount to a commitment to buy the underlying stock In that case, the stock and the option change in value dollar for dollar In general, the hedge ratio will depend on the strike price and time to expiration of the option and on the price of the underlying stock Table 5 shows estimated hedge ratios for twelve different call options on IBM common stock at the close of the markets on September 1, 1978 Note that deep-in-the-money contracts, like the April 240s, have hedge ratios near unity regardless of their expiration dates, while out-of-the-money contracts which are close to expiration (the October 300 contract) have lower hedge ratios

Hedge ratios and small price changes

To illustrate how writing call options can reduce the risk on a stock position, consider writing January 280 calls against a position in IBM stock As shown in Table 5, on September 1, 1978 a $1 00 increase (or decrease) in the price of IBM stock would have been accompanied by approximately a $0 77 increase (or decrease) in the price of the January 280 call option Suppose an investor owned 10,000 shares of IBM stock and wrote calls on 13 000 shares of the stock If his stock decreased in value by $1 00 per share, the options would decrease in value by $0 77 per share optioned The investor could then repurchase the options which he previously wrote, at a cost $10 000 less than the revenues he received when he wrote them ($10,000 = 13,000 shares optioned × $0 77 per share optioned) This gain just balances the decline in the value of his stock Conversely, had the price of IBM stock increased by $1 00 a share, the investor would have gained $10,000 on his stock position and lost $10,000 on his option position For this reason, the short position in options is a hedge against the risk of small changes in the price of the underlying stock The decision to write calls on 13 000 shares, rather than on 14,000 shares or 12,000 shares, is based on this balancing or hedging, *i e*, 13,000 = 10 000/0 77

Among the most active writers of call options for hedging purposes are securities firms which provide block positioning services to their customers When an investor wants to sell more stock than his broker can readily find buyers for, the broker may offer to purchase the remaining unsold stock for his own inventory, or to "position" the excess shares As long as the stock remains in his inventory, the broker has capital at risk Until 1973, this risk could be eliminated only by selling the positioned stock Because the markets in exchange-traded options have become so active, however, it is now sometimes more efficient for a broker to hedge his risk by writing call options rather than by selling the underlying stock

It should not be assumed that simply because an investor has hedged a long stock position by writing call options he therefore bears no risk The value of his portfolio may be insulated against small stock price changes, but it is not immune to losses which can result from sudden, large stock price changes Moreover, the investor must monitor continually the

[17] The hedge ratio of an option is also called the option delta a reflection of its definition as the *change* in option value associated with a small change in the stock price

Effect of Changes in the Hedge Ratio on a "Hedged" Position

An investor can lose money on a supposedly "hedged" position because the hedge ratio of an option changes with the price of the underlying stock. The variation in the hedge ratio which follows a stock price change is illustrated in Chart 2. Note that the hedge ratio becomes larger when the stock price rises, and grows smaller when the stock price falls. One consequence of this behavior is that a long position in stock and a short position in call options may be hedged but it is not riskless.

As was demonstrated in the text on page 34, on September 1, 1978, an investor who was long 10,000 shares of IBM stock and short January 280 call options on 13,000 shares was hedged against the risk of small changes in the price of the stock. If the stock price began to fall, however, the hedge ratio on the options would also decrease. Were the hedge ratio to fall from 0.77 (its value on September 1) to, say, 0.72, the investor hedging 10,000 shares of stock would need to increase his short option position to call options on 13,900 shares of IBM (13,900 = 10,000/0.72). If he fails to sell options on an additional 900 shares, then for every additional $1.00 decrease in the stock price he will lose $640 (−$640 = 0.72 x 13,000 − 10,000). Were the stock price to continue to fall, his risk exposure to further price declines would become progressively larger.

A similar argument applies in the case of increases in the stock price. If the stock price increased, the hedge ratio on the January 280 options would also increase. Were the hedge ratio to increase from 0.77 to, say, 0.80, the investor hedging 10,000 shares of stock would need to maintain a short position in January 280 calls on only 12,500 shares of IBM (12,500 = 10,000/0.80). Unless the investor buys back calls on 500 shares of stock, for every additional $1.00 increase in the stock price he will lose $400 (−$400 = − 0.80 x 13,000 + 10,000). This happens because his short position in calls on 13,000 shares now hedge 10,400 shares of IBM, yet the investor owns only 10,000 shares.

Hedge ratios and large price changes

The loss on a hedged position which can result when stock prices change by a large amount in a short interval of time provides an extreme example of the consequences of failing to maintain the correct number of short calls against long stock. Suppose again that an investor hedged on September 1, 1978 a position in 10,000 shares of IBM stock by writing January 280 call options on 13,000 shares. His portfolio would then be insulated from small positive or negative changes in the price of IBM stock. Suppose, however, another corporation announced on Tuesday, September 5, a cash tender offer for any and all shares of IBM common stock at a price of $400 per share, *i.e.*, at a premium of 36 percent over the market price of $293.50.[1] The value of a January 280 call would rise *immediately* to about $120 a share. This implies a gain of $106.50 per share on the stock ($106.50 = $400.00 new stock price − $293.50 old stock price) and a loss of $93.25 per share optioned ($93.25 = $120.00 new option price − $26.75 old option price). The investor would incur a loss of $147,250 ($147,250 = 13,000 shares optioned x $93.25 per share optioned, minus 10,000 shares owned x $106.50 per share owned). These losses are unavoidable because the investor will be unable to repurchase his calls while the price of IBM stock is rising; the stock price will move to about $400 a share in a single, large jump as soon as the tender offer is announced.

Naked options and covered options

Because the hedge ratio of a call option cannot exceed unity, an investor hedging a long stock position by selling calls can protect himself against unlimited losses due to stock price increases by writing calls on only as many shares of the underlying stock as he actually owns. This is called "covered" writing.

Covered option writing limits an investor's losses.[2] In the "worst case", where a stock price increase pushes the option hedge ratio almost to unity, any further losses on the short option position will be balanced by gains on the stock held long. Looked at another way, a covered option writer has just enough stock to deliver in the event his options are exercised, so he will never have to draw on any cash reserves to unwind his stock and option positions.

For an investor to hedge fully a long stock position against small stock price changes, he must write options on more stock than he owns. In the example of an investor hedging 10,000 shares of IBM by selling January 280 calls, the investor had to write options on 13,000 shares. Call options on 3,000 shares are not covered and are called *naked* options. It is the sale of these naked options which gives rise to the investor's risk exposure on *large* price increases, even though they must be written to complete the hedge against *small* price changes.

[1] While an "any and all" tender offer for IBM is unlikely in view of the amount of cash which would be required, tender offer premiums of 40 percent over the market price of the target stock are hardly unusual any more, and as there is trading in options on many companies much smaller than IBM, the example is not without merit.

[2] The maximum loss the investor can experience is the original value of his stock at the time he wrote the calls, less the proceeds from writing the calls. This loss will occur if the stock price falls to zero. Because his options are fully covered, he has *no* risk exposure to stock price increases, although his gains are limited to the strike price of the options plus the proceeds from writing the calls.

price of the stock, because hedge ratios change with stock prices. The number of options written against the stock may have to be increased or decreased from time to time to maintain the hedge. The box on page 35 discusses the implications of large stock price changes for hedged positions and the consequences of changes in the hedge ratio.

Speculating with call options

When an investor believes there is an unusually strong likelihood of a security appreciating rapidly in price, he may be willing to expose his capital to substantial risk by making a leveraged investment in that security. Options provide a remarkably efficient vehicle for leveraged speculation, because their values are extraordinarily sensitive to underlying stock prices. Where a stock price might increase by 5 or 10 percent on favorable news, an option can appreciate by 30 or 60 percent on the same news.

The elasticity of option prices

The elasticity of an option is defined as the *percentage* change in the value of the option which accompanies a 1 percent change in the value of the underlying stock.[18] Thus, elasticity is a measure of the relative price sensitivity of an option contract.

The elasticity of an option depends on the strike price and time to expiration of the option and on the price of the underlying stock. Table 6 shows the estimated elasticities of twelve call options on IBM stock at the close of the markets on September 1, 1978. Taking, as an example, the October 240 option, if IBM had closed on that day at a price 1.00 percent higher (at \$296.44 = 1.01 × 293.50), then an October 240 call option would have closed approximately 5.21 percent higher (at \$58.92 = 1.0521 × 56.00).

As shown in Table 6, for a given strike price, option contracts close to expiration are more elastic than contracts with relatively distant expiration dates. For contracts with a common expiration date, an out-of-the-money option will be more elastic than an in-the-money option.

The foregoing comments illustrate why out-of-the-money options close to expiration are considered volatile securities: they are extremely sensitive to movements in the underlying stock price. This sensitivity is well illustrated by the behavior of IBM options during the April 1978 market rally. Table 7 gives the prices of IBM stock and the April 240 call option on that stock at the close of the markets each day for the two weeks preceding the April 22 expiration date of the options. On April 12, the April 240 options were out-of-the-money because IBM stock was then trading at \$236.75 a share. Over the next nine days, however, the stock market enjoyed a substantial rally. The price of IBM stock rose to \$253.25 a share by April 21, and the April 240 calls expired in-the-money. Between April 12 and April 21, the April 240 calls appreciated from \$1.06 to \$15.25 per share optioned, an increase of 1,339 percent. Over the same interval, the price of IBM common stock showed a gain of 7 percent. The April 240 options clearly provided enormous leverage for an investor prescient enough to have predicted the mid-April rally. Of course, had the market fallen during April, those same options would have expired out-of-the-money and a holder would have lost his investment.

Writing naked options

Investors can speculate against declines in securities prices by writing call options without owning the underlying stock, or by writing *naked* options (see box on page 35). If an investor is primarily concerned with small price fluctuations, such naked writing will put him in a position comparable to that of a short seller. For example, an investor who wrote on September 1, 1978, January 280 call options on 13,000 shares of IBM would have had a position similar to that of an investor who sold short 10,000 shares of IBM stock on the same day. A \$1.00 decrease in the price of the stock would increase the wealth of both the short seller and the option writer by about \$10,000. (This is obviously true for the short seller. It is true for the option writer because the hedge ratio of the January 280 calls was 0.77 on September 1, 1978, as shown in Table 5.)

Should the price of an underlying stock rise instead of fall, the losses incurred by a writer of naked options will accumulate more rapidly than those of a short seller. This follows because the hedge ratio of an option increases with the price of the underlying stock. (The variation of the hedge ratio of an option with respect to stock price changes is described in the box on page 35.) January 280 calls on 13,000 shares of IBM were equivalent to 10,000 shares of stock on September 1, 1978, when IBM was trading at \$293.50 a share. However, if the stock price subsequently rose, the hedge ratio would begin to increase. If it reached, say 0.80, then every additonal \$1.00 increase in the price of the stock would cost the naked option writer \$10,400 (\$10,400 = 0.80 × 13,000 shares optioned.) A short seller of 10,000 shares would still be

[18] If a call option changes in value from C_0 to C_1 while the price of the underlying stock changes from S_0 to S_1, then the elasticity of the option is $e = ([C_1 - C_0]/C_0)/([S_1 - S_0]/S_0)$. $[C_1 - C_0]/C_0$ measures the relative change in price of the option contract and $[S_1 - S_0]/S_0$ measures the relative change in the stock price. Note that the hedge ratio is $h = [C_1 - C_0]/[S_1 - S_0]$, so the elasticity may also be defined as $e = h\ S_0/C_0$.

losing $10,000 for every $1 00 increase in the stock

An extreme example of this type of risk from writing naked options occurs when an out-of-the-money option is close to expiration Hedge ratios on such options are small If, however, the stock price rises and the option goes in-the-money, the hedge ratio of the option will change very rapidly to almost unity and the price of the option will increase to more than its now positive intrinsic value A writer of naked options would then face the risk of catastrophic losses from further increases in the stock price (because the hedge ratio is almost unity), and he can avoid that risk only by buying back his options at a substantial loss

The April 1978 experience in IBM options illustrates this point As shown in Table 7, on April 12, 1978, the April 240 calls on IBM had a hedge ratio of 0 34 and a price of $1 06 per share optioned By Wednesday, April 19, the April 240 calls had gone in-the-money as a result of increases in the price of IBM stock The price of the calls rose to $13 25 per share optioned and the hedge ratio had jumped to unity Speculators who wrote naked calls on April 12 suffered substantial paper losses by April 19 They then faced the choice of taking those losses immediately by buying back their much appreciated options or remaining exposed to the risk of additional stock price increases

Another difference between short selling and writing naked options is that, while a short seller eventually has to cover his borrowing of the stock sold short, a short position in options which expire out-of-the-money never has to be covered To a writer of options who looks toward the expiration date, if there is only a small probability of an option having positive intrinsic value on its expiration date, then there is a large probability that he will be able to keep the proceeds of his option sales Of course, as the April 1978 experience showed, there is always some finite probability that a rally will lead, unexpectedly, to options going in-the-money The losses borne by those who wrote naked options can then become catastrophic

Table 7

Closing IBM Stock and Option Prices in April 1978

Date	Stock price (dollars)	April 240 options Price (dollars)	Hedge ratio
April 10	241 25	2 94	60
April 11	239 88	2 06	53
April 12	236 75	1 06	34
April 13	238 00	1 44	41
April 14	243 50	1 75	75
April 17	250 13	1 75	99
April 18	251 63	1 88	1 00
April 19	253 00	13 25	1 00
April 20	253 25	13 25	1 00
April 21*	253 25	13 25	1 00

* Trading in options on the CBOE terminates at 3 00 p m Eastern time on the day prior to their expiration (April 22 in the above table) The underlying stock trades on the NYSE until 4 00 p m Thus the $2 00 time value of the option on April 21 may be a reflection of closing stock and option prices recorded at different times

Does the existence of an options market affect the markets for underlying stock issues?

One of the principal concerns expressed by the SEC when it imposed its moratorium on new options was whether options affect the market for underlying stocks This issue is important because corporations raise equity capital by selling stock, not by selling options If options somehow reduce the willingness of investors, in the aggregate, to hold stock, regulatory authorities might conclude that restrictions on option trading may be in the public interest

It appears that options could affect the prices of underlying stocks in three ways (1) by affecting the *level* of stock prices, (2) by affecting the *volatility* of stock prices, and (3) by inducing *fraudulent manipulation* of stock prices

Effects on the level of stock prices

As pointed out in the previous section, call options provide a convenient vehicle for optimistic investors who want to make highly leveraged investments in a particular stock Because they believe the stock is undervalued optimistic investors necessarily also believe that call options on that stock are undervalued [19] In buying options for their leverage, optimistic investors may bid option prices to a premium *relative* to the price of the stock As the options rise to a premium, arbitrageurs will enter the markets to sell what they perceive as relatively overvalued options and to buy the underlying stock to hedge their option sales They will continue to sell options and to buy stock as long as they continue to perceive the options as relatively overvalued Eventually, the buying activities of arbitrageurs will push up stock prices Thus, the purchase of call options by a group of optimistic speculators

[19] That is even though option prices may be in equilibrium with respect to the existing price of the underlying stock optimistic investors believe that the stock prices as well as likely to appreciate substantially in the future They will expect options to appreciate in value even more substantially because of the leverage of those securities

may find expression in rising stock prices through the perfectly normal activities of arbitrageurs.

The foregoing scenario suggests that call options, and especially highly elastic call options with substantial leverage, may facilitate the formation of speculative bubbles in stock prices. Such bubbles could collapse when the optimistic holders of options liquidate their positions, depressing the relative values of the options. Arbitrageurs would then reverse their former activities by buying back the options which they had previously sold and by selling the stock which they had previously bought. These stock sales may have a depressing effect on stock prices.

Effects on stock price volatility

The existence of an options market may increase the short-term volatility of stock prices, especially when a particular option series is close to expiration.

When a call option is close to expiration, it will have negligible time value and its price will be only slightly greater than its intrinsic value, where the latter is defined as the excess, if any, of the stock price over the strike price of the option. If the price of an in-the-money option which is close to expiration moves significantly above its intrinsic value, arbitrageurs will sell the option and buy stock in anticipation of an imminent exercise of the option. If the price of an option falls significantly below its intrinsic value, arbitrageurs will buy the option and sell the stock. The stock needed to deliver against the sale is obtained by exercising the option.

While arbitrage plays the important role of keeping stock prices and option prices at their "correct" relative values, it also leads to purchase and sale orders for stock, which would not have appeared in the absence of an options market. An in-the-money option close to expiration is a virtually perfect substitute for the underlying stock.[20] The existence of geographically separated trading in stock and options thus gives rise to a type of market fragmentation not much different from the more familiar fragmentation associated with multiple markets trading identical securities.

When trading in options and underlying stocks is fragmented, arbitrageurs will send purchase and sale orders to one or both markets as they seek to take advantage of transient price discrepancies. Indeed, the very existence of arbitrage orders is evidence that the markets were not previously well integrated. While this induced order flow is beneficial to both the options market and the stock market because it keeps prices on close substitutes in line with each other, it may also have the effect of inducing transient fluctuations in stock prices which would not have been present had the options and stock markets been better integrated. In particular, market makers may not realize that the sudden appearance of selling interest in a stock is the result of an option trading below its intrinsic value and may lower their bid and offer quotations for the stock too rapidly, only to induce countervailing purchase orders from arbitrageurs. Such surges in order flow between market centers could be anticipated whenever securities trade actively in multiple, fragmented, markets, but they may be especially important in the present context in view of the now substantial size of the options markets.

Observers have generally agreed that the deleterious consequences of market fragmentation can be mitigated by enhancing the integration of competing market centers. With respect to stock and options markets, such enhancement could be obtained either by geographic concentration of trading in both stock and options on the same exchange floor or by improved communications between exchanges trading in options and exchanges trading in stocks.[21] The box on page 28 discusses some of the consequences of trading stock and options in the same location.

Fraudulent manipulation of stock prices

A third way an options market can affect the prices of underlying securities is the unusually strong incentive options give for the fraudulent manipulation of stock prices. *Capping* is a frequently cited example of such manipulation.

Suppose a market participant has a naked short position on soon-to-expire call options with a strike price only a few dollars above the contemporaneous price of the underlying stock. If the options expire out-of-the-money, the investor can keep whatever price he received originally for writing the options. If, however, the stock price moves above the option strike price prior to expiration, the investor's losses from covering his short option position could be substantial. He may, therefore, try to "place a cap" on the stock price by short selling the stock whenever its price approaches

[20] That is, an investor can buy the stock or he can buy an in-the-money option which is close to expiration, knowing that it is almost certain that he will want to exercise the latter on the expiration date Conversely, a holder of the stock can either sell stock or write an in-the-money call option which is virtually certain to result in an exercise The idea of stock and in-the-money options being close substitutes is therefore quite similar to the more familiar observation that the purchase of stock in one market is a perfect substitute for the purchase of the same stock in some other market

[21] The role of communications in overcoming fragmentation is discussed in Kenneth Garbade, "Electronic Quotation Systems and the Market for Government Securities", *Quarterly Review* (Summer 1978), pages 13-20, and William Melton, "Corporate Equities and the National Market System", this *Review*, pages 13-25.

the strike price of his options. If he can defer what may be an ultimately irresistible stock price increase until after his options expire, he may incur less total loss (including the costs of eventually covering his short stock position) than were his options to expire in-the-money.

Manipulative stock transactions can also push stock prices above the strike price of an option. If an investor has a long position in options which are only slightly out-of-the-money, he may feel he would be better off buying stock (with the intent of pushing the stock price through the option strike price) and then selling his in-the-money options than simply allowing his options to expire out-of-the-money.

It appears that the incentives which options provide for the manipulation of stock prices are unlikely to be important except immediately before option expiration dates. Near those dates, there may be substantial rewards to a manipulator who can defer or accelerate a stock price change by a few days. At other times, the capital required to effect and maintain a prolonged change in the level of stock prices will be beyond the resources of almost all market participants. The SEC and self-regulatory organizations like the NYSE, the American Stock Exchange, and the CBOE have substantially enhanced their market surveillance programs and improved their ability to detect manipulative activities. These efforts are important for creating public confidence that the stock and options markets are fair and equitable for all participants.

Conclusions

The last five years have witnessed a remarkable growth in investor interest in options. This growth can be attributed to the much enhanced liquidity of exchange-traded option contracts. The limitation of contract terms to a modest number of expiration dates and strike prices resolved the problem of trading interest in OTC options being spread too thinly over too many different contracts to permit a viable secondary market. The creation of the OCC as a contractual intermediary eliminated the need for holders of options to evaluate the creditworthiness of ultimate writers. Greater homogeneity of both credit risks and contract terms reduced the "investigation" costs of trading in options and led to greater investor interest in those securities.

Exchange-traded options have now become important as both hedging and speculative devices. The ability to write call options against stock positions has given investors an important new way to reduce their risk exposure to price fluctuations on specific securities. On the other hand, because call option prices are extremely sensitive to the prices of underlying stocks, optimistic investors can obtain substantially leveraged returns from small capital commitments in options.

The growth of interest in option trading has also created new problems for regulators and for the securities industry in general. More frequent occurrences of manipulative practices like capping might be expected in view of the greater stake which more investors now have in options. Similarly, the greater liquidity of the options markets may encourage practices like front running (front running is described in the box on page 28). The SEC and the self-regulatory organizations have recognized the need for much more careful scrutiny of markets and trading practices in an environment of active options markets.

Because the experience with exchange-traded options is still relatively limited, there exist additional problems whose importance is difficult to assess at present. Call options could provide a vehicle for the formation of speculative bubbles in stock prices. The collapse of such bubbles would bring losses not only to options traders but also to investors in the underlying stocks. Nor is it entirely obvious that there is adequate preparation for the possibility of catastrophic losses by writers of naked call options. History suggests, however, that, as the interests of participants in the options markets become more entrenched, the chances for an orderly appraisal of these potential problems will diminish. Moreover, any reform which follows in reaction to catastrophic losses by writers of naked options will likely be excessive. The current SEC review of the options markets is thus both timely and important.

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Appendix: The Black-Scholes Option Pricing Model

In 1973, Fischer Black and Myron Scholes advanced a model for valuing call options on securities such as common stock.[1] Their model has since become widely accepted and used by financial market participants. The authors showed that the value of a call option depends on five parameters: (1) the price of the underlying stock, denoted S, (2) the strike price of the option, denoted E, (3) the time remaining to the expiration of the option, denoted t, (4) the level of interest rates, denoted r, and (5) the volatility of the price of the underlying stock, denoted v. The stock price S and the option strike price E are measured in dollars per share and the time t remaining to expiration is measured in years or fractions thereof. The interest rate r is usually taken as the rate on high-quality commercial paper having a maturity comparable to the expiration date of the option. The stock price volatility v is measured as the variance per year of the natural logarithm of the stock price.

The Black-Scholes model for the dollar value C of a call option is:

$$C = S \cdot N[d_1] - E \cdot N[d_2] \cdot e^{-rt}$$

where:

$$d_1 = \left\{ \ln[S/E] + (r + v/2)t \right\} / \left\{ vt \right\}^{1/2}$$

$$d_2 = d_1 - \left\{ vt \right\}^{1/2}$$

$$N[x] = (2\Pi)^{-1/2} \int_{-\infty}^{x} e^{-u^2} du$$

Chart 1 shows the predicted values of call options on IBM stock computed from the Black-Scholes model for three different values of t. In that chart, option values are expressed as a percentage of the strike price of the option, *i.e.*, as the ratio C/E. The stock price is also expressed as a percentage of the strike price, or as the ratio S/E. The interest rate was set at 8.5 percent per annum, or r = 0.085. This is approximately the rate on high-quality commercial paper that prevailed at the beginning of September 1978.

The only unobservable variable in the Black-Scholes model is the stock price volatility, v. This variable can be estimated by computing the value of v which leads to a predicted option price equal to the actual market price of the option.[2] When this was done for the twelve call options on IBM on September 1, 1978, the average v came out to be .0372. This implies that there was about a 66 percent chance that the price of IBM stock would vary in one day by less than 1 percent of its previous closing price.[3] The value of v = .0372 was used to compute the option values shown in Chart 1. The volatility parameter can also be estimated from the historical price volatility of a stock if one is willing to assume that the future price volatility will be like the historical volatility.

Clifford Smith has pointed out that the Black-Scholes option pricing model may be interpreted as the *expected intrinsic* value of an option, on its expiration date, times a discount factor which converts that future value to a present value.[4] The expected future intrinsic value depends on the probability that the option will expire in-the-money, and hence depends on the volatility of the underlying stock. Other things being equal, options on more volatile stocks have a higher probability of expiring with a greater in-the-money value than options on more stable stocks. Thus, the value of an option increases with stock volatility.

The Black-Scholes pricing model is frequently used by market participants to estimate the hedge ratio and the elasticity of an option. The hedge ratio is defined as the ratio of simultaneous *dollar* changes in option and stock prices. It can be shown that the hedge ratio of an option is $N[d_1]$. This result was used to compute the entries of Tables 5 and 7 and the curves of Chart 2. The elasticity of an option is defined as the ratio of simultaneous *percentage* changes in option and stock values. From the Black-Scholes model, this ratio is $S \cdot N[d_1]/C$. This result was used to compute the entries of Table 6. The values of the hedge ratio and elasticity of an option both depend on the volatility parameter. Because that parameter cannot be estimated without error and because a particular estimate depends on the method of estimation, the computed hedge ratio and elasticity can only be viewed as imperfect estimates of the true values.

[1] Fischer Black and Myron Scholes, "The Pricing of Options and Corporate Liabilities", *Journal of Political Economy*, 81 (May/June 1973), pages 637-54.

[2] This method of obtaining the volatility parameter is discussed by Richard Schmalensee and Robert Trippi, "Common Stock Volatility Expectations Implied by Option Premia", *Journal of Finance*, 33 (March 1978) pages 129-47.

[3] The variance of the log of the price of IBM stock is 0.0372 per year, or .000102 per day (.000102 = 0.0372/365). The standard deviation of the change in the log of the stock price over a one-day interval is therefore .0101 (.0101 = $(.000102)^{1/2}$), or about 1 percent. The probability that a normally distributed variable will be less than one standard deviation from its mean is about 66 percent, so the probability that the price of IBM will change by less than 1 percent in value in one day is about 66 percent.

[4] Clifford Smith, Jr., "Option Pricing: A Review", *Journal of Financial Economics*, 3 (January/March 1976) pages 3-51, at footnote 22.