STOCK MARKETS

Modern-day securities markets could not function without digital computers and sophisticated electronic communications systems. The primary reason for this has been an unending growth in the demand to trade securities by the public and financial intermediaries. The securities industry usually measures trading activity by volume—number of shares traded per unit of time. For example, on the New York Stock Exchange (NYSE) share volume for a single day did not surpass 50 million shares until 1978, and did not ever exceed 100 million shares until 1982. By contrast, the *average* daily trading volume was 526.9 million shares during 1997, and topped 1.2 billion shares on October 28, 1997, an all-time single-day record for the NYSE. The over-the-counter (OTC) market or, more properly, the Nasdaq stock market, has experienced even more rapid trading growth than the NYSE. On October 28, 1998, Nasdaq set an all-time record with 1.37 billion shares traded, or 1,307,800 individual trades in a single day. (Individual trades are typically in blocks of 100, 200, 300, etc. shares.) It is worth noting that Nasdaq is a high-tech, screen-based trading system, which links over 500 competing broker/dealer firms that make markets in Nasdaq-listed securities.

The relative importance of stock markets is measured by their total capitalized value, which is defined as the sum of the capitalized values of all stock traded in the market. For a single stock issue, capitalized value is the product of share price and the number of shares issued by the corporation. By this measure, the NYSE is the largest stock market in the world.

Stock markets provide the forum for individuals to invest in securities and for financial instruments to be readily converted into cash when needed. Stock markets contribute to social welfare by helping to efficiently allocate scarce capital by providing a reliable means of valuing assets (a corporation's market value) and assisting the flow of capital to private enterprise. Three important attributes of a stock market are: (1) transparency, (2) liquidity, and (3) low trading costs. Transparency means an investor is able to see all currently available bids and offers, and transact at the most favorable price. Suppose Mr. A wants to buy 100 shares of Microsoft at the best available price. Ms. B is willing to sell 100 shares of Microsoft, but at a minimum of $145 per share. A's broker arranges a trade at $145 per share. However, suppose Ms. C was willing to sell 100 shares at a limit of $144, but Mr. A's broker was unaware of this offer. Such a market is not transparent. Liquidity is the ability to quickly convert an asset (shares of stock) to cash at a "fair" price. If Mr. A had wanted to buy 50,000 shares of Microsoft, and if his bid raised the price of Microsoft over what he might have to pay for 100 shares, then this would be evidence of poor liquidity. Technology has contributed to the lowering of trading costs, as one might expect. On the other hand, technology has spurred the growth of alternative trading systems, where activity may not be fully disclosed to, or accessible to, public investors, thereby reducing transparency.

SECONDARY MARKET

The term "stock market" refers to what financial economists define as a component of an economy's secondary capital market. Investment securities (stocks and bonds) are first sold to buyers in the primary capital market. All subsequent trading takes place in the secondary market. Compare the purchase of a new car to a stock transaction. If someone purchases a new car, that is a primary market transaction. When one later sells the car, it is done in a secondary market. Likewise, the stock market is literally a market for used stock. Figure 1 depicts the flow of funds from the investor, through financial intermediaries to the primary and secondary capital markets.

Financial intermediaries act as middlemen between investors and the capital markets. Mutual funds, banks, and pension funds take the small driblets of savings flowing from households and repackage these flows as large chunks of money more suitable for efficient investment. Brokers act on

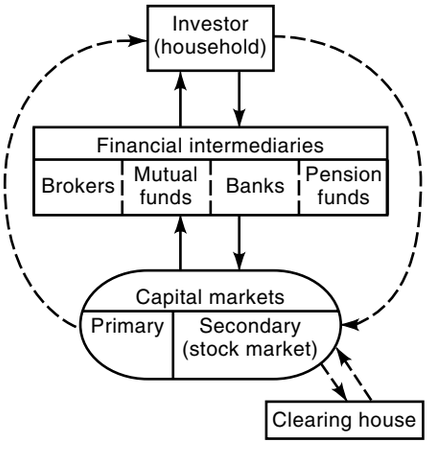

Figure 1. Flow of funds between households and the capital market.

behalf of small investors in dealing with the capital markets, although, as the dashed arrows in Fig. 1 indicate, it is possible for households to deal directly with the markets. The clearinghouse is a mechanism for transferring the ownership of shares after a trade occurs in the secondary market.

This article will take a broad view of stock market securities and the stock market so as to include derivative securities such as options and futures contracts. A derivative is a security whose market value is a function of the value of some other security or real asset (e.g., an agricultural commodity).

Organized Exchanges

The secondary capital market can be divided into two components: (1) the auction market and (2) the negotiated market. The organized stock exchanges, both national and regional, make up the auction market. They are characterized by trading primarily among commission brokers who represent the principals to the transaction. Furthermore, trading takes place in a particular location during certain hours. The two national stock exchanges in the US are the NYSE, sometimes called the "big board," and the American Stock Exchange (AMEX). Stock exchanges are located in almost every country of the world, and in this age of economic globalization and instantaneous communication, trading in one country can often affect stock prices in other countries.

National Exchanges

Figure 2 depicts how a trade is handled (order flow) for a stock traded on the NYSE. Trading on other exchanges is very similar. Because trading on the exchange is restricted to members, the public as well as financial intermediaries must pay a fee (commission) to a brokerage firm (a member of the exchange) to execute the trade. A "broker" is a firm or individual who brings together buyers and sellers; hence there are real estate brokers, mortgage brokers, and stock brokers. In a typical NYSE transaction the investor phones a broker and places a buy or sell order for a specified number of shares in a particular issue, say IBM. If the customer wants to buy or sell at the best currently available prices, then he or she must specify this as a "market order." The order is transmitted through the firm's communication system to the floor of the exchange, as shown in Fig. 2.

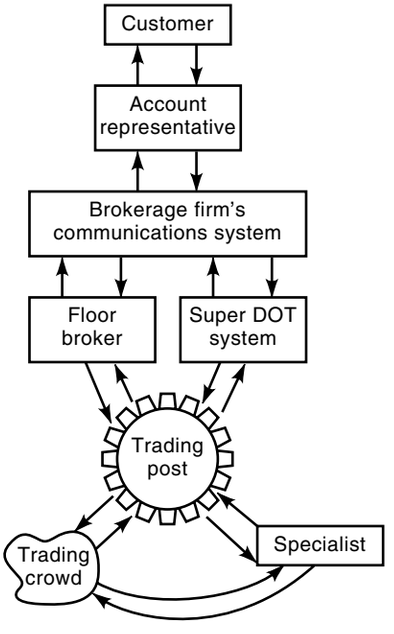

Figure 2. Order flow for a trade on the New York Stock Exchange.

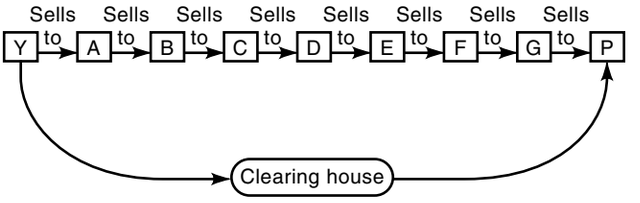

Figure 3. A trading post located on the floor of the New York Stock Exchange. Courtesy NYSE.

Prior to the latter half of the 1970s, all orders were sent by phone or teletype to the firm's New York office, and then to a booth located along one of the outside walls on the floor of the NYSE. A clerk would write down the order and give it to one of the firm's brokers who, in turn, would take the order to the trading post (see Fig. 3) where IBM was traded. At the trading post a market order was either executed by matching the order with the lowest offer for a buy order or the highest bid for a sell order currently available. Bids and offers are made by "open outcry." This process is known as a double auction because both buyers and sellers are participating in the bidding. Some investors place "limit" orders which specify a maximum buy price or a minimum sell price. If a limit order cannot be executed immediately, it is left with the specialist for the stock in question for possible later execution (see Fig. 2).

Specialists

The specialist is also a member of the exchange, but performs duties that are different from those of the commission broker. As suggested above, the specialist (about 400 specialist firms belong to the NYSE) tries to execute limit orders left by the commission broker, for which the specialist receives a commission if and when the limit order is filled. These orders are kept in the specialist's limit order book; the book cannot be viewed by other members of the exchange. Specialists also act as dealers in the same stocks in which they act as a broker. In general, a security dealer holds an inventory of stocks or bonds and buys and sells for the inventory. In acting as a dealer, the specialist quotes an ask price (an offer to sell) and a bid price (an offer to buy). Clearly, the ask price must be greater than the bid price. The difference of the ask–bid is called the "spread," and it is a source of profit to the specialist firm. When acting as a dealer, the specialist provides liquidity to the market; that is, buying when there are no sellers in the crowd, and selling when there are no buyers. Thus the specialist allows continuous trading in stocks during the hours when the NYSE is open. The spread can be thought of as compensation to the specialist for providing this service.

There are two methods for entering a trade into the NYSE's information network. An exchange reporter is located at each trading post. The reporter monitors trading among members of the crowd, and when a trade is completed, enters

the price and volume into a hand-held computer. The computer relays the trade to the Exchange's computers using wireless communications. Under the second method, a specialist at the trading post enters the trade using a keyboard.

In 1976, the NYSE began introducing the Designated Order Turnaround (DOT) System. Originally DOT was designed to transmit 100 share market orders (no limit orders) from member firm offices to the trading posts. By the mid 1980s this system had grown to the point to where it handled an average of more than 35,000 orders per day, or about 50% of all trades executed on the NYSE. The latest version of this system is known as the Super Designated Order Turnaround (SuperDOT) System, and it accepts both market orders (30,999 or fewer shares) and limit orders involving 99,999 or fewer shares. With SuperDOT the investor's brokerage firm can send the order directly to the specialist, whereupon it is displayed to the crowd at the post using a video monitor, and possibly executed. SuperDOT has greatly expanded the order-processing capacity of the NYSE. Although it is used by brokerage firms primarily as a vehicle for handling small orders, it can be programmed to send certain other orders directly to the firm's commission brokers for execution.

The introduction of SuperDOT has facilitated the operation of program trading strategies. Program trading is usually defined as purchases or sales of 15 or more stocks with a combined value of at least $1 million. The group of stocks purchased or sold is regarded by traders as a "basket" of stocks because the entire group is treated as if it were one security. Suppose a mutual fund manager wants to replicate a stock index such as the Dow Jones Industrial Average (DJIA). This can be accomplished through a program trade. The manager would instruct the commission broker to purchase the 30 stocks in the DJIA in the same proportions as each stock represents in that famous average. (Note: institutional investors, such as mutual funds, are barred from membership on the organized exchanges.) Or, in another example, the fund manager might want to purchase 50 stocks at the average volume-weighted prices for the day. In other cases, a portfolio manager might use a computer to monitor stock prices, in real time, and have the machine issue buy or sell orders when certain conditions are met. Such is the case with index arbitrage and portfolio insurance program trading. Under index arbitrage the computer tracks the difference between the Standard & Poor's (S&P) 500 Index and the financial futures contract on the S&P 500 stocks, which is traded on the Chicago Board of Trade (CBT). When the futures and index drift far enough apart, the program buys or sells all 500 stocks in the index and takes an off-setting position in the futures contract. Program trading has been blamed for causing excessive price volatility by some NYSE members and corporate executives. However, various studies have failed to uncover a link between program trading and volatility. Over the past decade, program trading has accounted for a slowly increasing share of exchange volume, reaching 16.8% in 1997, up from 9.9% in 1989, according to *Barron's* (1).

Regional Exchanges

Next in the hierarchy, after the NYSE and AMEX, are the regional stock exchanges. These are located in Boston, Philadelphia, Cincinnati, Chicago, and San Francisco. Historically, these exchanges came into existence for the trading of stock issues of interest to investors in their geographic area. Nowadays the regionals trade shares that are also listed on the NYSE or AMEX. Such shares are said to be "dually traded." The operation and order handling of the regionals is basically similar to the two national exchanges, including the specialist system.

Regional exchanges have historically provided competition and innovation for the national exchanges. For example, the Pacific Exchange (PCX), located in San Francisco, was the first stock exchange to develop an automated trading system. Continuing in that tradition, the PCX recently announced the introduction of the OptiMark Trading System, which is designed to provide automatic order formulation, matching, and execution of equity trades. The OptiMark Trading System, which runs on a supercomputer, is called "three-dimensional" in its design because it can represent the trader's demand or supply function, that is, the willingness of a trader to buy or sell as a function of price.

MARKET REGULATION

Following the great crash of 1929, the US Congress passed a number of laws to regulate securities markets and the trading of securities. The Securities Act of 1933 was the first major piece of legislation directed at the primary securities market and its sales practices. The Act outlaws fraud in security sales and requires that the sellers of new securities provide full disclosure of all pertinent facts about the issue. Hence, it is this law that requires that a potential investor be given a prospectus before the issuer can accept any money.

The Securities Act of 1933 brought regulation to the primary market, but did not provide any means for enforcing that law, nor did it provide for the regulation of the secondary market. This oversight was corrected a year later with the passage of the Securities Exchange Act of 1934. In part, this new legislature created the Securities and Exchange Commission (SEC) for the enforcement of the nation's securities laws. The law requires that securities exchanges register with the SEC, and that they agree to comply with the laws and regulations governing them. The approach taken by the SEC allows for a great deal of self-regulation by the exchanges. Therefore, each exchange is responsible for organizing its own procedures, consistent with the guidelines prepared by the SEC for the conduct of business, including disciplinary rules for members who fail to comply. The SEC has the power to enforce the laws in those cases where exchange self-regulation is found to be lax.

The continual introduction over the past two decades of new technology into the trading process has forced the SEC to rethink many of the features of its approach to the regulation of exchanges and other markets. According to the SEC (2), "two key developments highlight the need for a more forward-looking, flexible regulatory framework: (1) the exponential growth of trading systems that present comparable alternatives to traditional exchange trading; and (2) the development of automated mechanisms that facilitate access to foreign markets from the United States." Technology has made possible certain alternative trading systems that are not registered with the SEC or operated by a registered securities association. The SEC estimates that in 1997 alternative

trading systems accounted for almost 4% of orders for securities listed on the NYSE.

The SEC has also been indirectly responsible for the introduction of automation into the securities markets. In 1965 "The Special Study" of the SEC (3) called for the movement toward a national market system. The first step in this direction was not taken until 1974, when the NYSE and the regional exchanges introduced a consolidated ticker tape that indicates the prices, volumes, and quotations for securities in all markets in which such securities are traded. One year later Congress passed the Securities Acts Amendments of 1975, which, among other things, mandated the development of a national securities market system—the design of which was left to the securities industry. Hence, in 1977 the NYSE developed the Intermarket Trading System (ITS). The ITS is an electronic communications network (ECN) designed to connect all competing markets for NYSE-listed stocks. It enables brokers at one market location to connect to other market centers electronically, in order to obtain a better price for their customers, thus enhancing transparency. For example, a commission broker on the floor of the NYSE might be able to obtain a better price for a customer by filling a buy order through a trader at the Philadelphia Stock Exchange (PHLX) rather than from the crowd at the trading post in New York, or the stock's specialist.

NEGOTIATED MARKET

The negotiated market is composed of security dealers located all over the US. They communicate with one another by telephone and sophisticated electronic communications systems. In contrast to the auction market, the dealers negotiate the prices at which they will buy and sell securities for their inventory. This process is facilitated by the posting of bid and ask prices in all the securities in which the dealer "makes a market." Indeed, the dealers are often referred to as "market makers" to distinguish their function from that of a broker. The negotiated market differs from the auction market in two important respects: (1) there is no central location where trading takes place, and (2) prices are determined by a process of negotiation rather than through an auction.

Over-the-Counter Market

The term over-the-counter (OTC) market refers to the negotiated market. In the past, commercial banks could underwrite new security issues and make markets in stocks and bonds, that is, act as a dealer. In a bank lobby, investors could literally buy and sell stocks "over the counter," hence the name. After the crash of 1929 this activity was outlawed by the Glass–Steagall Act of 1933, although its prohibitions have been eroding in recent years. Today more stocks are listed on the OTC than on the NYSE, and the vast bulk of bond trading takes place in this market.

The Securities and Exchange Act gave the SEC authority to regulate the organized exchanges. In 1939 Congress amended the Securities and Exchange Act with the Maloney Act. The main purpose of Maloney was to extend similar control to the OTC market. The Act provided for the creation of a self-regulatory body(ies) to govern the OTC market in much the same way that the organized exchanges had been charged with policing their own activities under the 1934 Act.

The Maloney Act gives to a qualified association the power to draw up and enforce rules to prevent fraud and manipulative practices, to prevent unreasonable profits, and to protect investors and the public interest. The National Association of Securities Dealers (NASD) is the only significant organization registered under the provisions of the Act. In February of 1971, NASD introduced an automated quotation system called NASDAQ. In 1976 NASD purchased the NASDAQ system from its builder/operator, the Bunker Ramo Corporation, for about $10 million. Until the early 1990s NASDAQ stood for the National Association of Securities Dealers Automated Quotation System, but is now used as a noun—Nasdaq. The Nasdaq stock market is a subset of the OTC market, which is a broader market that encompasses bond trading, stocks not listed on Nasdaq, including those on the OTC Bulletin Board quotation system, and other securities. The OTC is operated by the NASD. The Nasdaq stock market has evolved to become the most highly automated trading system in the world. Approximately 4,500 securities are traded on the Nasdaq stock market. The entire OTC market includes over 15,000 securities. Figure 4 is a photograph of the Nasdaq Market Site in New York City, which displays trading information on the most important Nasdaq-listed stocks.

Before the introduction of Nasdaq, members of the OTC market communicated by voice over private wires or the switched telephone network. Upon receipt of a customer order the receiving firm would "shop the street," requesting quotations from dealers willing to continuously buy and sell shares for their own account. Normally three different dealers were asked to provide a bid and ask quote. After deciding which dealer had the best quote, the broker would then contact the dealer again in order to consummate a trade. In the meantime, the dealer's price may have gone up or down from the previously provided quote, and the latest quote may no longer be the best. The complications might prevent the customer from receiving the best price. Automation has greatly streamlined this process, and reduced the chance of trading at a stale price.

Today, each company that lists its shares on Nasdaq has a number of competing securities firms that make a market in its stock. The competing firms, or market makers, over 500 in total, compete with one another for investor orders by buying and selling for their own accounts over Nasdaq's electronic network of terminals, called "workstations." A minimum number of two market makers is a prerequisite for a company listing on Nasdaq. A typical Nasdaq stock has 11 market makers; some of the more actively traded stocks have 40 or more. The more actively traded stocks include household names such as Microsoft and Intel. Market makers are required to quote "firm" bid and ask prices. This means that market makers stand ready to execute transactions at their displayed prices on Nasdaq for the normal unit of trading (usually 100 shares) or for their displayed size limit, whichever is greater. Most transactions are automatically reported through a variety of electronic systems to data vendors. For other transactions the market maker must report the trade within 90 seconds using the workstation. The interested reader can see a mock-up of the Nasdaq Workstation II, which provides a Microsoft Windows-like display, on the internet at http://www.nasdaqnews.com/. Quotations in Nasdaq issues are displayed to investors continuously through nearly 350,000 terminals in 60 countries.

Figure 4. Nasdaq market site in New York City. Courtesy NASD.

Nasdaq provides for three levels of subscription to its services. Level III, the highest, is used by market makers, as described above. Level II connects the trading rooms of brokerage firms to Nasdaq. All bid and ask prices are displayed along with the name of the market maker providing the quote. Level I of Nasdaq is used by account representatives at brokerage firms to view the highest bid and the lowest ask price in all listed stocks, as well as last sale reports.

When an investor places a market order to buy or sell a Nasdaq stock, his or her broker will route that market order to the firm's trading room. If the firm makes a market in the stock, it will normally execute the order internally, as principal, at a price equal to or better than the best price being quoted in Nasdaq by all of the competing market makers. A firm that is not a market maker in the stock will execute the order with a market maker at another firm. This is done using SelectNet, an automated service that enables brokers to route orders, negotiate terms, and execute trades in Nasdaq securities without verbal contact between trading desks. For small orders of 1000 shares or less, the firm is likely to execute the transaction with a market maker using the Small Order Execution System (SOES).

The most important Nasdaq stocks, about 3900 in total, are assigned to the National Market System (NMS). The primary significance of being listed on the NMS is that these securities are automatically marginable. Marginability means that the investor can borrow part of the purchase price of a stock. Less actively traded issues belong to the Small Cap Issues section of Nasdaq, which numbers about 1300 issues. Some of these stocks may be margined.

Starting in 1997, Nasdaq began phasing in two new SEC order-handling rules. Both rules enhance the transparency of the Nasdaq market. The first of the new rules concerns limit orders—orders to buy or sell a security at a specific price. In the past, limit orders were not routinely displayed when those prices were better than the market maker's quote. Under the new rules, a market maker that receives a limit order price better than its best current quote must display the limit order price and size on the trading screen.

The second rule amends Nasdaq's Quote rule. In today's markets, quotes can be displayed in two different ways: (1) through public markets for everyone to see, or (2) through private systems that are visible only to certain professionals. These private systems—called Electronic Communications Networks (ECNs)—include systems like Instinet (see the section titled Third and Fourth Markets, below), which is owned by Reuters. In the previous structure, orders placed on ECNs may have been priced more favorably than quotes placed publicly, but they were not publicly displayed beyond the private system's own subscribers. Under the new rules, if a market maker enters an order into an ECN, and that order is priced better than the displayed quote, the market maker must display the price of the ECN order in its quote. Currently four ECNs are permitted to display their best market maker quotes on Nasdaq's own trading screens. Investors, therefore, are able to see the best possible price at which market makers, on and off Nasdaq, are willing to trade a security.

The rules and regulations of the NASD allow members to trade securities among themselves at prices which may be different from the prices paid by the public. As a consequence, a customer purchasing stock through a broker will probably pay a price that is higher than that paid by the broker. This difference is called a "markup." The "markdown" is defined in an analogous manner. In either case, the customer may also be charged a commission on top of the markup or markdown. The magnitudes of the markup–markdown is seldom more than 5%, and is monitored by the SEC.

In order to manage its increasing number of transactions, Nasdaq undertook a $180 million technology upgrade in 1995. The computer network was upgraded to the point where Nasdaq is now capable of trading up to one billion shares a day. Nasdaq's primary computer system is based in Trumbell, CT, with a back-up facility in Rockville, MD. Driven by a Unisys 2200/900 mainframe (with a fourfold increase in speed

over the previous mainframe), the current system can process 560 transactions per second. The roll-out of the Nasdaq Workstation II was also part of the 1995 upgrade (5,780 Workstation IIs now sit on the desks of 5,780 broker/dealers nationwide). Communication lines that connect members to the central computers in Trumbull and Rockville were upgraded to 56,000 baud from 9,600 baud. More recently, NASD announced an agreement in principle between Nasdaq and OptiMark Technologies, Inc. to offer investors and market makers access to the OptiMark trading system. OptiMark is also scheduled for use by the Pacific Exchange (see the "Regional Exchanges," subsection above).

THIRD AND FOURTH MARKETS

Stocks listed on the NYSE need not be traded exclusively on the Exchange or the regional exchanges. Indeed, there is no law that prevents an individual from selling stock to a friend, neighbor, or perfect stranger. The third and fourth markets conduct trading in NYSE-listed stocks, completely away from any central stock exchange. The historic impetus behind the formation of the third and fourth markets was to avoid paying the fixed commissions charged by NYSE member firms. In other words, before deregulation by the SEC in 1975, NYSE members acted as a cartel in pricing their services. Although fixed commissions were ended by the SEC on May 1, 1975, the third and fourth markets live on in the present era of negotiated commissions.

The term "third market" refers to the trading of any exchange-list stock, NYSE or regional, in the over-the-counter market. The third market continues to exist because it can trade a stock even when an exchange has halted trading in the stock, and it provides a means of after-hours trading. Particularly violent price swings on an exchange may trip a so-called "circuit breaker," which halts trading in most stocks, or the exchange may decide to halt trading in a single stock, pending confirmation or denial of some rumor about the corporation. At such a point, trading moves over to the third market.

Prior to 1976 exchange rules prevented NYSE members from acting either as dealers in the third market or executing orders involving NYSE-listed securities for their customers in the third market. In its efforts to establish a national market system the SEC has ruled that exchange members may trade in the OTC stocks that were listed on the NYSE after April 29, 1979.

Large institutional investors such as pension funds, mutual funds, and bank trust departments collectively have more money invested in common stocks then do US households. (Of course, the institutions, for the most part, are acting as fiduciaries for households.) In the 1960s, in order to avoid the high commissions charged by NYSE members, institutional investors began trading directly among themselves over an electronic communications network called Instinet, which is today owned by Reuters, PLC. The system permits a subscriber (1) to enter and take limit orders, or (2) to negotiate directly with other counter-parties on an anonymous basis. More recently, the Portfolio System for Institutional Trading (POSIT) and the Crossing Network have been introduced to the fourth market. These new systems permit institutions to trade portfolios of stocks directly with each other, thereby making possible program trading in the fourth market. The latest entry into the fourth market is the Arizona Stock Exchange (AZX), which is a completely electronic trading system that conducts periodic, single-price auctions. Individual investors can trade on the AZX if they have an account, or have an account with a broker who is connected to the AZX.

Matching Versus Crossing Systems

An order "matching" system allows participants to display firm, priced orders to other participants and the execute against other orders in the system. Examples of matching systems are Instinet, the Island System, and Tradebook.

A "crossing" system allows participants to enter unpriced orders, which are then executed with matching interest at a single price, typically derived from the primary public market for each crossed security. Therefore, there is no independent price-discovery mechanism in a crossing system. Prices may vary on such systems throughout the trading session if the market operates over a time interval when the associated primary market is open, or prices may be fixed at a single level, such as the closing price for an after-hours trading session.

STOCK CLEARING

Broker A has an order to buy 100 shares of IBM, and Broker B has an order to sell 100 shares of IBM. The two brokers meet on the floor of the Exchange and strike a deal at $115 per share. Although A has agreed to buy, and B has agreed to sell, most of the real work connected with the transaction remains to be done. In particular, ownership must be transferred and payment made by Broker A. For a period of 100 years, deliveries of shares and cash settlements between members of the NYSE were made directly between the brokers involved. A small army of messengers scurried around Wall Street, dropping off share certificates and picking up checks. The system was both inefficient and unreliable. It was also risky: messengers moving around the financial district were often intercepted by thieves.

Today the manual clearing operation has been replaced by a system of bookkeeping entries. A "regular way" purchase and sale agreement calls for delivery of the securities and receipt of payment on the third business day following the day of agreement. Thus shares sold on the floor the regular way on Monday will be delivered on Thursday. Most stocks are sold the regular way. Records of transactions are quickly sent electronically to a "clearinghouse." The operation of the clearinghouse is as follows: at the end of the day, both sides of the reported trades are verified for consistency, then all transactions are netted out. Each broker receives a list of the net amounts of securities to be delivered or received along with the net amount of money to be delivered or collected. Therefore, each day each broker settles with the clearinghouse instead of numerous firms.

In 1976 the National Securities Clearing Corporation (NSCC) was established to take over clearance and settlement for the major stock exchanges and market places. Owned by the NYSE, AMEX, and NASD, NSCC now clears and settles about 99% of all stock and bond trading in the US, as well as most mutual fund transactions. The International Securities Clearing Corporation (ISCC), a wholly owned subsidiary of NSCC formed in 1985, provides clearance and set-

tlement to US brokers trading in foreign markets. Custody of most stock certificates is kept by the Depository Trust Company (DTC). An issuing corporation transfers certificates to the DTC where they are held. The DTC maintains computerized records which show the securities owned by its member firms (brokers, banks, mutual funds, etc.). Therefore, the delivery of securities from one broker to another can be carried out as paperless transaction, in which one account is credited and the other debited for the shares involved. When the issuing corporation pays a dividend, those shares held by the DTC receive an aggregate payment, which is, in turn, credited to members accounts based on their holdings. The member has the option of withdrawing the dividend as cash. Not all brokerage firms, banks, or mutual funds are members of NSCC. Nonmembers must pay a member firm to carry out their clearing operations.

The formidable record-keeping and accounting duties of the NSCC are handled by large mainframe computer installations located in Manhattan and Brooklyn, NY. Some work is also done on workstations. The computer facilities are managed by the Securities Industry Automation Corporation (SIAC).

FOREIGN STOCK MARKETS

Stock markets are located in every region of the world, including South America, Europe, Africa, Asia, and the Pacific Rim. In North America, outside the US, the two major exchanges are the Toronto Stock Exchange (TSE) and the Mexican Stock Exchange (Bolsa Mexicana de Valores, or BMV). The BMV is a private institution, incorporated as a limited company with variable capital, which operates under a concession from the Mexican government. Its owners are authorized brokerage firms. Unlike the US stock exchanges, it operates as both the primary and secondary capital market in Mexico. Trading on the secondary market makes use of computers and electronic communications. At the end of 1997, market capitalization was over $145 million, spread among 200 different stocks.

Incorporated in 1878, the TSE is the second largest organized exchange in North America and among the top 10 in the world. In 1996 its market capitalization reached $301.3 billion Canadian. Twenty years ago the TSE launched the Computer Assisted Trading System (CATS) on an experimental basis with 30 stocks. The success of the experiment encouraged the TSE to greatly expand the system and make it permanent. CATS combines the traditional principles of continuous auction trading with modern computer technology. Orders are entered into computer terminals located in brokers' offices and collected in central computer files. The central computer displays limit orders against which others may trade. Market orders are matched against limit orders with the best price that is in the file. If the best limit order is for fewer shares than needed to fill the market order, the remainder of the market order is then put in the system as a limit order at that price. (The investor is free to change this price at any time.) Trading on the TSE is now done exclusively with CATS; with the closing of the TSE's 145-year-old trading floor on April 23, 1997, open-outcry trading came to an end.

Europe

Every country that is a member of the European Union (EU) has at least one stock market. The three largest are in London, Paris, and Frankfurt. The London Stock Exchange (LSE) traces its origins back to the seventeenth century. The original trading room was located in Threadneedle Street, and the building was called the Stock Exchange. Today the London Stock Exchange is still located in Threadneedle Street, but is housed in a modern high-rise office building. The Financials Services Act of 1986—the "Big Bang"—changed the UK's system of regulating investment business. These changes included the elimination of fixed brokerage commissions, the opening of exchange membership to corporations, and the allowing of foreign firms to purchase existing member firms. Since the Big Bang, the development of computer-based systems to support the financial services industry has been a continuous process. In 1986 the London Stock Exchange moved away from face-to-face dealing on the trading floor to a quote-driven system, which allowed market makers to display their quotes on a computer screen. Negotiations moved off the floor to telephones located in member firms' offices. For the most frequently traded stocks, trading took place on the Stock Exchange Automated Quotations (SEAQ) service, through which share prices were determined via competitive quotes from market makers.

In October 1997, trading in the 100 stocks making up the Financial Times index moved from SEAQ to the Stock Exchange Electronic Trading Service (SETS). At the heart of SETS is an electronic order book, which enables buyers and sellers to post their bid and ask prices, and to have their trades matched automatically on the screen. The SETS system can also handle limit orders, something that cannot be done with SEAQ.

For shares which are traded less frequently, the Exchange operates a system called SEATS Plus, the Stock Exchange Alternative Trading Service. Securities on this screen-based system are traded through a combination of quotes and orders.

Many of Europe's stock exchanges were first organized as call markets. In a call market, trading is allowed only at certain times. In such a market, when a security is "called," those individuals who are interested in either buying or selling it are brought together at one spot on the exchange floor. Usually there is an explicit auction in which prices are called out by a clerk until the quantity demanded balances the quantity supplied. Shares are then exchanged at this price.

The Paris Bourse, in 1986, replaced the existing call system with a screen-based order-driven trading system, Cotation Assistee en Continu, or Continuously Updated Quotation System (CAC). At the same time a number of reforms were introduced, including the abolishment of publicly appointed brokers, and the liberalization of trading commissions. In 1995, a new trading system, SUPERCAC, began operations. The system is able to accommodate a variety of new order types. It is designed to improve the treatment of orders present at the opening of the market. The old system would fill all orders at the same price, fragmenting them if necessary, whereas SUPERCAC will serve them in a "first in, first out" basis, intact, and in order of their placement in the order book.

The stock market structure in Germany combines several different trading systems, including floor trading, an electronic trading system, and an off-exchange telephone market. Floor trading is still done across eight regional exchanges with many companies listed on several exchanges—Frankfurt

is the most important. The floor trading system uses a limit order book, and assigns each stock to one official broker. However, this official broker does not act as a dealer, as is the case with the specialist system used in the US. An electronic trading system called the Integrated Stock Exchange and Information System (IBIS) operates in parallel with floor trading. About 200 banks, investment firms, official brokers, and independent brokers participate in this system. The system covers 100 or so high-volume stocks, plus options, public-sector bonds, and foreign DM bonds. IBIS participants enter binding prices, although the system does not automatically match bid and ask prices, even if the quotes are equal. The trader must enter an approval of the transaction before the quotes are matched—then a confirmation of the transaction appears on the screen.

Along the Pacific Rim, the most important stock exchanges are located in Japan, Hong Kong, Australia, Taiwan, and Singapore. The Tokyo Stock Exchange (TSE) is the largest exchange in Japan. Its trading system is unique among all other exchanges in the world. First, the TSE conducts two trading sessions every business day: the morning session runs from 9:00 a.m. to 11:00 a.m., and the afternoon session from 12:30 p.m. to 3:00 p.m. The market has two categories of members: (1) regular members, who are brokers trading for the public, or their own account, and (2) *saitori* members, who function solely as intermediators for transactions between regular members. *Saitori* are forbidden from trading any listed stock for their own account, or from accepting orders from the public. At the opening of each session trading takes place according to the *itayose* method of trading, which is similar to a call market in operation. The *saitori* tries to find a price (anticipated transaction price) that will maximize the number of shares traded as in a call market. All market orders are filled, along with sell limit orders below the transaction price, and buy limit orders above the transaction price. Limit orders at the transaction price may not be completely filled. After *itayose* is completed, the *zaraba* method is put in operation by the *saitori.* Under *zaraba,* orders are processed continuously as they are received, with market orders matched against unfilled limit orders, and new limit orders filled, if possible, against previously unfilled limit orders. Unlike most other exchanges, the TSE enforces price limits on trading. The price limits specify a minimum and maximum price for each stock, based upon the previous day's closing price.

Another unique feature is the categorization of stocks on the TSE in terms of trading facilities. The most active stocks are traded on the floor using the *itayose* and *zaraba* methods under the direction of the *saitori.* The less active stocks are traded by the Computer-Assisted Order Routing and Execution System (CORES). On November 26, 1990, the Floor Order Routing and Execution System (FORES) was introduced to assist trading in the most active stocks. Recent reforms on the TSE include the admission of foreign firms as members (1986), and the partial deregulation of brokerage commissions (1994).

DERIVATIVES

An important development in investment opportunities over the past two decades has been the explosion of new markets for derivative instruments. A derivative instrument is a financial obligation whose value depends on the value or performance of some more basic financial security. There are three basic types of derivative instruments: (1) futures contracts, (2) option contracts, and (3) swap contracts. The primary feature of a swap is the exchange (or swap) of one time sequence of cash flows for another. Swaps usually involve bonds, whose interest payments represent the sequence of cash flows. Futures and options are explained below.

Futures Contracts

A futures contract is defined as a contract to buy a specified quantity of a specified asset, at a specified price, on a specified future date. Profit or loss on the contract is realized each day up until the expiration of the contract through a process of "marking to market" at the close of trading each day.

The specified price in the contract is the "futures price." This price is contrasted with the "spot" or "cash" price, which is the price for immediate delivery of the asset or commodity. There are two ways to earn a profit in a futures contract. The first is to buy, in the hope that on the expiration day the cash price is greater than the futures price on the purchase date. The second method is to sell a futures contract, in anticipation that at the contract expiration date the cash price is less than the futures price. The net supply of futures contracts is zero; this is because for every buyer there must be a seller. The number of contracts outstanding at any particular time is called the "open interest." Those traders who buy a contract have a long position, while those who sell have a short position.

The difference between the current spot price on an asset and the corresponding futures price is known as the basis for the futures (basis = spot price − futures price). A trader with a short position in a futures contract and a long position in the underlying asset (meaning that the trader owns the asset) will profit if the basis is positive and widens, and lose money if the basis is negative and narrows. A falling futures price benefits those who are short futures and a rising spot price benefits those who are long futures.

There are two types of traders in a futures market—hedgers and speculators. Hedgers buy and sell futures to offset an otherwise risky position in the spot market. A typical hedger either produces or uses the asset. In order to reduce their risk exposure (the risk of an adverse change in the spot price) hedgers trade with speculators. Speculators buy and sell futures for the sole purpose of making a profit by closing out their positions at a price that is better than the initial price. The speculator provides a service to the hedger by taking on the hedger's price risk. Any profit made by the speculator is compensation for providing this service.

A classic example of a hedger is the farmer. The farmer has a long position in an agricultural commodity, say corn, but faces the risk of a decline in the spot price during the period from planting to harvest. Selling futures contracts to speculators is a natural way to eliminate this risk. The early futures exchanges in the United States were organized for the purpose of trading futures in agricultural commodities. The first of these, the Chicago Board of Trade (CBT), began operation in 1848. Since then trading has expanded to include industrial commodities, natural resources, precious metals and, most recently, financial instruments. Figure 5 is a photograph of the financial futures floor of the Chicago Board of Trade.

Figure 5. The financial futures trading floor at the Chicago Board of Trade. Courtesy CBT.

New York City and Chicago are home to most of the organized exchanges located in the United States. The trading of futures is facilitated by the creation of contracts that are standardized with respect to the type, amount, and quality of the traded asset, and the delivery month. Futures trading takes place through an auction system of open outcries of bids or offers. Although the buyer has the option of taking delivery of the commodity, this is seldom done. About 99% of all contracts are settled through a reversing trade; a buyer will sell sufficient contracts to net out the initial long position, and a seller will buy an offsetting number of contracts.

A key aspect in futures trading is the significant leverage that results from risking only a portion of the value of a contract. Whenever a futures contract is created, both buyer and seller are required to post security deposits that are intended to guarantee that they will, in fact, fulfill their obligations; this deposit is referred to as "initial margin," and is approximately 5% to 15% of the total purchase price of the futures contract.

The crude oil contract traded on the New York Mercantile Exchange (NYMEX) calls for the future delivery of 1000 barrels of light, sweet, crude oil. At a price of $17.50 per barrel, one contract has a value of $17.50 $\times$ 1000 = $17,500. At 10% initial margin, a deposit of $1,750 controls crude oil worth $17,500. A $.10 change in the futures price will result in a $100 gain or loss per contract, depending on whether the trader is long or short. The rate of return on the trader's initial margin of $1,750 is therefore $\pm$5.7%, which is considerably higher than the 0.59% change in the futures price of crude oil. Leverage greatly enhances gains and magnifies losses. It is the latter aspect of leverage that makes futures speculation very risky.

Each futures exchange has an associated clearinghouse that becomes the "seller's buyer" and the "buyer's seller." The purpose of the clearinghouse is to provide assurance to a trader that the other party will fulfill his or her obligation. Without such assurances, impersonal trading on exchanges would not be possible. The role of the clearinghouse is illustrated in Fig. 6. Although a contract may pass through many hands over its life, as shown in Fig. 6, the clearinghouse is Y's buyer, and P's seller. The clearinghouse is in a risky position because it guarantees both sides of a contract. This risk is reduced somewhat by "marking to market" each day, and the

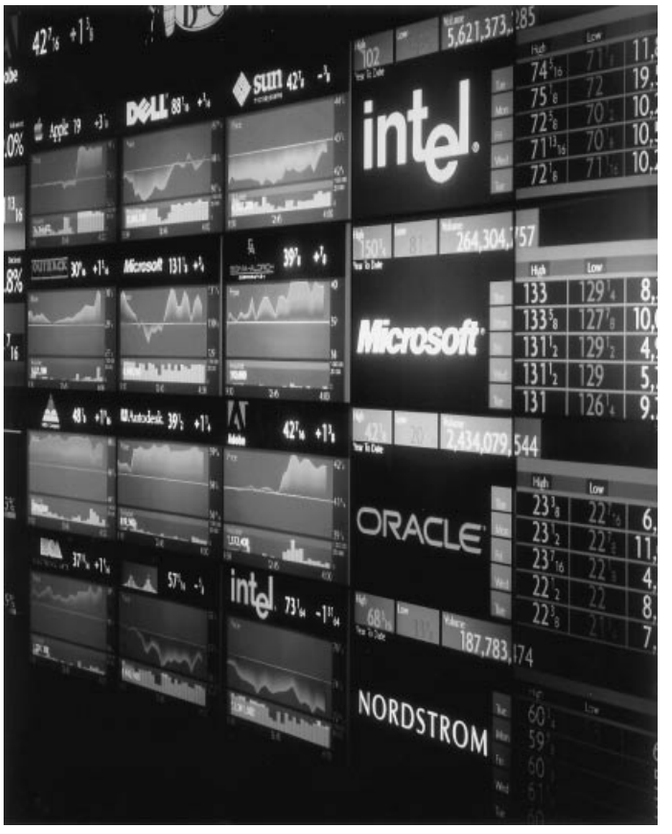

Figure 6. The clearinghouse acts as the buyer to the seller and as the seller to the buyer in a futures trade.

initial margin requirement. Marking to market means that the equity in each trader's account is adjusted to reflect the change in the settlement (closing) price from the previous day's trading. If the equity in an account falls below a certain level (maintenance margin), then the trader must deposit additional cash in the account, or liquidate positions.

The most important development in futures markets over the past two decades has been the introduction of, and speculator growth of, financial futures. These contracts are based on foreign currencies, interest rates, and stock market indices. As measured by trading volume, the importance of financial futures now exceeds the traditional agricultural and natural resource contracts. Indeed, the S&P 500 financial futures contract is the most actively traded contract in the world.

The two most important exchanges for the trading of financial futures are the Chicago Board of Trade (CBT) and the Chicago Mercantile Exchange (CME). Most foreign currency futures are traded on the CME. Speculators in these contracts are betting on changes in the value of a foreign currency, vis à vis the US dollar. Corporations with foreign operations use the contracts to hedge against unfavorable changes in exchange rates.

Interest rate futures are traded on both the CBT and the CME. In effect, traders are speculating on the future course of interest rates, although the actual contracts call for the delivery of a quantity of bonds or certificates of deposit. The CBT offers contracts in longer-term instruments, such as long-term US Treasury Bonds, and US Treasury Notes with maturities of two, five, or ten years. For example, the five-year US Treasury Note contract calls for delivery on the expiration day of five-year notes with a face value of $100,000.

The interest rate contracts traded on the CME involve instruments with maturities on the order of three months. The CME offers contracts in US Treasury Bills, negotiable certificates of deposit, and Eurodollar deposits. Treasury Bills are debt instruments issued by the US Treasury. They are pure discount securities (profit is the difference between the purchase price and the redemption value), and are issued with maturities of 90, 180, and 365 days. Eurodollars are US-dollar-denominated certificates of deposit issued by a European bank.

Index trading takes place in contracts based on the level of a stock market index. These contracts offer the opportunity to speculate on the future level of stock markets, both domestic and foreign. Contract settlement can only be done through a reversing trade; delivery of the securities comprising the index does not occur. Some of the stock market indices with associated futures contracts are the Dow Jones Industrial Average, the Standard & Poor's (S&P) 500 Index, the S&P Midcap Index, Nikkei 225 Stock Average, and the Nasdaq 100 Index.

Option Contracts

Options are contractual obligations that are traded on organized exchanges through an auction system of trading with open outcries of bids or offers. Most options are contracts on common stock, although options on futures contracts are of growing importance. An option, as the name implies, gives its buyer the right, but not the obligation, to exercise the option and take possession of a quantity of stock at a predetermined price. As is the case with futures contracts, the net supply of option contracts is zero—for every buyer there must be a seller. A "call option" specifies that the seller must deliver a quantity of common stock shares to the option buyer, and a "put option" gives its owner the right to deliver shares to the seller of the option.

Below is a list of some of the terms and definitions used in options trading:

- *Strike Price.* The strike price is the price per share at which an option contract is exercised—the price paid by a call owner and the price received by a put holder. It is also known as the exercise price.
- *Expiration Date.* This is the last day when the option contract can be exercised.
- *In the Money.* A call option is "in the money" if the market price of the stock exceeds the strike price, and a put option is "in the money" if the market price of the stock is less than the strike price.
- *Out of the Money.* If an option is not in the money, then it is either "at the money" (market price = strike) or "out of the money."
- *Premium.* The market-determined price for an option contract is termed the premium, and is always equal to or less than the price of the underlying stock. Typically, premiums are much less than the stock's price.
- *European Option.* This can only be exercised on the expiration date of the option contract.
- *American Option.* This option can be exercised at any time during the life of the option contract, including the expiration date.

With few exceptions, option trading takes place on organized exchanges using contracts that are standardized with respect to the strike price, number of shares, and the expiration date. The purpose of trading is to determine the option premium. Exchanges begin trading a new set of options on a given stock every three months. The newly created options have roughly nine months before they expire. In the United States, common stock options are traded on the Chicago Board Options Exchange (CBOE) and on the American, Pacific, Philadelphia, and New York stock exchanges. Options are also traded on many foreign stock exchanges. Next consider some of the economic principles that determine an option's premium.

Let S_t denote the stock's share price at t ($0 \leq t \leq T$), C_t the call's premium, X the strike price, and T the initial time to expiration. The contract is created at $t = 0$, and it expires at $t = T$. The call's premium, C_t, can be written as a function of three parameters

$$C_t = C(S_t, T - t, X) \tag{1}$$

Note that $T - t$ is the time remaining before expiration. At expiration, a call will only have value if it is in the money. Therefore,

$$C_T = C(S_T, 0, X) = \text{Max}\{0, S_T - X\} \tag{2}$$

The max function, $\text{Max}\{0, S_t - X\}$ ($0 \leq t \leq T$) is referred to as the intrinsic value of the call. Prior to expiration, the call

premium is equal to the intrinsic value plus a time premium:

$$C_t = \text{Time premium} + \text{Max}\{0, S_T - X\} \qquad (0 \le t \le T) \qquad (3)$$

For a call option the time premium is nonnegative. It can be thought of as representing the probability that the call will be in the money at expiration.

Financial theorists are interested in how option premiums are determined when the contracts are traded in a perfect market. This area of study has developed the most quantitative models found in financial economics. Indeed, this research spawned the field of Financial Engineering. Robert Merton and Myron Scholes shared the Nobel Prize for Economics in 1997 for their pioneering work in options pricing theory. The models revolve around the market values of three assets: (1) a risk-free bond, such as a T-Bill, (2) the price of the underlying stock, and (3) the option premium. The basic idea is to exactly replicate the cash payoff to one of the assets, using a portfolio that is formed by combining the other two assets in prescribed proportions. The theory makes important use of the fact that, in a perfect market, identical assets must sell for the same price. Therefore, the replicating portfolio, often called a "hedge portfolio," must have the same market price as the asset which it replicates. Given that two of the three asset prices are known, it often is possible to solve for the value of the third asset. These ideas are illustrated in the following examples. In order to keep the analysis simple, the examples consider a European call option on a stock whose price at expiration is described by a binary probability distribution.

Example 1. Determine a call premium.

$$\text{Strike}(X) = \$100$$

$$\text{Current stock price } (S_0) = \$100$$

$$\text{Stock price at expiration } (\tilde{S}_T) = \begin{cases} \underline{\text{Price}} & \underline{\text{Prob.}} \\ \$110 & .5 \\ \$90 & .5 \end{cases}$$

The expected value of $\tilde{S}_T$, $E\{\tilde{S}_T\}$, is \$100. Risk-free, pure discount, bonds exist, and carry an interest rate of 6%:

$$r_F = .06$$

Each bond pays \$1 when it matures at $t = T$. The present value ($t = 0$) of each bond is

$$B(0,T) = \frac{\$1.00}{1 + r_F} = \frac{\$1.00}{1.06} = \$.9434$$

Form a portfolio that perfectly replicates the value of the stock at expiration, $t = T$.

$$H_o: \text{Value of portfolio at } t = 0$$
$$H_T: \text{Value of portfolio at } t = T$$

The composition of the portfolio is

$$H_o: 90 \text{ bonds} + 2 \text{ calls}$$
$$90B(0,T) + 2C_o$$

At expiration:

$$H_T:\ 90 + 2\text{Max}\{0, (110 - 100)\} = \begin{cases} 90 + 20 = 110 & \text{if } S_T = 110 \\ 90 + 0 = 90 & \text{if } S_T = 90 \end{cases}$$

Thus, the portfolio replicates the payoff to the stock. In a perfect market its value must be equal to the stock price.

$$H_0:\ 90(.9434) + 2C_0 = 100$$
$$C_0 = \$7.55$$

Example 1a. Increase the current stock price to \$105.

$$X = \$100$$
$$S_o = \$105$$
$$r_F = .06$$
$$\tilde{S}_T = \begin{cases} \$110 & \Pr = .5 \\ \$90 & \Pr = .5 \end{cases}$$
$$H_o: 90B(O,T) + 2C_o = 105$$
$$C_o = \$10.05 > \$7.55$$

A 5% increase in the current stock price results in a 33% increase in the option premium. This illustrates the important principle that option premiums are more volatile than the price of the underlying stock, and therefore more risky to the investor.

Example 2. Create a risk-free portfolio using the stock and option.

$$X = \$100$$
$$S_o = \$100$$
$$r_F = .06$$
$$\tilde{S}_T = \begin{cases} \$110 & \Pr = .5 \\ \$90 & \Pr = .5 \end{cases}$$

Form a risk-free portfolio by holding a share of stock long and selling short two call options. A short position is created by "writing" an option.

$$H_o:\quad S_o - 2C_o$$
$$H_T \quad = \begin{cases} 110 - 2(10) = 90 & \text{if } S_T = \$100 \\ 90 - 0 = 90 & \text{if } S_T = \$90 \end{cases}$$

Therefore, H pays \$90 in each state of nature, and is a perfect substitute for 90 risk-free bonds.

$$H_o: 100 - 2C_o = 90B(O,T) = \$84.91$$
$$C_o = \$7.55$$

C_O is unchanged from Example 1, as should be the case.

Example 2 is significant because it illustrates the thinking behind the Black-Scholes formula, the most famous formula in financial economics. Black and Scholes (4) consider the problem of valuing a call option on a stock that does not pay a dividend, and is traded in a perfect market where trading

in the stock and option takes place in continuous time. They assume that stock prices follow a random walk with positive drift. Because the stock doesn't pay a dividend, and because the stock price tends to drift up over time, it is not rational to exercise an American call prior to expiration. Consequently, the American and European calls will trade at identical premiums. Under these assumptions, the Black-Scholes formula can be considered to value American and European call options.

A random walk with drift is represented mathematically as an Itô stochastic differential equation

$$dS = S_t \mu dt + S_t \sigma dz_t \tag{4}$$

where μ is the drift term, z_t is a Wiener-Levy process, and σ^2 is the variance of dS/S_t. Let subscripts on $C(S, t)$ denote partial derivatives with respect to the first and second arguments of the call premium. The risk-free hedge portfolio is formed by holding one share of stock long, and $1/C_1(S, t)$ call options short. Note that $1/C_1(S, t) > 1$. If the hedge is adjusted continuously in response to changes in the stock price, then, as in Example 2 above, the value of the hedge portfolio is independent of the stock price and will earn the risk-free rate of return. By equating the change in the value of the hedge portfolio over dt to the return on the risk-free bond over dt, Black and Scholes derive the following partial differential equation (PDE):

$$C_2(S,t) = r_F C(S,t) - r_F S\left(\frac{1}{C_1(S,t)}\right) - \sigma^2 S^2 C_{11}(S,t) \tag{5}$$

Under a suitable translation of variables, Eq. (5) reduces to the heat-transfer equation of physics. By imposing the appropriate boundary conditions and by making the reverse translation of variables in the solution of the heat-transfer PDE, one can write the call premium as

$$C(S,t) = SN(d_1) - Xe^{r_F(t-T)}N(d_2) \tag{6}$$

where $N(\ )$ is the normal CDF function, and

$$d_1 = \frac{\ln(S/X) + (r_F + \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}}$$
$$d_2 = d_1 - \sigma\sqrt{T-t}$$

Equation (6) is the Black–Scholes formula.

A key assumption in the Black–Scholes analysis is the proposition that stock returns are an independent, and identically distributed Gaussian stochastic process as specified in Eq. (4). Empirical evidence, such as that presented in Hinich and Patterson (5), suggests otherwise. The extent to which the violation of the independent Gaussian assumption can explain the observed discrepancies between Black–Scholes prices and observed call option premiums is not known.

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STORAGE, BUFFER. See BUFFER STORAGE.

STORAGE CIRCUITS. See BICMOS MEMORY CIRCUITS.

STORAGE, CONTENT-ADDRESSABLE. See CONTENT-ADDRESSABLE STORAGE.

STORAGE DEVICES, QUANTUM. See QUANTUM STORAGE DEVICES.

STORAGE, HOLOGRAPHIC. See HOLOGRAPHIC STORAGE.

STORAGE, INTERLEAVED. See INTERLEAVED STORAGE.

STORAGE, MAGNETIC. See MAGNETIC STORAGE MEDIA; MAGNETIC SWITCHING.

STORAGE MEDIUM. See DATA RECORDING.

STORAGE RING, SUPERCONDUCTING MAGNETS. See SUPERCONDUCTING MAGNETS FOR PARTICLE ACCELERATORS AND STORAGE RINGS.

STORAGE SYSTEMS, DIGITAL. See DIGITAL STORAGE.

STRAIN GAUGES. See STRAIN SENSORS.