

people can express their preferences only in terms of ordering among a set of things. If a person is given a choice between A and B, he can say:

1. he prefers A to B, or
2. he prefers B to A, or
3. he is indifferent between the two.

Given these expressions of individuals, the social choice model derives a market choice that optimizes the satisfaction of preferences of individual traders.

Constraint Logic Programming

CLP (Constraint Logic Programming) is employed as new information technology to structure and implement the trade match algorithms of IET. CLP is an extension of logic programming where unification (symbolic pattern matching) is replaced by constraint satisfaction. In CLP qualitative preferences are expressed as symbolic relations and are logically inferred to draw conclusions. On the other hand, a mathematical solver like the simplex method searches for market equilibrium using price and quantity. It should be

noted that satisfaction of qualitative preference is difficult to achieve after optimal transaction price and quantity are found. The qualitative preference should be satisfied while the economic model simultaneously maximizes the total exchanged volume. For this reason, the trade match algorithms of IET integrate both approaches in a dynamic way so that the logical inference approach for preference satisfaction can interweave with the mathematical computation for market equilibrium during the market process. The dynamic integration of logical inference and simplex method in CLP allows us to apply complex trade match rules in order to satisfy qualitative preferences, while the economic model simultaneously searches for market equilibrium.

Concluding Remarks

This study illustrates how an economic theory can be integrated with a social choice theory in order to improve the trade matches of commodity orders in electronic trading. We are currently developing a prototype of IET. We plan to do market simulations with the prototype in

order to validate its market performance. The IET system is a new form of market: it aims to create a new market microstructure for commodity exchanges. Thus this study is significant to trading system developers for commodity items such as cotton, grain, cattle, hogs, coffee, tea, and sugar. During the past decade, organizations in various industries have captured a significant portion of their markets through the strategic use of information technologies. The IET system enables organizations involved in commodity exchanges to increase their market share by applying information technology earlier than their competitors. ■

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How Financial Markets are Going On-line

Discussions of electronic securities markets in the 1970s revolved around the question of whether computers could support the processing requirements of modern, high-volume trading. In the 1980s, we asked when will screen-based markets replace traditional floor exchanges. The questions of whether and when have been answered. In the 1990s the question is who will be left behind.

Many industries today claim to be in the midst of an "Information Technology (IT) Revolution." Purchasing airline tickets, making hotel, or theater reserva-

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tions, and withdrawing cash from the bank after business hours are nearly certain to occur through on-line systems. Manufacturers and their suppliers are creating electronic links for ordering parts, maintaining inventories, and distributing design details for new products and components. Many of these initiatives began within the past 15 years as the price-performance characteristics of computers and telecommunications networks improved dramatically.

IT in Financial Markets

In financial markets, the IT Revolution began over 150 years ago. The telegraph, invented in 1838 by Morse and Vail, was quickly used to transmit prices between New York and Philadelphia and New Orleans, replacing horse and train

journeys, thus accelerating market news from a week to half a day. The Transatlantic cable, which in 1866 established telegraph communication between New York and London, affected pricing and changed trading practices in those cities' currency, stock, and bond markets [3]. Time lags of 20 days were reduced to minutes, and the average absolute price differences for identical securities traded in the two cities' markets dropped 69 percent from their previous levels. Thomas Edison's electromechanical stock ticker (1867), and Alexander Graham Bell's telephone (1876), were also rapidly adopted and enabled financial markets to extend their reach and importance in the economy. New York-based brokerage houses that established a presence in other parts of the country became known as "wirehouses" for their reliance on telegraph communications. IT will maintain its crucial role in supporting market activities: no trader today operates without real-time data services and computer-based analytical tools. Market information about prices, interest rates, transactions, investor supply and demand, and company and economic news is at the

heart of any trading operation. Consequently, the major international markets from Japan to Switzerland are making increased use of IT. While IT is capable of making the traditional trading floors obsolete and supporting 24-hour international markets, no consensus is emerging on the design of an integrated global financial market, and many technological and regulatory issues remain unsolved. Multiple, fragmented markets may be a consequence of the lack of coordination. Despite its long presence, IT's influence on financial markets themselves continues to be a subject of debate and controversy.

Financial Market Functions

Financial markets perform four functions in the economy:

1. Raising capital: Expanding into new markets, building roads and plants, and initiating the development of new products and services requires funding that often comes from issuing debt or equity securities.
2. Enabling wealth to be transferred across time periods: For instance, a new home buyer borrows money today to be repaid in the future, while those with net savings can invest or lend money today to provide themselves with greater wealth in the future.
3. Meeting the demand for resales that match investors wishing to sell with those wishing to buy. A purchaser of

bonds that will mature (i.e., are fully-paid off) in 30 years may not want to hold the security until the maturity date, and will often choose to sell at an intermediate time. Stock exchange and other financial markets match buyers and sellers and facilitate trading.

4. Providing for the 'discovery' of the prices at which trades should occur, and thus place values on assets and the companies that reflect their risk and their prospects for growth and profitability.

The Principal Financial Markets

Most traded instruments such as common stock or equity, bonds, notes and bills fall into one of several standard categories, and markets may differ depending on the timing of the asset's transfer. Often, a transaction occurs today for a financial instrument that the purchaser may not own for several months or years into the future. In cash or spot markets, ownership of the traded instrument is transferred immediately. Options contracts confer the right to buy or sell an asset or financial instrument at a specified strike price during the contract lifetime, which ends on the option's expiration date. In forward or futures markets, a price and a delivery date for the transfer of ownership sometime in the future are specified. Futures and options are called derivative securities because their prices are derived from the cash market price for the underlying asset. The derivatives markets are among the most rapidly growing financial markets. Volumes at the Chicago Board of Trade (CBOT) and the Chicago Mercantile Exchange (CME), the world's two largest futures markets, tripled between 1982 and 1992. Both exchanges are using IT to maintain their international dominant position.

Trading Technology

Automation serves a number of functions in financial markets, yet most markets are incompletely automated and retain some manual functions. The following market functions are amenable to automation:

1. *Order collection:* With IT, once an order is entered, details such as size, limit price, and time are accessible for an investor's control and measurement purposes, and for transmitting to a chosen market system.
2. *Order routing:* The DOT system (Designated Order Turnaround) was introduced in 1976 for order routing on the New York Stock Exchange (NYSE). It enables member firms to electronically route and limit orders from their offices to the specialist post on the market floor, bypassing the floor broker's booth.

In 1992, 78 percent of NYSE orders arrived via DOT. The remainder arrive via phones to floor traders' booths.

3. *Price determination:* This function is often supported by systems that aggregate the orders. The Arizona Stock Exchange (AZX) is a screen-based market for trading stocks after the close of the NYSE floor. It uses a single price call auction mechanism to find a price at which the quantity to buy equals the quantity to sell.
4. *Order execution and confirmation:* Reuters' Dealing 2000 system is an example where buy and sell orders in the foreign exchange market are matched electronically. Details of executed trades are transmitted back to the trade participants for confirmation. No more than several seconds elapse between order entry and final trade confirmation.
5. *Trade reporting and surveillance purposes:* In the case of a fraud or market manipulation, an audit trail of trades can speed investigations. An example is the StockWatch system at the NYSE.
6. *Broad dissemination of market information:* The Consolidated Tape System (CTS) was introduced in 1976, and imposed unified trade reporting rules, and facilitated ticker publication of last sale information occurring in any

action costs. Integration and international linkages can be achieved with systems that share information between markets and enable participants to pass their positions from one market to another. A number of markets including the CME and the Singapore International Monetary Exchange (SIMEX) have automated facilities for "mutual offset". With mutual offset, a position in one market can be used to offset the margin required in another market. For instance, a 15 contract long position acquired in Chicago in T-bond futures, which is offset by a short position of 10 contracts of the same instrument in Singapore, requires margin to be put up for just the net position of 5 contracts. Settlement efficiency is enhanced with systems. The number of questioned trades (QTs), don't knows (DKs), and fails drops when trading is automated and trade details are captured electronically, reducing costly exception processing. The data vendors such as Reuters and the exchanges themselves spend a large percentage of their operating budgets on technology for information retrieval and trading support. The NYSE spent a third of the 1990 budget of \$300 million and London's LIFFE devotes 35 percent of its operating budget to IT. The Securities and Exchange Commission (SEC), the industry regulator in the U.S., is currently phasing in its Electronic Data Gathering, Analysis and Re-

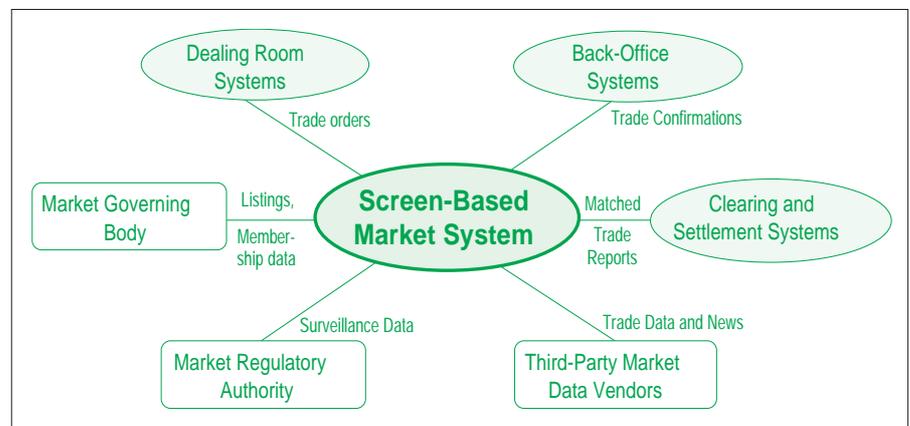


Figure 1: Representation of automated financial markets

of eight U.S. stock markets. Previously only NYSE and American Stock Exchange (AMEX) trades were reported on the ticker.

Benefits and Costs of IT

IT has many benefits in financial markets. First, visibility is increased, enabling investors to monitor the market, and to time the execution of their trading strategies. Systems provide the ability to handle increased volumes of business, and contribute valuable economies of scale. In automated markets, greater trading volumes lead to fractional increases in overall costs, and a lowering in per trans-

retrieval system (EDGAR) for on-line filing of public disclosure documents from corporations and investment managers. EDGAR will cost \$75 million, and by mid-1996 will replace paper filings which total 10 million pages per year from the 14,000 companies registered with the SEC.

Foreign Exchange

We now look at a few examples of on-line-markets. Today's most active and most automated global market is in foreign currencies. In 1992, daily turnover was estimated at close to \$1 trillion. Over a third of all FX trades today are executed on-line between market participants

spread across the globe. Table 1 shows the largest FX centers, but significant trading also occurs in Singapore (fourth, with \$80 billion traded daily in 1992), Zurich, Toronto, and Hong Kong. The FX

(\$ billion)	March 1986	April 1992	April 1992
London	90	187	303
New York	58	129	192
Tokyo	48	115	128
Total	196	431	623

Table 1: Daily FX trading volumes

market is dominated by the world's largest banks, most of which trade currencies 24 hours a day from technologically sophisticated dealing rooms in the major financial centers. There is no market floor for institutional spot market trading of currencies. The FX trader's desk contains an abundance of information systems and data feeds which together have an annual cost of \$30'000 to \$50'000. Four primary components are:

1. High-density phone system with speed-dialing, display keys for counterparties, and buttons for muting the phone and for multiparty conversations.
2. Real-time market data provided by third-party vendors such as Reuters and Telerate.
3. Computer-based analytics to chart prices, and analyze relationships among financial instruments and economic data.
4. On-line transaction processing system for data capture and transfer from one account to another via an electronic funds transfer system (such as CHIPS in the U.S.).

The 1973 introduction of the Reuters Monitor, which displays competing bank dealers' FX quotes, spurred the development of the FX market. About 177,000 Reuters terminals were installed around the globe in 1990. Each terminal can access 73'000 pages of continuously updated financial news and market prices. In 1981, Reuters introduced Dealing, an interactive dealing system that enables subscribers to negotiate and execute FX trades over their terminals. For the first terminal at a site, Monitor costs \$1'800 a month and Dealing is \$5'400. About 19,000 Dealing terminals existed in 1992.

London Stock Exchange

In 1985 the London Stock Exchange introduced SEAQ-International, a screen-based dealer market for the shares of foreign companies. In each stock, there are a number of dealers, or market makers, that provide bid quotes (price for buying shares from customers), and ask quotes (price for selling shares to customers). There is also an indication of the

number of shares the market maker is willing to commit to at those prices. For instance, 50~50 means 50'000 shares bid and 50'000 shares offered, and 1L means 100'000 shares. The inside quotes on the SEAQ screen represent the best bid and offer available in London. They are prominently displayed, double sized, in a yellow strip at the top of the screen for each stock. The intent is to give a rapid and accurate indication of the price at which the next trade in any share could be expected to occur. Once a trade is executed, the details of price and number of shares are transmitted to the Exchange which then publishes the stock's cumulative trading volume and the prices of the most recent transactions on the screen above the yellow strip. By negotiating over the phone, a trader can usually buy and sell in larger quantities than those shown, and market makers will often trade at prices different than those on the screen. SEAQ was modeled on the NASDAQ (National Association of Securities Dealers Automated Quotations) market in the US, which was introduced in 1971 as a screen display of trading prices for OTC stocks. NASDAQ and SEAQ enable dealers to be geographically dispersed. In fact, international SEAQ market makers (49 firms in January 1993) are located in cities like Paris or Frankfurt. Due to its location and its use of IT, London is the

(\$ billion)	1983	1987	1991	1992	1.Q. 1993
SEAQ International	nil	0.433	1.12	1.30	1.85
SEAQ Domestic	0.445	2.06	1.42	1.71	2.21

Table 2: Daily equities trading volumes in London

most global stock exchange today, listing about 760 non-UK stocks, compared with 121 foreign stocks traded on the NYSE. With SEAQ, the exchange succeeded in establishing an interactive market for trading of non-UK securities away from their home exchanges. The growth in trading volume on SEAQ International (see Table 2) has outpaced that of the UK domestic stock market in recent years.

Globex

Globex was initiated by Reuters and the CME with tremendous fanfare in September 1987. Under pressure from members that saw duplicate development as wasteful, the CBOT abandoned its competing Aurora project in March 1991, and joined Globex as a sponsor. Globex was developed at a cost of \$80 million, and opened in June 1992. It is not a 24-hour market, and only operates after the 2:30 P.M. close of the Chicago floor markets. Trading hours are 6:00 P.M. to 6:00 A.M., but plans exist to add a 2:30 P.M. to 4:00

P.M. session. In September 1993 Globex was handling 30,000 contracts a day via 385 linked terminals, up from 1,800 contracts daily in the month after the launch. Hence, Globex' activity is just 2% of the volume of the two Chicago floor markets.

Conclusions

This article surveyed some computer innovations that are transforming the financial market worldwide. Today's markets are increasingly based on screen price displays, and traders often operating from well-equipped dealing rooms, rather than physical trading floors. Further financial markets around the world are in the midst of a dramatic transformation. Regulatory and market barriers have fallen, and automation continues to restructure trading processes, lowering the costs of transacting and monitoring financial markets. Observers have declared "The End of Geography"[6] in financial markets, for location plays a greatly diminished role in investors' decisions. International market integration is occurring at a rapid pace, and globalization is no longer a buzzword; it has arrived.

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