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Automating the Price Discovery Process: Some International Comparisons and Regulatory Implications

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Abstract

Automated trade execution systems are examined with respect to the degree to which they automate the price discovery process. Seven levels of automation of price discovery are identified, and 47 systems are classified according to these criteria. Systems operating at various levels of automation are compared with respect to age, geographical location, and type of securities traded. Information provided to market participants, and asymmetries of information between traders with direct access to the automated market and outside investors also are examined. It is found, for example, that the degree of asymmetric information increases with the level of automation of price discovery. The potential for trading abuses related to prearranged trading, noncompetitive execution, and trading ahead of customers is analyzed for each level of automation. Certain levels of automation widen the opportunities for trading abuses in some respects, but may narrow them in others.

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Summary

Computerized trade execution systems automate the price discovery process by determining prices and quantity allocations. The systems operate according to a programmed set of rules that process bids, offers, and other information into market transactions. In practice, there is considerable diversity in the way this process works. Seven levels of automation of the price discovery process are considered in this paper: (1) passive pricing with prices obtained from another market; (2) use of price improvement rules; (3) negotiation capability, which dilutes the automation of the pricing process; (4) participation in trades by responding to quotes on a screen at the touch of a button; (5) automated continuous auctions supported by electronic limit order books; (6) periodic auctions in which all orders are executed at a single price determined by the system; and (7) automated auctions combined with securities pricing models.

On an international basis, 47 automated trade computerized financial markets are classified according to the degree to which they automate the price discovery process. Systems operating at each level are analyzed with respect to age, geographical location, and types of financial instruments traded. The age profile of system automation reveals some convergence to the continuous automated auction design; some persistent differences can be traced to the types of securities traded on these systems.

Differences in the degree of automation of price discovery are examined with respect to variations in the type of information provided to system traders and to asymmetries in information provided to participants with direct system access, compared with that provided to outside investors. It is found that the degree of asymmetric information generally grows as the level of automation increases, although automated systems have the capability of equalizing information to all participants.

The level of automation is proposed as a key factor in determining the potential for trading abuses. In particular, prearranged trading, noncompetitive execution of trades, and trading ahead by customers who do not have direct access to the automated market are examined within a framework that relates the level of automation to the potential for abuse. At some levels, notably in automated continuous auctions supported by electronic limit order books, possibilities for abuse may be wider than under conventional open outcry pit trading. It is argued that direct regulation of the form of the program governing trade execution is not desirable for some levels of automation, however, because such regulation could seriously hamper liquidity provision to the market. Overall, the level of system automation should affect the way in which regulatory authorities carry out their obligations.

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I. Introduction

Computerized trade execution is the final step in the automation of financial trading market operations. An automated market structure consists of a communications technology for passing messages between traders and a set of rules that restrict message types and govern the means by which a given set of messages translates into transactions. These rules are programmed into an automated trade execution algorithm, which determines transactions prices and quantity allocations.

Enabling this process of price discovery is a basic function of any trading market mechanism. Interest in the automation of the price discovery process is manifest in both the long list of computerized trade execution systems currently in operation and the degree of international regulatory activity surrounding the idea. Tables 1 and 2 contain information on 47 automated trade execution systems for futures and options, and stocks and bonds, respectively, operating as formal exchanges. 1/ At least five international organizations currently are addressing issues relating to the automation of the trade execution process. 2/

The most recent growth in automated execution is in futures and options markets, where 76 percent of the automated systems have come on line after 1987, or are soon to be operational. The vast majority of these newer automated futures and options markets are located in Europe or the Pacific region. In contrast, about 56 percent of stock systems were built prior to 1988, and the preponderance of these are in North America. Most automated systems operate during regular trading hours, although automation obviously has the potential to enable 24-hour trading. Only two stock systems and four futures/options systems operate during some portion of the night.

A complete discussion of automated trade execution systems involves order execution priority rules, the precise form of the trade matching algorithm, and a description of alternative information transmission and display mechanisms. 3/ The goal of this paper is more modest. The purpose here is to describe systems in terms of the degree to which they automate the price discovery process. Trade matching systems that use prices taken

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1/ This means that the market is regulated as an exchange in its domestic market. The definitions for such treatment vary from country to country. Excluded from the list presented here are proprietary systems, which are not registered as exchanges. Full names of systems listed in the tables and their associated exchanges are given in the appendix.

2/ Groups addressing such issues include the International Federation of Stock Exchanges, the International Organization for Standardization, the International Society of Securities Administrators, the Organization for Economic Cooperation and Development, and the International Organization of Securities Commissions. The last group has focused most clearly on issues surrounding automated trade execution, per se. See IOSCO, 1990.

3/ See Domowitz, 1992a for a typology of systems.

from another market for the purpose of executing transactions provide no automation of price discovery, for example. Other systems embody algorithms that compute transactions prices based on order flow and market conditions, completely endogenizing the discovery process.

Alternative means of automating price discovery raise questions about market efficiency, the degree of regulatory oversight required, and the nature of trade abuses possible within the automated market. For example, Glosten, 1991 shows that an automated continuous auction, operating under price and time priority rules with an electronic order book, dominates a traditional specialist market in the sense of revenue comparisons. The electronic exchange provides as much liquidity as possible, and eliminates the incentive for investors to break up trades into sequences of smaller transactions. The analysis in Domowitz and Wang, 1992 suggests that automated periodic markets that completely endogenize the price discovery process may exhibit lower price volatility and smaller spreads than an automated continuous market with an electronic book. Within a particular class of continuous automated markets, Domowitz, 1992b indicates that tradeoffs in market efficiency measures exist between systems limited to orders at the best price only and those that use electronic books that represent bids and offers at all possible prices. Even automated trade matching systems, which lack an automated price discovery mechanism, affect trader welfare and market liquidity. 1/

Seven levels of automation of the price discovery process are discussed in Section II of this paper. The classifications are not based on some notion of an idealized automated market structure; rather are based on the characteristics of systems already in existence or soon to be operational. The levels are designed to be mutually exclusive. As a consequence, an automated market structure may embody a combination of these levels of automation.

In Section III, world trading systems are analyzed and classified into the seven levels of automation of price discovery. The diversity of system design with respect to levels of automation leads to an examination of systems with respect to age, geographical location, and type of instruments traded. Some convergence of design over time is identified, and remaining differences are linked to instrument type and location.

The degree of automation of price discovery is then related to two types of informational differences between systems. The first concerns information available to system traders, such as the availability of order book data and the identity of traders. The second concerns asymmetries in information provided to participants with direct system access and that

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1/ See Domowitz, 1990a. Welfare of market makers and dealers is shown to suffer in automated systems lacking a price discovery mechanism, in which retail customer welfare is maximized. This is argued to have deleterious effects on the provision of liquidity to the market.

provided to outside investors. The degree of asymmetric information generally grows as the level of automation of price discovery increases, although automated systems have the capability of equalizing information flow to all participants.

The proposition that the level of automation of price discovery is a key factor in determining the potential for trading abuses is taken up in Section IV. Regulatory practices vary widely around the world, and it is not possible to provide an international comparison of system regulation in the same way as the price discovery comparisons. On the other hand, issues of prearranged trading, noncompetitive execution of trades, and trading ahead of customers who do not have direct access to the automated market are common across many jurisdictions. Each of these three problems is examined by relating the level of automation to the potential for abuse. It is found that the spirit of regulatory laws can be violated in these areas, despite adherence to specific language with respect to exposure of orders to the market. Possibilities for abuse may be wider in some dimensions than under conventional pit trading. Particularly important is the fact that regulation of the form of the trade execution algorithm may not be desirable in order to rule out noncompetitive trading, depending on the degree of automation of price discovery. The overall implication is that the level of system automation can affect the way in which regulatory authorities carry out their obligations.

II. Levels of Automation of Price Discovery

The potential for efficiently discharging the fundamental task of price discovery in financial markets by computerized systems has been formally recognized for almost 30 years, 1/ but there is considerable diversity in how this task is carried out. The purpose of this section is to characterize differences in automated systems by the degree of automation of the price discovery process. The following steps are based on the characteristics of the systems listed in Tables 1 and 2. They are ranked in order from the lowest degree of automation of price discovery to the highest.

1. Price taken from another market

The earliest systems perform trade matching based on time and order type priorities, with the transaction price determined from a floor or telephone market operating at the same time. There is no price discovery mechanism. Such systems typically provide automated execution for limited sizes of orders. For example, RAES operates in tandem with the options trading floor of the Chicago Board of Options Exchange. The crowd in the

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1/ See Special Study of Securities Markets, Report of the Special Study of the Securities and Exchange Commission, 1963, in H.R. Doc. No. 95, 88th Congress, 1st Session, pp. 358 and 678.

Table 1. Automated Futures and Options Exchanges

System (Exchange)	Date	Hours	Number of Securities/ Products	Country	Level of Automation
GLOBEX (CME)	1992	Night	100 (potential)	USA	4 5 7
ATS/2 (IFOX)	1989	Day	4	Ireland	5
FAST (LFOX)	1990	Day	4	UK	5
APT (LIFFE)	1989	Night	1	UK	4
ATS (NZFOE)	1985	Night	11	New Zealand	5
SYCOM (SFE)	1989	Night	5	Australia	4 5
FACTS (TIFFE)	1989	Day	4	Japan	5
AUTOM (PHLX)	1990	Day	37	USA	1
DTB (GFOE)	1990	Day	19	Germany	5
S-MART (MEFF)	1990	Day	2	Spain	5
MOFEX (MOFF)	1990	Day	2	Spain	5
SOFFEX (SOFFE)	1988	Day	14	Switzerland	4 5 3 (blocks)
CORES-F (TSE)	1988	Day	1	Japan	5
CORES-O (TSE)	1989	Day	1	Japan	5
SFTS (OSE)	1988	Day	2	Japan	5
OTS (OSE)	1989	Day	1	Japan	5
TGE (TGE)	1988	Day	6	Japan	6
RAES (CBOE)	1985	Day	180	USA	1
AUTO-EX (AMEX)	1985	Day	All equity options	USA	1
POETS (PSE)	1991	Day	Listed equity options	USA	1
SOM (SOM)	1985	Day	13	Sweden	5

Table 2. Automated Stock and Bond Exchanges

System (Exchange)	Date	Hours	Securities	Country	Level of Automation
SEATS (ASX)	1987	Day	All ASX listed stocks	Australia	5
CAC (Paris)	1986	Day	All stocks Most bonds	France	5 3 (blocks)
IBIS (FSE)	1991	Day	30 stocks 29 bonds	Germany	4 5
GTB (Milan)	1991	Day	Most stocks (phased in)	Italy	5
MORRE (ME)	1990	Day	All stocks	Quebec	1
SIB (SSE[1])	1991	Day	116 stocks	Spain	5
SAEF (LSE)	1989	Day	LSE listed stocks	UK	1
BEACON (BSE)	1987	Day	Stocks traded over ITS	USA	1'
NSTS (CSE)	1985	Day	425 stocks (2,700 capability)	USA	1' 4 5
MAX (MSE)	1981	Day	Exchange listed stocks	USA	1' 2
ABS (NYSE)	1976	Day	Bonds	USA	5
OHT (NYSE)	1991	Night	NYSE stocks	USA	1
SCOREX (PSE)	1969	Day	Listed stocks	USA	1'
PACE (PHLX)	1976	Day	Listed stocks	USA	1
SOES (NASD)	1985	Day	NASDAQ stocks	USA	1
CORES (TSE)	1982	Day	1,612 TSE stocks	Japan	5
STS (OSE)	1991	Day	1,009 OSE stocks	Japan	5
CLOB (SSE)	1987	Day	SSE, HK listed stocks	Singapore	5
CATS (TSE)	1977	Day	850 TSE stocks	Canada	5
HKTS (SEHK)	1993	Day	SEHK listed stocks	Hong Kong	5
ELECTRA (CSE)	1987	Day	2,000 bonds 275 stocks	Denmark	5
MATCHMAKER (VSE)	1988	Day	1,500 Stocks	Canada	5
MAX-OTC (MSE)	1987	Day	OTC stocks	USA	1'
SAX (SSM)	1989	Day	Listed stocks, bonds	Sweden	5
OLS (NYSE)	1986	Day	Odd lots for NYSE listedstocks	USA	1

[1] Spanish stock exchanges: Madrid, Barcelona, Bilbao, Valencia.

pit is trading continuously, and the best bid and offer outstanding on the floor at any given time are transmitted to RAES, providing prices at which system orders are executed. The NASD's SOES operates in a similar manner, with executions against the dealer providing the best quotes in SOES, but at the best bid or offer in the entire NASD market for the stock. Generally speaking, execution takes place against a limit order book or directly against a specialist, dealer, or market maker, often on a rotating basis. Some mechanisms of this type expose the incoming system order to the specialist or market maker for a few seconds, in order to allow the trader to improve the existing quote, if market conditions permit. This is a form of manual interference with the execution process, however. Such systems still must be considered as lacking an automated price discovery mechanism.

2. <u>Price from another market with a price improvement algorithm</u>

The manual exposure of orders to a market maker for price improvement can be automated. Some computerized systems execute trades based on a consolidated best bid or offer (CBO) from multiple markets. The guaranteed execution price of small orders is the best price from all markets, but the order may be transacted at an even better price, depending on the size of the bid-ask spread and market conditions.

The basic idea is illustrated here with the Midwest Stock Exchange's Enhanced SuperMax rules for market orders. Only the buy side is illustrated; sells are completely symmetric. A tick is the minimum price variation allowed, and primary market generally refers to the New York Stock Exchange.

(1) If execution at the CBO would not create a double up or down tick based on last sale in the primary market, the order is executed at the CBO.

(2) If execution at the CBO would create a double up or down tick based on last sale in the primary market, then stop the order.

(3) For stopped buy orders:

(a) if the next primary market (PM) sale is less than or equal to the last sale, execute at the last sale price;

(b) if the next PM sale represents a double down tick or zero minus tick from the last sale, fill the order at the last sale price plus 1/8;

(c) if the next PM sale price is greater than the last sale price, execute at the next PM sale price;

(d) if the next PM sale price is inferior to the stop price (the consolidated best offer), fill at the stop price.

For stopped orders, the idea is to compare the last sale price to the next sale price, and use the direction of the market to determine price. 1/ An order is never transacted at a price worse than the best bid or offer across markets, but may receive improved pricing based on trends in the primary market. The MSE's procedure represents a step up in the automation of price discovery, in that the computer assesses market conditions and prices the trade accordingly for execution against the specialist, dealer, or market maker. 2/

3. Some negotiation capability exists in the system

Negotiation capability between potential buyers and sellers can be provided in an otherwise fully automated system. Negotiation options generally are determined by order size in such cases, being reserved for large blocks of securities. In SOFFEX, for example, although there exists a special automated execution facility for priced blocks, it also is possible to advertise desired quantity without a price, inviting negotiation. Once a price is agreed upon, the block is electronically executed. This price, however, has an impact on executions from the regular limit order book, under the SOFFEX quantity priority rules for the participation of small orders in block trades. In particular, some portion of the block trade is matched against eligible orders in the limit order book, at the price of the block. In that sense, negotiation dilutes the degree of automation of the price discovery process even for orders which are executed without benefit of negotiation.

4. Direct removal of quotes from the trading screen

Direct removal of quotes refers to the capability of hitting a bid or lifting an offer shown to the market. In other words, a trader may participate in a trade advertised by an existing quotation on the screen and/or in a limit order book by touching a button. This action is not equivalent to a market order. A market order always is executed at some price, although not necessarily at the price outstanding at the time the order is submitted. Hitting a bid, for example, is the user-initiated way

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1/ It may not be obvious that the algorithm yields price improvement, but it must be remembered that improvement is relative to the existing quote at the time of the stop, not to an actual sale price. For example, suppose the market is 5 1/8-5 3/8, and the last sale was at 1/8. Consider the following cases: (a) The next sale is at 2/8. Then execution is at 2/8, which is better than the stop of 3/8; (b) The next sale is at 0. Execution is at 1/8, improving on 3/8; (c) The next sale is at 1/2. Execution is at 3/8, the stop price; (d) The next sale is at 4 7/8. This is a double down tick, and the execution is at the last sale plus 1/8, i.e., 2/8, which again improves on 3/8.

2/ The algorithm essentially is an automated version of the stop procedure used by the specialists on the NYSE. See the NYSE Floor Official Manual, June 1991, p. 16, for an explanation of stopping rules.

of entering a sell order at the current best bid price displayed at the time of order entry. Whether the order is completely or partially filled, or not filled at all, it is discarded from the system after initial processing. If two traders react to a bid on the screen by hitting a key, only the first to do so will receive execution. The order is not saved for execution at another price, as would be the case with the level 5 systems discussed below.

Different versions of the hit/take option exist. Some mechanisms limit the electronic keystroke to the best bid or offer, for example, for all or part of the size advertised at the best price. GLOBEX offers the alternative of submitting a sell price, say, indicating that the trader will sell all quantity offered at prices down to the price indicated. Such a variation is very similar to straight limit order submission, however.

5. Automated continuous double auction

In automated continuous double auction systems, bids and offers are submitted continuously over time. Transactions occur when the orders cross; i.e., when the price of the best offer to buy is equal to or greater than that of the best offer to sell. Price is determined endogenously within the system, based on order flow and a set of priority rules. These priority rules determine the place of an incoming bid or offer in the queue of orders. Priorities can be set in terms of price, time, quantity, order type, and trader classification, among others. Market orders are executed against quotes from the limit order book on many systems.

Given the endogeneity of the price discovery process, differences in automated auction design have implications for relative market efficiency and the need for market making operations on the system. Harris, 1990 links certain priority rules to the provision of liquidity, for example. A system that offers the option of hiding the size of a bid or offer may provide protection to individual traders, but precedence might be given to those who display size, thereby making a commitment to supply liquidity to the market. Time priority encourages liquidity by giving primary access to order flow to the most timely supplier of liquidity. 1/

6. Automated periodic single-price auction

Automated periodic single-price auctions are computerized forms of the clearing house auction discussed in Mendelson, 1982. Few markets are wholly organized around this design, but virtually all automated continuous double auction markets use the clearing house auction for the market opening. Bids and offers are submitted over some period and executed together at a single price at a single point in time. The price is calculated by minimizing the

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1/ It is interesting that not all automated auctions have a time priority rule. It is possible, for example, to impose price priority combined with a sharing rule for the participation in contraside order flow.

total bid/offer size imbalance and/or by maximizing the total volume traded over possible transactions prices. Execution priority rules still play some role in clearing house designs, because the discreteness of prices may prevent finding a price at which supply precisely equals demand.

Automated clearing house auctions are not simply periodic versions of the computerized continuous auction, however, and may have very different implications for liquidity supply and trading behavior. Price discovery is more automated in the sense that there is less human interaction with the price setting process. The single transaction price represents the effects of aggregate supply and demand from multiple orders. The limit order price in a periodic auction determines only whether the order is executed, while in a continuous setting, the limit price controls both the price received if execution occurs, and the likelihood of execution. 1/

7. Automated auction with pricing model

A system may produce trade matches based on criteria other than price. In particular, a volatility quote is an alternative means of quoting options, by bidding or offering the implied volatility of the underlying security. For the purpose of trade matching, a volatility quote is treated like any other price, and all the same rules apply with respect to execution in an automated auction system. Following execution, a price is determined from an option pricing model, using real-time capture of the price of the underlying security and interest rate, as well as time to expiration and the strike price, as additional inputs to the pricing algorithm. The price is used to calculate the amount due to the purchaser of the option contract, and is considered fungible with respect to options prices from standard price auctions for the purpose of clearing and settlement.

The motivation for this kind of auction stems from concerns over stale quotes in options markets, where the underlying price and interest rate may change too quickly for traders to adjust multiple quotes in an automated environment. Options trading decisions most often are based on volatility estimates, which change slowly relative to shifts in the price of the underlying security. GLOBEX has applied for permission to inaugurate volatility trading, noting that the method is similar to trading in the over-the-counter market in interbank currency options. 2/

1/ Harris, 1990 discusses the implications of such differences with respect to liquidity supply.

2/ See letter to Jean A. Webb, Commodity Futures Trading Commission, from Todd Petzel, Chicago Mercantile Exchange, dated 21 June, 1991, and Federal Register, Vol. 56, No. 147, 31 July, 1991.

III. Comparisons of Automated Trade Execution Mechanisms

Automated trade execution systems often embody some combination of these levels of automation. The last column of tables 1 and 2 contains a classification of systems with respect to the degree of automation of price discovery for futures/options and stock/bond systems, respectively. 1/ In the tables, 1' refers to level 1 combined with manual exposure to a market maker or specialist on the exchange. Such combinations account for 45 percent of all systems operating at level 1. There are several ways in which variations in the level of automation of price discovery might be compared. A breakdown by age, broad geographical location, and type of instrument traded is presented in Table 3, supplemented by data on information displayed to traders in systems characterized by various levels of automation. Each cell of the table contains the number of systems operating at a certain level of automation, for each system characteristic.

1. Differences by age, geographical location, and instrument type

The age profile of system automation suggests some convergence of mechanism design. Of the systems built prior to 1988, 42 percent lack a price discovery mechanism, corresponding to level 1, while 46 percent are constructed as automated double auctions. The latter design is the basis of about 60 percent of systems constructed in 1988 or later, while the number of new level 1 systems declined dramatically. There is a corresponding growth over time in systems embodying level 4, the hit/take keystroke, rising from 4 percent of systems prior to 1988 to over 17 percent thereafter. All but one of such automated markets combine levels 4 and 5, however. Every system operating as an exchange constructed after 1989 precludes negotiation, contributing to higher overall levels of automation of the price discovery process. In general, not only is the number of computerized markets growing over time, but the level of automation within this market structure is increasing as well.

There are some differences in the level of automation across systems for the trading of futures and options, as opposed to stock/bond systems. Only 15 percent of futures and options markets operate without a price discovery mechanism, in the sense of level 1. Over 37 percent of automated stock systems lack endogenous price discovery. Overall, stock/bond and futures/options markets exhibit roughly the same percentage of systems operating as automated auctions, but the alternative of direct removal of quotes from the market is far more prevalent in the futures and options markets. This may be due in part to the cultural differences in trading tradition between stocks and futures.

1/ As noted previously, automated continuous double auctions virtually all use the clearing house auction to open trading. This is omitted in the tabular descriptions, and only systems employing the clearing house auction as a primary means of trading are classified as such.

Table 3. Automation of Price Discovery by System Characteristics

	Level of Automation							Total
	1	2	3	4	5	6	7	
Pre-1988	10	1	1	1	11	0	0	24
1988-1989	1	0	1	3	9	1	0	15
1990-1993	4	0	0	2	10	0	1	17
North America	14	1	0	2	5	0	6	28
Europe	1	0	2	3	13	0	0	19
Pacific	0	0	0	1	12	1	0	14
Display	0	0	0	2	4	0	1	7
Book	2	0	1	3	14	0	1	21
BBO only	12	1	1	4	10	1	0	29
Quote ID	0	0	1	1	3	0	0	5
Stocks/Bonds	11	1	1	2	15	0	0	30
Futures/Options	4	0	1	4	15	1	1	26

Note: Each cell contains the number of systems operating at levels of automation 1-7, for each system characteristic.

These differences between instruments are not independent of time or geographical location, however. Most of the early stock systems were built in North America, and level 1 systems comprise fully 50 percent of automation in the United States and Canada. There are no such trade matching mechanisms in the Pacific region, defined to include Hong Kong, Japan, Singapore, Australia, and New Zealand. Only 5 percent of European systems lack some form of endogenous price discovery mechanism. Similarly, markets operating as automated auctions comprise only 18 percent of North American computerized markets, while 86 percent of Pacific, and 46 percent of European systems run at level 5. Many of these European systems are constructed for futures and options trading, corresponding to the overall growth in the global market for derivative securities, and are far newer than their North American counterparts.

2. Differences by information displayed to system traders

The remainder of Table 3 is devoted to tabulations of the level of price discovery automation by information provided to system users. The set of information considered here is not complete, but is relevant with respect to market efficiency and regulatory concerns. In the table, "book" refers to systems that show all or a significant part of the limit order book in real time, while "BBO" refers to systems displaying only the best bid and offer outstanding in the system, or, in the case of level 1 systems, in the corresponding floor or telephone market. 1/ A level of automation is positively associated with "Quote ID" if the corresponding system displays the identification of traders posting bids and offers. "Display" is an execution priority protocol. Some systems, such as GLOBEX and CATS, assign higher priority to bids and offers whose size is publicly displayed to the market than to orders that are submitted, but not shown to system participants. A level of automation is associated with "display" if a system operating at that level embodies such hidden size. It is possible, of course, for a system to allow hidden size without a lower priority being assigned to such an order. All systems examined here attach a special priority to orders not displayed to market participants, however.

Display precedence is most important in automated auction systems, especially those that show the entire electronic limit order book. Exhibition of the book offers a free option to the market by publicizing orders. Traders who do not want their orders displayed should be protected, but at a cost in terms of execution, given the desirability of providing all information to the market for the sake of market efficiency. 2/ The data

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1/ Globex, for example, is designed to show the best five bids and offers, with aggregate size at each price. Level 1 systems often have no independent information display of their own, but the best quotes in the corresponding floor or telephone market are available to traders through information vendors.

2/ See Harris, 1990 for a general discussion of display priorities, and Domowitz, 1992a for a classification of systems along this dimension.

only partially support this intuition, with roughly 57 percent of automated auction systems embodying hidden size. Several of these systems also operate at level 4, accounting for the number of mechanisms allowing direct removal of quotes in a system with display priority.

It is intuitively plausible that automated continuous auction systems would be more likely to show the book, and this is born out in the data. Over 65 percent of systems that show the book operate at level 5, while 10 percent of such systems lack a price discovery mechanism. Only 34 percent of mechanisms showing only the best bid and offer are constructed as automated auctions. It is interesting that the majority of these are automated futures and options markets.

Automated systems are anonymous for the most part, but there are exceptions, concentrated in the trading of stocks. Trader identification will play a role in the regulatory discussion of the next section, and it is pertinent to associate identification with the level of automation. Of the systems that do identify traders to the market, 75 percent are automated continuous auctions and most of the remainder operate under the protocol of direct removal of quotes. The SOFFEX block negotiation facility allows for identification in the sense that an advertisement to trade comprises a desired buy or sell quantity and identification of the advertising party.

3. Differences by degree of informational asymmetry

Substantial asymmetries between information provided to direct system participants and that given to outside investors who submit orders to traders or brokers on the system are documented in Domowitz, 1992a. 1/ The major differences are found in the provision of quotation and last sale information. Table 4 contains some data relating the types of asymmetric information to the level of automation of the price discovery process. Each cell in the table contains the number of systems operating at each level of automation, for which the order book, the BBO, the quantity available at the BBO, or the size of the last trade is revealed to system traders but not to the investing public. Data on information available to the public is not available for all systems in Tables 1 and 2, however. A total of 13 futures/options systems and 17 stock/bond systems are represented in Table 4. 2/

There are virtually no informational asymmetries associated with level 1 systems. Most such systems, as well as those operating at level 2, do not have system-provided price or quotation displays. Information taken from the associated floor or telephone market is transmitted to all market

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1/ It also is true that direct system participants receive unequal treatment with respect to information in some designs. These informational differences generally are limited to trader identification protocols, however.

2/ These systems are marked with an asterisk in the appendix.

Table 4. Price Discovery and Informational Asymmetry

Asymmetric Information	Level of Automation						
	1	2	3	4	5	6	7
Book	1	0	0	3	9	0	1
BBO	0	0	1	0	7	0	0
BBO Size	0	0	1	1	9	0	0
Size of last trade	0	0	0	2	3	0	1
Total Systems	13	0	2	5	13	0	1

Note: Each cell contains the number of systems operating at levels of automation 1-7, for which the information is provided to system traders, but not to outside investors submitting orders for execution on the system. The total figure is the number of systems operating at each level, for which this determination can be made.

participants, including outside investors, via quote vending services. Only NSTS has a system display which reveals book information to system users.

The vast majority of automated continuous auctions and systems allowing direct quote removal discriminate against the outside investor with respect to book information. In fact, 54 percent of automated auctions do not even offer the best bid and offer to the public, with an even higher percentage denying the public information with respect to the aggregate quantity available at the BBO. 1/ Although the price of the last transaction is universally reported, the size of the transaction is often disclosed only to direct system participants.

Complete transparency for continuous markets may be defined as the real-time dissemination of transactions prices and volumes as well as all bid and ask prices, with size. It appears that transparency by this metric declines as the level of automation increases, although there is no need for this to be the case. 2/ There are two ways to think about this assertion, the first relating to a comparison of different automated systems and the second pertaining to a comparison of automated markets with pit trading.

Within the class of automated systems, the claim that transparency to the public declines with the level of automation is directly supported by the data in Table 4. There are few asymmetries in levels 1 through 3. On the other hand, 3 of 5 systems at level 4, 9 of 13 systems at level 5, and 1 of 1 at level 7 discriminate with respect to the availability of book information. There is no discrimination with respect to the BBO at levels 1 through 4, but 7 of 13 systems operating at level 5 report the BBO to system traders in real time, but not to the public. A total of 9 of 13 level five systems also fail to provide the total size available at the best bid and offer to investors without direct access to the system.

With respect to a comparison of automation with pit trading, Sundel and Blake, 1991 note that there is no reason for participants with terminals to have a greater informational advantage over the public than they currently enjoy on the traditional trading floor. Computerized execution makes it

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1/ These include, for example, IBIS for stocks and SFTS for futures.

2/ It is certainly true that "openness" of the market, within regulatory tradition, does not mean that every participant must receive the same information. There are potential costs associated with full transparency, including increased market maker risk resulting in larger spreads. The evidence on such points from more traditional markets is not conclusive, however. For example, the Securities and Exchange Commission claims that transparency increases in the United States in both order driven and quote driven markets for major equities increased rather than decreased market liquidity. See Letter from Brandon Becker, Deputy Director, Securities and Exchange Commission to Shokichi Takagi, Directory, Secondary Market Division, Securities Bureau, Ministry of Finance, Japan, dated 29 July, 1991.

possible to achieve more informational symmetry than under the pit trading paradigm. Yet, automation of the price discovery process appears to be providing more information to system traders than typically available in the pits, while maintaining the status quo with respect to reporting to the public. 1/ For example, the Chicago Mercantile Exchange acknowledges that electronic book information allows traders to "see behind" the best quote to obtain a better idea of the depth of the market, while the floor provides information only with respect to the best quotes shouted out in the pit. 2/ To the extent that the book does provide more information, discrimination with respect to book access increases informational asymmetry. In fact, the issue goes a bit deeper. Off-floor exchange members currently are denied pit information, putting them on the same footing in this respect as the general public. In an automated environment, access to market information provided by the system is a function of membership status, not of location. All that is required is a computer terminal in the members' offices. Thus, information flow to exchange members is enhanced, while the public receives the same information as under traditional floor trading.

IV. Implications of the Level of Automation for Regulation

Technological innovation in market structure tends to lead, rather than follow, changes in regulatory law and practice. The literature on regulation of automated trade execution systems is small, but growing as a consequence. 3/ The characteristics of the trade execution algorithm, which govern the degree of automation of price discovery, can be important factors in determining the potential for trading abuses. As a result, the degree of automation influences the nature and level of regulatory oversight. Although regulatory issues vary widely across national boundaries, some themes are common to most jurisdictions. Three such areas of concern are discussed here: prearranged trading, noncompetitive execution

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1/ Sundel and Blake, 1991 make this point only with respect to the GLOBEX system. The data presented here suggests that the phenomenon is much more widespread.

2/ See Sundel and Blake, 1991, footnote 35, for a full text of the CME's statement and references.

3/ See Domowitz, 1990b, 1992b for discussion and economic analysis of United States regulatory law pertinent to the approval of the Globex system. (Sundel and Blake,1991) provide a lawyer's view of the same issue. A regulator's perspective on automation is supplied by (Ruder and Adkins,1990). Corcoran and Lawton, 1992 present an overview of the link between automation issues and degree of regulatory oversight. Domowitz, 1992c addresses international issues raised by the International Organization of Securities Commissions. Lee, 1992 discusses the legal definition of an exchange under both the U.S. and U.K. regulatory systems, in light of developments in automated market structure.

of trades, and trading ahead of customers who do not have direct access to the automated market.

1. Prearranged trading

A prearranged trade is a transaction stemming from an agreement between market participants to trade against each other without exposing their orders to the market. Discussion of prearrangements in automated systems must loosen this definition somewhat to include strategies that result in prearranged trades despite exposing the orders to the market in the sense of entering the order into the automated trading system.

Prearranged trading generally is considered harmful to the price discovery process. Although violation of time priority is the most common consequence, abuses related to prearrangements are potentially broader in scope. Prearrangements can be used to move money between accounts and to pay back trading favors. For example, an arrangement may be made to fill a particular order through an accommodating trader, who then reimburses through another prearranged trade. Kerb trading also is a form of prearrangement.

Prearrangements can be perfectly legal in systems lacking an endogenous price discovery mechanism. "Preferencing" is the practice of routing a customer's orders to a particular system participant by prior agreement. The market is protected from abuses commonly associated with prearranged trading by the requirement that preferenced orders must be executed at the best quote of any dealer or market maker, regardless of whether the preferenced dealer is offering the best price at the time. 1/ Preferencing also can be allowed on systems embodying automated price improvement, with the trade carried out at the price determined by the system. The practice of purchasing order flow is another form of preferencing, but it is not unique to automated systems. Although preferencing is a legal form of prearrangement in some automated markets, it does provide some individual disincentive with respect to aiding price discovery by the posting of better quotes. A dealer without substantial preferencing arrangements has less incentive to offer a better quote, since the order flow at his or her quote will go to a preferenced dealer. In this sense, preferencing creates a "free rider" problem with respect to price improvement. Proponents of such prearrangements argue, however, that preferencing provides one of the few ways in which dealers can establish and maintain a reputation for good executions in an otherwise anonymous market.

The anonymity of most systems makes prearranged trading difficult in the sense that counterparty selection is an important element of the process. Anonymity is not universal among automated auctions and

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1/ SOES, MAX-OTC, and SAEF all have this rule built into the system, for example. See Huang and Stoll, 1991 for a discussion of the advantages and disadvantages of preferencing arrangements.

level 4 systems, and is sacrificed in certain negotiation designs. The SOFFEX system exposes negotiated trades to the market, however, by allowing participation in the trade via the regular limit order facility. Although this is a step in the right direction, it does not necessarily rule out abuses associated with prearranged trading. Negotiated trades may still offer the ability to execute a series of transactions which appear competitive, but which involve no market risk to the accommodating trader or have no effect on the trader's net position. 1/ This statement is easily extended to systems which may not have negotiation features, but allow counterparty selection through the identification of traders quoting bids or offers.

In anonymous systems operating at levels 4, 5, and 7, prearrangements are virtually impossible as long as the market is sufficiently liquid. In order to obtain execution, two traders must each submit orders within the bid-ask spread, and there must be no matchable orders just entered into the system. A thin market allows prearranged trading, however, despite anonymity. For example, traders may simply satisfy the few outstanding bids or offers and then enter the orders they wish to cross. Signalling identity is not difficult in an illiquid market. Traders can agree to submit orders of a prearranged odd size in order to increase the probability of a cross.

It is thought that abuses associated with prearranged trading are effectively ruled out by adopting an automated single-price auction, as described under level 6. 2/ The comments above concerning thin markets still apply, however. Prearrangement strategy must simply be modified to enable manipulation of the clearing price. Such manipulation is easiest in systems which allow both submission and cancellation of orders up to the last moment. A rule permitting new submissions, but prohibiting cancellation of orders for a short period prior to the auction, would help to eliminate the possibilities for manipulation of the auction by two parties acting in consort. 3/

2. Noncompetitive trading

Noncompetitive trading is a failure to execute transactions openly and competitively during regular trading hours in such a way as to result in a price that accurately reflects existing market conditions. There are several ways in which this may occur, including taking the opposite side of a customer order for the trader's account, without properly giving other traders an opportunity to participate.

1/ Wash trades, for example.

2/ See, for example, Corcoran and Lawton, 1991.

3/ The automated opening in GLOBEX contains such a feature. Wunsch's SpaWorks, a propriety system now operating as the Arizona Stock Exchange, embodies cancellation penalties, but does allow both cancellations and submissions until the call.

Level 1 systems utilize time as the sole factor in determining order priority and are competitive only if the corresponding floor or telephone market offers market efficiency in the sense of price discovery. Regulatory attention in terms of noncompetitive trading should therefore continue to focus on the traditional market. The same cannot necessarily be said of level 2 systems, in which the price of the trade is determined by the computer, with order priority solely in terms of time. In this case, proper regulation requires a technical assessment of the computerized algorithm governing price discovery. Such an evaluation may take on several forms. On a very basic level, there is a purely mechanical concern with respect to whether or not an "approved" algorithm is implemented correctly. Simulation of the system under varying market conditions may yield information with respect to the pricing efficiency to be expected through the processing of orders through the pricing mechanism. Market efficiency also may be judged by comparing system-generated price improvement with that supplied by the specialist on the primary exchange. Under the hypothesis that specialist pricing does indeed reflect current market conditions, this is a test of the competitive nature of the automated pricing algorithm.

A trader cannot engineer a noncompetitive trade in the sense of failing to expose orders to the market in systems operating under levels 4 through 7, and in systems allowing negotiation constrained by order exposure post-negotiation. It is possible, however, to interfere with a fair cross of orders in levels 4, 5, and 7. For example, a trader could immediately enter a personal order on the opposite side of the market, at a price enabling a match with a customer order submitted only a moment previously. Success depends on the degree of liquidity in the market, i.e., on the lack of other matchable orders on the contra side of the customer order. Level 4 systems would allow the trader to instantaneously pick off the customer order.

The design of the system could be forced to exclude the type of trader interference described above. The programming of the execution algorithm might prohibit a trader from hitting an order entered by the same trader. Regulating the design of the algorithm in such fashion can have undesirable consequences for market liquidity, however. For example, the execution algorithm can be programmed in such a way as to prevent a trader from entering orders on both sides of the market within a specified period of time. This rules out some forms of noncompetitive execution with respect to customer orders, but prevents efficient market making or scalping operations. Thus, direct regulation of system design may not be sufficient to solve the problem. Although technical assessment of the price discovery

process remains important for automated systems, oversight may be required on a continuous basis, rather than a one-time approval of the system itself. 1/

3. Trading ahead of a customer

Trading ahead is the practice of trading as a principal on the same side of the market for which a customer order is received, before execution of the customer order. Trading ahead is the abuse most associated with dual trading.

Trading ahead is not of much interest in the regulation of systems operating at levels 1 and 2, except to the extent that manual intervention on the part of a market maker is allowed. 2/ No new regulatory problems arise in this case.

Negotiation capability for block trades poses potential problems with respect to trading ahead if dual trading is allowed. In this case, the trader need not even place a personal order in the system before a customer's block order. An advertisement to trade the customer's block can be either preceded or immediately followed by the placement of a personal order in the regular limit order book on the same side of the market. The time element involved in negotiated trades may make such actions feasible.

Automated systems operating at levels 4, 5 and 7 present a substantially different challenge with respect to oversight of trading ahead. On the traditional trading floor, a trader typically cannot personally trade a different security without moving to another pit, or at least to another spatially distinct spot on the floor. In contrast, some automated futures systems allow trading on the corresponding options from the same terminal, and all stock systems permit virtually simultaneous transactions in a broad listing of equity issues. This creates many more opportunities for trading ahead on an automated system, relative to existing floor trading practice. A trader holding a customer order to buy a large amount of futures contracts can expect that the value of call options on that future will rise along with the futures price. Trading ahead now can be accomplished by submitting a personal order to buy the call options ahead

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1/ This approach was adopted in approving the GLOBEX system, for example. Rule 531 of the Chicago Mercantile Exchange dictates that a GLOBEX terminal operator must wait for "a reasonable period of time" before entering an order on the opposite side of the market, after entering a customer order. The CFTC did not require programming the algorithm to prevent noncompetitive trading abuses.

2/ This statement ignores the fact that a lack of written order tickets may allow a terminal operator to delay the entry of a customer order until a personal order is entered, without much risk of detection. Abuses of this type, associated with terminal operator freedoms and access, constitute the focus of the regulatory discussion in Sundel and Blake, 1991. See also Corcoran and Lawton,1992.

of the customer's buy order for the futures contracts. Similarly, it is common knowledge that some stocks and commodities are closely related with respect to the direction of their price movements. Trading ahead may be enabled by prior placement of personal orders in the different, but price-related commodity, from a single terminal location.

4. More or less regulation for automated markets?

In the United States, "the public interest" is defined in terms of reliable price discovery and broadbased information dissemination, and the Commodities Exchange Act states that any market must show that its activities are not contrary to the public interest. 1/ In the case of automated markets, this calls attention to the programmed mechanism that generates prices based on market information and messages between traders, as well as to the asymmetries of information examined in section III.3.

The point of the discussion above is not that more regulation is needed to achieve the desired goal of reliable price discovery; rather a shift in focus of regulatory oversight and the way in which this end is achieved is required in the case of automated markets. Differences in the level of automation of the price discovery process create alternative tradeoffs and dictate a varied approach to the problem. The potential restrictions on liquidity supply by direct regulation through the form of the execution algorithm itself constitute one example.

A corollary to this statement is that the regulatory framework historically used for floor trading is not necessarily suitable for automated exchanges, given the vast gap between the two forms of trading institutions. For example, mere computerization of the information available from the system and adoption of the same procedures used to monitor floor trading, albeit with better information, should be questioned. Computerized trade execution certainly makes possible more precise audit trails than previously available. On an intuitive level, many of the problems examined above can be handled through this superior audit capability. Surveillance programs for automated systems require special programming to handle detection of many of the potential abuses discussed previously. The most obvious example concerns the possibility of trading ahead by using orders in a different, but highly related, instrument. It is notable that the CME originally did not write its surveillance protocols to detect trading ahead on the GLOBEX system, when the abuse involved both futures and options. 2/ Regulators must, therefore, also oversee and approve the form of surveillance programs specialized to computerized systems, in addition to formulating policies with respect to the oversight of the automated trade execution algorithm itself. This would appear to be true for all levels of automation discussed in this paper.

1/ See Sections 3 and 5(g) of the Commodities Exchange Act.

2/ See letter to John Lawton, Commodity Futures Trading Commission, from Eileen T. Flaherty, Chicago Mercantile Exchange, dated 17 July, 1989.

V. Concluding Remarks

Although this paper presents an international comparison of automated market structures, nothing has been said about international trading activity. Automated exchanges do enable trading in foreign securities, especially in the futures and options markets. The APT system, for example, is used for the trading of Japanese, U.S., and German government bond futures, in addition to domestic financial contracts. Sweden's SOM handles German stock index futures and options. U.S. Treasury bond futures are traded in Japan on CORES-F.

Yet, despite the global proliferation of automated trade execution systems, they are not yet leading a movement towards globalization of trading activity. In fact, only two automated stock systems operating as exchanges and three futures/options systems allow for cross-border trading. 1/ Although there are no real technological barriers, technology costs can be very high. For example, to maintain a dedicated circuit from New York to Tokyo can involve from 5 to 7 telecommunications companies. 2/ Maintaining equality with respect to access and response times across large distances, while keeping total response time short, also can be costly in terms of development effort.

A strategic factor limiting automated cross-border trading is one of liquidity. Even within any given country, competition between exchanges and over the form of the trading institution is focused on accessibility, instruments traded, fee schedules, and best execution, a catch-all which covers speed of execution, reporting, and pricing. It is not unreasonable to expect that new financial market structures must first win the competitive battle with respect to liquidity on their home turf. OM International, which markets the SOM system on an international scale, indeed has adopted this view as part of its overall strategic outlook. The idea behind OM's business is to establish a set of locally feasible automated markets, followed by international linkages to further increase liquidity.

1/ These include GLOBEX, FAST, and SOM for futures and options, and IBIS and BEACON for stocks. IBIS maintains only a single terminal in London, however, and the BEACON link is limited to Montreal. DTB is planning cross-border trading, particularly with respect to France and Switzerland. Even simple international order routing linkages have often been unsuccessful, however. The Australian options link with Montreal, Vancouver, and the European Options Exchange in the Netherlands was discontinued in February, 1991. The automated trading link between the American Stock Exchange and the Toronto Stock Exchange survived only from September, 1985, to October, 1988.

2/ See Office of Technology Assessment, 1990.

The larger impediments to automated trading markets and their global interaction are those of regulation and accepted standards. Basic technical standards obviously are required for financial communications. Technical details as to how automation of the trade execution process should occur globally, and the minimum level of technology to be used by all participants, can be just as vital. Finally, procedural standards relating to the actual method of trade matching, as well as to post-trade clearance and settlement links with automated systems, may be the most important and least understood of all.

SYSTEM ACRONYMS

ABS*	Automated Bond System
APT	Automated Pit Trading
ATS	Automated Trading System
ATS/2	Automated Trading System, updated
AUTO-EX*	Automated Exchange
AUTOM*	Automated Options Market System
BEACON*	BSE Automated Communications and Order Routing Network
CAC*	Cotation Assistee en Continu
CATS*	Computerized Automated Trading System
CLOB	Consolidated Limit Order Book
CORES*	Computerized Order Routing and Execution System
CORES-F*	CORES for futures
CORES-O*	CORES for options
DTB	Deutsche Terminborse
ELECTRA	name, no acronym
FACTS	Fully Automated Computerized Trading System
FAST	Fully Automated Securities Trading System
GLOBEX*	Global Exchange
GTB*	Generale Telematico di Borsa
HKTS	Hong Kong Trading System
IBIS*	Integrated Trading and Information System
INSTINET	Institutional Trading Network
MATCHMAKER	name, no acronym
MAX*	Midwest Automated Execution System
MAX-OTC	MAX for over the counter stocks
MOFEX*	Mercado de Opciones y Futuros Financieros
MORRE*	Montreal Registered Representative System
NSTS*	National Securities Trading System
OHT*	Off Hours Trading
OLS	Odd Lot System
OTS*	Options Trading System
PACE*	PHLX Automated Communications and Execution
POETS*	Pacific Options Exchange Trading System
RAES*	Retail Automated Execution System
SAEF	SEAQ Automated Execution Facility
SAX	Stockholm Automated Exchange
SCOREX*	Securities Communication Order Routing and Execution System
SEATS*	Stock Exchange Automated Trading System
SFTS*	Stock Futures Trading System
SIB*	Sistema de Interconexion Bursatil
S-MART*	Securities Market
SOES*	Small Order Execution System
SOFFEX*	Swiss Options and Futures Exchange
SOM	Stockholm Options Market
STS*	Securities Trading System
SYCOM*	Sydney Computerized Overnight Market
TGE	Tokyo Grain Exchange

EXCHANGE ABBREVIATIONS

AMEX	American Stock Exchange
ASX	Australian Stock Exchange
BSE	Boston Stock Exchange
CBOE	Chicago Board Options Exchange
CME	Chicago Mercantile Exchange
CSE	Cincinnati Stock Exchange
CSE	Copenhagen Stock Exchange
FSE	Frankfurt Stock Exchange
GFOE	German Futures and Options Exchange
IFOX	Irish Futures and Options Exchange
LFOX	London Futures and Options Exchange
LIFFE	London Intern'l Financial Futures Exchange
LSE	London Stock Exchange
ME	Montreal Exchange
MEFF	Mercado Espanol De Futuros Financieros
MOFF	Mercado de Opciones Y Futuros Financieros
MSE	Midwest Stock Exchange
MSE	Milan Stock Exchange
NASD	National Association of Securities Dealers
NYSE	New York Stock Exchange
NZFOE	New Zealand Futures and Options Exchange
OSE	Osaka Securities Exchange
PHLX	Philadelphia Exchange
PSE	Pacific Stock Exchange
PSE	Paris Stock Exchange
SEHK	Stock Exchange of Hong Kong
SFE	Sydney Futures Exchange
SOFFE	Swiss Options and Financial Futures
SOM	Stockholm Options Market
SSE	Singapore Stock Exchange
SSE	Spanish Stock Exchanges
SSM	Stockholm Stock Market
TGE	Tokyo Grain Exchange
TIFFE	Tokyo Intern'l Financial Futures Exchange
TSE	Tokyo Stock Exchange
TSE	Toronto Stock Exchange
VSE	Vancouver Stock Exchange

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