Equally Open and Competitive: Regulatory Approval of Automated Trade Execution in the Futures Markets

Ian Domowitz

1. INTRODUCTION

Regulatory concern continues over the adoption of automated trade execution mechanisms. While lauding the potential of automated trade execution systems to better control and prevent trade practice abuses, the General Accounting Office (GAO) warns that technical reviews of such systems must be conducted to ensure that the risks associated with the replacement of traditional open outcry auction methods by automated systems do not diminish an exchange's competitiveness and efficiency [GAO (1986b)]. On an international level, the International Organization of Securities Commissions calls for assessments of the algorithmic design and pricing properties of automated derivatives markets as part of their principles for regulatory oversight of such markets [IOSCO, (1990)].

The purpose of this article is to conduct one such technical review, which is particularly pertinent with respect to the legal and economic difficulties inherent in defining a futures market within a computer. The problem is that open outcry floor trading is so entrenched as to have found a place within the language and provisions of domestic regulatory law. While the 1975 amendments to the Securities and Exchange Act effectively gave the Securities and Exchange Commission the "power to classify markets . . . in any manner it deems necessary or appropriate in the public interest,"[1] the CFTC is forced to judge new market mechanisms with respect to the competitiveness of open outcry auction.[2]

Financial support from the National Science Foundation, the Center for Urban Affairs and Policy Research, Northwestern University, and the Center for the Study of Futures Markets, Columbia University is gratefully acknowledged. Jianxin Wang provided excellent research assistance. Two anonymous referees and the editor of this journal provided extremely helpful comments and suggestions.

[1]Senate Report No. 75, 94th Congress, 1st Session, at 7 (1975).

[2]It is interesting to note the rationale behind the dismissal of all charges against 19 Chicago Board of Trade members by Commodity Futures Trading Commission administrative law judge George Painter on 10/19/90. In judging trading fraud, he concluded that "the trading which occurred is the best that could be expected in light of the archaic trading methodologies still prevalent in the pits today." He further noted that "[technological advances in the futures industry] stop at the pit's edge. Trading continues to be done by open outcry, hand signals, grunts and groans." See *The Wall Street Journal,* Monday 22 October, 1990, p. 1.

Ian Domowitz is a Professor of Economics at Northwestern University.

The Journal of Futures Markets, Vol. 13, No. 1, 93–113 (1993)
© 1993 by John Wiley & Sons, Inc.
CCC 0270-7314/93/010093-21

One such new market design is examined in detail in this study, namely, the Globex futures trading system of the Chicago Mercantile Exchange (CME). Globex is an automated system for trading futures and options outside regular floor trading hours in Chicago. This system is of interest for several reasons. The global scope of its operation is potentially large. The system operates in consort with a group of exchanges around the world. Reuters is a partner in the project, and currently has offices in 170 cities as well as information terminals active in 118 countries. Globex provides a precise laboratory for analysis of automated market mechanisms, as opposed to an academic description of an "ideal" system of some kind. Although there are some differences in how such automated systems operate in other countries and across financial instruments, the price and time priority structure of Globex is basic to many of these market designs, and is, therefore, of general interest.[3] Finally, the CFTC approved Globex in February, 1989, including a detailed review of the CME's requested rule changes for the system by the Division of Markets. The GAO noted, however, that the CFTC did not provide a detailed technical assessment of the system with respect to the proposed exchange's competitiveness and pricing efficiency [GAO, (1989b)]. Such an evaluation is a central point of this study.

The institutional design of any transactions system affects market performance, generally measured with respect to the norm of a perfectly competitive market, e.g., the Pareto optimality of equilibrium outcomes. The complexity of implementable automated trade execution systems precludes a rigorous mathematical demonstration of efficiency or competitiveness along such lines.[4] Much research into the efficiency properties of open outcry auction has been conducted in experimental settings, involving either humans [e.g., Plott (1982)] or computerized inputs to the auction mechanism [e.g., Gode and Sunder (1990)]. The objective behind such laboratory experiments is to create a manageable microeconomic situation in which sufficient control can be maintained to gain accurate measurements of the phenomenon under study [Wilde (1980)]. Computerized simulations are developed in this article that are designed to accomplish this objective. Several measures of market competitiveness and efficiency are offered.

The classical benchmark is Walrasian clearing, and the standard is Pareto optimality. In the context of the environments examined here, a system attains a Pareto optimal allocation if and only if total trader surplus is maximized [e.g., Plott and Smith (1978)]. Other concerns such as liquidity, volatility, and the size of the bid–ask spread are important also in the consideration of market design and performance. Measures are developed in this article to provide some guidance with respect to such concerns.

The regulatory criteria examined in this article are described in the next section. Section 3 contains a description of the subset of Globex rules that is relevant to this study. Rules of open outcry pit trading used to construct the experiments are given there as well. The experimental design is described in section 4, and the main results relating to efficiency and competitiveness of the two trading institutions are contained in section 5.

2. FROM THE TRADING PIT INTO THE COMPUTER: SOME REGULATORY ISSUES

Pricing efficiency in the market is linked to the physical characteristics and locale of the market, the mode of trading, and some definition of effective competition. The first aspect

[3]See Domowitz (1992a) for a description of alternative futures market designs and comparisons with automated stock and bond exchanges.

[4]Satisfactory theory does not even exist for strategic floor trading in the context of continuous open auctions. Friedman (1984) provides an excellent discussion of the problems involved.

concerns a comparison between a floor or pit where traders can meet face to face and a market within a central computer facility accessed by possibly anonymous traders sitting at computer terminals in disparate geographical locations. The second issue relates to a regulatory requirement that prices be set via the open outcry auction system. This system is replaced by the algorithm programmed to generate transactions given a set of bids and offers sent to the central computer. The third aspect involves the basic economic notion that free competition yields the best possible pricing within any market. The Commodity Exchange Act treats each one explicitly.

The focus of this article is on a particular part of the legislation, namely the CFTC's Regulation 1.38, which states that

> All purchases and sales of any commodity for future delivery, and of any commodity option . . . shall be executed openly and competitively by open outcry or posting of bids and offers or by other equally open and competitive methods in the trading pit or ring or similar place provided by the contract market.

With respect to "the similar place," there is no further guidance. Other sections of the Commodity Exchange Act, however, refer to Congressional expectations that trading will take place on a centralized "floor" but leave the precise nature of the floor open.[5] It has been argued that the physical trading floor is such an important element of a healthy futures market that its replacement alone could destroy the market.[6] The existence of several operational futures markets without trading floors is the counterargument. A Senate Report contains an interpretation of the purpose of Regulation 1.38 in regard to the trading location requirement, namely, that "all trades are focused into the centralized marketplace to participate in the competitive determination of the price of futures contracts."[7] A centralized marketplace can easily be conceptualized as a facility in which all relevant market information is available and which can be accessed by qualified market professionals on an equal basis. A computer qualifies as well as a physical pit under the law.[8]

The phrase in Regulation 1.38 concerning "equally open . . . methods" focuses attention on the information content of trading and links this to open outcry methods. Posting is deemed an acceptable "open" method. The CFTC defines posting as

> . . . the practice of displaying a prevailing bid or offer which, while posted on a blackboard, is subject to execution should the necessary buying or selling interest develop in the contract.[9]

Blackboard trading has been almost completely replaced mostly by pit trading in the futures industry, but the practice still prevails for contracts in which volume is low. Traders announce bids and offers to an exchange clerk. The clerk writes the price, quantity, and contract month on a blackboard, along with the trader's initials. The highest bid and the lowest offer have priority with respect to execution. If ties occur, orders are executed in the sequence in which they were posted. Trades are executed at the price of

[5]See Section 2 of the Act, for example, which specifies the definition of floor brokers and their meeting place for the purpose of trading.

[6]See Melamed (1977) for such an argument. An excellent example of debates on the topic, both for and against, can be found in the recorded transcript (as opposed to the written *Proceedings*) of the Conference on Automation in the Futures Industry, June 15, 1977, on file at the offices of the CFTC.

[7]Senate Report No. 93-1131, 93rd Congress, 2nd Session, at 16 (1974).

[8]Counterarguments to this statement must rely on the relation of the physical facility to the actual mode of trading or the competitive process itself. See Domowitz (1990b) for a detailed discussion of such possibilities.

[9]See 46 *Federal Register* 23519, April of 1981.

the posted order in cases where the best bid is higher than the best offer. Transactions are recorded on a separate blackboard in chronological order. This record includes the time of the trade, price, size, and the initials of the executing floor brokers.

This procedure is replicated by the Globex system, with one exception. The Globex system does not identify the trader.[10] The display of the ten best bids and offers with associated quantities at each price provides more information than formally available in the pit. On the floor only the best bid and offer, with size, is collected and posted by clerks. In this sense, Globex is more open than floor trading. On the other hand, the disparity between information available to system traders and that given to retail customers is greater than that under floor trading.[11]

Some trade abuses which affect the "openness" of the market should be easier to control with automated trade execution systems. Trading activity on an automated trade execution system can be recorded to the nearest hundredth of a second, providing a near perfect audit trail. Investigators should be able to more easily identify trading relationships and ferret out trade practice abuses. The GAO (1989a, b) supports this view. "Kerb trading," the practice of trading after official exchange closings, impossible because the automated system does not allow trades to occur outside set periods. Officials of the CME and foreign futures exchanges also suggest that trading abuses within the open outcry auction process often include cases in which trades are executed in a noncompetitive fashion, and cases where customers receive worse prices than the existing best bid and offer [GAO (1989b, 1990)]. Noncompetitive execution (cross trading and bucketing) are not possible under rules such as those of Globex.[12]

Although issues of location and openness of information seem settled, the problem of "equally competitive" relative to open outcry auction remains. Section 15 of the Commodity Exchange Act directs the CFTC to "endeavor to take the least anticompetitive means of achieving the objectives of this Act . . . in approving any bylaw, rule, or regulation of a contract market." The Commission has disapproved a proposed type of trading session on the grounds that "decreased competition may impair the effectiveness and efficiency of the price discovery process and the ability of the market accurately to reflect the forces of supply and demand."[13] This type of phrase is loaded with terms that demand precise definition. In particular, any comparison of two market designs requires quantifiable benchmarks for the notions of competition and efficiency. Such measures are discussed later in section 5. The following section contains an algorithmic description of Globex and compares it to the open outcry auction system.

3. INSTITUTIONAL DESIGN: GLOBEX AND FLOOR TRADING

Globex is a strict price and time priority mechanism. Trades take place at the price of orders standing on the electronic order book. This guarantees that all new orders are

[10]At the time of CFTC approval, the Globex system called for closed book system; i.e., only the best bid and offer outstanding and the quantity available at those prices were to be displayed. This appeared to contravene CME Rule 522, which sets out minimum standards for posting design, and calls for the exhibition of all outstanding bids and offers, with size. See Domowitz (1990b) for discussion of the regulatory problems of closed book systems.

[11]Participants without a terminal, e.g., retail customers, receive the price and quantity of the best bid and offer and last executed transaction for each instrument traded. They do not see the book. See Domowitz (1992a) for evidence on such informational asymmetries across systems on a global basis.

[12]On the other hand, neither the open outcry auction system nor an automated trade execution system is proof against collusive arrangements by brokers prior to the entry of bids and offers into the system.

[13]See 46 *Federal Register* 23516, April 27, 1981, in reference to the Commodity Exchange, Inc., proposed straddle session.

filled at the best available price at the time of order entry. Only limit orders are accepted. A buy and sell order may be matched if they are for the same instrument and order prices are compatible. Orders are traded up to their maximum potential by completely filling the order on one side (buy or sell). At the conclusion of the matching process, there is no additional trade potential. The following formalization of the trade matching algorithm is taken from Domowitz (1990a):

1. *Order Eligibility*

   A new order is eligible to be matched with a standing order and a trade will result whenever the following conditions occur:

   1.1. One order is a buy order and the other is a sell order.
   1.2. The two orders are for the same contract.
   1.3. The price of the buy order is greater than or equal to the price of the sell order.

2. *Transaction Price Determination*

   If an order match is possible according to the criteria of Rule 1, then the trade will take place at the price of the standing order.

3. *Trade Quantity*

   If an order match is possible according to Rule 1, then the trade will take place for a quantity equal to the smaller of:

   3.1. The remaining quantity of the new order.
   3.2. The remaining quantity of the standing order.

4. *Market Exposure*

   If there are multiple standing orders eligible for matching against a new order, then matching will be considered in priority sequence until one of the following conditions is attained:

   4.1. The new order is completely filled.
   4.2. All eligible standing orders have been considered.

5. *Standing Order Priority*

   5.1. Price: for buy orders, higher price is higher priority; for sell orders, lower price is higher priority.
   5.2. Time: Within the same price and quantity type, older orders have higher priority.

There also is a display priority rule, but the details are not relevant to the work reported here.[14] Similarly, there are special rules governing the setting of an opening price in the Globex system and pertaining to the changing or placing of an order "on hold." The latter concerns time priorities and also is not relevant, except to the extent that cancellation is allowed. An order can be canceled at any time during the trading session. The resubmission of such an order is treated as a new bid or offer with respect

[14]Display priority assigns a special place in the queue of orders to bids and offers submitted to the system, but not shown to market participants. See Domowitz (1990a) for examples in the context of the Globex system. Harris (1990) and Domowitz (1992a, 1992b) contain a general description and discussion of display priorities.

to time priority. Analysis of the opening is quite a separate problem from that considered in this article; see, for example, Cohen and Schwartz (1989) and Stoll (1990). Explicit instructions to attempt to hit a bid or lift an offer also are accepted, but not modeled here.

An example may help to clarify the details of the matching algorithm. Consider the following sets of bids and offers for one specific contract:

Time	Bid	Bid Quantity	Offer	Offer Quantity
11:00	58.86	5		
11:01			59.70	2
11:02	58.87	1		
11:03			59.18	6
11:04			59.18	5
11:05	59.19	10		

At 11:02 there are five contracts bid at 58.86, one at 58.87, and two offered at 59.70. No trades take place because the bids and offer do not cross. The bid of 58.86 remains on the book, although there exists a better one. The spread is 0.84. Two offers are sequentially entered at 59.18 for six and five contracts; the offer of six contracts arrives first. These trades are recorded for the purpose of the example at times 11:03 and 11:04, respectively, but these bids could have been made virtually simultaneously, with the time between them being a fraction of a second. Computers in general, and Globex in particular, do not allow ties in terms of time and fractions of a second have meaning within an automated trade execution system. A bid is then made at 59.19 for ten contracts. The 11:03 offer is cleared first at a price of 59.18, the price of the standing order. Four contracts are left at the bid of 59.19, and they are matched with four of the five contracts offered at 11:04. The record will show ten contracts traded at a price of 59.18. The remaining contract offered at 59.18 stays on the book and retains its time priority; i.e., should an appropriate bid arrive, this contract will be traded before a new contract offered at 59.18 at 11:06. The new spread at 11:05 is 0.31.

Orders are exposed to the entire Globex market by means of the electronic order book. This book, together with strict time priority, comprise the main difference between the automated system and the floor trading process. Strictly speaking, floor trading rules dictate that the highest bid and the lowest offer have precedence, and when two bids or offers enter the market at roughly the same time, the bid or offer with time priority has priority for execution. A contract is traded when the outstanding bid or offer is accepted, with the price of the transaction being at the price of the standing order. A new auction starts with each new completed transaction, and the priority of bids and offers does not carry over from auction to auction.

The reality of pit trading is more complex. Strict time priority is not always clear in an active futures pit. The result often is violation of the time priority rule. Price priority may even be sacrificed on occasion across different locations in the pit. Finally, a strict interpretation of the rules dictates a new auction after each transaction, signifying no memory of bids or offers in the last auction. Traders are cognizant, however, of bids and offers at the best prices a few moments before. Further, such bids and offers often are virtually instantaneously and simultaneously shouted out again after a transaction occurs.

The models of floor trading used here maintain price priority, but allow for violation of time priority. A bid or offer at a worse price than is outstanding in the market has no standing. On the other hand, if several standing bids are at the same price, an incoming offer eligible for a cross may be matched against any of the standing bids. The problem of memory after a transaction occurs gives rise to two different models. In the first, the auction rule is interpreted strictly, and traders must sequentially resubmit orders to the floor. The second model effectively ignores the new auction rule by allowing all best bids and offers outstanding at the time of the transaction to remain in the market following the transaction. This may be interpreted as the simultaneous reentry of such orders after a transaction occurs.[15] This model of trading creates an implicit order book on the floor, consisting of all bids and offers at the best prices at all times. Such an implicit book is of variable length, depending on the number of ties at the best price, the number of transactions at that price, and the probability of seeing a better bid or offer enter the market.[16]

4. THE MARKET ENVIRONMENT: EXPERIMENTAL DESIGN

The experimental design of the market environment is common to many auction experiments. Each market consists of a fixed number of traders and a set of demand and supply schedules. Six sets of demand and supply schedules are used and illustrated in Figures 1–6. As noted by Plott (1982) efficiency measures are sensitive to the shapes of supply and demand curves. Several possibilities are examined to establish the robustness of conclusions as to the efficiency of an automated system relative to open outcry auction. The range of prices varies across markets, ranging between 2 and 18. The minimum price variation or tick size is 2. The equilibrium price in each market is 10. Markets containing 6, 12, and 24 traders are considered. This yields 18 different market environments to be analyzed across the institutions of Globex and the two models of open outcry auction trading, for a total of 54 experiments.

Each step on the demand schedule represents the price of a limit buy order received by a trader for execution in the market. Similarly, the steps of the supply schedules represent sell orders. Orders are for a single contract. All traders receive an identical distribution of orders at the beginning of a trading period. Traders are either buyers or sellers. A buyer receives one order each period at each price (step) of the demand curve, and a seller receives a single sell order per period at each step of the supply curve. Orders are handled by traders according to price priority. A buyer attempts to fill the buy order with the highest price first, and a seller fills the sell order with the lowest price first.[17] When attempting to fill an order, the price of that order constitutes the trader's reservation value. A bid or offer submitted to the market by the trader cannot be worse than the reservation value.

Traders with unfilled orders are randomly chosen to make bids or offers. If a trader has an order active on the floor or on the Globex book at the time chosen, the trader cancels

[15]Realistically, the truth is probably somewhere between these alternatives. Only a subset of best bids and offers are shouted out again in practice. This creates no qualitative difference in the results reported in section 5, however.

[16]Stationary probability distributions for best bids and offers on an order book are characterized in Domowitz and Wang (1992), for example. It is possible also to construct an implicit book on the floor using prices other than the best bid and offer, i.e., embodying the possibility that traders even remember inferior bids and offers. Comparisons of Globex-style order books and such implicit memory on the floor are offered in Bollerslev and Domowitz (1992).

[17]The specification of payoff schedules in this way allows control of the supply and demand curves in the market. In experimental parlance, each subject is assigned to be either a buyer or seller. Buyers receive an endowment of a "right to buy" a certain number of units at any price between zero and some upper limit. The so-called "redemption values" of the units bought are a nonincreasing set of numbers corresponding to the steps of the demand curve. Steps of the supply curve correspond to sellers' "costs." Profit is calculated as the price at which the unit is bought or sold minus the redemption or cost values.

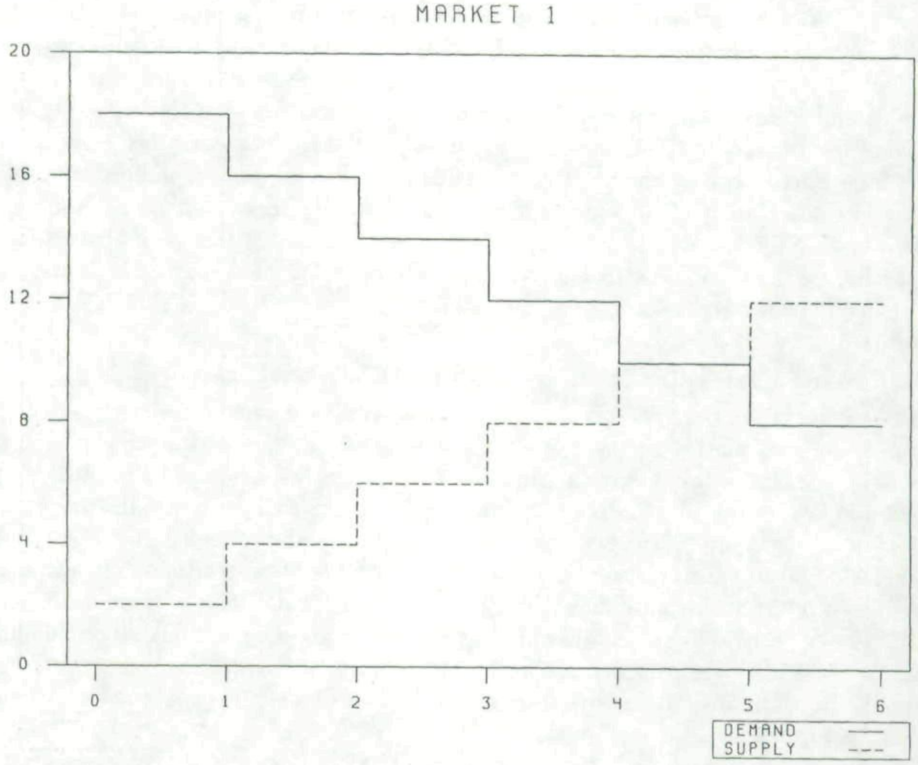

Figure 1

the existing bid or offer and resubmits one at a better price, according to the procedure described below. A period ends when the highest reservation value for buyers is lower than the lowest reservation value for sellers, i.e., when no further trade is possible.

Trading strategy is deliberately kept as simple as possible to focus on the differences in market environments on efficiency outcomes across the two institutions. Laboratory experiments with both human and computer "robot" traders carried out by Gode and Sunder (1990) reveal that only a mild form of individual rationality is required to maximize the total exploited surplus in double auctions. It is their characterization of a "weakly rational" trader that is used here, augmented by the order cancellation and resubmission strategy outlined above. Traders do not know other traders' reservation values. They do not learn and they have no memory. The only "memory" in the system is derived from the Globex book or the implicit floor book of best bids and offers. It is the differential effect of these institutional constructs that is to be isolated.

The weakly rational strategy of Gode and Sunder is simply a no-loss constraint on a randomized bid/offer process. A trader who buys cannot bid above the underlying reservation (order) value; a trader who sells cannot offer a contract at a price below the order value. Bids and offers are generated from discrete distributions over the possible set of prices in the market subject to this constraint. For the results reported here, all prices are equally likely to be chosen, but more complicated distributions do not change the qualitative comparisons of efficiency across institutions.

Consider a trader with orders to buy at prices of 18, 16, 14, 12, and 10 in market 1. Suppose the two orders at 18 and 16 have been filled already. This trader submits a bid at

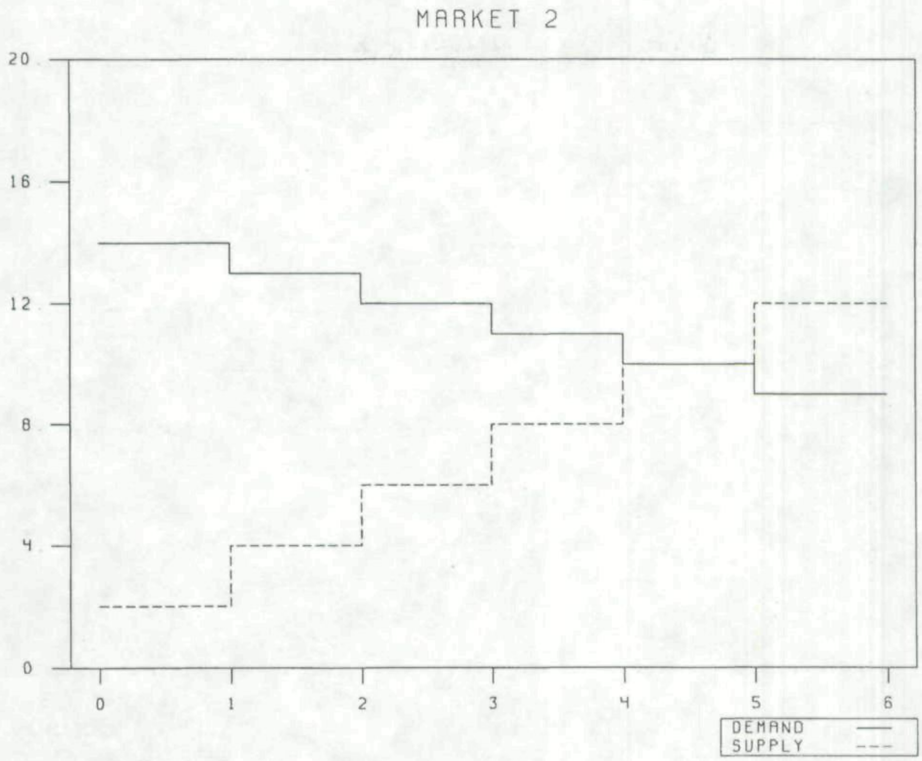

Figure 2

a price p, drawn from a discrete distribution over (2, 4, 6, 8, 10, 12, 14). The realization is $p = 12$, say. Given the current state of the market, if a trade is possible according to the rules of Globex or open outcry auction, the transaction is executed and recorded. The trader's profit or surplus then is the difference between the price of the order (14) and the price at which the trade is made, namely the price of the standing order in this example, which must be less than or equal to 12 to generate the transaction. Suppose the existing state of the market does not allow a trade, however; i.e., there exists no standing order to sell at a price less than or equal to 12. On Globex, the bid of 12 is recorded in the book. On the floor, it becomes a standing order if no better bids exist in the market at this time.

Two possibilities are now open. First, an offer may arrive that results in a trade, i.e., the offer is at a price at or below 12. If this occurs, the trade takes place at the price of the standing bid, which is 12. The trader's surplus is then 2, the difference between the transaction price and the reservation price of 14. Second, the hypothetical trader may be selected to participate again before the bid of 12 is cleared off the Globex book by a transaction or before the floor quote is superseded by a better bid. In that case, the trader cancels the existing bid, and a new bid is made, drawn from a discrete distribution over (12, 14); i.e., the trader may improve the bid in the new round, lacking any takers in previous rounds. This feature differentiates the computerized strategy used here from the Gode–Sunder paradigm. It serves to narrow spreads on average, which is realistic, and ensures that orders on the Globex book do not grow too stale to be useful.

The trading process continues until no further trades are possible. Each such market environment is replicated 100 times, providing 100 observations on the pattern of

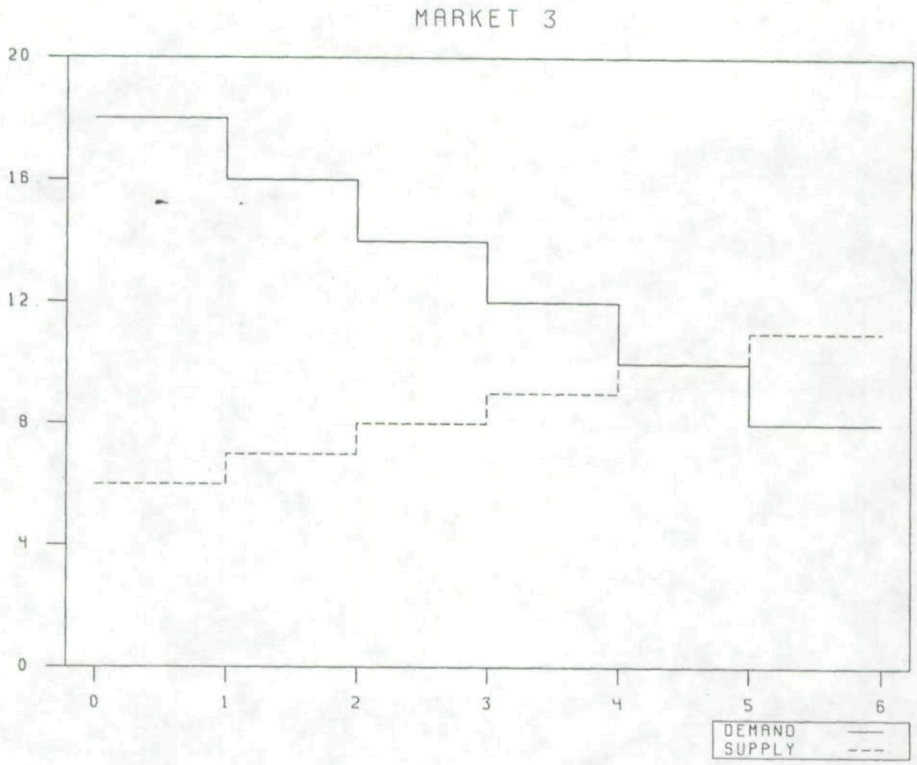

Figure 3

transactions prices, average bids, offers, surplus, and the number of trades required to clear the market. These are used in the construction of performance measures, which are the subject of the next section. The results reported in the tables of this study are based on completely independent trials. This corresponds to the end of a trading day on Globex, and the book is cleared prior to the next replication.[18]

5. INSTITUTIONAL STRUCTURE AND PERFORMANCE

The efficiency of the Globex system relative to the institution of open outcry auction is judged based on two broad categories of performance measures. The first category relates to efficiency as introduced by Plott and Smith (1978), based on total trader surplus. In market experiments of this type, the system attains a Pareto optimal allocation if and only if the total available profit is extracted from the market. The ratio of profit extracted to total potential surplus is examined, as well as several related measures that shed additional light on the surplus extraction issue. The second group of measures pertain to efficiency concepts and issues raised in the financial market microstructure literature. Differences in the liquidity or depth of market are examined along with overall price volatility. The bid–ask spread is affected by the trade execution system, and the spread is another measure of market efficiency. In the discussion of the evidence that follows,

[18]It is possible to design the experiments so as to mimic 100 periods within a trading day. In this case, the Globex book carries over from period to period. This practice accentuates aspects of trading performance most heavily dependent on the electronic order book, but the implicit floor book also carries over, leaving the qualitative comparisons between the two unchanged.

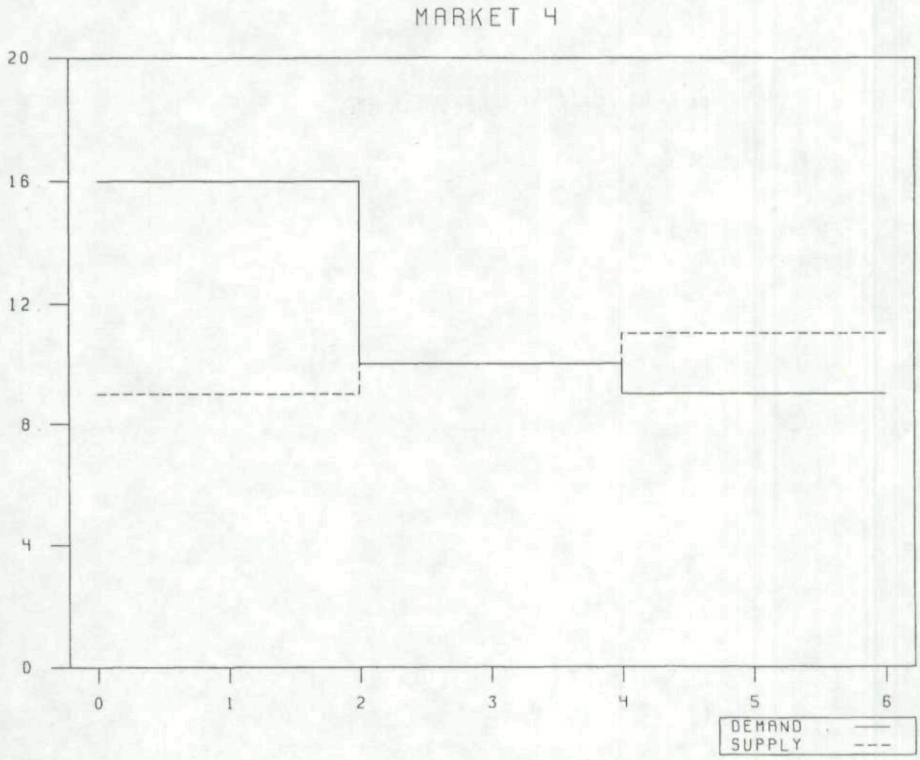

Figure 4

Floor 1 represents the model of trading where a transaction signals a new auction, with resubmission of bids and offers from all traders. Floor 2 represents the situation where all best bids and offers remain in the market; or, equivalently, are instantaneously resubmitted after a transaction occurs.

Trader Surplus

Efficiency based on extraction of total surplus in experiments with humans is almost 100% after a few learning periods in many double auction experiments with open outcry trading rules. The weakly rational traders under both floor models considered in this article achieve 99% efficiency with as few as six traders, which is consistent with the theoretical results of Friedman (1984).[19] The standard error on these percentages for the open outcry mechanism is virtually zero across experiments. The same results are obtained in the Globex mechanism, providing no basis for discrimination between the two systems.

Some additional information on efficiency in surplus terms is available by considering surplus as a ratio to the number of bids and offers required to clear the market. This is presented in Table I for all market environments. Full surplus extraction is achieved in Globex at the cost of a greater number of bids and offers than is required under either floor institution. The percentage difference in this measure across the automated and floor

[19]Friedman establishes the possibility of 100 percent efficiency in markets with as few as three participants.

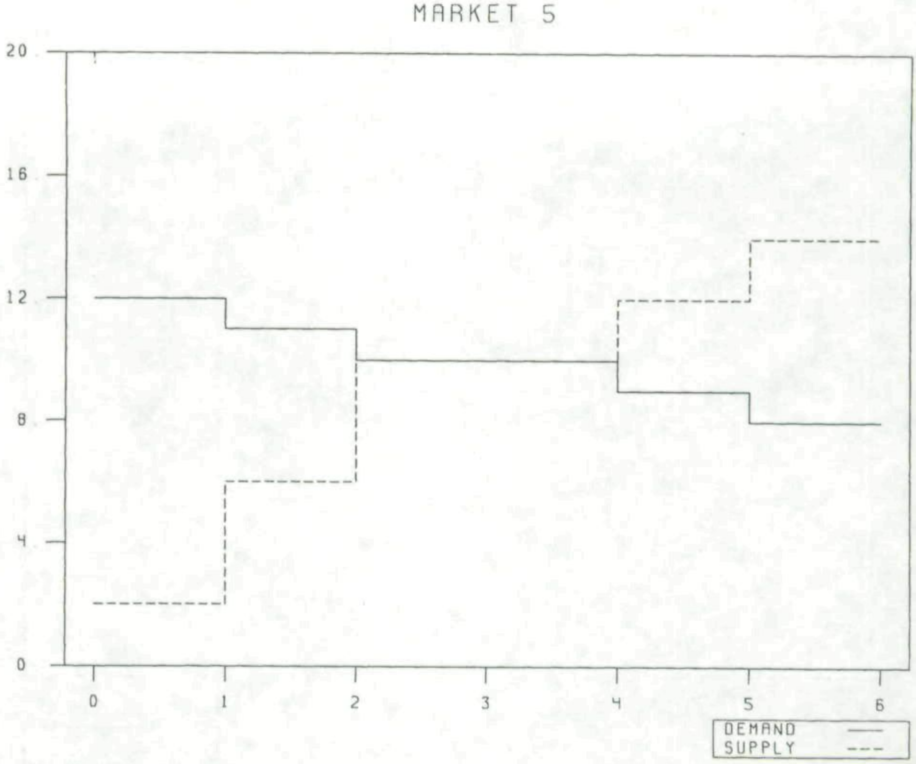

Figure 5

institutions is substantial, and roughly constant across supply and demand environments and number of market participants. By this measure, the floor is clearly more efficient.

Convergence to the competitive equilibrium occurs in both the automated and floor institution in the sense that most surplus is extracted. Average trading prices also are very close to the equilibrium price of 10 in virtually all cases, and the dispersion around equilibrium is not very large, considering the simplistic nature of the trading strategy and the minimum tick size.[20] The speed of convergence to equilibrium can be documented by examining the percentage surplus extracted as the number of bids and offers, relative to the total required to clear the market, grows. The percentage surplus extracted by the first 20% of all bids and offers is illustrated in Table II across institutions and market environments.[21] Averaging across the different supply and demand environments, speed of convergence to equilibrium under Globex is 87% of that under either floor trading institution for the case of six traders. The difference drops to 82% as the number of market participants grows to 24, but this is not a great decline, and the differences are significant at reasonable levels of statistical significance. The slower speed of convergence to equilibrium observed for Globex is consistent with the results on surplus per bid and offer.

[20]In market 1, for example, the mean trading price on Floor 1 over 100 market replications is 10.1 with a standard deviation of 3.3, while the average price through the Globex system is 10.3 with a standard deviation of 3.2.

[21]Similar qualitative differences are observed for other percentiles, but the absolute differences across institutions narrow as the percentile grows from 20% to 100%.

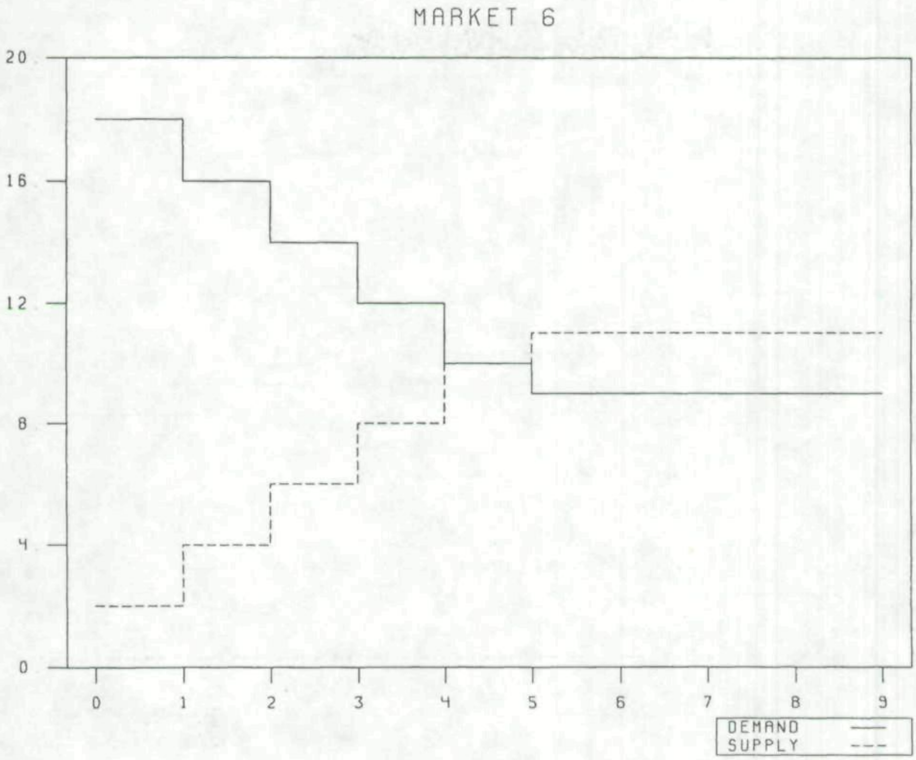

Figure 6

Volatility, Liquidity, and the Spread

The issue of volatility is of general concern and is especially evident in regulatory discussions of program trading strategies. All other things equal, a system design which exhibits lower volatility relative to another mechanism in the same market environment might be considered preferable. The relationship between volátility, profits, and transactions costs also suggests the desirability of lower price volatility in system design.

In Kyle's (1985) model of trading, profit and volatility are inversely related. Volatility declines as information is absorbed into prices, measured here as the standard deviation of transactions prices. Information differences between the market mechanisms considered here exist only through the Globex book, or relative to the variable length book of best bids and offers embodied in Floor 2. The Globex system implicitly contains more information about the market at any given point in time. Fast assimilation of information stabilizes prices, and it is easy to conceive of a consolidated order book as a market stabilizer on an intuitive level as well. Such intuition is borne out in the data. The results contained in Table III show that in 12-trader markets, for example, price volatility is 9–16% lower in Globex than in Floor 1, depending on supply and demand conditions. Similar results hold with respect to volatility in Floor 2. The average drop over all 12-trader markets is 12%, moving from the floor to Globex. Greater differences are evident as the market grows in size. For the 24-trader markets, the average percentage difference is 18.5%, with a range of 17–23%.

Table I
SURPLUS TO NUMBER OF BIDS AND OFFERS RATIO

	Market Type	1	2	3	4	5	6
Globex	6	1.7	1.2	1.2	.95	.98	1.7
		(0.32)	(0.19)	(0.19)	(0.26)	(0.29)	(0.33)
	12	1.7	1.1	1.1	.74	.89	1.5
		(0.23)	(0.18)	(0.19)	(0.18)	(0.20)	(0.26)
	24	1.6	1.0	1.0	.69	.75	1.4
		(0.19)	(0.16)	(0.15)	(0.15)	(0.16)	(0.23)
Floor 1	6	2.9	2.1	2.1	1.7	1.9	3.0
		(0.44)	(0.31)	(0.36)	(0.48)	(0.56)	(0.60)
	12	3.1	2.2	2.1	1.6	1.7	3.1
		(0.41)	(0.27)	(0.25)	(0.28)	(0.32)	(0.39)
	24	3.1	2.2	2.2	1.5	1.7	3.2
		(0.26)	(0.18)	(0.19)	(0.23)	(0.28)	(0.24)
Floor 2	6	3.2	2.2	2.2	1.9	2.0	3.1
		(0.60)	(0.44)	(0.43)	(0.62)	(0.55)	(0.51)
	12	3.3	2.4	2.3	1.8	2.1	3.4
		(0.46)	(0.33)	(0.30)	(0.41)	(0.52)	(0.48)
	24	3.6	2.7	2.7	2.1	2.2	3.8
		(0.37)	(0.33)	(0.31)	(0.35)	(0.38)	(0.42)

Notes: Market types range over supply and demand configurations (1–6) and number of traders in the market (6, 12, 24). The surplus to bid and offer measure is calculated as the ratio of total surplus extracted to the number of bids and offers made. Standard deviations are in parentheses.

Cohen, Maier, Schwartz, and Whitcomb [CMSW (1978)] relate transactions costs to volatility. As transactions costs increase, price volatility increases. In the experiments here, transactions costs are represented through the effort required to achieve execution, described by the percentage of bids and offers that result in trades. Open outcry trading effort often is greater than 50% more than that required by traders on Globex by this measure. The differences in surplus extraction between the two mechanisms are basically zero, on average, suggesting that the volatility-trading costs effect is simply greater than the profitability–volatility link in the situations examined here.

There is a pronounced market size effect on volatility in both institutional designs. Volatility drops much faster in Globex relative to open outcry as the number of traders grows. Globex volatility declines in markets of 24 traders relative to six traders range from 16–24%, averaging 20% across all six supply and demand configurations. Declines in open outcry price volatility average 10% as the market grows to 24 traders, with a smaller range of 8–14% decreases. Globex offers lower price volatility in each market configuration and at each size level. The rate at which the standard deviation of prices declines with the size of market is faster under the Globex institutional design.

Another measure of market performance is the size of the spread, i.e., the difference between the best bid and offer outstanding in the market. Bollerslev and Domowitz (1990) show a link between properties of the spread and the design of market mechanisms which bears on volatility properties of markets. Black (1971) states that one of the conditions of a liquid market is the existence of small spreads, relating the size of the spread to

Table II
CONVERGENCE

	Market Type	1	2	3	4	5	6
Globex	6	0.46	0.45	0.45	0.31	0.44	0.48
		(0.12)	(0.13)	(0.11)	(0.16)	(0.16)	(0.11)
	12	0.51	0.50	0.51	0.42	0.49	0.54
		(0.07)	(0.09)	(0.08)	(0.15)	(0.14)	(0.10)
	24	0.53	0.56	0.56	0.51	0.60	0.60
		(0.07)	(0.07)	(0.07)	(0.13)	(0.12)	(0.09)
Floor 1	6	0.51	0.51	0.53	0.37	0.50	0.52
		(0.11)	(0.11)	(0.12)	(1.7)	(0.19)	(0.11)
	12	0.58	0.60	0.60	0.54	0.64	0.61
		(0.09)	(0.10)	(0.10)	(0.16)	(0.14)	(0.08)
	24	0.63	0.68	0.66	0.68	0.74	0.66
		(0.07)	(0.07)	(0.09)	(0.14)	(0.11)	(0.07)
Floor 2	6	0.49	0.51	0.50	0.37	0.49	0.51
		(0.11)	(0.12)	(0.11)	(0.19)	(0.21)	(0.12)
	12	0.54	0.59	0.59	0.53	0.59	0.60
		(0.09)	(0.10)	(0.10)	(0.17)	(0.15)	(0.10)
	24	0.61	0.66	0.65	0.64	0.70	0.66
		(0.07)	(0.08)	(0.09)	(0.12)	(0.11)	(0.07)

Notes: Market types range over supply and demand configurations (1–6) and number of traders in the market (6, 12, 24). The convergence measure is calculated as the percentage of total surplus extracted by the first 20% of all bids and offers required to clear the market. Standard deviations are in parentheses.

market efficiency. Madhavan (1990) formally relates the size of the spread to market efficiency in the sense of price discovery.

Results on bid–ask spreads are reported in Table IV. Differences across trading institutions are negligible in six-trader markets. In 12-trader markets, the spread is 9–21% larger in all markets under the Floor 1 model, relative to Globex. Similar but smaller differences exist in the comparison of Globex spreads to Floor 2, with its implicit book. The percentage increase over Globex spreads is anywhere from 30% to 41% for the larger 24-trader markets.

A decline in the spread is expected as the market grows. This theoretical prediction is given by CMSW (1986), who link the size of the spread to thinness of markets. Thinness is defined in terms of order arrival rates. In the setup considered here, order arrival increases one-for-one with the number of traders. The average spread drops much faster under Globex as the market grows in size, however. The average decrease in the spread across market environments is 40% in Globex as size increases from six to 24 traders, compared to 21% under Floor 1 and 27% under Floor 2.

Liquidity is a difficult concept, in part because it is not one-dimensional. Kyle (1985) discusses it in terms of market tightness and depth.[22] Tightness is defined as the cost of turning over a position in a short period of time. A satisfactory level of market liquidity embodies the idea that such a cost should be small. Such a cost certainly is a function

[22]Kyle also uses the notion of market resiliency in discussions of liquidity. Resiliency is defined as the speed of convergence of prices to an underlying fair value. The convergence measure of Table II provides a score for resiliency.

Table III
TRANSACTION PRICE VOLATILITY

	Market Type	1	2	3	4	5	6
Globex	6	3.0	2.4	2.4	1.9	2.1	2.9
		(0.58)	(0.53)	(0.55)	(0.62)	(0.78)	(0.57)
	12	2.6	2.1	2.1	1.8	2.0	2.6
		(0.44)	(0.42)	(0.40)	(0.50)	(0.57)	(0.44)
	24	2.3	1.9	1.9	1.6	1.6	2.4
		(0.36)	(0.29)	(0.28)	(0.44)	(0.42)	(0.32)
Floor 1	6	3.3	2.5	2.5	2.2	2.3	3.2
		(0.57)	(0.51)	(0.51)	(0.48)	(0.73)	(0.54)
	12	3.1	2.4	2.4	2.0	2.2	3.0
		(0.39)	(0.33)	(0.28)	(0.33)	(0.44)	(0.38)
	24	3.0	2.3	2.3	1.9	2.0	2.9
		(0.31)	(0.25)	(0.22)	(0.21)	(0.33)	(0.27)
Floor 2	6	3.2	2.5	2.6	2.2	2.3	3.1
		(0.57)	(0.51)	(0.42)	(0.58)	(0.71)	(0.63)
	12	3.1	2.4	2.3	2.0	2.2	3.0
		(0.42)	(0.34)	(0.33)	(0.39)	(0.43)	(0.39)
	24	2.8	2.2	2.3	1.9	2.0	3.0
		(0.30)	(0.24)	(0.24)	(0.27)	(0.34)	(0.30)

Notes: Market types range over supply and demand configurations (1–6) and number of traders in the market (6, 12, 24). Transactions price volatility is calculated as the standard deviation of transactions prices. Standard deviations are in parentheses.

of the order execution rate, and is modeled as such by Treynor (1981) in the context of changing portfolio positions. This cost is far higher under open outcry auction than on Globex as is evident from Table V. The order execution rate is reported in this table, defined as the percentage of bids and offers that result in trades. These percentages are not very high, as might be expected of memory-less automaton traders, but human traders usually do not achieve execution rates beyond 20–25%[23] The rate rises with the number of traders under Globex trading rules, but declines in the open outcry auction environment. The important point, however, is that the order execution rate for Globex trading is 50–60% greater than that of trading in the floor models in most cases. The order execution rate also is interpretable as a measure of how efficiently traders utilize the communications capabilities of the market. In the comparison undertaken here, it is the communications resource embedded in the institutional design, namely the Globex book, that provides the difference in performance.

Market depth is defined by Black (1971) as the market's ability to absorb quantity without an appreciable effect on price. Kyle (1985) relates depth to a parameter which indexes the effect of order flow on price changes. The price disturbance from each trade should be small if the market is liquid. Equivalently, the ratio of trades to price volatility should be large, and the number of trades per transaction price standard deviation is used here as a liquidity measure. Results for all market environments are reported in Table VI. Liquidity by this measure is much higher on Globex. In markets with

[23]See Gode and Sunder (1990) on this point. The results of this study are comparable to theirs with respect to the rates achieved by weakly rational strategies.

Table IV
MARKET SPREAD

	Market Type	1	2	3	4	5	6
Globex	6	4.5	4.2	4.2	4.4	4.1	4.3
		(0.92)	(0.90)	(0.84)	(1.2)	(1.0)	(0.95)
	12	3.8	3.3	3.4	2.9	3.1	3.5
		(0.54)	(0.60)	(0.55)	(0.64)	(0.64)	(0.57)
	24	3.1	2.5	2.6	2.2	2.2	2.7
		(0.39)	(0.35)	(0.38)	(0.38)	(0.38)	(0.41)
Floor 1	6	4.6	4.2	4.1	4.2	4.1	4.4
		(0.80)	(0.72)	(0.84)	(1.0)	(1.0)	(0.85)
	12	4.3	3.7	3.7	3.5	3.5	3.9
		(0.51)	(0.61)	(0.28)	(0.74)	(0.69)	(0.61)
	24	4.0	3.4	3.4	2.9	3.1	3.5
		(0.42)	(0.44)	(0.45)	(0.44)	(0.42)	(0.46)
Floor 2	6	4.5	4.0	4.0	3.9	4.0	4.1
		(0.85)	(0.78)	(0.89)	(1.1)	(0.99)	(0.95)
	12	4.1	3.6	3.6	3.2	3.2	3.6
		(0.56)	(0.59)	(0.66)	(0.73)	(0.76)	(0.72)
	24	3.7	3.0	3.1	2.5	2.7	3.1
		(0.43)	(0.47)	(0.54)	(0.49)	(0.47)	(0.49)

Notes: Market types range over supply and demand configurations (1–6) and number of traders in the market (6, 12, 24). The market spread is the difference between the best bid and offer outstanding in the market. Standard deviations are in parentheses.

12 traders, liquidity is 6–19% lower under the open outcry trading model of Floor 1, 13% lower on average. Slightly smaller, but still significant differences, are observed in comparisons with Floor 2. The relative differences are intensified as the market grows. For 24-trader markets, open outcry auction exhibits liquidity 17–28% lower across market environments than Globex, averaging 22% worse performance.

These results also suggest a size effect on market depth not only for each institution, but differentially across market mechanisms. The amount of liquidity in the market increases dramatically with size. This size effect is the core of policy discussions concerning the liquidity of markets.[24] Liquidity in terms of the market depth measure increases an average of 5.3 times in Globex as the market increases in size from six to 24 traders. Smaller increases of 460% are observed under open outcry. The rate of change is faster under Globex, and market depth on a per trader basis is better there as well.

6. CONCLUDING REMARKS

Given the CFTC's role in the approval of market mechanisms, Congressional directives, and the definition of "the public interest" contained in the Commodity Exchange Act, the main issue in any debate over floor trading versus computerized trade execution is

[24]See Melamed (1977) for an example of such discussion in the context of automated trade execution versus floor trading.

Table V
ORDER EXECUTION RATE

	Market Type	1	2	3	4	5	6
Globex	6	19.1	16.9	17.3	16.1	15.5	18.7
		(3.2)	(2.8)	(2.4)	(3.3)	(3.1)	(3.1)
	12	19.4	16.5	16.6	14.2	15.4	17.9
		(2.2)	(2.5)	(2.8)	(2.5)	(2.2)	(3.0)
	24	19.5	16.3	16.6	14.4	14.5	16.9
		(2.3)	(2.3)	(2.3)	(1.8)	(2.4)	(2.6)
Floor 1	6	14.2	12.1	11.6	11.2	11.6	14.2
		(2.8)	(2.5)	(2.8)	(3.2)	(3.4)	(2.8)
	12	12.5	9.7	9.5	8.1	8.1	11.4
		(1.9)	(2.0)	(1.9)	(1.9)	(2.1)	(2.3)
	24	10.8	8.0	8.2	5.8	6.4	9.6
		(1.6)	(1.4)	(1.5)	(1.3)	(1.3)	(1.6)
Floor 2	6	15.5	12.4	12.2	10.8	11.2	14.2
		(3.3)	(2.7)	(2.9)	(4.4)	(3.3)	(3.4)
	12	13.0	10.5	10.1	8.3	8.9	11.3
		(2.1)	(2.2)	(2.1)	(2.3)	(2.0)	(2.1)
	24	11.6	8.8	8.8	6.7	7.2	10.4
		(1.7)	(1.9)	(1.8)	(1.6)	(1.7)	(1.6)

Notes: Market types range over supply and demand configurations (1–6) and number of traders in the market (6, 12, 24). The order execution rate is calculated as the percentage of bids and offers that result in trade. Standard deviations are in parentheses.

the competitiveness of the price discovery process.[25] The evaluation of automated trade execution conducted in this study is based on a precise description of the rules governing the price discovery process in the new Globex futures trading system. The open outcry auction is found to perform as well or better than Globex in terms of measures relating to competitive surplus. Although surplus extraction is virtually 100% in both institutions, convergence to competitive equilibrium is slower in the Globex design and more trading effort is required there to extract total surplus. However, Globex exhibits lower volatility with respect to transactions prices, and the rate at which volatility declines with market size is faster in Globex. The automated trade execution system also performs considerably better with respect to liquidity measures such as market tightness and depth. Finally, to the extent that the market spread is a measure of efficiency, the Globex system shows superior performance in terms of both the size of spread and its rate of decrease as the size of the market grows.

The predictive value of the spread is not as good in the Globex system as under open outcry. The role of the spread in the price discovery process is a common theme in several studies of the microstructure of financial markets. Early literature, as surveyed in Stoll (1989), posits that the spread is a function of order processing costs. The theoretical prediction in this case is that transactions price should be a simple average of the endpoints of the spread. This prediction also holds if the spread reflects adverse

[25]Section 3 of the Commodities Exchange Act defines the public interest as reliable price discovery, broad-based price dissemination, and effective hedging against price risks. Section 5(g) states that any market must show that its activities are not contrary to the public interest.

Table VI
MARKET DEPTH

	Market Type	1	2	3	4	5	6
Globex	6	4.7	6.1	6.2	4.6	4.4	4.9
		(1.0)	(1.6)	(1.8)	(2.2)	(2.4)	(1.2)
	12	11.0	13.7	13.8	10.7	9.0	11.3
		(2.0)	(3.0)	(2.9)	(4.5)	(3.4)	(2.1)
	24	25.4	32.3	32.2	24.7	25.2	24.6
		(4.3)	(5.3)	(5.2)	(7.8)	(8.7)	(3.5)
Floor 1	6	4.4	5.8	5.9	3.9	4.0	4.4
		(0.92)	(1.4)	(1.6)	(1.4)	(1.8)	(0.82)
	12	9.3	12.0	12.1	8.7	8.5	9.6
		(1.2)	(1.9)	(1.7)	(2.3)	(2.3)	(1.5)
	24	19.4	26.0	25.6	20.4	18.2	19.7
		(2.2)	(3.1)	(2.7)	(3.5)	(3.7)	(1.9)
Floor 2	6	4.5	5.8	5.4	4.1	3.8	4.7
		(1.0)	(1.4)	(1.1)	(2.1)	(1.6)	(1.1)
	12	9.3	12.2	12.4	9.2	8.3	9.6
		(1.5)	(2.0)	(1.9)	(2.3)	(2.6)	(1.5)
	24	20.1	26.5	25.8	20.1	18.4	19.6
		(2.2)	(3.3)	(3.1)	(3.9)	(4.1)	(2.1)

Notes: Market types range over supply and demand configurations (1–6) and number of traders in the market (6, 12, 24). The liquidity measure is calculated as the ratio of the number of trades to the transactions price standard deviation, multiplied by 100. Standard deviations are in parentheses.

information costs.[26] In Madhavan (1990), the spread contributes to price discovery in the sense that the best point estimate of price, conditional on market information, is the average of best market bids and offers.

Average differences between the realized transactions prices and the predicted bid–ask average are very small under both market designs, in the range of 0.5–1%. The standard errors of such estimates are quite large, however, and little can be said beyond the fact that no conventional statistical support exists for a difference between the theoretical prediction and realized prices. Similarly, no statistical or economic difference exists between market mechanisms. The large dispersion around these differences suggests that a statistic based on variability around the theoretical price may yield some additional information. The ratio of the standard deviation of trading prices to the standard deviation of the bid/ask average provides one such measure. The point estimates suggest that Globex prices are consistently farther away from the bid/ask average than open outcry auction prices, but these differences still are not statistically significant.

CFTC Regulation 1.38 requires that an automated trade execution system be "equally open and competitive" relative to open outcry auction in order to qualify as a market under existing regulatory law. This study maintains that an automated system is as open as an outcry system and probably easier to monitor with respect to compliance issues. Using an array of market efficiency measures, this article suggests that Globex, in particular, is also equally competitive. It should be noted that Globex fails some market efficiency measures but this is compensated for by success on other measures.

[26]A third reason for the spread, a dealer inventory effect, is not relevant here.

Bibliography

Black, F. (1971): "Toward a Fully Automated Exchange," *Financial Analysts Journal,* 27:29–35 (July-August), 25–28, 86–87 (November-December).

Bollerslev, T., and Domowitz, I. (1990): "Price Volatility, Spread Variability, and the Role of Alternative Market Mechanisms," *Research in Futures Markets* (to appear).

Bollerslev, T., and Domowitz, I. (1992): "Some Effects of Restricting the Electronic Order Book in an Automated Trade Execution System," in *Double Auction Markets: Theories, Institutions, and Experimental Evaluations,* Friedman, D., Geanokoplos, J., Lane, D., and Rust, J. (eds.). Redwood City, CA: Addison-Wesley.

Cohen, K.J., Maier, S.F., Schwartz, R.A., and Whitcomb, D.K. (1978): "The Returns Generation Process, Returns Variance, and the Effect of Thinness in Securities Markets," *Journal of Finance,* 33:149–167.

Cohen, K.J., Maier, S.F., Schwartz, R.A., and Whitcomb, D.K. (1986): *The Microstructure of Securities Markets,* Englewood Cliffs, NJ: Prentice-Hall.

Cohen, K.J., and Schwartz, R.A. (1989): "An Electronic Call Market: Its Design and Desirability," in *The Challenge of Information Technology for the Securities Markets,* Lucas, H.C. and Schwartz, R.A. (eds.). Homewood, IL: Dow Jones Irwin.

Domowitz, I. (1990a): "The Mechanics of Automated Trade Execution Systems," *Journal of Financial Intermediation,* 1:167–194.

Domowitz, I. (1990b): "When Is a Marketplace a Market? Automated Trade Execution in the Futures Market," in *Innovation and Technology in the Markets: A Reordering of the World's Capital Market System,* Siegel, D. (ed.). Chicago: Probus.

Domowitz, I. (1992a): "A Taxonomy of Automated Trade Execution Systems," manuscript, Northwestern University, Evanston, IL.

Domowitz, I. (1992b): "Automating the Continuous Double Auction in Practice: Automated Trade Execution in Financial Markets," in *Double Auction Markets: Theories, Institutions, and Experimental Evaluations,* Friedman, D., Geanokoplos, J., Lane, D., and Rust, J. (eds.). Redwood City, CA: Addison-Wesley.

Domowitz, I., and Wang, J. (1992): "Auctions as Algorithms: Computerized Trade Execution and Price Discovery," *Journal of Economic Dynamics and Control* (to appear).

Gode, D.K., and Sunder, S. (1990): "Efficiency of Double Auctions with Weakly Rational Traders: Market As a Partial Substitute for Individual Rationality," Graduate School of Industrial Administration, working paper no. 1990-15, Carnegie Mellon University, Pittsburgh, PA.

Harris, L.E. (1990): *Liquidity, Trading Rules, and Electronic Trading Systems,* Monograph 1990–4, New York University Salomon Center, Leonard N. Stern School of Business, New York, NY.

IOSCO (1990): "Screen-Based Trading Systems for Derivative Products," Report of the Technical Committee, International Organization of Securities Commissions.

Kyle, A.S. (1985): "Continuous Auctions and Insider Trading," *Econometrica* 53:1315–1335.

Friedman, D. (1984): "On the Efficiency of Experimental Double Auction Markets," *American Economic Review,* 74:60–72.

Madhavan, A.N. (1990): "Trading Mechanisms in Securities Markets," working paper no. 16-90, Rodney L. White Center for Financial Research, The Wharton School, University of Pennsylvania, Philadelphia, PA.

Melamed, L. (1977): "The Mechanics of a Commodity Futures Exchange: A Critique of Automation of the Transaction Process," *Hofstra Law Review,* 6:149–172.

Plott, C.R. (1982): "Industrial Organization Theory and Experimental Economics," *Journal of Economic Literature,* 20:1485–1527.

Plott, C. R., and Smith, V. L. (1978): "An Experimental Examination of Two Exchange Institutions," *Review of Economic Studies,* 45:133–153.

Stoll, H. (1989): "Inferring the Components of the Bid–Ask Spread: Theory and Empirical Tests," *Journal of Finance* 44:115–134.

Stoll, H. (1990): "Principles of Trading Market Structure," working paper no. 90-31, Financial Markets Research Center, Vanderbilt University, Nashville, TN.

Treynor, J. (1981, January-February): "What Does It Take to Win the Trading Game?" *Financial Analysts Journal* 55–60.

United States General Accounting Office (1989a): "Futures Markets: Strengthening Trade Practice Oversight," GAO/GGD-89-120.

United States General Accounting Office (1989b): "Futures Markets: Automation Can Enhance Detection of Trade Abuses but Introduces New Risks," GAO/IMTEC-89-68.

United States General Accounting Office (1990): "Futures Markets: Information on Six Foreign Automated Trading Systems," GAO/IMTEC-90-43FS.

Wilde, L. (1980): "On the Use of Laboratory Experiments in Economics," in *The Philosophy of Economics,* Pitt, J. (ed.). Dordrecht: Reidel.

Copyright of Journal of Futures Markets is the property of John Wiley & Sons, Inc. / Business and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.