Noise in the Price Discovery Process:
A Comparison of Periodic and Continuous Auctions

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Abstract

Price volatility and market efficiency is examined for an automated periodic auction mechanism and a continuous automated auction, using data on five futures contracts which obviate ambiguities due to periods of non-trading. Theoretical results suggest equality of price volatility across periodic and continuous mechanisms, depending on order arrival rates. The empirical analysis consists of direct comparisons via variance ratios and variance ratio tests conditional on a model of price and value adjustment. The periodic auction yields the same volatility as the continuous market for a stock index contract, while the periodic market is associated with lower volatility for currency futures, consistent with order flow considerations. Tests fail to reject market efficiency for the index contract and three out of four currency futures, regardless of trading mechanism.

I. Introduction

An understanding of the effects of alternative market mechanisms on the price discovery process is important for the future of financial markets. The design of auction markets, in particular, may be loosely classified into automated continuous auctions, floor or open-outcry markets, and periodic call auctions.[1] The focus of this paper is on comparisons between the periodic call auction and the two forms of continuous trading systems.

The nature of our comparisons is confined to the examination of price volatility across trading mechanisms. Jones and Kaul (1994) note that economists' fascination with volatility is deserved, because it reflects the information transmission process. Markets with noisier price signals may be considered less informationally efficient for any particular security.

Our work complements other research, which contrasts a periodic auction operating at the beginning of a trading day with a single continuous trading mechanism that operates thereafter.[2] The variance of open-to-open returns typically is found to be higher than the close-to-close return variance, suggesting higher volatility of the periodic auction market relative to continuous trading.

Higher variance at the opening can be due to the long period of non-trading which precedes it, as opposed to differences in market mechanisms. The work of Amihud and Mendelson (1991) confirms this intuition. They find that comparisons of periodic and continuous trading markets, for which a two-hour period of non-trading precedes the call auction, yield substantively the same estimates of return volatility. They call for an experiment in which continuous trading takes place right up to the periodic auction.

We respond by examining the GLOBEX periodic and continuous auctions, and floor trading, on the Chicago Mercantile Exchange, for which the time between the close of trading on the floor and the opening batch auction is

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[1] This sweeping statement masks a variety of differences in the design of automated auction structures in practice; see Domowitz (1993) and Domowitz and Madhavan (2000).

[2] See Amihud and Mendelson (1987), Stoll and Whaley (1990), and Amihud, Mendelson, and Murgia (1990). This literature is well summarized in Amihud and Mendelson (1991).

only half an hour.[3] For a stock index contract, there is additional information on the underlying index up to 15 minutes before the GLOBEX opening.

We first discuss the results of theoretical work, which addresses the relative volatility of prices to be expected in automated continuous and periodic auctions of the general form found in the GLOBEX system. The theoretical results highlight the connection between tradeoffs in volatility across market structures and liquidity in the form of market intensity. For any fixed interval between periodic auctions, Volatility declines with order arrival rates in both periodic and continuous settings, but at a slower rate in the continuous auction. Price volatility is typically greater in the continuous market than in the batch auction, but the reverse is true when order arrival rates are low. Thus, there is no clear prediction as to relative volatilities between auctions that is independent of factors beyond the markets' design

Our basic empirical analysis consists of variance ratio tests applied to open-to-open (batch auction) returns and close-to-close (continuous auction) returns. We deviate from previous work in three respects. Methodologically, the variances are computed via generalized method-of-moments (GMM), yielding standard errors and a variance ratio test which is robust to any serial correlation and conditional heteroskedasticity in the data. Second, we compare the periodic auction both to the automated continuous auction and to floor trading. The nature of the markets examined in previous work does not allow for both types of comparisons. Finally, we analyze the issues in the context of a futures market, whereas other studies employ stock market data. Our sample consists of trading information for futures contracts on the S&P 500 index and four currencies, the German Deutschemark, Japanese Yen, British Pound, and Swiss Franc. The results for currency futures, in particular, are different in some respects from those obtained using stocks or stock indexes, and offer insights with respect to relative liquidity considerations.

We also follow Amihud and Mendelson (1987, 1989) by distinguishing between the value of a security and its observed price. These authors propose a model to differentiate between the speed of adjustment of market prices to new information and noise in price fluctuations attributable to frictions in the

[3] In this paper, the terms batch auction and periodic auction are used interchangeably.

trading mechanism. Estimated autocorrelations in returns, reflecting market efficiency, are interpreted therein through the model's theoretical parameters. We complement Amihud and Mendelson's work by demonstrating how to estimate the theoretical parameters directly, obviating the need for indirect inference. A test for market efficiency is formulated based on the structural model. A specification test of the model is suggested by examining the variance of shocks to the security's underlying value. Although price volatility may depend on the market mechanism, the variance of shocks to value do not. Our procedure permits a test for the equality of the latter volatility across market structures.

Several conclusions are reached through the empirical analysis. Consistent with work the Japanese stock market, there is no statistically significant difference in price volatility across continuous and periodic auctions for the stock index contract. Volatility is lower in the periodic market for currency contracts, however, in both statistical and economic terms. This result is rationalized through relatively low order arrival rates to the continuous market due to the operation of the overnight foreign exchange market. As order arrival rates to the continuous market fall, the theory predicts the increasing plausibility of lower volatility in the periodic auction. Although price volatility may differ across market structures due to liquidity effects, the variance of shocks to underlying contract value is found to be the same across auction types. Both market structures provide efficient pricing, in the sense of speedy and complete adjustments to shifts in value.

II. Automated Auction Design and Volatility

We briefly review the design of continuous and periodic automated auctions in this section, concentrating on the GLOBEX trading system, the basis of our empirical analysis. Differences between automated continuous systems and floor trading also are noted, but are discussed elsewhere.[4]

[4] See, for example, Bollerslev and Domowitz (1991). Coppejans and Domowitz (1999a) analyze continuous trading on Globex and the CME floor. A review of the growing literature comparing automated trading with floor trading is given in Domowitz and Steil (1999). Institutional discussion and analysis is provided by Pagano and Roell (1990) and Huang and Stoll (1991), but we have hardly exhausted the literature here.

A. Automated Continuous Double Auctions

In an automated continuous double auction, the processing of bids and offers into transactions occurs on a sequential basis through time. In the system design considered in this paper, the basic trader-to-computer messages are bids and offers expressed as price-quantity pairs, i.e., limit orders. All bids and offers are written into a limit order book for processing. GLOBEX permits the viewing of a limited number of bids and offers, ranked by price and accompanied by aggregated volume at each price.[5] The existence of the limit order book is a fundamental difference between GLOBEX and floor trading on the Chicago Mercantile Exchange (CME). Generally speaking, the fact that a system accepts and processes bids and offers which do not represent improvement over the existing "best" market quotes is the major design difference between automated continuous auctions and open outcry trading. In the latter market, a new quote has standing in the market and may be processed into a trade only if it is equal to or better than the best quote in the market.

The trade execution function in a continuous auction is an algorithm that enables order matching according to a set of rules governing the priority of submitted bids and offers. Domowitz (1993) documents a variety of possible configurations in this respect. GLOBEX is primarily governed by rules giving priority first to price, then to time. Matching can occur under two circumstances. First, a limit bid and a limit offer may match in price. Second, a user may "hit" the bid or "lift" the offer on the book by a keystroke, without submitting a corresponding limit order on the other side of the market. Orders may be cancelled at any time. All trading is anonymous.

B. Periodic Single-Price Auctions

In automated periodic auctions, quotes from traders are transmitted sequentially, but all transactions are executed together at a single price at a single predetermined point in time. The transactions price applied to all eligible

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[5] On GLOBEX, this is complicated by the allowance of quantity bid or offered that is not shown to market participants, and has a lower priority with respect to trade execution. See Domowitz (1990) for discussion and examples. Empirically, we have no access to data on quantities bid or offered, and this feature of the system is not subject to analysis.

orders, i.e., those for which the bid is higher than and the offer is lower than the transaction price, is calculated by an algorithm that maximizes total trade volume at that price. For continuous prices and volumes, this is equivalent to equating supply and demand. Priority rules are still required, however, because the discreteness of prices and quantities in financial markets may preclude an equilibrium at which supply equals demand exactly at an admissable price. Alternative rules and examples are given by Domowitz and Madhavan (2000).

The auction process is split into a pre-trading period and the clearing operation described above. Messages to the system again consist of limit orders, although there exist systems that allow unpriced market orders in practice. Cancellations are allowed at any time during the pre-trading period.

There are differences in the amount of information revealed to traders during the pre-trading period across system designs. Data can consist of tabulated bids and offers, visual display of supply and demand curves on some periodic basis, or no data at all, i.e., a sealed bid auction. Systems such as that of the Arizona Stock Exchange offer options with respect to how much information a trader wishes to show to the rest of the market. GLOBEX displays an indicative opening price at staggered intervals during the pre-trading period, calculated from orders on the book at those times.

C. Theoretical Volatility Comparisons Between Auction Types

Mendelson (1982) presents a model of the periodic auction, and Domowitz and Wang (1994) construct an analogous model of the automated continuous double auction under price and time priority rules. Both models adhere closely to the design of the GLOBEX system, but there are some differences. The Mendelson analysis is for a sealed-bid auction, and the model of the continuous market allows for the viewing of only the best bid and offer on the limit order book.[6] The qualitive conclusions from a comparison of the two nevertheless shed light on the empirical results to follow, and on the existing results of Amihud and Mendelson (1989, 1991) for the Japanese stock market.

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[6] The Domowitz and Wang (1994) model is easily extended to the conditioning of trading activity on information with respect to a finite number of orders on the book, and delivers the same basic conclusions as described below. We do not know of an analogous extension of the Mendelson (1982) analysis. Details with respect to

Using different techniques, Mendelson and Domowitz/Wang obtain results concerning the distribution of prices in the respective markets. Mendelson provides an explicit calculation of price volatility, while the latter is derived from the price distribution derived by Domowitz/Wang. In the model of the periodic auction, volatility increases as the time between auctions is shortened. For any given interval between auctions, volatility declines with order arrival rates. In the continuous auction model, volatility also declines with increases in market intensity, but generally at a slower rate than the periodic auction, especially for low order arrival rates.[7]

Price volatility is generally greater in the continuous market. This result is reversed, however, for short times between auctions in the periodic market and/or when order arrival rates are very low. Thus, there is no clear prediction as to relative volatilities between market structures that is independent of factors other than the market microstructure.

Volatility is equalized across markets for some combination of an inter-clearing time and relative order arrival rates in the two markets. Amihud and Mendelson (1991) indeed find that when the periodic auction is held only two hours after continuous trading stops, it has essentially the same volatility as that of the closing transactions of continuous trading sessions. On the other hand, while such a result is consistent with the theory, other outcomes are possible, depending on relative intensity of order flow.[8] We now turn to our own empirical examination of the volatility relationships between periodic and continuous futures market trading mechanisms.

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assumptions concerning order arrival processes and the like are fully described in the two references.

[7] This result relies on an increase in the expected length of the order book as order flow increases, an intuitively plausible result. Cohen, Maier, Schwartz, and Whitcomb (1978) reach a similar conclusion. In their model, variance decreases as the value of shares increases, implying less "thinness" in the market for such shares. In turn, as the market becomes less thin, reflected in an increase in order arrival rates, the number of orders on the book might reasonably be expected to increase.

[8] See also Ho, Schwartz, and Whitcomb (1985). Call market orders are associated with trader reservation prices therein, and the aggregated curves reflecting buying and selling pressure become inelastic at the point where supply meets demand. Slight shifts in the curves then have accentuated impacts on price, resulting in higher volatility relative to a continuous market.

III. Empirical Results

The data used in this paper are the basis of a larger project devoted to automated and open outcry trading on the CME (Coppejans and Domowitz, 1999a). The latter research requires continuously recorded quote and transaction data. Roughly three months of such data, over the period 7/1/94 to 9/30/94, were made available to us for analysis.[9] We analyze futures contracts on the S&P 500 index, and for the four major currencies traded on GLOBEX, namely the Deutschemark (DM), Yen, British Pound (BP), and Swiss Franc (SF). The work is restricted to trading on the September contract, eliminating observations which are close enough to the end of a cycle as to be unrepresentative, given traders' proclivity to roll over positions to the next expiration in advance of the expiration date. Weekend effects also are eliminated. This leaves us with relatively few observations on a daily basis. On the other hand, we estimate a maximum of two parameters based on any individual series used in the analysis. The precision of the estimates obtained is quite good, permitting sharp rejections of relevant null hypotheses.

For all contracts, there are 30 minutes between the cessation of floor trading and the GLOBEX single-price auction. Trading hours vary for the S&P relative to the currencies. On central standard time, the floor stops trading in the S&P contract at 3:15 p.m., and the GLOBEX open is at 3:45. Currency floor trading stops at 2:00 p.m., with a GLOBEX opening at 2:30. In the case of the S&P, there are only 15 minutes between the last computation of the index based on the close of trading in the underlying stocks and the GLOBEX opening.

A. Variance Ratio Analysis

If the nature of the trading mechanism has no effect on noise in the price discovery process, the volatility of price changes observed from the periodic auction should be the same as that obtained from trading on the GLOBEX continuous auction or open outcry trading, all else equal. It is true, however, that floor trading on the CME generates far larger trading volume than GLOBEX

[9] The data were supplied by K2 Capital Management, Inc., a Chicago-based commodity trading advisory firm.

trading.[10] Comparisons between the GLOBEX periodic auction and continuous trading system are, therefore, the most relevant. Nevertheless, we present evidence with respect to floor trading as well, noting differences in volatility between the two continuous auction mechanisms.

The daily prices considered are denoted P_0^G, P_c^G, and P_c^F, which represent the GLOBEX opening auction price, the GLOBEX closing price, and the closing price on the CME floor, respectively. The returns here are simply changes in price, given by $R_{jt}^i = P_{jt}^i - P_{jt-1}^i$, for *i*=*G* (GLOBEX) and *F* (floor), and *j*=*o* (open) and *c* (close), where *t* indexes trading days. We exclude weekend periods of nontrading from the analysis, consisting of GLOBEX opening on Sundays and floor closings on Fridays.

We define the relevant variances as follows: $\sigma_{00}^G = \text{var}(R_{0t}^G)$, $\sigma_{cc}^G = \text{var}(R_{0t}^G)$, and $\sigma_{cc}^F = \text{var}(R_{ct}^F)$, where the *oo* and *cc* subscripts denote open-to-open and close-to-close, respectively. The ratios of open-to-open relative to close-to-close variances are given in table 1, together with significance levels of a variance ratio test against the null hypothesis that the ratio is unity. All estimates and corresponding standard errors are computed via GMM, taking any conditional heteroskedasticity and serial correlation in the data into account. For the reader who believes that volatility is time-varying, the figures in table 1 are consistent estimates of the ratios of average volatilities, and the significance levels of the variance ratio tests are justified asymptotically.[11]

The results for the S&P 500 are reminiscent of those of Amihud and Mendelson (1991). The ratio of periodic auction returns to continuous automated auction returns is 1.128, not significantly different from unity. Although the ratio of periodic auction returns to those generated through floor trading is formally statistically different from one, the point estimate of the ratio is 1.056, not substantively different from the theoretical value under the null hypothesis. The difference between the automated auction and floor trading

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[10] Floor trading on the CME is more liquid than that on GLOBEX, in dimensions other than volume; see Coppejans and Domowitz (1999a).

[11] See Coppejans and Domowitz (1999b) for explicit discussion and examples.

comparisons is reflected in the ratio of the variances of those continuous returns, $\sigma_{cc}^{G}/\sigma_{cc}^{F}$, which is 0.94.

The periodic auction is less volatile for currencies. The GLOBEX-to-GLOBEX variance ratios for the currencies uniformly reject the null hypothesis, with ratios ranging from 0.512 to 0.755. It is too early to claim that the periodic market is more informationally efficient, however. The theory predicts differences depending on order flow considerations.

Although order flow is unobserved here, there is a channel through which we can interpret the currency results. Instead of placing an order into Globex, a currency trader may convert such an order via the mechanism of exchange-for-physical and place it in the interbank foreign exchange market. Alternatively, and for large trade sizes, the trader may trade directly in the cash market. Similar mechanisms are unavailable for the stock index contract. The interbank market is very liquid, and this practice is quite common. One implication is that order arrival rates to the Globex system in the currencies are attenuated, relative to what they might be were the interbank market not present. As order arrival rates to the continuous Globex market fall, the theory predicts the increasing plausibility of lower volatility in the periodic auction.

Open outcry floor variances are generally smaller than GLOBEX continuous trading variances for all currencies, yielding larger variance ratios relative to the periodic auction. Although statistical significance varies, three of the four ratios are quite close to unity, ranging from 1.039 to 1.091. The average variance ratio for all currencies taken together is 0.998. On a substantive level, we so not see much of a difference between trading mechanisms, based on trading activity at the open and at the close of the respective continuous trading sessions.

B. Volatility and Price Adjustment

The use of microstructure models in variance ratio analysis to correct for predictable frictions in the market is advocated by Smith (1994). Amihud and Mendelson (1987, 1989) also suggest that the nature of the trading mechanism may affect the adjustment of prices to security value, as well as affecting volatility. We adopt the Amihud and Mendelson (1987) model of price adjustment to comply with the former suggestion, and to investigate the latter possibility.

The model distinguishes between the observed price of the security, *P*, and the actual value of the security, *V*. Prices are hypothesized to follow a noisy partial adjustment process, represented by

$$P_t - P_{t-1} = g\left[V_t - P_{t-1}\right] + \varepsilon_t$$

where the error sequence $\{\varepsilon_t\}$ is a white noise process with zero mean and variance σ .[12] The adjustment coefficient, g, is constrained to lie between zero and two. If $0 < g < 1$, there is incomplete adjustment of price to the true value, inducing positive serial correlation in returns; for $g > 1$, the market overcompensates, and excess negative correlation in returns is to be expected. Market efficiency in this model is interpreted as $g = 1$, i.e., complete instantaneous adjustment to shifts in value.

Changes in value are modeled by assuming that value follows a random walk with drift, according to

$$V_t = \mu + V_{t-1} + \eta_t$$

where the error term is an i.i.d. shock with mean zero and variance ν . Amihud and Mendelson (1989) estimate the autocorrelations of $R_t = P_t - P_{t-1}$ for open-to-open and close-to-close returns in the Japanese market. They interpret their results in light of the theoretical implications of the model expressed as functions of the adjustment parameter and the two variances.

We take a different approach. Given three orthogonality conditions derived from the model structure, one can estimate the three main parameters, g, σ, and ν, directly. Alternatively, constraining g to equal 1, the three orthogonality conditions allow the estimation of the two variances, while providing a test of market efficiency via a test of the overidentifying restriction imposed by the constraint.

[12] We omit the traditional square on all variance definitions within the model, in order to accommodate the various superscripts and subscripts required later in the empirical implementation of the model.

We follow the latter avenue here. Empirical orthogonality conditions for GMM estimation of the variances follow immediately from the following moment conditions,

$$Var(R_t) = \frac{g}{2-g}\nu + \frac{2}{2-g}\sigma$$

$$Cov(R_t, R_{t-1}) = \frac{g}{2-g}\left[(1-g)\nu - \sigma\right]$$

$$Cov(R_t, R_{t-2}) = \frac{g(1-g)}{2-g}\left[(1-g)\nu - \sigma\right].$$

A test of the hypothesis, g=1, is based on the existence of the overidentifying restriction provided by cov(R_t,R_{t-2})=0 under the null, and the results in Hansen (1982). The first two moment equations are derived by Amihud and Mendelson (1987). The third is derived similarly via recursion formulas.

The use of the extra restriction to test market efficiency would appear to deprive us of the ability to test the validity of the overall model. The model structure offers a way out of this difficulty, however. Although the variance of shocks to price changes, σ, depends on the market mechanism, the variance of disturbances to shifts in value, ν, does not. Technically, this follows from the fact that the error sequence, $\{\eta_t\}$, is an exogenous input to the model.

More intuitively, price is a signal of value, with noise that depends on market structure, since the actions of the market produce price. In contrast, one might consider the sort of information summarized in $\{\eta_t\}$. For example, changes in value might occur given unexpected changes in earnings for companies within the S&P 500. Such earnings depend on the fundamentals of the companies involved, not on their current stock price or the trading market microstructure. A similar analogy for currencies is unexpected changes in the political climate. Clearly, political events are not different across periodic and continuous auctions. A test of the model is, therefore, provided by examining the equality of estimates of ν across trading systems.

In our interpretation of the empirical results, the notation with respect to the variance of price changes is the same as used in the preceding section. We also define ν_{00}^{G}, ν_{cc}^{G}, and ν_{cc}^{F} to be the GLOBEX open-to-open, GLOBEX close-to-close, and floor close-to-close variances of innovations to value.

Results are reported in table 2, in the form of significance levels for various tests of equality of variances and model structure. Our previous comments with respect to time variation in volatility also are valid in this more general context. In the table, g^{G} and g^{F} denote the adjustment parameter for GLOBEX and the floor. We have set all adjustment parameters to unity in the estimation, obviating the need for further notational differentiation between continuous and periodic auctions.

Echoing the results reported earlier, there is no difference in return volatility across GLOBEX periodic and continuous auction mechanisms for the S&P 500 contract. We cannot reject the hypothesis that g = 1, regardless of the nature of the continuous trading system. To the extent that the model is a good characterization of price movements, this result implies that both the continuous and periodic auction provide an efficient market environment.[13] We cannot reject the hypothesis that the variance of shocks to the contract value process is equal across the periodic and continuous auctions. This finding provides some validation of the model's structure, and lends credibility to the other results.

Return volatility for the periodic auction is again statistically different from that for the GLOBEX continuous auction for three of the four currencies. Equality cannot be rejected for three of the four in the comparison between the periodic auction and floor trading, however. These results are substantively the same in nature as those discussed in the last section.

Except for the British Pound, the results imply that both the periodic auction and continuous trading are efficient mechanisms. It is intuitively plausible that the relatively more liquid markets come closer to the ideal of market efficiency, however. The British Pound is the least liquid contract considered here. Over our sample period, there were only 16 Pound trades per

[13] We note that market efficiency is not a uniquely defined concept, and may mean different things in different contexts. Any operational definition of market efficiency is model-specific, in particular. In the model considered here, efficiency means

day on Globex, versus 107 per day for the Yen, for example. This relative lack of liquidity also is evident in the floor market. The same comparison yields 689 trades per day in the Pound and 1684 trades per day in the Yen.

IV. Concluding Remarks

Our comparisons between the GLOBEX trading systems appear to suggest that the periodic mechanism yields lower price volatility. This result holds for the currencies, regardless of method of computation, and is consistent with the theoretical finding that volatility is typically higher in the continous auction.

Based on the variance ratio tests, it is tempting to conclude that the periodic auction provides an informationally efficient environment, relative to the automated continuous auction. The link between variance ratios and trading costs derived by Hasbrouck and Schwartz (1988) also would imply that the periodic auction provides a lower cost environment in which to trade. There are several reasons to believe that these conclusions may be premature, however.

Our results for the S&P 500 contract imply that volatility across periodic and continuous mechanisms is the same. The results contained in Amihud and Mendelson (1989, 1991) for the Japanese stock market yield conclusions similar to our findings for the S&P 500. These findings also are consistent with the theoretical models, in that volatility across market mechanisms is equalized for some combinations of time between auctions and intensity of order flow.

Our tests for market efficiency address the information question, supplementing the variance ratio analysis. We find no efficiency differences across market structures. Efficiency is defined in the Amihud and Mendelson framework as complete and instantaneous price adjustment to changes in the security's value. Their model of price and value adjustment is validated by the data. Market efficiency in the GLOBEX-to-GLOBEX comparison holds empirically for all contracts save the British pound, for which there are liquidity problems.

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instantaneous price adjustment. In other settings, efficiency may mean the irrelevance

The lower volatility in the periodic market for currency futures may have a connection with the existence of the interbank foreign exchange market. To the extent that traders place cash and exchange-for-physical orders during the overnight session in that market, order arrival rates to the continuous GLOBEX market are attenuated and may, indeed, be quite low. The theoretical results then predict lower volatility in the periodic market, even for moderate market intensity in the batch auction. Interpreted within the Hasbrouck and Schwartz (1988) framework, it is no surprise that trading costs are exacerbated in a low liquidity environment, regardless of market mechanism.

These empirical and theoretical factors lead us to the following conclusion. Differences in market quality are small across prevailing forms of market microstructure. The important factor is the environment within which the market structure operates. Volatility is theoretically higher or lower across periodic and continuous auctions depending on relative order flow. Securities trading simultaneously in dual markets have different price characteristics than those trading in a single market. Market structure appears to have only secondary, and often minor, effects compared to factors arguably exogenous to the design of the market itself. This conclusion is consistent with the findings in Coppejans and Domowitz (1999a), based on intraday data, as well as with the literature comparing automated auctions with floor-based open-outcry systems, summarized in Domowitz and Steil (1999).

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of certain information in equilibrium.

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Table 1

Variance Ratio Analysis

	$\sigma_{00}^{G} / \sigma_{cc}^{G}$	$\sigma_{00}^{G} / \sigma_{cc}^{F}$
S&P 500	1.128 (0.539)	1.056 (0.002)
DM	0.520 (0.000)	1.048 (0.289)
YEN	0.720 (0.060)	1.039 (0.472)
BP	0.755 (0.015)	0.813 (0.004)
SF	0.512 (0.000)	1.091 (0.215)

Note: Entries in this table represent GMM estimates of the respective variance ratios. Figures in parentheses are the significance levels for a test that the variance ratio is one; e.g., a reported value greater than 0.05 would imply a failure to reject the null hypothesis of unity at the 5 percent level of statistical significance.

Table 2

Microstructure Model Tests

	$\sigma_{00}^{G} = \sigma_{cc}^{G}$	$\nu_{00}^{G} = \nu_{cc}^{G}$	$\sigma_{00}^{G} = \sigma_{cc}^{F}$	$\nu_{00}^{G} = \nu_{cc}^{F}$	$g^{G} = 1$	$g^{F} = 1$
S&P 500	0.950	0.617	0.000	0.167	0.774	0.194
DM	0.000	0.775	0.823	0.424	0.172	0.989
YEN	0.000	0.850	0.495	0.000	0.569	0.551
BP	0.629	0.000	0.042	0.675	0.000	0.001
SF	0.000	0.850	0.528	0.435	0.353	0.615

Note: Figures in this table represent significance levels for a test of equality noted in the column headings; e.g., a reported value greater than 0.05 would imply a failure to reject the null hypothesis of unity at the 5 percent level of statistical significance. These significance levels are based on GMM estimates of the parameters of interest in the microstructure model described in text.