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Anonymous electronic trading versus floor trading

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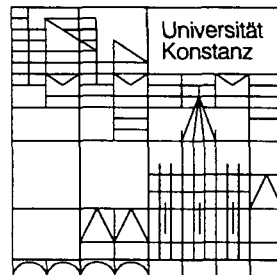
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Sonderforschungsbereich 178
„Internationalisierung der Wirtschaft“

Diskussionsbeiträge



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Fakultät für Wirtschafts-
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Dieter Hess

**Anonymous Electronic Trading
Versus Floor Trading**

11. DEZ. 1995 ^{Weltwirtschaft}
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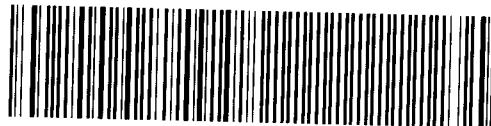
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ANONYMOUS ELECTRONIC TRADING VERSUS FLOOR TRADING

Abstract

This paper compares the attractiveness of floor trading and anonymous electronic trading systems. It is argued that in times of low information intensity the insight into the order book of the electronic trading system provides more valuable information than floor trading, but in times of high information intensity the reverse is true. Thus, the electronic system's market share in trading activity should decline in times of high information intensity. This hypothesis is tested by data on BUND-Future trading. This future is traded on the German and on the British futures exchange. The empirical results support the hypothesis.

1 Introduction

In the last two decades security trading on exchanges has undergone various changes. Rules and regulations have been tightened; equally important, many of the new exchanges have been set up as electronic screen-based trading systems where traders communicate only via computer systems. In addition, some of the old stock exchanges have been transformed from a floor into an electronic screen-based trading system, for example, the London and the Paris Stock Exchanges. Strong competition between the two systems has emerged. Each system claims advantages over the other. In the ongoing fight for superiority, the systems have been modified to strengthen their competitiveness. For example, floor trading systems use more and more electronic support such as electronic order transmission, settlement and information systems. Therefore, some convergence between both systems has been observed.

The evolution of electronic screen based and floor trading systems makes it impossible to define each system precisely. Various differences exist among electronic screen based systems, the same is true of the various floor trading systems. Some features of the systems are chosen voluntarily by an exchange while others are imposed by regulators. Still most electronic trading systems share one important feature which is the anonymity of trading, i.e., names of traders do not appear on the screen. Hence, no trader knows with whom he trades.¹ Therefore, the information revealed otherwise by the names of the traders is lost. In addition, observation of traders' behavior is ruled out. This makes it impossible to guess whether an order is motivated by liquidity needs or by private information. Information diffusion related to names and observable behavior of traders is lacking in these electronic trading systems.

Floor trading systems provide this information. All traders can observe each other. Although a trader may disguise his motives and even deceive other traders, the latter is likely to impair a trader's reputation and, thus, render future trades more costly for him. Therefore, barriers to deceptive behavior exist so that other traders can infer information from observing his behavior.

¹ An exception is the APT-system of the LIFFE (London International Financial Futures Exchange). This electronic trading system is in operation only before and after floor trading. Trading volume is very modest. In this system, floor trading is imitated; therefore names of traders appear on screens.

While this information is not provided by anonymous electronic trading systems, they usually offer traders insight into the limit order book. Most floor trading systems do not reveal this information. Traders may use this information to infer trends of the market. If, for example, the order book shows many buy orders, but few sell orders, this may indicate a price increase.

The purpose of this paper is to investigate the importance of this information differential between electronic and floor trading systems for market participants. As we observe both trading systems which differ in many features, it is impossible to ascribe a decisive role to this information differential in the competition between both systems. Yet this differential may be important. One method to look into this issue is to relate this information differential to certain characteristics of the trading situation. Thus, we attempt to argue that this information differential does not unanimously support the competitive strength of one or the other system, but that such support depends on the trading situation. The observable variables portraying the trading situation are price volatility and trading activity.

The main hypothesis advanced in this paper states that the information value, provided by the insight into the limit order book in the electronic trading system, relative to the information value of observing traders in the floor trading system, declines when the intensity of private and public information arrival increases. In other words, the hypothesis states that information diffusion in a floor trading system relative to that in an electronic trading system renders floor trading more attractive in times of high intensity of information arrival. Therefore, trading activity in a floor system should grow at a higher rate than in an electronic system when more information arrives.

This hypothesis is tested by analyzing the trade of the BUND-Future contract, a future contract on long-term bonds issued by the German government. This contract is traded in almost identical design at the Deutsche Terminbörse (DTB) and at the London International Financial Futures Exchange (LIFFE). The DTB offers an anonymous electronic screen based trading system with continuous auctions while the LIFFE offers continuous trading among traders in a floor system. As the contracts traded on both exchanges are almost identical, the trade data allow us to compare trading activity at each exchange and relate it to price volatility and aggregate trading activity. Since it is impossible to observe the arrival of private information directly, we follow Admati/Pfleiderer [1988] who argue that new private information is

reflected in the time patterns of price volatility and trading volume. Therefore, we investigate the relationship between the DTB's market share in trading activity and price volatility; also we investigate the relationship between the DTB's market share and aggregate trading volume which equals the sum of trading volumes at both exchanges. If our hypothesis is correct, then the DTB's market share in trading activity should be inversely related to price volatility and aggregate trading activity.

The paper is structured as follows. Section 2 portrays both trading systems and draws some conclusions from their comparison. In section 3 the competitive strength of both systems will be evaluated; special emphasis will be placed on the evaluation of the information differential between both systems contingent on the intensity of information arrival. Section 4 presents the test results from the trade of the BUND-Future contract at the DTB and the LIFFE. Some conclusions are offered in section 5.

2 Description of Trading Systems

Floor trading systems vary considerably in their design, the same is true of electronic screen based trading systems. The characterization of both systems chosen here relates closely to the trading systems of the LIFFE and the DTB since data of these exchanges will be analyzed.²

2.1 The Floor Trading System

The floor system is assumed to be a dealer-driven system in which dealers trade continuously through open outcry. Whenever a trader wants to buy or sell a security, he asks for a quote. Dealing in the security is not restricted to certain authorized dealers so that every trader may answer the quote request. Quotes are valid as long as "breath is warm"; the number of securities or contracts for which the quote is valid is limited through regulation of the exchange. The trader who requested the quote may accept the best offer or refuse trading. Traders are dual capacity traders, i.e. they may trade on their own account and on customers' accounts. Thus, traders also act as brokers.³ As there is no official market maker, an official order book does not

² For a general discussion of different trading systems see Pagano/Roell [1990], [1992].

³ Dealers do not have outside customers for whom they transact.

exist. Every trader keeps his own book with orders from his customers. Transaction prices are published immediately by the exchange so that traders and other people know them immediately. Transaction volumes are published with short delays. Names of traders are not published by the exchange, also quotes are not published. This information is immediately available only to the people on the floor.

2.2 The Electronic Screen Based Trading System

The electronic screen based trading system is assumed to be a continuous auction system with automatic order matching in which traders communicate only via computer screens without revealing their names⁴. If two orders can be matched, then the automatic auction mechanism chooses as matching orders those with the best prices. If a trader wants to buy or sell a security, then he has three choices. (1) He buys at the lowest ask price or sells at the highest bid price of the limit order book which is displayed on the screen. If the number of securities or contracts, for which the best price is quoted, is less than the number which the trader wants to buy or sell, then he may simultaneously trade at the second best, third best price and so on. Thus, a large order may be matched with several orders at different prices; the trader extracts the consumer rent. (2) The trader who refuses to trade at the best prices available on the screen puts a limit order into the system. This order may be matched then with some other order which is not yet in the system. The trader can always withdraw a non-matched order from the system. (3) The trader may wait for better prices to be displayed on the screen and hide his order.

If the exchange has appointed one or more market makers for a security or a contract, then they have to answer quote requests of other traders. The automatic matching system precludes any privilege of market makers in trading, i.e. an order is matched with another order regardless of whether this order comes from a market maker or not. The exchange may reward market makers by charging them lower fees.

Traders are also dual-capacity traders. Information on transaction prices and volumes is published instantaneously in the electronic system.

⁴ Trade is opened in many electronic exchanges through a batch auction.

2.3 Differences Between the Trading Systems

Although both systems appear to be very different, they share many common features. Both systems are operating continuously so that, in principle, orders can always be executed. Immediacy of trade is assured in the floor system through quote requests. Usually electronic exchanges appoint market makers for products with a thin limit order book in order to assure immediacy. Execution risk is eliminated in both systems: the quotes from the floor tell the trader at which prices he can trade. Similarly, in the electronic system the trader knows the limit order book and, thus, the prices at which an order can be executed. Publication of trade information is instantaneous in the electronic system, it is also very fast in the floor system.

Besides these similarities there exist some major differences between both systems. (1) Trade in the electronic exchange can be supervised more effectively since all information on orders and trades is recorded with time stamps. Thus, trading behavior which is inconsistent with rules and regulations can be detected easier. (2) Mistrades, i.e. trades at erroneous terms, are less frequent in electronic systems. Moreover, mismatches of trades such that matched buy and sell orders do not fit together are ruled out in electronic systems. (3) The electronic system offers traders insight into the anonymous limit order book. The floor system allows traders no insight into an official limit order book, but traders can observe names and behavior of other traders. The importance of this information differential will be discussed in the next section. (4) A large order can be matched in the electronic system with several orders of the limit order book at different prices. This allows the trader to extract the consumer rent from the orders in the limit order book as has been emphasized by Glosten [1994]. In addition, Glosten points out that the limit order book offers traders the advantage that they can partition a large order into various small orders with different limit prices so as to optimize their ordering vis-à-vis informed traders.

In the floor system, the number of securities or contracts for which a quote is valid is usually fairly high, so that an order is executed at one price only. Even if this is not true, competition among dealers urges them to quote similar prices. Thus, extracting consumer rents appears to be more difficult in the floor system.

This does not prove, however, that a trader gets a better price in the electronic system. Arbitrage

between the electronic and the floor system is usually effective reducing price differences to at most two ticks. Whether an order is executed at a better price in one or the other system, depends on bid-ask spreads and price sensitivity to order volume in both systems. Suppose the bid-ask spread in the electronic system, defined as the difference between the highest bid price and the lowest ask price in the limit order book, is smaller than that in the floor system, but its price sensitivity to order size is higher. Then small orders are executed at a better price in the electronic system whereas large orders obtain a better price in the floor system. Therefore, it is often argued that large investors get a better deal in dealer markets than in auction markets (cf. Pagano/Roell [1992, pp. 621f.]).

3 Competitive Strength of Trading Systems

This section discusses some factors affecting the competitive strength of electronic vis-à-vis floor trading. Some aspects of this competition have already been addressed in the previous section. Here we will concentrate on transaction costs and the information differential.

3.1 Transaction Costs

Pagano [1989] argues that trade in a security or a contract tends to concentrate in one market since this provides the highest level of liquidity and the most efficient pricing mechanism. Admati/Pfleiderer [1988] argue that for similar reasons intraday trade tends to concentrate at times when liquidity is expected to be highest. Still we observe quite often fragmentation of trade, i.e. the same security or contract is traded at different exchanges. Hence, there exist some reasons for fragmentation. In the following, transaction costs will be discussed first. It turns out that transaction costs partly support concentration of trade and partly support fragmentation of trade.

3.1.1 Advantage of the Firstly Established System

Suppose that both trading systems have their advantages and disadvantages. Then the system which is established first is likely to attract a higher market share of trading even after the competing system has been established. The reason is quite simple. A trading firm necessarily establishes its trading facilities at the first trading system as long as the other system does not

exist. This implies the setup of back office and front office facilities for the first system, training of people for the first system and establishing connections with the other trading firms. This setup cost is substantial. When the second trading system is established, a different setup is required. Naturally, trading firms hesitate to set up new trading facilities for the second trading system if they do not anticipate significant advantages with the second system. Therefore, a hysteresis effect exists which benefits the firstly established system at the expense of the second. Thus, given the initial concentration of trade, fragmentation will occur later only if the second system offers advantages over the first to some clientele of traders.

Casual evidence supports this reasoning. Consider the BUND-Future trade. The BUND-Future is an interest rate future on German government bonds with residual maturity between 8 ½ and 10 years. The LIFFE started the BUND-Future trade in September 1988; the DTB followed in January 1991. The market share of the DTB in the number of BUND-Future contracts traded gradually increased, it appears to have stabilized now around 30 percent. Thus, the firstcomer LIFFE still retains the bulk of the trading volume.

This is also true of the BOBL-Future contract; here, however, the DTB is the firstcomer. The BOBL-Future contract is an interest rate future on German government bonds with original maturity of at most 5 ¼ years and residual maturity of at least 3 ½ years. The DTB launched the BOBL-Future in October 1991; the LIFFE followed in January 1993. The trade at the LIFFE ended more or less in June 1994 although the official delisting was deferred until December 1994.

The LIFFE launched a 3-month-EURO-DM contract in April 1989 whereas the DTB started a 3-month-FIBOR-DM contract in March 1994. A similar contract was also launched at the MATIF, the French futures exchange, in April 1989. Still the market share of the LIFFE is about ⅔ while the market share of the DTB is usually below 5 percent. This may, however, be explained not only by the LIFFE being the first exchange to trade this contract, but also by the fact that the German money market is subject to a reserve requirement while the Euromarket is not. In any case, these casual observations support the competitive advantage of the exchange which first launches a contract.

3.1.2 Operating Transaction Costs

The advantage of the firstly established system is based on the cost of setting up trading facilities. In the long run, the operating transaction costs incurred by traders may be equally or more important for the choice among different trading systems. Operating transaction costs include the annual inhouse costs (personnel costs, communication costs, room costs, etc.) plus the transaction costs of trades (fees of the exchange, bid-ask spreads).

There is little disagreement that electronic screen based trading involves lower annual inhouse costs than floor trading. In an electronic system there is no need for concentration at one location, even cross-border screen based trading is possible provided that the necessary legal and technical requirements for cross-border transactions and settlements are satisfied.

Controversial, however, is whether the transaction costs of trades are higher or lower for electronic screen based trading. Beneviste/Marcus/Wilhelm [1992] argue that the bid-ask spread should be lower on the floor since observation of traders and sanctioning power of dealers allow dealers to distinguish information traders and liquidity traders⁵. If dealers can impose sufficient sanctions so that traders reveal their private information in trading, then a separating equilibrium may be obtained. In an anonymous market a pooling equilibrium is obtained. Hence the adverse selection problem is weaker on the floor leading to lower bid-ask spreads and higher trading volume. Higher trading volume, in turn, implies that prices are based on a larger set of information so that adverse selection is even more unlikely (cf. Glosten/Milgrom [1985], Stoll [1989])⁶. Moreover, a higher trading volume reduces price sensitivity to order size so that portfolio adjustments are less costly. Therefore, dealers should be ready to offer smaller bid-ask spreads.

⁵ Madhavan [1992] shows for a continuous dealer system and a continuous auction system with the latter not being anonymous that price competition between dealers eliminates the "wedge" between the transaction price and the expected value of the asset whereas strategic behavior in auction markets distorts prices and thus induces inefficiency.

⁶ This inverse relationship between the bid-ask spread and trading volume is questioned by George/Kaul/Nimalendran [1994]. They show that the impact of adverse selection on trading volume and the bid-ask spread depends on whether liquidity trading decreases in transaction costs at an increasing or a decreasing rate.

Comparing two trading systems with effective price arbitrage then would imply that the anonymous electronic system with the smaller trading volume would charge a higher bid-ask spread. This would create a strong incentive for all liquidity orders to concentrate on the floor. Hence, the anonymity of the electronic system would not allow the camouflage of information traders so that the electronic system would collapse.

So far we have ignored Glosten's arguments in favor of the open limit order book of the electronic system. Risk-averse traders can put very small orders at various prices into the book to protect themselves against adverse selection whereas on the floor quotes are valid for larger order sizes (Glosten [1994]). This should allow for a smaller bid-ask spread in the limit order book so that small orders would obtain a better price in the electronic system. For larger orders the electronic system would charge a higher bid-ask spread so that these orders would obtain a better price on the floor.

If then liquidity traders use both systems and if floor dealers can only imperfectly distinguish between liquidity and information traders, then information traders would also trade in both systems. As large liquidity orders go to the floor, the high volume of these orders would improve camouflage for information traders (Kyle [1985]). On the other hand, the sanctioning power of dealers would encourage information traders to use the anonymous electronic system. Hence, it seems plausible that the electronic system offers a smaller bid-ask spread for small orders, but its price sensitivity to order size is higher than that of the floor so that large orders obtain a better price on the floor.

So far there is little empirical support for this statement. That competition among exchanges affects bid-ask spreads, has been demonstrated by McInish/Wood [1992] for the USA and for Europe by Pagano/Roell [1993]; Schmidt/Iversen/Treske [1993] show for Germany that regional floor exchanges with small trading volume compete through smaller bid-ask spreads against a German interbank electronic trading system with much higher trading volume.⁷ Finally, Kofman/Bouwman/Moser [1994] investigate data from the BUND-Future trading at the DTB and the LIFFE over six weeks. Using the Roll-measure, they find that the DTB offers a tighter

⁷ The main floor exchange is in Frankfurt; the regional floor exchanges are endangered in their existence and, therefore, have to offer small bid-ask spreads in order to survive.

bid-ask spread. Correcting this measure for conditional expected returns as suggested by George/Kaul/Nimalendran [1991], they find the opposite result, however.

3.1.3 The Importance of Different Sources of Information

In this subsection we attempt to evaluate the information differential between a floor and an electronic trading system contingent on the intensity of information arrival. This information differential may be one determinant of the competitive strength of a trading system. If the differential affects traders' preferences for one system, then this should affect the market share of this system⁸. The market share of the electronic system is defined as its trading volume per period, divided by the aggregate trading volume of both systems per period. If the importance of the information differential depends on the intensity of information arrival, then the same should be true of the market share.

We discuss the information differential in relation to the intensity of information arrival since the time pattern of price volatility and volume can also be explained partly by the time pattern of information arrival. Thus, in an empirical test the time pattern of information arrival may be proxied by that of volatility and volume. The usual argument supporting this says that whenever new information arrives, traders and investors revise their expectations and, consequently, their portfolios. Hence trade volume increases, and at the same time, price volatility increases because the revision in expectations leads to a revision of equilibrium prices. As the price does not instantaneously jump to its new equilibrium price, it takes some time for the market participants to find out the new equilibrium price by trial and error. In this time period, volatility is higher than normal. Admati/Pfleiderer [1988] caution us to distinguish between private and public information. They argue that private information plays the dominant role. This is supported by empirical findings. The positive relation between volume and volatility is well documented (e.g., Karpoff [1987], Lee/Ready/Seguin [1994]); equally interesting is the finding

⁸ The term "traders' preferences for a system" should be interpreted as the preferences of those managers in a bank or a broker house who decide in which system to trade. If the firm is trading itself in both systems, then it can freely decide on its trading in both systems. If the firm is a member only in one system, then trading in the other system is more costly since in addition the intermediary has to be paid. Also preferences of outside investors matter. They may also switch their trades from one system to the other depending on their expectation as to in which system they will get the best deal.

of Berry/Howe [1994] that there is only a moderate positive relationship between public information and volume, but an insignificant relation with volatility. Blume/Easley/O'Hara [1994] extend this line of reasoning by differentiating between more and less reliable new information. While new information raises volatility, the extent to which it also raises trade volume is positively related to the reliability of the new information.

Now we compare periods which differ in the intensity of information arrival with respect to the impact of the information differential on traders' preferences. In periods of low information intensity, trade volume is low and transactions are infrequent; therefore information on the last trade is fairly old so that the limit order book information of the electronic system is more updated and, hence, an important indicator of market developments. Also, in such a period, traders are relatively inactive so that observation of their behavior on the floor does not reveal much about their intentions and, thus, does not permit reliable predictions of their activities over the next hour. Finally, in such a period there is not much to be gained from conversation among traders since new information to be evaluated is lacking. Hence, in a period of low information intensity, the order book information of the electronic system appears to offer more signals for predicting market developments than observation of traders on the floor.

This picture changes significantly in periods of high information intensity. Then various effects can be expected:

- (1) Due to high volatility, traders will reduce their volume of revealed limit orders since placing a limit order in the order book of the electronic system is equivalent to writing an option. The value of this option increases with volatility. As the trader does not get an option premium for writing the option, he will reduce the share of his orders revealed in the order book. Alternatively, the trader may shorten the average time span for the display of an order in the order book. Both reactions reduce the information content of the order book in periods of high volatility.
- (2) The relative importance of the order book information is also reduced by the fact that frequent trading with high trading volume yields continuously brandnew information on prices and trading volume. Besides the improvement in the timeliness of information, the amount of information increases with trading frequency. As this information on trade is available in both systems, the relative importance of the order book information in the

electronic system is reduced.

- (3) In periods of high information intensity, observation of other traders becomes more informative. If, for example, the same trader buys several times, then this indicates that he may act on private information or that outsiders place large buy orders. In addition, the body language of active traders is likely to reveal something about their next trades although they may try to camouflage their intentions. Finally, discussing new information with other traders helps each trader to better understand and evaluate the new information. These benefits exist only in floor trading, not in electronic trading.
- (4) In periods with much new information the danger of adverse selection increases. As the identity of the trading partner is unknown in an anonymous electronic system, there is little protection against adverse selection; traders may refuse trading or reduce their limit orders in the order book. In a floor system, traders build up a reputation for fair trading. Every trader knows the other traders so that information trading is considered unfair although it is not ruled out. But there is some sanctioning power of traders creating a barrier to adverse selection (Pagano/Roell [1993, p. 10], Beneviste/Marcus/Wilhelm [1992]). This barrier becomes more important in periods of high information intensity.

All the preceding arguments support the hypothesis that floor trading gains attractiveness relative to electronic trading in periods of intensive information arrival. The first three arguments indicate that the order book information becomes less important in periods of intensive information arrival relative to the information of the floor system provided through observability of traders. The fourth argument is based on the reputation of fair trading which becomes more essential in periods of intense information arrival. Therefore the information differential should favor electronic trading in times of low information intensity and floor trading in times of high information intensity. This leads to our first hypothesis.

Hypothesis 1: *Traders' preference for trading on the floor vis-à-vis the electronic system increases with the intensity of information arrival.*

A potential counterargument should not go unnoticed. In periods of high trading volume the number of mistrades where matched buy and sell orders do not fit together is likely to be relatively high. This problem only exists on the floor. Therefore, this might be an argument for electronic trading in times of high trading volume.

Both variables in hypothesis 1, preference and intensity of the information arrival, are not directly observable. Therefore we have to use proxies. We use the market share of the electronic system in aggregate trading activity as a proxy for traders' preferences. Given the positive relation between the intensity of information arrival and price volatility, we use volatility as a proxy for information. Then hypothesis 1 leads to hypothesis 2.

Hypothesis 2: *The market share of the anonymous electronic system declines when price volatility increases.*

Similarly, high information intensity raises aggregate trading volume. This leads to the related hypothesis 3.

Hypothesis 3: *The market share of the anonymous electronic system declines when aggregate trading volume increases.*

If hypotheses 2 and 3 are supported in an empirical test, then the test results are consistent (1) with the assertion that the information differential favors floor trading in periods of high information intensity and (2) with the volume effect. If, however, hypothesis 2 is rejected whereas hypothesis 3 is not, then this can be interpreted as evidence for the claim that an increase in aggregate trading volume raises the average order size and, hence, the market share of the floor system because large orders are executed at better terms in the dealer market.

If both hypotheses are not rejected, but the empirical support of hypothesis 3 is stronger, then this indicates that both effects exist: First, high information intensity favors floor trading. Second, high average order size favors floor trading. As aggregate trading volume should be positively correlated with average order size and volatility, the presence of both effects should provide stronger empirical support for hypothesis 3 as compared to hypothesis 2 since hypothesis 2 addresses the effect of price volatility only. There is little reason to believe that volatility increases with average order size.

In any case, it is desirable to separate the average order size effect and the volatility effect. This can be done as follows. First, we run a regression of aggregate trading volume on volatility. The

error term in this regression is that part of aggregate trading volume which is uncorrelated with volatility and normalized to zero mean. If average order size varies independently of volatility, then this error term should reflect this. The error term should be high (low) when average order size is high (low). Therefore, in a second step we regress the market share of the electronic system on price volatility and on this error term. If price volatility still has a significant impact on the market share, then this provides strong support for hypothesis 2. Therefore we state hypothesis 4 as an extended version of hypothesis 2.

Hypothesis 4: *The market share of the electronic system declines when price volatility increases and/or the average order size increases independently of price volatility.*

4 Empirical Results

4.1 Database

The preceeding hypotheses will be tested by data on the BUND-Future trades at the DTB and the LIFFE. The contracts traded at both exchanges are almost identical. There is a slight difference in the settlement procedures which is relevant only in the rare case of physical delivery. Thus it is safe to consider both contracts as identical. The LIFFE started the BUND-Future trade in September 1988; the DTB followed in January 1991. Thus, the LIFFE was the first to establish this trade which gives it an advantage in market share. Twelve Bund-Future contracts have been analyzed; the first contract's maturity was March 1991, the second contract's maturity June 1991, then September 1991, December 1991 and so forth until the twelfth contract with maturity December 1993. The contract with maturity 3/93 is exceptional because the DTB-contract permitted Treuhand bonds to be delivered at maturity while the LIFFE-contract did not. This led to a price differential between LIFFE- and DTB-prices of 35 basis points on average with DTB-prices being lower. For both exchanges we use time stamped data and daily data. Time stamped data contain the trade price and the volume of each transaction. Daily data include summary statistics on trade data for each contract: daily volume, highest and lowest price during one day, opening and settlement prices. The DTB supplied time stamped data as well as daily data for the period from January 1991 to December 1993; from the LIFFE we obtained time stamped data from January 1991 to May 1992 and daily data from September 1988 to December 1993.

Trades rarely occur simultaneously at both exchanges. At the LIFFE there is at least one trade in almost every three minute interval, except for trading around noon. We observe trades in roughly 94% of the intervals. At the DTB we find trades in 66% of the intervals for the first contract (March 1991). This figure increases steadily as volume grows rapidly; e.g., for the June 1992 contract, trade takes place in 88% of these intervals, for the December 1993 contract in 95%.

There is one problem with the trade volume data from the LIFFE. In periods of high trading frequency the number of Bund-Future contracts per trade is often announced to be 21. This number is certainly incorrect in many cases. But the LIFFE claims that aggregating the numbers of traded contracts per day gives a correct number. A comparison of time stamped data with

summary statistics proved this statement to be true. As we use the daily trading volume, LIFFE-daily data should provide correct numbers for our study.

This problem makes it impossible to analyze order sizes at the LIFFE. But it is also very hard to estimate order sizes at the DTB. First, it is possible that the order book permits only partial execution of an order. Second, an order may be executed at different prices so that different trades have to be added up. Third, a large order is usually split into several small ones. Due to the anonymity of trade, it is impossible to know which orders are part of a larger one. Therefore, we refrain from estimating order sizes.

Contract	No. of obs.	Volume DTB [contracts traded]				Volume Liffe [contracts traded]				Market share DTB [%]			
		Min.	Max.	Mean	Std. dev.	Min.	Max.	Mean	Std. dev.	Min.	Max.	Mean	Std. dev.
3/91	34	1484	6345	3350	1108	14832	77255	41933	15780	4.79	10.75	7.66	1.65
6/91	51	1856	10727	5754	1821	20706	82899	39808	11628	6.83	19.95	12.75	2.92
9/91	57	2661	22015	7806	3049	15292	117634	38950	18912	11.78	28.24	17.37	3.36
12/91	59	5117	52398	14233	9560	17650	75137	37128	13632	16.15	46.16	26.37	8.10
3/92	54	4978	31002	20568	5281	2989	87301	49694	19789	22.34	62.48	31.24	7.18
6/92	53	10442	32301	21509	5260	22252	92656	55852	18052	21.59	41.44	28.46	3.63
9/92	58	7063	39365	19846	7446	16812	99691	44543	18564	23.70	45.57	31.22	4.04
12/92	59	6161	47618	20950	7455	14085	113974	56421	20090	18.73	34.56	27.34	3.55
3/93	53	2428	30250	14698	6004	9583	90061	44841	20071	17.87	34.62	25.22	3.98
6/93	59	15952	46521	29826	7159	30637	120528	77952	24308	22.26	36.11	28.22	3.05
9/93	61	13031	47945	30268	7374	33312	136733	73975	20998	24.17	35.91	29.27	2.65
12/93	60	19207	67586	36095	10566	39504	181722	97307	33185	21.02	35.68	27.48	3.06

Table 1: Summary Statistics on Daily Trading Volume of the BUND-Future at the DTB and the LIFFE and the Market Share of the DTB. Trading volume is measured by the number of contracts. The contract identification a/b refers to the month a and the year b of expiration. The number of observations for a contract is the number of days on which both exchanges were open and this contract was the most actively traded contract. For each contract, the summary statistics (minimum, maximum, mean, standard deviation) refer to the observed daily trading volumes and the daily market share of the DTB in trading volume.

Table 1 provides some summary statistics on the daily trading volume of the BUND-Future contract. For each day, the trading volume of that contract is used which has the highest trading volume. Except for the last three or four days before maturity of a contract when traders switch

into the next contract, trade concentrates in the nearby maturing contract. All findings in this study are based on data of the most actively traded contract which is normally the front month contract. The BUND-Future trade stops at the LIFFE one working day ahead of the DTB. To avoid biases in the calculation of market shares around the roll-over date we exclude the first and the last three days for each contract in all calculations .

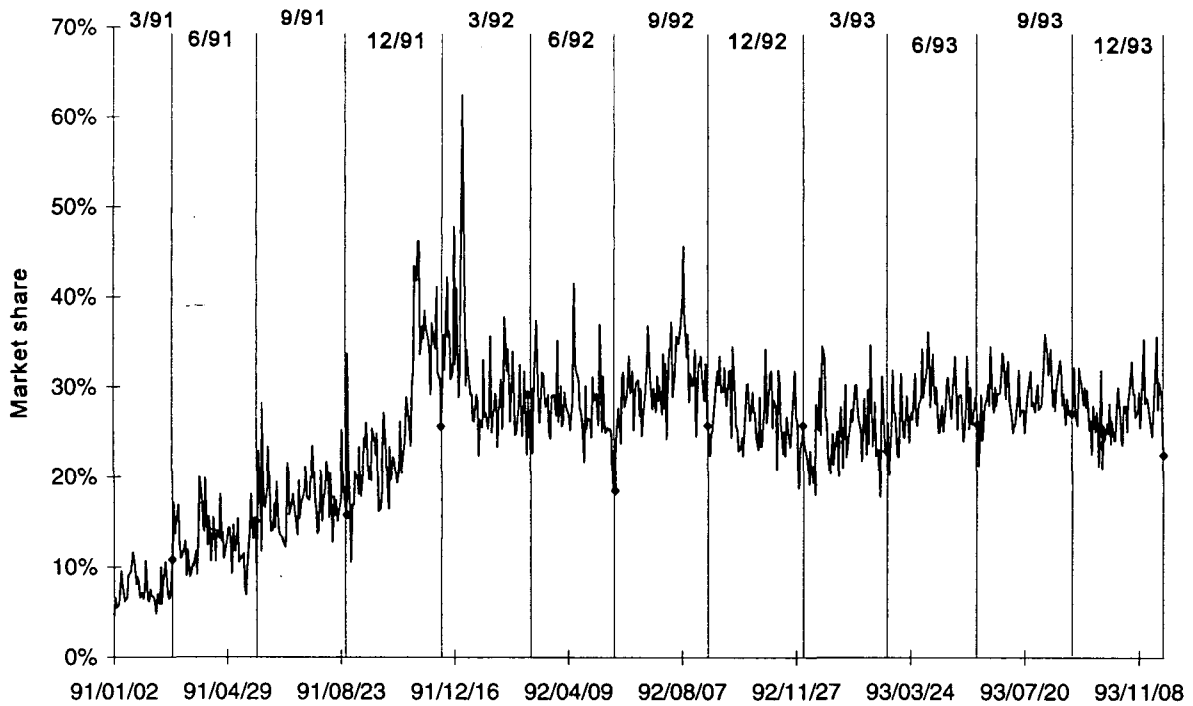


Figure 1: Daily DTB-market share in BUND-Future contracts traded at the DTB and the LIFFE

When the DTB started trading in BUND-Futures in January 1991, its market share in this contract until March 3 was on average 8%. Until the end of 1991 the market share of the DTB increased to 26% on average, reaching the highest level in the period from late October 1991 to January 1992 when the German banks launched a joint effort to increase trading volume in Frankfurt. For some single days in this period, DTB's market share exceeded 50% with a maximum of 62%. Therefore, the market share of the DTB in this period appears to be biased so that the empirical findings for the contracts maturing in December 1991 and in March 1992 have to be interpreted with much caution. Hence the market share for the first three contracts is biased because of the start-up phase while the market share of contracts 12/91 and 3/92 is biased through the joint effort. Therefore the most reliable inferences can be made from the contracts

6/92 - 12/93. For the contracts 6/92 to 12/93, the average market share of the DTB varied within a fairly narrow range of 25% to 31%. Thus, the contract 3/93 which was exceptional because of the DTB-LIFFE difference in deliverable bonds, does not display an unusual market share; it is only slightly lower.

Figure 1 depicts the DTB's market share in daily trading volume of the front month BUND-future contract. DTB's market share in all three contracts differs only insignificantly from that in the front month contract. The mean difference between DTB's market share in all three contracts traded at the same time and it's market share in the most actively traded contract is only .06 percent.

4.2 Estimating Price Volatility

Many measures of price volatility are used in empirical studies (cf. Lee/Ready/Seguin [1994]). We aim to measure daily price volatility. One measure we use is the daily high-low, i.e. the difference between the highest and the lowest price on the same day. This measure uses very little information of the price series and is sensitive to price errors, i.e. errors which are created either by false price reporting or by erroneous price agreements. Since the data released by the exchanges do not correct these errors, we checked the data for extreme outliers and eliminated those. Thus, the derived daily high-low is hopefully not biased.

As alternative volatility measures we use the standard deviation of prices of one day as well as the standard deviation of price changes within one day. The main difference between the standard deviation of prices and that of price changes is that the former is affected by a trend. Suppose that we consider average prices over 3-minute-intervals. Let T denote the daily number of those intervals (160 for 8 hours). Let $\mu + \varepsilon_i$ be the price change between interval i and $(i - 1)$, with μ being a trend and ε_i the trend-independent price change. If we ignore the intradaily variation in price volatility so that $\sigma^2(\varepsilon_i) = \sigma^2(\varepsilon) \forall i$ and assume that $\text{cov}(\varepsilon_i, \varepsilon_{i+\tau})$ equals c for $\tau = 1$ and is close to 0 for $\tau > 1$, then the daily variance of price changes, $\sigma^2(\Delta P)$, is

$$\sigma^2(\Delta P) \approx \sigma^2(\varepsilon) - 2c/T .$$

The daily variance of prices, σ_p^2 , is

$$\sigma^2(P) \approx \frac{T}{6} \left[\sigma^2(\epsilon) + 2c + \sigma^2(\mu) (1+T/2) \right] .$$

Herein it is assumed that the expected trend of the futures price, $E(\mu)$, is 0.

Hence $\sigma^2(P)$ and $\sigma^2(\Delta P)$ differ by the factor $T/6$, through the effect of the covariances c and through the variance of the price trend. If the covariances and the variance of the price trend are close to zero, then the standard deviation of prices divided by that of price changes should be roughly equal to 5 ($\approx \sqrt{160/6}$).

One could use every price recorded at an exchange to compute these standard deviations. This leads to strong biases, however, since the time span between two successive trades itself is a random variable which is distributed differently at both exchanges. Suppose, for example, that the price follows a geometric Brownian motion. Then the volatility estimate derived from the DTB prices would be higher than that derived from the LIFFE prices since the average time span between trades at the DTB is higher. One could explicitly take into consideration the time span in the volatility estimate. But this is tricky since the time span in the electronic system is zero whenever an order is matched with several orders in the order book at different prices. Therefore, we compute an average price in every three minute interval between 9.00 a.m. and 5.00 p.m. Frankfurt time. If there is no trade in such an interval, we take the average price from the last interval. Hence we assume that the price change is equal to zero if no trade occurs. This creates an error-in-variables problem (Stephan/Whaley [1990]). The choice of the time interval reflects a compromise between the attempt to constrain the missing data problem and the attempt to constrain the loss of information through aggregation of data.

Moreover, we aim to purge the volatility estimates from the effects of bid-ask spreads which may differ across exchanges. Averaging prices over 3-minute intervals achieves this better than taking, for example, opening or closing prices of these intervals. Thus, we hope that these average prices are not biased by bid-ask spreads. Still, as indicated by Amihud/Mendelson [1987], estimated variances are likely to be biased upwards relative to "true" variances because of noise.

Contract	Daily standard deviation of price changes [Ticks]			Daily standard deviation of prices [Ticks]			Daily high-low [Ticks]		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
3/91	0.885	3.934	1.808	2.272	24.732	8.575	19	105	45.71
6/91	0.802	2.359	1.349	2.271	15.614	6.496	11	60	32.69
9/91	0.603	2.900	1.115	1.677	15.979	5.232	13	66	26.20
12/91	0.492	1.357	0.902	1.232	14.847	4.681	11	52	22.90
3/92	0.584	1.804	1.016	1.704	11.754	5.056	11	65	26.82
6/92	0.627	1.732	1.079	1.697	16.421	5.584	11	59	27.91
9/92	0.513	2.679	0.993	1.007	17.557	4.703	9	78	23.53
12/92	0.612	2.754	1.370	1.567	22.572	6.865	11	102	35.51
3/93	0.422	1.707	0.907	0.870	11.959	4.550	7	72	25.11
6/93	1.056	2.575	1.593	3.153	18.867	8.752	19	69	41.75
9/93	0.745	2.097	1.339	2.245	21.384	6.491	13	65	31.80
12/93	0.823	2.604	1.342	1.792	17.801	6.447	11	84	32.27

Table 2: Summary statistics on volatility-estimates - Daily standard deviation of prices, price changes (prices are averaged over three-minute intervals), and daily high-lows at the DTB. The minimum, maximum and mean of each volatility measure are derived using only those days of a contract when it is the most actively traded one.

Table 2 reports summary statistics on estimates of daily standard deviations of 3-minute-average prices and of the changes of 3-minute-average prices at the DTB. The mean daily standard deviation of prices is about 5 times that of the mean daily standard deviation of price changes. This indicates that autocorrelation of price changes and the variance of the price trend do not play a major role. An analysis of the DTB-data shows that the autocorrelation of price changes depends on the prices being analyzed. The autocorrelation of the daily 3-minutes-average prices is usually positive in the range between 0 and .3 with an average of slightly less than .2. This contrasts with an autocorrelation of around -.2 of the price changes obtained from the original transaction prices. This indicates a positive bid-ask spread which is removed through averaging prices. In addition, table 2 shows summary statistics of the daily high-low.

4.3 Differences Between DTB- and LIFFE-Prices

We need to investigate differences between the BUND-Future prices at the DTB and the LIFFE for two reasons. First, price differences show how effective arbitrage between both markets works and, hence, how well integrated markets are. Second, since we have available time stamped transactions data from the LIFFE only for the first half of the investigation period, we need to demonstrate that volatility estimates based on DTB-data are very similar to those based on LIFFE-data.

Figure 2 shows frequency distributions of the differences between 3-minutes-average prices at the DTB and the LIFFE for the first six contracts since the start of the DTB. Negative price differences mean that the average price in a three minute interval was higher at LIFFE. Table 3 reports means and standard deviations of price differences.

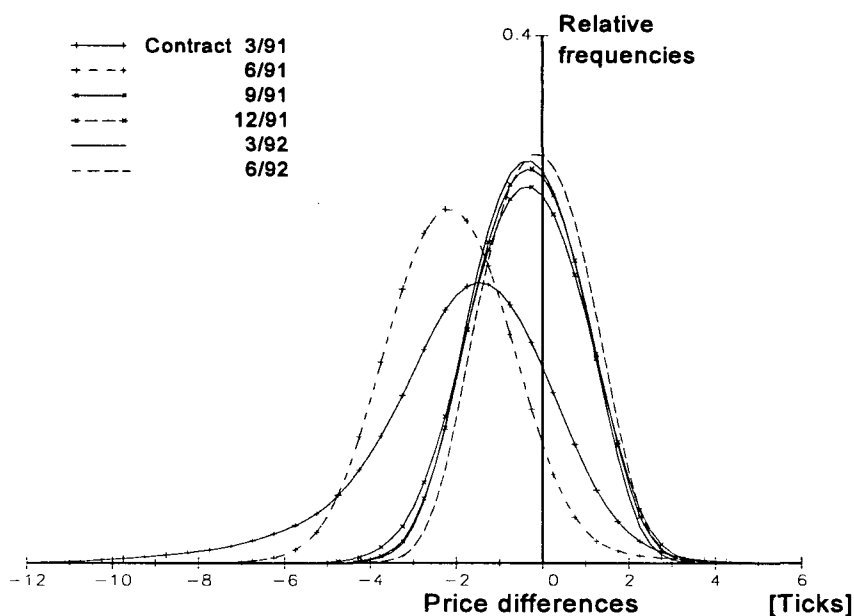


Figure 2: Relative Frequencies of Differences between Average Prices at the DTB and the LIFFE.

Substantial arbitrage opportunities existed in the first two traded contracts: on average, prices at the DTB are lower by 1.89 ticks for the 03/91 contract and by 2.10 ticks for the 06/91 contracts. However, prices of the following contracts are much more integrated: mean price differences of the next three contracts are roughly one-third of a tick, and for the 06/92 contract only 0.14 ticks. The standard deviation of price differences is also steadily declining. These figures

suggest a learning phase at the DTB. Therefore, results for the first contracts have to be interpreted with caution.

Contract maturity	Price differences [Ticks]			
	Mean	Standard deviation	Skewness	Kurtosis
03/91	-1.8901	1.9369	-1.0472	5.6826
06/91	-2.1043	1.1205	0.6472	5.7873
09/91	-0.3673	0.8839	-0.1954	4.3807
12/91	-0.3217	0.7349	-0.2624	3.6522
03/92	-0.3583	0.6706	-0.3399	4.0566
06/92	-0.1390	0.6105	0.0003	4.6810

Table 3: Summary statistics on price differences between the DTB and the LIFFE

These figures indicate that after the initial learning phase both markets are well integrated. Therefore, volatility estimates derived from the two markets are very similar. Table 4 illustrates this for the first six contracts based on average transaction prices for 3-minutes-intervals. The first three columns display averages of the daily standard deviations of prices at the DTB and the LIFFE and the correlation between them. Columns 4-6 display the corresponding figures for prices changes. Note that the figures of table 4 are computed exclusively from those days for which time stamped data are available from both exchanges and, thus, mean standard deviations for the DTB are slightly different from the figures reported in table 2.

Contract maturity	Average of daily standard deviations of prices		Correlation between standard deviations of prices	Average of daily standard deviations of price changes		Correlation between standard deviations of price changes
	DTB	LIFFE		DTB	LIFFE	
	(1)	(2)		(4)	(5)	
03/91	8.7265	8.7943	0.9970	1.8085	1.7077	0.9661
06/91	6.4222	6.4331	0.9981	1.3475	1.3361	0.9671
09/91	5.2102	5.2991	0.9986	1.1040	1.1346	0.9884
12/91	4.6949	4.9451	0.9987	0.8978	0.9641	0.9527
03/92	4.9883	5.1224	0.9963	1.0090	1.0775	0.9695
06/92	5.5167	5.4831	0.9992	1.0640	1.1332	0.9456

Table 4: Averages and correlations of daily standard deviations of prices and of price changes at the DTB and at the LIFFE. These figures are derived from those days for which data were available from both exchanges.

Table 4 shows that both exchanges have very similar standard deviations. However, the correlation among the standard deviations of prices is clearly higher than that among standard deviations of price changes. This indicates the existence of trends which reinforce correlation of prices.

The high degree of integration of both exchanges in terms of pricing is also confirmed by the daily high-low; here we have data for all contracts from both exchanges. In table 5, we compare the daily highs and daily lows at both exchanges. Except for the first two contracts and contract 3/93, the average difference in daily highs is less than 2 ticks. The average difference in daily lows ranges between +1 and -1 tick. These figures show that differences are rather stable. For contract 3/93, LIFFE-prices are much higher because of the difference in deliverable bonds. This does not imply, however, that trades switch to one exchange. As long as prices move in parallel at both exchanges, hedgers and speculators can trade at either exchange. This may explain why the DTB's market share is not significantly affected.

Contract	Daily high _{DTB} - Daily high _{LIFFE}			Daily low _{DTB} - Daily low _{LIFFE}		
	Min.	Max.	Mean	Min.	Max.	Mean
3/91	-10	18	-1.933	-8	11	-0.300
6/91	-13	6	-2.300	-9	1	-1.820
9/91	-3	10	-0.474	-11	6	-0.316
12/91	-9	4	-0.915	-7	15	0.203
3/92	-5	7	-0.407	-9	1	-0.685
6/92	-3	6	-0.396	-13	2	-0.170
9/92	-3	7	-0.569	-4	2	0.172
12/92	-15	22	-1.220	-6	5	-0.102
3/93	-54	-8	-35.804	-49	-5	-34.804
6/93	-3	6	-0.125	-20	2	-0.946
9/93	-3	6	-0.569	-11	2	-0.690
12/93	-3	11	-0.298	-9	25	0.228

Table 5: Summary statistics on differences of daily highs and daily lows.

The strong integration of both markets in terms of pricing does not rule out that one market is leading the other. Regressing price changes of one market against leaded and lagged price changes of the other one shows that sometimes there are some significant leads, but they can go

both ways, i.e. sometimes the DTB leads the LIFFE and vice versa. Therefore, a stable lead-lag-relationship is not visible. This is consistent with the findings of Franses/van Ieperen/Kofman/Martens/Menkveld [1994]. It supports our confidence that both markets are well integrated.

4.4 Tests of Hypotheses

There are various possibilities to test hypotheses 2 and 3. First, we test for cointegration of the observed time series. To check whether the observed variables can be characterized as integrated processes we use an augmented Dickey-Fuller test (see Hamilton [1994]). Testing against the hypothesis that the observed series follow trend stationary processes, the null hypothesis of unit root processes could be rejected at the 1% level for all the series used in this study, i.e., market share, trading volumes at each exchange, aggregate trading volume and the three volatility measures. Hence, cointegration is ruled out.

Second, we run regression tests with the market share being the dependent variable. The market share MS is necessarily constrained to the interval [0,1] so that a normal distribution is ruled out. The transformed market share $MS_t^* \equiv \ln \left[MS_t / (1 - MS_t) \right]$ does not have this drawback and, therefore, is used in the regressions.

Simple OLS-regressions of the transformed market share on volatility generate substantial autocorrelation in the regression residuals and, therefore, do not permit reliable inferences. This is plausible since the daily market share displays a first order-autocorrelation of about .84. Similarly, the daily standard deviation of prices shows a first order-autocorrelation of .57; this is the reason why it has become common to model returns by GARCH-processes. Also the aggregate trading volume has positive first order-autocorrelation. Therefore we use regressions with lagged variables. We also include a trend variable since, at least, aggregate trading volume grows over time. The general structure of the regressions is:

$$MS_t^* = b_0 + b_1 t + b_2 x_t + b_3 x_{t-1} + b_4 MS_{t-1}^* + \varepsilon_t .$$

The symbols are defined as follows:

$Vol_{D,t} \equiv$ trading volume of the Bund-Futures contract at the DTB at day t ;

$Vol_{L,t}$	\equiv	trading volume of the Bund-Futures contract at the LIFFE at day t;
MS_t	\equiv	market share of the DTB at day t $\equiv Vol_{D,t} / (Vol_{D,t} + Vol_{L,t})$;
MS_t^*	\equiv	$\ln[MS_t / (1-MS_t)]$;
x_t^*	\equiv	daily standard deviation of prices $\sigma_t(P)$, or daily standard deviation of price changes $\sigma_t(\Delta P)$, or daily high-low HL_t , or daily aggregate trading volume $\ln[Vol_{D,t} + Vol_{L,t}]$;
HL_t	\equiv	the difference between the highest and lowest Bund-Futures price at the DTB on day t;
b_i	\equiv	regression coefficients, $i = 1, \dots, 5$;
ε_t	\equiv	disturbance term at day t.

As we face errors in the observable variables, we would prefer to use an instrumental variables approach (see Cuthbertson et. al. [1992]). However, our attempts to find instruments that reduce the influences of measurement errors significantly, have failed so far. Therefore we report only OLS-results.

Table 6 presents the results from regressing the transformed market share on the three volatility measures. The regressions are run separately for each contract. Table 6 shows in columns (2)-(4) the regression coefficients b_2 , b_3 and b_4 for the regression on the daily standard deviation of price changes. Stars indicate significance levels computed from heteroscedasticity-consistent standard errors (see Hamilton [1994]). In addition, the adjusted R^2 and the Breusch-Godfrey test statistic are shown. Since ordinary Durbin-Watson statistics are biased in presence of lagged dependent variables, we use a Breusch-Godfrey test to check for autocorrelation in the residuals (see Greene [1993]).

In columns (7) and (8), the regression coefficient b_2 and the adjusted R^2 for the regression on the daily standard deviation of prices are displayed. In columns (9) and (10), the regression coefficient b_2 and the adjusted R^2 for the regression on the daily high-low are displayed. Coefficients of lags in both of these volatility measures were insignificant for almost all contracts.

Con- tract (1)	$\sigma_t(\Delta P)$ (2)	$\sigma_{t-1}(\Delta P)$ (3)	MS_{t-1}^* (4)	adj. R ² (5)	Breusch- Godfrey (6)	$\sigma_t(P)$ (7)	adj. R ² (8)	HL _t (9)	adj. R ² (10)
3/91	-0.1116 [*]	0.1719 ^{***}	0.4080 ^{**}	0.277	2.39	-0.0053	0.036	-0.0031	0.092
6/91	-0.2523 ^{***}	0.2638 ^{**}	0.5213 ^{***}	0.257	5.25	-0.0025	0.107	0.0012	0.116
9/91	-0.2568 ^{***}	-0.0161	-0.0525	0.169	8.02	-0.0302 ^{***}	0.143	-0.0075 ^{***}	0.170
12/91	-0.2594 ^{**}	0.0686	0.6026 ^{***}	0.746	9.57	-0.0058	0.744	-0.0054 [*]	0.753
3/92	-0.8715 ^{***}	0.5703 ^{***}	0.4333 ^{***}	0.607	7.28	-0.0582 ^{***}	0.440	-0.0131 ^{***}	0.432
6/92	-0.3951 ^{***}	0.0264	-0.0857	0.302	8.03	-0.0262 ^{***}	0.270	-0.0077 ^{***}	0.304
9/92	-0.1551 ^{***}	0.0211	0.2493 [*]	0.247	6.63	-0.0285 ^{***}	0.238	-0.0044 ^{***}	0.226
12/92	-0.1983 ^{***}	0.0963 [*]	0.2693 ^{**}	0.249	4.69	-0.0184 ^{***}	0.252	-0.0046 ^{***}	0.255
3/93	-0.3547 ^{***}	0.0707	0.2092	0.196	10.74	-0.0286 ^{***}	0.134	-0.0056 ^{***}	0.107
6/93	-0.2238 ^{***}	0.0644	0.1086	0.280	7.05	-0.0192 ^{***}	0.336	-0.0063 ^{***}	0.387
9/93	-0.0649	0.0570	0.4709 ^{***}	0.223	5.37	-0.0121 ^{***}	0.307	-0.0036 ^{***}	0.307
12/93	-0.0595	0.0613	0.1676	0.033	4.84	-0.0145 ^{***}	0.125	-0.0041 ^{***}	0.175

Table 6: Regression of the transformed daily DTB-market share in trading volume on the daily standard deviation of price changes (columns 2-6), the daily standard deviation of prices (columns 7 and 8) and the daily high-low (columns 9 and 10). Stars indicate significance levels of regression coefficients and the Breusch-Godfrey test (*** 1%; ** 5%; * 10%).

The figures in table 6 show rather similar results for the three volatility measures. Except for one all coefficients of the volatility measures are negative as hypothesized. Looking at individual contracts, the only one positive coefficient for HL_t is not significant. For each volatility measure nine or ten of the twelve coefficients are significantly negative. Interestingly, the last two coefficients for the standard deviation of price changes are not significant while the coefficients for the standard deviation of prices and for the high-low are highly significant. Except for the first two contracts, the impact of the lagged volatility measure is much smaller as shown in column (3); the sign of the coefficients varies; only a few are significant. More important are the lagged transformed market share (column (4)). These coefficients are mostly positive with part of them being significant. This reflects the positive autocorrelation in the transformed market share. The inclusion of the lagged transformed market shares is essential to get acceptable levels of the Breusch-Godfrey statistics. These relationships are similar for the three volatility measures. The adjusted R²'s are very similar for the standard deviation of prices and for the high-low, so that the explanatory power of these volatility measures is similar. The adjusted R²'s are slightly higher on average for the standard deviation of price changes.

Contract (1)	$\ln[\text{Vol}_{D,t} + \text{Vol}_{L,t}]$ (2)	$\ln[\text{Vol}_{D,t-1} + \text{Vol}_{L,t-1}]$ (3)	MS^*_{t-1} (4)	adj. R^2 (5)	Breusch- Godfrey (6)
3/91	-0.2753***	0.0932	0.3530**	0.247	2.85
6/91	-0.2471*	0.0979	0.4833***	0.161	4.55
9/91	-0.3329***	0.0382	0.0242	0.287	8.34
12/91	-0.1698*	0.1697**	0.6462***	0.765	4.98
3/92	-0.5622***	0.0196	-0.0281	0.820	6.50
6/92	-0.3041***	-0.0919	-0.1287	0.430	3.91
9/92	-0.1762***	0.0279	0.2088*	0.260	9.22
12/92	-0.3318***	0.1125*	0.3192**	0.452	6.21
3/93	-0.2144***	0.0698	0.1985	0.164	7.30
6/93	-0.3429***	-0.0033	0.0725	0.495	7.16
9/93	-0.1202**	0.0902*	0.4904***	0.283	4.69
12/93	-0.2256***	-0.0020	0.0490	0.226	9.39

Table 7: Regression of DTB's market share in trading volume on aggregate trading volume, i. e. the sum of DTB's and LIFFE's trading volume.

Table 7 presents the results from regressing the transformed market share on the logarithmic aggregate trading volume. Comparing tables 6 and 7 shows somewhat stronger results for the logarithmic aggregate trading volume replacing the volatility measure. Aggregate trading volume seems to give a better explanation for the transformed market share: All regression coefficients on aggregate trading volume are negative and significant. The adjusted R^2 's are higher on average.

The correspondence of results in tables 6 and 7 could be explained by the volume effect. In order to test this, we run for each exchange regressions of the following type:

$$\ln \text{Vol}_{i,t} = b_0 + b_1 t + b_2 \sigma_t(P) + b_3 \sigma_{t-1}(P) + b_4 \ln \text{Vol}_{i,t-1} + \varepsilon_t; \quad i = D, L$$

The setup of table 8 is the same as that of table 6 and 7. The volume effect is impressively supported. All the volatility coefficients are significantly positive. Most coefficients of the lagged volatility are not significant. With one exception, the lag 1-volume has a positive impact at both exchanges which is partly significant. The explanatory power of the volume effect as indicated by the adjusted R^2 is for some contracts higher at the LIFFE while for others it is

higher at the DTB. On average, however, the explanatory power is much the same. When the standard deviation of prices is replaced by the standard deviation of price changes or the high-low, comparable results are obtained.

Panel a: Logarithmic trading volume at DTB - $\text{Ln} [\text{Vol}_{D,t}]$

Con- tract	$\sigma_t (P)$	$\sigma_{t-1} (P)$	$\text{Ln}[\text{Vol}_{D,t-1}]$	adj. R^2	Breusch- Godfrey
3/91	0.0491 ^{***}	0.0063	0.1155	0.486	6.04
9/91	0.0514 ^{***}	0.0185	0.2782 ^{**}	0.388	6.31
6/91	0.0636 ^{***}	0.0165	0.0908	0.494	14.69 [*]
12/91	0.0742 ^{***}	0.0057	0.4899 ^{***}	0.760	3.53
3/92	0.0587 ^{***}	0.0122	0.4514 ^{**}	0.407	10.42
6/92	0.0477 ^{***}	0.0026	0.2268	0.369	2.68
9/92	0.0808 ^{***}	0.0014	0.1878 [*]	0.659	9.95
12/92	0.0487 ^{***}	-0.0085	0.3259 ^{***}	0.694	5.36
3/93	0.0547 ^{***}	-0.0128	0.5582 ^{***}	0.613	8.73
6/93	0.0365 ^{***}	0.0064	0.0047	0.478	3.45
9/93	0.0478 ^{***}	0.0028	0.2710 [*]	0.419	4.05
12/93	0.0591 ^{***}	0.0034	0.0080	0.449	8.51

Panel b: Logarithmic trading volume at LIFFE - $\text{Ln} [\text{Vol}_{L,t}]$

Con- tract	$\sigma_t (P)$	$\sigma_{t-1} (P)$	$\text{Ln}[\text{Vol}_{L,t-1}]$	adj. R^2	Breusch- Godfrey
3/91	0.0535 ^{***}	0.0213 ^{**}	-0.1391	0.508	3.71
6/91	0.0511 ^{***}	0.0231	0.0207	0.343	4.94
9/91	0.0952 ^{***}	0.0279 [*]	0.0125	0.550	8.78
12/91	0.0795 ^{***}	0.0200	0.1109	0.418	10.29
3/92	0.1185 ^{***}	0.0167	0.4613 ^{**}	0.492	6.21
6/92	0.0726 ^{***}	-0.0013	0.2799 [*]	0.491	8.32
9/92	0.0988 ^{***}	-0.0090	0.2708 ^{***}	0.685	12.70
12/92	0.0672 ^{***}	-0.0033	0.2451 [*]	0.556	4.14
3/93	0.0894 ^{***}	-0.0178	0.6075 ^{***}	0.623	8.38
6/93	0.0538 ^{***}	-0.0051	0.2118 ^{**}	0.519	7.91
9/93	0.0606 ^{***}	-0.0116	0.1539	0.541	5.43
12/93	0.0734 ^{***}	-0.0167	0.2379 ^{**}	0.502	10.67

Table 8: Regression of the logarithmic daily trading volumes of the DTB (Panel a) and the LIFFE (Panel b) on the daily standard deviation of prices.

The market share of the DTB declines when price volatility increases and when aggregate trading volume increases. Moreover, the volume effect is strongly supported by the data. Therefore it is not clear whether price volatility or volume drives the results. In order to separate volatility and volume effects, we first regress aggregate trading volume on the standard deviation of price changes:

$$ATV_t = c_0 + c_1 t + c_2 \sigma_t(\Delta P) + \xi_t$$

with ATV_t being the daily aggregate trading volume. ξ_t is the detrended aggregate trading volume which is not explained through price volatility. It is uncorrelated with price volatility and normalized to zero mean. Then we run a bivariate regression of the transformed market share of the DTB on the standard deviation of price changes and on ξ_t :

$$MS_t^* = a_0 + a_1 t + a_2 \sigma_t(\Delta P) + a_3 \xi_t + a_4 MS_{t-1}^* + \eta_t .$$

Since the lagged standard deviation of price changes does not explain much, it has been omitted.

Table 9 presents the results of this regression. Coefficients a_0 and a_1 are not shown. All regression coefficients a_2 and a_3 (columns (2) and (3)) are negative as hypothesized. All coefficients of price volatility except for the last two are significant while two thirds of the ξ_t -coefficients are significant. Overall, the explanatory power as measured by the adjusted R^2 is higher for the bivariate regression as compared to the univariate regression in table 6.

The same kind of analysis using the standard deviation of prices or the high-low gives similar results: About the same number of coefficients a_2 and a_3 are significant; however, now the coefficients a_2 of the last two contracts are highly significant while those of the first two contracts are not significant. The explanatory power as measured by the adjusted R^2 's is almost the same for all three volatility measures.

Contract (1)	$\sigma_t(\Delta P)$ (2)	ξ_t (3)	MS_{t-1}^* (4)	adj. R^2 (5)	Breusch- Godfrey (6)
3/91	-0.1199**	-0.3175**	0.2933*	0.232	4.04
6/91	-0.2329***	-0.1041	0.4938***	0.170	3.18
9/91	-0.2573***	-0.3676**	0.0018	0.286	9.94
12/91	-0.2543**	-0.0428	0.6054***	0.750	9.28
3/92	-0.7477***	-0.5424***	-0.0539	0.821	7.10
6/92	-0.3726***	-0.2968***	-0.0381	0.416	5.44
9/92	-0.1547**	-0.1121	0.1968*	0.271	8.63
12/92	-0.1649***	-0.3618***	0.2042*	0.437	9.78
3/93	-0.3315***	-0.0762	0.1570	0.203	8.23
6/93	-0.1980***	-0.3557***	0.0852	0.495	6.93
9/93	-0.0533	-0.1400**	0.4524***	0.252	4.46
12/93	-0.0614	-0.3963***	0.0215	0.337	7.89

Table 9: Regression of the transformed daily DTB-market share in trading volume on the daily standard deviation of price changes and the volatility independent aggregate trading volume ξ .

4.5 Discussion

The empirical results support hypothesis 2: the market share of the DTB is inversely related to price volatility. This supports our hypothesis that the information differential between the electronic and the floor trading system induces some traders to switch their trading activities from the DTB to the LIFFE in times of high volatility. It is noteworthy that the regression results are similar across the three volatility measures. This indicates that their information content is comparable. The difference between the standard deviation of prices and that of price changes is that the former increases with a price trend. The high-low is equally affected by a strong trend as by highly variable price changes.

The empirical support for hypothesis 3 is slightly higher compared to that for hypothesis 2. As has been discussed before, hypothesis 3 can be derived (1) from the impact of new information on trading volume and from (2) for the claim that larger orders go to the floor and, thus, reduce the DTB's market share. This claim appears to be justified even more in the BUND-Future

example since the average market share of the DTB is less than half of the LIFFE's share. This by itself supports the presumption that price sensitivity to order size is smaller at the LIFFE, irrespective of differences in trading systems. Therefore, large orders should preferably be placed at the LIFFE. Hence, if the fraction of large orders increases so that the average order size and aggregate trading volume increase, then this is a second reason for the DTB's market share to go down in times of high aggregate trading volume. Therefore one would expect that the transformed market share of the DTB can be explained better by aggregate trading volume than by price volatility. Our empirical results support this conclusion to some extent.

The correspondence in the explanatory power of the volatility measures and aggregate trading volume can be partly explained by the strong evidence on the volume effect. As aggregate trading volume can be well explained by volatility, the substitutability between volume and volatility in explaining the market share does not come as a surprise.

A better insight into the effects of price volatility and the average order size on the market share is obtained by regressing the DTB's market share on price volatility and on the volatility independent aggregate trading volume. The latter may be interpreted as a proxy for the volatility independent average order size. Table 9 indicates a stronger impact of price volatility on the market share than of the volatility independent volume. This is clear support for hypothesis 4 with the main emphasis still being placed on price volatility. Hence it appears that the electronic system's market share goes down in periods of high information intensity.

Another potential effect on the market share can be attributed to the fact that the activity in trading options on the BUND-Future is stronger at the LIFFE than at the DTB. In periods of high volatility, trading strategies which use futures and options may require more frequent portfolio adjustments which can be made more efficiently at the exchange with the more liquid option market.

5 Conclusions

This paper argues that the information differential between an anonymous screen based trading system and a floor trading system should increase the attractiveness of the latter in periods of high information intensity which are also periods of high volatility and high volume. The insight

into the order book of the electronic screen based system is less valuable in periods of high information intensity . Placing orders in the order book becomes less attractive since it amounts to writing an option at zero price which becomes more valuable. With higher volatility and higher volume, more information is available from observing actual trades so that the information of the order book is less valuable. Also traders are more active so that on the floor more information can be inferred from observing the names and behavior of the active traders. Moreover, the reputation effect which is precluded by anonymity of electronic trading becomes more important in periods of high information intensity. All this makes floor trading more attractive in those periods. Besides, large orders seem to go to the floor since price sensitivity to order size appears to be smaller on the floor. Therefore, an increase in average order size should also raise the floor's market share in aggregate trading volume.

These hypotheses are tested by analysing the trade data of the BUND-Future contract which is traded in almost identical design at the DTB and the LIFFE. Arbitrage between both exchanges works very well, at least from December 1991 onwards. The hypothesis that the market share of electronic trading is inversely related to price volatility is supported by the data. The explanatory power is about the same regardless of whether volatility is measured by the daily standard deviation of average prices of three-minute-intervals, by the daily standard deviation of price changes or by the daily difference between the highest and the lowest price.

Equally supported is the inverse relation between the DTB's market share and aggregate trading volume. This may not come as a surprise since the volume effect is impressive at both exchanges. Our evidence is also consistent with the claim that large orders go preferably to the floor. Still, high volatility appears to have a stronger negative impact on the anonymous electronic trading system's market share than average order size. This finding presents a challenge to electronic exchanges. They should consider changes in their setup so as to improve their competitiveness in periods of high volatility and volume.

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