Market Liquidity and Depth on Computerized and Open Outcry Trading Systems: A Comparison of DTB and LIFFE Bund Contracts

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INTRODUCTION

Futures contracts have been bought and sold by "open outcry" on exchange floors since the birth of futures markets in the 19th century. Over the past decade, however, several exchanges have introduced computerized markets. In some cases, the computerized trading systems are designed to supplement open outcry by extending trading hours; examples include GLOBEX, the London International Financial Futures Exchange's (LIFFE) Automated Pit Trading System (APT), and the New York Mercantile Exchange's Access system. In other cases, such as the Swiss Options and Financial Futures Exchange (SOFFEX) and the Deutsche Terminborse (DTB), all trading is conducted on the computerized system.

Computerized trading is substantially different from open outcry. This raises the question: Which mechanism is the most efficient way to trade futures contracts? Since one of the most important attributes of an efficient trading mechanism is liquidity, an answer to this question requires a comparison of the liquidity of open outcry and computerized

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trading systems. This article presents the results of just such a comparison. Specifically, it compares the liquidity of the German Bund futures contracts traded simultaneously via open outcry on the LIFFE and via CTS on the DTB.

Given that many market participants and scholars have argued that open outcry markets should be substantially more liquid than computerized markets, the results of this comparison are startling. Most importantly, over the period July, 1992–June, 1993, the computerized DTB Bund market was both more liquid and deeper than the open outcry LIFFE Bund market. Spreads on the DTB were no higher than, and sometimes lower than, spreads on the LIFFE. Moreover, unexpected volume shocks led to smaller price shocks on the DTB than on the LIFFE. Furthermore, increases in expected volume led to *lower* price volatility on the DTB even though they led to higher volatility on the LIFFE. These results obtained even during very active months (e.g., September, 1992, during the European Monetary Union crisis). In sum, the evidence from the DTB and LIFFE strongly suggests that an automated system can be more liquid and deeper than an open outcry market.

The comparison between the DTB and LIFFE Bund contracts is especially informative because both contracts are on the same instrument, and are traded contemporaneously. Thus, traders on each market have access to the same fundamental information, and the same fundamentals should determine the prices on each exchange. Thus, the only major difference between the Bund contracts is the method of trading, which makes this study a nearly controlled experiment on the relative liquidity and depth of open outcry and computerized markets.

This research expands upon earlier empirical work on automated systems. This literature includes pieces by Grunbichler, Longstaff, and Schwartz (1994) who compare information transmission in equity index futures trading on automated systems (the DTB and IBIS) and open outcry systems (the CME and NYSE); Schmidt and Iverson (1993), who compare spreads on three alternative automated systems for trading German equities; Shyy and Lee (1995) who examine bid–ask spreads for the DAX equity index and the Bund contract traded on DTB, respectively; and Kaufman and Moser (1995), who compare spreads and information flows on the DTB and LIFFE Bund markets.

LIQUIDITY PROVISION ON THE CTS AND OPEN OUTCRY MARKETS

Most traditional U.S. futures use an open outcry auction mechanism. In this system, so-called local traders (locals) are the primary suppliers of liquidity. Locals are individuals trading their own capital. They can trade with one another, or compete with one another to fill orders submitted to the floor of the exchange through brokers. The population of locals in a particular market provides these off-the-floor customers with trading partners even if there is an imbalance of buy and sell orders reaching the floor. When the flow of buy (sell) orders from off the floor exceeds the flow of sell (buy) orders, locals tend to sell (buy) contracts. Thus, they supply liquidity by absorbing order flow imbalances. They profit by selling at a price that is, on average, higher than the price at which they buy. This difference between a local's buy and sell prices is the effective bid–ask spread.

In recent years automated futures and options exchanges have entered the market. Examples of such computerized trading systems (CTS) include the DTB, SOFFEX, the MEFF, and Globex, a joint venture between Reuters and several futures exchanges. In contrast to open outcry futures and options exchanges, local traders are not the primary liquidity suppliers on CTS. Instead, traders at large financial institutions, or sophisticated market making firms such as Nations CRT, Sesquehanna Securities, or Timber Hill are the main suppliers of liquidity. Traders for these firms enter bids and offers into the computer trading system; customers can also enter limit orders and thereby supply liquidity to the market.

Small local traders are relatively unimportant suppliers of liquidity on automated exchanges due to the structure of the costs incurred to participate in a computerized trading system. Computerized systems require a substantial investment in computer equipment and market analytics. Moreover, most computerized systems charge relatively high fixed fees for the rental of terminals or communications lines. On other exchanges, e.g., the DTB, traders must acquire a very large guarantee (500,000 deutsche marks on the DTB) from a clearing firm to become a member. To obtain such a guarantee, a trader must have a large amount of capital. Also, the fixed fees paid to enter an automated market in these ways are largely unrecoverable. This limits the pool of potential locals.[1]

In contrast, the fixed costs of becoming a local on an open outcry exchange may be very small. It is possible to become a local on an open outcry exchange by renting an exchange seat. Moreover, even if a trader

[1]Individuals can form partnerships or trade through other firms to spread these large fixed costs among several traders. This is observed to a limited degree on the DTB. However, this strategy makes it more difficult for clearing firms to monitor the credit risk attributable to each individual trader. This, in turn, increases clearing costs and therefore reduces the advantages of this sort of entry by local traders.

buys an exchange membership, it can be resold, so the investment is partially recoverable.

AN ECONOMIC ANALYSIS OF LIQUIDITY SUPPLY ON CTS AND OPEN OUTCRY

Computerized trading and open outcry trading differ on numerous dimensions. These include:

Information flows

It is well known that information asymmetries are among the most important determinants of market liquidity. Market makers lose money when trading with individuals that possess superior information. Thus, the more severe are information asymmetries, the less liquid and less deep the market. Since market makers have access to different information in computerized and open outcry environments, the severity of information asymmetries may differ in these two types of trading systems.

Traders on the floor of an exchange observe information about the order flow. They also know which brokers are bidding and offering. Since they have information about the customers a particular broker represents, they may be able to infer some information about fundamental and technical conditions simply by noting which brokers are buying and which are selling. Floor traders can also sometimes observe the signaling of orders from phone clerks to brokers, thereby enabling them to anticipate large incoming orders, and to adjust their spreads accordingly. Scalpers on an exchange floor also have the opportunity to observe the trading of other market participants. They may therefore know that a particular trader is heavily long or short, and can make inferences about the likely future behavior of their competitors. Floor traders also argue that their ability to "look other traders in the eye" also provides valuable information about the motives of their competitors, and that this (to some degree) limits their vulnerability to being "picked off" by a more informed individual.

At the same time, however, floor traders do not have real time access to much fundamental information. In contrast, so-called "upstairs" traders operate from offices equipped with computer terminals that provide immediate access to information concerning prices in other markets, market analytics, and breaking news. Some market participants claim that this ready access to information gives upstairs traders an information advantage over floor traders.[2] Floor traders also lack good information about market depth. Since only the best bid and offer can be announced, and since brokers conceal limit orders that are away from the market, locals do not know the depth of quotes.

In a computerized system, market makers and other participants have little or no information on the identity of counterparties. The DTB system, for example, simply reports bids and offers and quote sizes. It does not reveal who enters the quote. Moreover, spatially isolated computerized traders do not have exposure to the same information about the "feel" of the market, or the motivations of potential counterparties, that is available to traders who are face-to-face with their competitors in the pit.

These potential information disadvantages of a CTS may be offset by other factors. In particular, screen traders are "upstairs," and can therefore obtain information on prices and news from other computer screens located near the trading system screen. Moreover, most computer trading systems, including DTB and GLOBEX, report information about market depth. DTB, for instance, lists the 10 best bids and 10 best offers, and the size of each quote.[3]

The mechanics of trading also affect the vulnerability of liquidity suppliers to better informed traders. Specifically, a liquidity supplier is less vulnerable to being picked off, the more rapidly he can withdraw a quote in response to new information. A quote is like a short option position with a time to expiration equal to the time required to revise a quote. In an open outcry system, a quote is valid only as long as the trader's "breath is warm." In this environment, a trader need not explicitly withdraw a quote. As a result, an open outcry liquidity supplier is short an option with an extremely small time to expiration. In contrast, in most computerized systems, including DTB and GLOBEX, the liquidity supplier must explicitly withdraw a quote from the system. This is time consuming. This may effectively expose the quote for a longer time period, and thereby increase the value of the short option position. Alternatively,

[2]Most open outcry market makers have access to analytics available on terminals in booths on the trading floor but they must leave the trading area to view the terminals.

[3]The effects of an open order book on liquidity are ambiguous. Glosten (1994) notes that traders submitting limit orders provide an option to other traders. In particular, limit orders that are away-from-the-market offer protection to at-the-market limit orders; the holder of the at-the-market limit order knows the bid or offer of the away-from-the-market orders and can, thereby, limit a loss to the difference between the best and next best quotes. If the limit order book is open (as is the case on DTB and GLOBEX), traders know the degree to which they are protected against adverse price moves. Harris argues that this information may reduce competition among potential liquidity suppliers, and therefore impair liquidity. Domowitz and Wang (1994) and Bollerslev and Domowitz (1991) identify the open order book as the main feature that differentiates open outcry and automated trading systems.

the CTS market maker may closely monitor and refresh his quotes almost continuously to reduce his vulnerability to adverse selection. This continuous monitoring is costly, however. To economize on monitoring costs, the CTS liquidity supplier may choose to refresh quotes less frequently than his open outcry counterpart. Ceteris paribus, his would tend to make it costlier to supply liquidity in the computerized system than the open outcry environment.

The Financial and Physical Capacity of Liquidity Providers

Liquidity suppliers on open outcry exchanges tend to be self-employed locals. Although some locals have access to substantial capital, many locals are thinly capitalized. This limits their ability to absorb large order imbalances. The more thinly capitalized the locals, the less deep the market. This is currently a concern in many markets. Some traders and market users argue that increased trading by futures funds taxes the capitalization of open outcry pits, thereby leading to "choppier" (i.e., less deep) markets.

As noted earlier, large, well-capitalized firms (primarily banks) supply liquidity on the computerized systems examined empirically in this article. This access to capital would contribute to market depth. It should be noted, however, that the number of liquidity suppliers on the computerized systems is relatively small. A small number of well capitalized firms may not be able to provide a deeper market than a small number of less well capitalized locals.

Liquidity suppliers may also be constrained by their physical capacity. For example, in an open outcry market, a market maker must negotiate a trade and then record the results. This process is time consuming. Given the number of traders in a pit, therefore, the number of orders that can be processed in a given interval in constrained. Liquidity suppliers on computerized trading systems are also physically constrained in their ability to enter and execute orders. Again, it is not clear whether open outcry market makers are more or less physically constrained than their CTS counterparts.

Error Costs

Errors occur with some frequency in open outcry trading. So-called "out-trades" result when two traders in the pit enter different details about a particular trade. For example, an out-trade can result if trader A reports that he has bought from trader B, and trader B reports that he has bought from (rather than sold to) A. Similarly, an out-trade can result if A and B enter different prices or quantities for a particular trade, or if A reports that he has transacted with B, but B reports no matching transaction with A. Such errors are inevitable in the hurly-burly of an open outcry system.

Errors can impose substantial costs on traders. In addition to the financial risk posed by out-trades, traders must spend time and effort to resolve trades that do not clear due to error. In equilibrium, these costs are shifted, at least in part, from liquidity suppliers to liquidity demanders in the form of higher spreads or thinner markets.

Errors can occur in a computerized system, but the miscommunications that cause out-trades in an open outcry environment are not possible in a CTS. A trader can enter an incorrect bid or offer into the system, but once the bid or offer is entered, it is executed automatically, and there is no possibility of disagreement between the buyer and seller about price, quantity, or trade direction.

The Costs of Monitoring the Creditworthiness of Liquidity Suppliers

The success of any trading system is predicated on the knowledge that parties to a contract will fulfill their obligations. As a result, futures exchanges take extraordinary precautions to monitor the creditworthiness of market participants. Most importantly, exchanges have established clearinghouses that guarantee contractual performance. These guarantees are backed by the capital of the clearinghouse, and its ability to call on the capital of clearinghouse members to meet its obligations in the event of a customer default. Moreover, all customers are subject to margin requirements. These margins serve as a performance bond that gives traders an incentive to perform on their contractual obligations.

In addition, the traders who execute transactions on both open outcry and automated systems must receive guarantees from clearing members. The cost of providing these guarantees is passed onto the liquidity suppliers, and thus is a determinant of the costs of making markets. In turn, these costs are largely determined by the technology available to monitor trading activity.

The means of monitoring the creditworthiness of traders on open outcry systems differ dramatically from those available on computerized systems. In an open outcry system, clearing firms impose trading limits upon the locals that they clear in order to reduce their exposure to financial risk. It is impossible, however, for clearing firms to monitor the activities of local traders on a real time basis. Although clearing firms have personnel on the floor who observe the activities of their locals, they cannot continuously observe the trading of their locals, or their financial condition. As a result, it is possible (although certainly not common) for locals to trade opportunistically by exceeding their trading limits, or to take on excessive risk. The events in the Chicago Board of Trade Treasury Bond pit on October 22, 1992, illustrate this possibility. At that time two traders with virtually no capital entered orders to sell thousands of T-bond futures contracts and bought hundreds of puts on these futures. The pit monitors of their clearing firm eventually removed the offending parties from the pits, but not before their trading had imposed severe losses on the firm clearing one of the individual's trades. Although an extreme case, this illustrates the potential agency problem faced by clearing firms, and the limitations on their ability to monitor traders.[4]

In contrast, clearing firms on some computerized systems (e.g., DTB) can monitor the activities of the traders they clear on a real time basis. Globex is in the process of adding this feature. That is, trading and clearing functions can be integrated in a computerized system. Moreover, it is possible to enter pre-established trading limits into a CTS that prevent market makers from carrying a position that is larger than their capital warrants; a trader cannot submit a trade that causes his position to exceed the pre-set limits established by his clearing firm. Thus, a clearing firm in a CTS is less vulnerable to opportunistic behavior by a liquidity supplier because it can detect such behavior immediately, and intervene quickly to prevent it.

The superior monitoring technology inherent in CTS would tend to reduce the costs of supplying liquidity on such systems relative to these costs on open outcry exchanges. Thus, the lower costs of monitoring creditworthiness is a potential advantage for CTS.

Physical Environment

The physical environments of open outcry and computerized trading are obviously different. Some of the implications of these differences (e.g., differences in error costs and the speed of quote revision) have already been discussed. Others deserve mention as well. Specifically, open outcry

[4]Local traders are also concerned about their reputation, and this helps to deter them from engaging in such opportunistic behavior. A local with a reputation for such behavior will find it difficult to obtain a clearing agreement, or will pay a very high price to do so. However, traders with limited capital, or who face the prospect of leaving the market due to financial difficulty, may not be adequately constrained by reputation alone. Thus, explicit monitoring by clearing firms is still necessary.

trading taxes the endurance of liquidity suppliers. Especially in fast, heavily traded markets, trading in the pit is physically punishing, and puts severe strain upon the nerves and voices of traders. In contrast, computerized trading is less exhausting, but requires intense concentration and good motor skills. Again, it is by no means clear which environment is more challenging, and thus more costly.

Another aspect of the physical trading environment deserves comment. It is well known that open outcry markets sometimes fragment into submarkets when trading volume surges. When the noise in a pit rises, and a large number of individuals crowd into the pit, it is difficult for traders in one part of the pit to communicate their bids and offers to any but the nearest of the other traders. In this environment, different prices can prevail at different parts of the pit at the same time.[5] In this case, the market is fragmented, and its ability to aggregate information is compromised. This fragmentation may also reduce market liquidity and depth because the amount of competition for any order is reduced.

CTS are not vulnerable to this type of fragmentation. However, it is possible that a surge of orders could strain the capacity of a system to process and match orders. Such capacity on communications or data processing capacity could impair liquidity and depth. Again, it is by no means clear whether computerized trading is more or less constrained in its ability to handle surges in orders efficiently.

The differences in the physical environments of open outcry and CTS may influence liquidity and depth in another way. As noted earlier, most CTS are anonymous; no trader using the system knows who is entering a bid or an offer. In contrast, in an open outcry regime all traders in a pit can observe who is trying to buy and who is trying to sell. In addition to affecting the severity of asymmetric information problems (discussed above), this difference in environment can affect the behavior of liquidity suppliers. Specifically, due to this ability to observe the activities of all traders in the pit, locals in an open outcry system may be able to collude tacitly to the disadvantage of customers who need to buy or sell large quantities on short notice. This sort of activity is less likely to succeed in an anonymous computerized system. Moreover, any such collusion would tend to reduce market depth and make prices choppier.

To see how this is possible, consider the following argument. Floor traders frequently know that a particular broker handles large orders for a particular customer who needs rapid execution. For simplicity, assume that this broker enters a buy order in the pit; a similar argument holds

[5]Baker (1984) provides empirical evidence of market fragmentation in CBOE options pits.

for sell orders. The other floor traders know that this customer may be willing to pay a price substantially above the current market price to execute this trade rapidly. By acting in concert, the locals can bid up the price to the detriment of the customer.

This raises the question of whether it is plausible to assume that locals on the floor can effectively cooperate to disadvantage a customer order in this fashion. The economic theory of collusion suggests that the conditions in an exchange pit may indeed facilitate such cooperation. This theory implies that tacit cooperative agreements can survive in groups that interact repeatedly over time, and whose members can observe each other's behavior. Due to repeated interaction, the group can punish individuals who defect from the cooperative agreement by refusing to trade with them, or only trading on unfavorable terms. Similarly, those who cooperate can be rewarded; for example, a trader who cooperates with other locals may find that they are willing to help him get out of a large position when the market moves against him. The punishments and rewards are credible because any defections are observed in the public environment of the pit; a trader who defects cannot escape detection, and thus faces the potential of punishment. Since locals interact on a daily basis, and sometimes over an unpredictably long period of time, the theory implies that cooperation may indeed occur in an open outcry regime.

It should be noted that the effect on prices of such cooperation between locals may be limited; locals may be able to extract only a tick or two from a customer who needs to buy or sell in a hurry. The effect of cooperation on prices is limited by two factors. First, if locals force prices too far away from the true market, the gains from defecting from the cooperative agreement may exceed the costs of punishment. Second, traders off the floor can submit limit orders in competition with locals; this competition from upstairs limits the amount by which locals can move prices through cooperation.

Since exchange floors are considered the epitome of a competitive environment, some may question the plausibility of tacit collusion there. Certain patterns of behavior commonly described by floor traders are, however, strongly consistent with this interpretation.[6] Moreover, many floor traders argue that dual trading benefits brokerage customers because when a dual trader makes a bid or offer, other floor traders do not know whether that represents the relatively price insensitive trade of a customer, or a more price sensitive personal trade.[7] As a result of this

[6]See Baker (1984) for a study of how informal social norms among traders can enforce cooperative arrangements.

[7]A dual trader buys and sells for both customers and his own account. That is, a dual trader combines

uncertainty, it is argued that locals trade less aggressively with dual traders than with pure brokers. This is consistent with the notion that there is some tacit collusion on the floor.

In contrast, in certain anonymous computerized trading environments, such collusion is less likely because (a) traders do not know the source of any order, and (b) it is impossible to observe (and thus punish) any trader that defects from a tacit cooperative agreement. Market makers could tacitly collude on spreads, but they do not know whether a bid or offer inside the collusively set spread reflects cheating by another market maker, or the entry of a limit order by a customer. This reduced ability to detect "cheating" undermines the stability of any collusive agreement.[8] Moreover, in an anonymous automated environment, it is impossible to determine the identity of a cheater. Thus, when cheating is suspected, it is necessary to engage in indiscriminate "punishments" through the cutting of spreads. Such indiscriminate punishments are more costly to those imposing them than punishments directed at a particular cheater (as is possible in an open outcry environment). These considerations imply that it is both more difficult to detect cheating and more costly to punish cheaters on an anonymous automated system than an open outcry system. As a result, tacit price setting by market makers in an automated environments is less likely (and perhaps substantially so) than in an open outcry environment. This differential vulnerability to cooperation among market makers implies that prices in open outcry markets could be more volatile than prices in automated environments, and move more in response to volume changes than prices in automated markets, all else equal.[9]

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brokerage and market making activities. The U.S. Congress recently passed legislation that banned this practice unless an exchange could demonstrate that a) it had the ability to prevent fraud by dual traders, or b) dual traders were essential to the hedging or price basing functions of futures markets. The statements about the benefits of dual trading to brokerage customers were obtained initially from interviews with floor traders in the crude oil, gasoline, and heating oil markets at the New York Mercantile Exchange. These interviews were conducted in preparation of a report for the NYMEX to the CFTC on the role of dual trading at the exchange. These views have been confirmed in interviews with traders on the Chicago Board of Trade and the Chicago Mercantile Exchange.

[8]See Stigler (1964) for the seminal treatment of the relationship between cartel stability and the ability to detect cheating on price fixing agreements. See Tirole (ch. 6, 1989) for a summary of the modern game theoretic treatment of the issue.

[9]The foregoing discussion is primarily relevant to "order driven" automated systems, as opposed to "quote driven" systems like NASDAQ. All automated futures trading systems are order driven, and almost all of the widely used systems preserve considerable anonymity; LIFFE's APT system identifies those entering quotes, as did the Chicago Board of Trade's abortive Aurora system. Collusion is more likely to occur on a quote driven system like NASDAQ than an order driven automated system. This is true for several reasons. First, quote driven systems (including NASDAQ) reveal who is posting the quote. It is therefore possible to identify the party defecting from a tacit spread setting agreement. This permits punishment of defectors specifically, and limits the need to punish all other market

Summary

In sum, the process of supplying liquidity on a computerized system differs substantially from that of supplying liquidity in an open outcry regime. A priori, it is not clear that one trading system dominates the other. Some attributes of computerized trading (e.g., access to same information as upstairs traders) seem to make it cheaper to supply liquidity on an automated system, whereas other factors (e.g., ability to withdraw quotes instantaneously) plausibly have the opposite effect.

It is commonly argued, however, that open outcry trading is inherently more liquid and deep than computerized trading. Among scholars, Miller (1991), and Grossman and Miller (1986) argue that market makers on a computerized system are far more vulnerable to adverse selection than locals on a trading floor. They therefore conclude that floor trading is more liquid than automated trading. This is also the opinion of a substantial segment of the trading community. For example, Melamed (1977) asserts local traders cannot "scalp" an automated market with the same ease as they can an open outcry one, and thus concludes that automated exchanges will be less liquid than trading floors. He also argues that the exposure of quotes on an automated system will make traders reluctant to submit limit orders, and that this reluctance will cause automated markets to be more volatile and less deep.

In contrast to these pessimistic sentiments, Bollerslev and Domowitz (1990) attempt to compare the dynamics of prices on open outcry and automated trading systems using an experimental methodology. Their simulations predict that spreads and price volatility should be lower in automated regimes. These simulations abstract completely from the actual institutions and mechanisms of liquidity provision, however, and are therefore of limited use in making predictions concerning the relative liquidity of open outcry and computerized trading systems. In particular, they take the quote generation process as exogenously given instead of an endogenous function of the costs of supplying liquidity on each type

makers indiscriminately when cheating is suspected. This reduces the costs of punishment, and makes successful collusion more likely. Moreover, public orders are not posted on most quote driven systems, again including NASDAQ as a primary example. This also facilitates detection of cheating on a quote driven system, and shelters market makers from the competition of public limit orders; this last factor, in turn, reduces the elasticity of demand for market maker services and increases the profitability of collusion. There have been numerous allegations of collusive spread setting on NASDAQ. See, for instance, Christie and Schultz (1994). Other practices in the NASDAQ market, including extensive vertical integration and payment for order flow, may also reduce competition between market makers. Thus, due to the significant institutional and operational differences between quote driven systems and automated systems, existence of collusion on NASDAQ (if proved) does not undercut the conclusion that tacit collusion is more difficult on order driven automated futures trading systems than in open outcry or quote driven automated markets.

of system. Mendelson and Peake (1991) and Ross (1992) dispute the assertions cited above that traders will be reluctant to expose their orders on a computer screen. They argue that contracts traded on automated systems should be more liquid than open outcry contracts.

The relative liquidity and depth of CTS and open outcry is therefore a matter of considerable controversy. The controversy cannot be resolved by theory alone. Empirical evidence is necessary. The next section provides such evidence.

EMPIRICAL TESTS OF LIQUIDITY AND DEPTH: DTB AND LIFFE BUND FUTURES DATA

This section compares the liquidity and depth of the automated DTB Bund futures contract to the liquidity and depth of the open outcry LIFFE Bund futures contract. The data employed are the time and sales records of the DTB and the LIFFE. These data record the time of each trade to the minute on LIFFE, and to the 1/100th of a second on DTB. They also record the price.

The nature of the available data determine the volume measure. The data from LIFFE report only the number of trades that occur. They do not report the number of contracts traded. In contrast, the DTB data report both the number of trades, and the number of contracts bought/sold in each trade. Since the objective of this work is to make comparisons across exchanges, the volume measure used in the analysis of depth is the number of trades during a 15-minute time interval.

Although it would be desirable to have information on the number of contracts traded, an analysis of the DTB data suggest that the results reported below are not an artifact of the volume measure employed. Specifically, all of the tests of market depth employing the number of trades in a 15-minute interval to measure volume are replicated using the number of contracts traded in a 15-minute interval. All results are qualitatively similar. Most importantly, the R^2's from regressions using the two different volume measures are equal to the third or fourth decimal point. Moreover, any differences tend to favor the regressions using the number of trades as the volume measure. Thus, the DTB data strongly suggest that the number of trades is an effective volume measure.[10]

[10]Recent work by Jones, Kaul, and Lipson shows that the number of trades, rather than the total number of contracts exchanged, is a superior measure of volume for NASDAQ stocks. They find that controlling for the number of trades, the number of shares traded has no marginal explanatory power over absolute price changes.

Liquidity

The measure of liquidity employed is the bid–ask spread. Since spreads are not observed directly in futures markets, it is necessary to estimate them. Two measures are used here. The first is due to Thompson–Waller (1988). They estimate the bid–ask spread as the average absolute tick-to-tick price change over a time interval. Formally, if during an observation interval t there are n price changes observed, the estimated spread over this interval is

$$S_t = \sum_{i=1}^{n} |P_{i+1} - P_i|$$

The primary limitation of this measure is that transactions price changes may be due to changes in the equilibrium price, rather than to movements between the bid and ask prices. This biases the spread estimate upwards.

The second spread measure is due to Roll (1984). He notes that the bid–ask bounce induces negative correlation in price changes. He shows that if markets are efficient, the underlying distribution of price changes is stationary, and buy and sell orders arrive with equal probability, then the effective spread can be estimated as

$$s = 2\sqrt{-\mathrm{cov}(\Delta P_t, \Delta P_{t-1})}$$

where $\mathrm{cov}(\Delta P_t, \Delta P_{t-1}) = E(\Delta P_t - E\Delta P_t)(\Delta P_{t-1} - E\Delta P_{t-1})$, and ΔP_t is the price change over the time interval. The primary weakness of this measure is that the estimated covariance is sometimes positive, and thus the spread is undefined.

The Roll measure is estimated by determining the sample first-order autocovariance in 15-minute price changes for each month. Observations spanning trading days are omitted because (a) price dynamics when the market is open may differ from the dynamics when the market is closed, and (b) the duration of the interval from the close to the open exceeds 15 minutes.

Table I reports the mean, median, and mode Thompson–Waller spread by month for the two Bund contracts. The mean TW spread for the DTB market is smaller than its LIFFE counterpart for 9 of the 12 months in the sample. For these 9 months, the difference in the spread is statistically significant at the 5% level for 2 months, and at the 1% level for 2 months. For the three months in which the LIFFE TW spread is smaller than the DTB TW spread, this difference is never statistically significant. This evidence is consistent with the hypothesis that the DTB

TABLE I

Bund Futures Bid–Ask Spreads Estimated with the Thompson–Waller Method

	Mean			*Median*		*Mode*	
	DTB	*LIFFE*	*p-value*	*DTB*	*LIFFE*	*DTB*	*LIFFE*
Jul 92	.0149	.0153	.5774	.0107	.0114	.01	.01
Aug 92	.0168	.0182	.0374[a]	.0133	.0146	.01	.01
Sep 92	.0233	.0241	.4510	.0174	.0184	.01	.01
Oct 92	.0236	.0256	.01089[a]	.0190	.0210	.01	.01
Nov 92	.0138	.0163	1.27E-9[b]	.0121	.0136	.01	.01
Dec 92	.0144	.0160	.045[a]	.0125	.0138	.01	.01
Jan 93	.0151	.0168	1.94E-5[b]	.0131	.0140	.01	.01
Feb 93	.0164	.0177	.0332[a]	.0125	.0140	.01	.01
Mar 93	.0238	.0251	.3399	.0191	.0195	.01	.01
Apr 93	.0249	.0243	.4735	.0200	.0195	.01	.01
May 93	.0228	.0221	.3793	.0190	.0190	.01	.01
Jun 93	.0231	.0230	.8700	.0191	.0192	.01	.01

The column labeled "*p*-value" reports the probability that true spreads are equal on the DTB and the LIFFE, given the estimated spreads. [a]Implies that the spread estimates are significantly different at the 5% level.
[b]Significantly different at the 1% level.

spread is not greater than, and is sometimes smaller than, the LIFFE spread.

The medians reported further support this hypothesis. The median TW spread on DTB is smaller than the median TW spread on LIFFE for 11 of the 12 months in the sample. Since the median is less affected by outliers (which could be caused by changes in equilibrium prices, rather than oscillation between the bid and ask), the median may be a better measure of the spread than the mean. Finally, the modal average 15-minute price change equals one tick for each contract for each month. This suggests that each market is most often a one-tick market.

Table II reports the Roll spread estimate for the two Bund contracts. Several of the estimated covariances in the DTB sample are positive. Entries where the estimated covariance is positive are marked with an "a." All of the LIFFE contract covariances are negative, and hence all the spreads are positive.

An examination of the table reveals that in months when spreads for both contracts are defined, the Roll estimator of the LIFFE spread is greater than the Roll estimator of the DTB spread. Moreover, these differences between estimated spreads are all highly significant. The column in the table labeled "$\chi^2(3)$" reports a test statistic for the hypothesis that the LIFFE and DTB autocovariances (and hence spreads) are equal.[11]

[11]This statistic was derived by Box (1949). See Morrison (1967) for an analysis of this statistic.

TABLE II

Bund Futures Bid–Ask Spreads Estimated with the Roll Method

Month	*DTB*	*LIFFE*	$\chi^2(3)$
JUL 92	.00223	.00654	843.31
AUG 92	.01779	.02742	130.3
SEP 92	[a]	.02017	[a]
OCT 92	.0141	.02575	238.3
NOV 92	.01607	.01843	20.4
DEC 92	[a]	.01316	[a]
JAN 93	.00754	.01509	608.4
FEB 93	[a]	.01104	[a]
MAR 93	[a]	.01750	[a]
APR 93	.00846	.01825	388.3
MAY 93	.0133	.02055	133.4
JUN 93	.00422	.01341	759.4

The column labeled "$\chi^2(3)$" reports the Box Statistic testing the hypothesis that the DTB and LIFFE spread estimates are equal. This statistic is distributed as a chi-square with 3 degrees of freedom. All of these differences are statistically different from 0.

[a]Represents months where price change autocorrelations are positive, and thus the Roll Estimate is undefined.

This statistic is approximately distributed as a chi-squared variate with 3 degrees of freedom. The .995 significance value for this statistic is 12.8. All of the reported test statistics are far larger than this value; hence, the p-value for each statistic is essentially zero. Thus, the data decisively reject the hypothesis that the DTB and LIFFE Bund futures spreads are equal. The Roll estimator implies, therefore, that spreads are lower on the DTB.

The fact that some estimated DTB autocovariances are positive, while all the LIFFE autocovariances are negative, also supports the conclusion that the DTB contract is more liquid. The positive autocovariances indicate that their is no pronounced "bounce" in Bund futures prices on the DTB. The occasional inability to detect reversals in price changes suggests that any bounce induced by the spread is very small relative to fundamentals-induced price changes. In contrast, the consistently negative autocovariances on LIFFE indicate that there is a systematic tendency for price reversals on that market's Bund contract. Given that the same fundamental information flows to each market, this comparison suggests that the spread-induced component of 15-minute price changes is more pronounced on the LIFFE.[12]

[12]The median of the product of the current and lagged price changes is zero for all months for the DTB Bund contract, whereas the median of this product is always negative for the LIFFE Bund contract. This is further evidence that price reversals are more pronounced on the LIFFE contract. This is consistent with the hypothesis that the DTB contract is more liquid.

There is an alternative explanation of these results. George, Kaul, and Nimalendran (1991) show that the Roll measure may be biased if expected returns are time varying and positively autocorrelated; this problem is likely to be more acute, the lower the frequency of the data. Moreover, the bias proxies for the degree of information asymmetry; positive autocorrelations are attributable to adverse selection in the market-making process. Kofman and Moser (1995) show that the positive autocorrelation is greater on DTB, the lower the frequency of observation; autocorrelations are negative (positive) with frequency of less (more) than five minutes. Thus, the positive autocorrelations in the 15-minute DTB data may reflect higher adverse selection costs in that market.

Taken together, the evidence concerning the Thompson–Waller and Roll spread estimates implies that the DTB Bund contract is no less liquid, and possibly more liquid, than the LIFFE Bund contract.[13] One interpretation that is consistent with the evidence is that market maker order processing costs are lower and adverse selection costs are higher on the DTB, and on balance the bid–ask spread is equal on LIFFE and DTB because these factors off-set one another almost exactly. This explains the near equality of the Thompson–Waller spread estimates for DTB and LIFFE, the lower DTB Roll spread estimates, and the occurrence of positive autocorrelations in the DTB price change data in some months. It is also consistent with the findings of Moser and Kaufman (1995).

Depth

Prices in deep markets move little in response to large volumes. Therefore, to test each market's depth, the absolute value of the price change during each 15-minute interval in the sample is regressed against volume measures. The volume measures employed are expected volume, unexpected volume, and positive unexpected volume. Volume is broken into expected and unexpected components because volume shocks may have different effects on prices than anticipated changes in volume. For example, unexpected volume changes may be due to the arrival of new information, which exacerbates the adverse selection problem and re-

[13]Shyy and Lee (1995) examine minute-by-minute bid ask quotes on LIFFE and DTB as reported on Reuters in the 8–19 November, 1993 period. They find that the average quoted spread on DTB is .3 ticks greater than on LIFFE. The difference between their findings and the results reported here could result from the fact that the present study measures the realized, as opposed to the quoted spread. For example, the quoted spread may be good for a small quantity, whereas the spread calculated using the methods in the text reflects spreads for the average quantities traded. Their time period is different from the one studied here. This could also account for the difference.

duces market depth. The theory of Admati and Pfleiderer (1988) suggests another reason why market depth may depend upon whether volume changes are expected or unexpected. They argue that traders who can time their trades choose to trade when volume is expected to be high in order to reduce their vulnerability to adverse selection problems. This implies that markets should be deeper when volume is expected to be large. Moreover, market making resources can enter the market if the demand for these services is expected to increase. These various arguments also suggest that positive volume shocks may have different effects on price changes than negative volume shocks. Positive volume shocks may signal a greater intensity of informed trading, and may tax the capacity of market makers. Thus, the empirical estimates allow for the possibility of asymmetric response to positive and negative volume shocks.

A natural way to estimate these relationships is through a two-step procedure of the type originally pioneered by Barro (1977). In the first step, a volume equation is estimated using OLS. The fitted values from this equation serve as estimates for expected volume in a second volatility/depth equation, and the residuals from the volume equation are used to measure unexpected volume in the second step.

First consider the volume equation. Recent empirical work [see Schwert (1990); and Gallant, Rossi, and Tauchen (1990)] suggests that lagged volumes and lagged volatility help predict volume movements. Therefore, expected volume during a 15-minute interval is estimated as the fitted value from the following regression equation:

$$V_t = a + \sum_{i=1}^{5} \beta_i V_{t-i} + \sum_{j=1}^{5} \theta_j |\Delta P_{t-j}| + \lambda \sigma_{t-1} + \varepsilon_t$$

where V_t is the trading volume in interval t, σ_{t-1} is a measure of lagged volatility, and ε_t, is an error term. The measure of lagged volatility used in the results reported below is the difference between the highest price and the lowest price from the previous 15-minute interval. This term, plus the lagged absolute price changes, captures the effect of expected price volatility on volume. Finally, the measure of unexpected trading volume is ε_t.

The magnitude of absolute price changes is also affected by the volatility of the underlying price series. To control for this σ_{t-1} is included in the depth regressions. This variable will effectively proxy for volatility to the extent that there are persistent, time varying components in price variances.

In the second step, market depth is determined by estimating the following price volatility model:

$$|\Delta P_t| = \phi + \delta EVOL_t + \gamma UVOL_t + \mu UVOLPOS_t + \rho\sigma_{t-1} + \eta_t$$

where $EVOL_t$ is the expected volume in a 15-minute interval measured by the fitted value from (3), $UVOL_t$, $= \varepsilon_t$, $UVOLPOS_t = \varepsilon_t$ if $\varepsilon_t > 0$, $UVOLPOS_t = 0$ if $\varepsilon_t \leq 0$, and η_t is an error term.[14] The coefficients on the various volume terms are measures of the depth of the market. Positive unexpected volume is included to determine whether the effects of volume shocks on price volatility are asymmetric, as documented in Bessimbinder and Seguin (1993).

A separate set of volume and volatility regressions is estimated using OLS for each calendar month from July, 1992 through June, 1993. The expected volume and unexpected volume variables in the volatility equation are generated regressors. Pagan (1984, Theorem 7) shows that the OLS estimates of the coefficients for these variables are consistent. Moreover, Pagan shows that the OLS standard errors on the unexpected volume variables are consistent. However, the OLS standard errors for the expected volume coefficient are inconsistent. Murphy and Topel (1985) provide a simple adjustment for these standard errors.

The regression results are reported in Table III. The t-statistics on the expected volume variable are calculated using the Murphy–Topel adjustment. Several findings stand out.

First, for the DTB contract, the coefficient on expected volume is positive for only two months (July and October, 1992), and coefficients are not statistically significant at the 5% level. In fact, the coefficient on expected volume for this contract is negative for 10 months, and significantly so (at the 1% level) for 5 months. In contrast, for the LIFFE contract, the coefficient on expected volume is positive and significant for 7 months, and negative and significant for only a single month. For all but two months, the coefficient on expected volume from the DTB regression is smaller than the coefficient on expected volume from the LIFFE regression.

These results imply that expected increases in volume have a smaller effect on prices on the DTB than on the LIFFE. This evidence is highly

[14]Other specifications are also employed, but the results obtained do not differ substantially from those reported below. In particular, lagged absolute price changes are included, but the lagged difference between high and low prices uniformly performs better as a measure of lagged volatility. Moreover, regressions are run in absolute returns, rather than absolute price differences, but the essential results are unchanged. Finally, following Bessimbinder and Seguin (1993), the price changes are purged of all predictable components by regressing price changes on lagged price changes, the lagged difference between high and low prices, and lagged volume. These regressions explain virtually none of the changes in prices, and, therefore, regressions of the absolute value of unexplained component of price changes on expected and unexpected volume and lagged volatility are virtually identical to those reported below.

TABLE III

Estimates of Market Depth in the DTB and LIFFE Bund Contracts

PANEL A—DTB BUND
(T-Statistics in Parentheses)

Month	*Constant*	σ_{t-1}	$EVOL_t$	$UVOL_t$	$UVOLPOS_t$	R^2
JUL 92	.00365	.475	2.30E-4	5.04E-4	−4.48E-4	.5993
	(3.71)	(18.96)	(1.84)	(6.03)	(−4.48)	
AUG 92	.00832	.621	−3.21E-4	2.71E-4	−2.60E-4	.5437
	(5.89)	(21.54)	(−2.83)	(3.02)	(−2.29)	
SEP 92	.00766	.629	−2.31E-4	4.52E-4	−4.35E-4	.6152
	(4.78)	(20.79)	(−1.69)	(3.89)	(−2.85)	
OCT 92	−.0021	.663	1.25E-4	3.83E-4	−3.42E-4	.5687
	(−.98)	(20.82)	(.94)	(3.59)	(−2.44)	
NOV 92	.00587	.526	−5.00E-5	2.44E-4	−1.98E-4	.3813
	(5.80)	(16.20)	(−.58)	(2.28)	(−1.37)	
DEC 92	.00512	.531	−1.51E-4	2.35E-4	−2.11E-4	.3970
	(3.25)	(18.71)	(−1.53)	(2.55)	(−1.98)	
JAN 93	.00584	.556	−1.61E-4	7.34E-5	−4.75E-5	.4078
	(3.69)	(17.57)	(−1.64)	(.83)	(−.42)	
FEB 93	.00497	.647	−8.83E-5	3.14E-4	−1.61E-4	.6353
	(4.20)	(25.84)	(−1.00)	(3.29)	(−1.25)	
MAR 93	.00898	.728	−3.39E-4	5.01E-4	−5.02E-4	.6187
	(5.21)	(28.98)	(−2.96)	(5.13)	(−3.91)	
APR 93	.00847	.692	−3.09E-4	3.78E-4	−3.07E-4	.6156
	(4.13)	(24.62)	(−2.77)	(4.29)	(−2.78)	
MAY 93	.00296	.716	−2.56E-4	6.07E-5	9.77E-5	.5221
	(1.42)	(22.76)	(−3.36)	(.66)	(.79)	
JUN 93	.0097	.704	−4.25E-4	8.80E-5	−7.43E-5	.4510
	(5.27)	(21.89)	(−6.51)	(.84)	(−.54)	
			PANEL B—LIFFE BUND			
JUL 92	.00399	.0134	3.71E-4	2.60E-4	5.88E-4	.3042
	(2.28)	(.302)	(2.43)	(2.49)	(4.08)	
AUG 92	.00236	.0502	5.32E-4	4.35E-4	3.86E-4	.3187
	(1.09)	(1.21)	(3.95)	(3.93)	(2.44)	
SEP 92	.00605	.0389	4.12E-4	3.26E-4	7.78E-4	.3187
	(2.80)	(.73)	(3.30)	(2.38)	(3.92)	
OCT 92	.0194	.233	−6.17E-4	4.10E-4	4.37E-4	.2281
	(5.12)	(4.27)	(−.45)	(3.48)	(2.54)	
NOV 92	.00989	.0999	1.86E-4	3.04E-4	1.12E-4	.1425
	(6.31)	(2.97)	(2.12)	(3.49)	(.90)	
DEC 92	.00981	.152	1.75E-4	3.01E-4	1.25E-4	.1605
	(5.51)	(16.20)	(2.14)	(3.44)	(1.25)	
Jan 93	.00973	.153	6.71E-5	3.21E-4	1.51E-4	.1997
	(4.57)	(3.43)	(.71)	(3.96)	(1.31)	
FEB 93	.00554	.177	2.57E-4	2.96E-4	4.50E-4	.2611
	(2.45)	(3.82)	(2.16)	(3.06)	(3.19)	
MAR 93	.00667	.592	−5.07E-4	−5.74E-4	1.60E-3	.3093
	(1.45)	(10.81)	(−2.97)	(−2.95)	(5.74)	

TABLE III (Continued)

Estimates of Market Depth in the DTB and LIFFE Bund Contracts

PANEL A—DTB BUND
(T-Statistics in Parentheses)

Month	*Constant*	σ_{t-1}	$EVOL_t$	$UVOL_t$	$UVOLPOS_t$	R^2
APR 93	.0113	.1596	7.77E-5	3.08E-4	36.70E-4	.3038
	(3.74)	(3.45)	(.69)	(2.97)	(4.36)	
MAY 93	.0108	.179	2.39E-4	3.48E-4	2.71E-4	.1900
	(4.07)	(3.02)	(2.65)	(3.07)	(1.58)	
JUN 93	.021	.0878	−5.58E-5	3.76E-4	2.46E-4	.1833
	(9.17)	(1.58)	(−.80)	(3.37)	(1.59)	

In both panels, the *t*-statistics on $UVOL_t$ and $UVOPOSL_t$ are calculated using OLS standard errors. The *t*-statistics on $EVOL_t$ are calculated using the method of Murphy and Topel (1985).

suggestive. In particular, the fact that absolute price changes on LIFFE increase in magnitude when expected volume increases is consistent with the hypothesis that market making capacity on that exchange is constrained, and that entry of market making capacity cannot occur over short time periods.[15] Conversely, the fact that absolute price changes on DTB often decrease in magnitude when expected volume increases suggests that market making capacity can enter the market quickly when volume is expected to rise. This fact is also consistent with the Admati–Pfleiderer hypothesis. In their theory, discretionary traders tend to trade when volume is expected to be high. One implication of this theory is that the market should be deeper when expected volume is large. The results from the DTB are consistent with this view; the results from the LIFFE are not.

Second, for the DTB contract, for each month the coefficient on $UVOL_t$ is positive, the coefficient on $UVOLPOS_t$ is negative, and the sum of the coefficients on $UVOL_t$ and $UVOLPOS_t$ is not statistically different from 0.[16] Conversely, for the LIFFE contract, for all but one month the coefficient on $UVOL_t$ is positive, the coefficient on $UVOLPOS_t$ is always positive, and the sum of the coefficients on $UVOL_t$ and $UVOLPOS_t$ is always positive and statistically different from zero. Moreover, for each month, the sum of the unexpected volume coefficients in the LIFFE re-

[15]See Brock and Kleidon (1992) for a theory of liquidity premised on the assumption that market making capacity is limited.

[16]Theorem 7 in Pagan (1984) implies that significance tests for the sum of the coefficients based on OLS standard errors are correct because the standard errors on regressors generated by residuals from the first step of a two-step process are consistent.

gression is larger and statistically different from the sum of the unexpected volume coefficients from the DTB regression.

These results imply that the DTB contract is deeper than the LIFFE contract. Perhaps most importantly, the fact that the sum of the DTB unexpected volume coefficients is consistently statistically indistinguishable from zero implies that *positive* unexpected volume shocks do not induce large price moves, whereas *negative* unexpected volume shocks are associated with smaller price moves. That is, large positive volume shocks do not appear to increase DTB price volatility dramatically. In contrast, price changes on the LIFFE increase (decrease) in magnitude as volume increases (decreases) unexpectedly, but there is a pronounced asymmetry in the response to positive and negative shocks. Specifically, on LIFFE a positive volume shock has a larger effect on the magnitude of price changes than a negative volume shock of identical magnitude.

These results imply that the DTB Bund contract is substantially deeper than the LIFFE Bund contract. Both expected and unexpected volume changes have a smaller impact on price changes at DTB than at LIFFE. In particular, unusually large volumes have a far smaller effect on prices on the DTB than on the LIFFE.

Summary and Caveats

The evidence from the Bund futures markets is inconsistent with the hypothesis that open outcry exchanges are inherently deeper and more liquid than their automated counterparts. This raises a question: If the DTB is equally or more liquid than LIFFE, why is it still the smaller exchange (with a market share of about 35% relative to LIFFE's 65%) and why is it not growing relative to LIFFE?

There are at least two possible answers to this question. First, the statistical measures of liquidity and depth examined herein may not adequately measure the true liquidity and depth of the two markets. Thus, further research, perhaps employing novel measures of liquidity, is warranted.

Second, it must be recognized that liquidity is only one of the determinants of the cost of executing an order. Ceteris paribus, one would expect traders to execute trades on the most liquid and deepest market. However, *ceteris* may not be *paribus* as other costs of executing orders—most importantly, the cost of access—may differ between LIFFE and DTB. For example, brokerage, exchange, and clearing fees may differ between the two markets. Market participants interviewed state that the costs of order execution are higher on DTB than on LIFFE, due in part to high exchange trade fees and greater competition in the provision of brokerage services in London than Germany. Moreover, the internal administrative costs customers incur to process orders may differ between markets. Thus, even though the evidence suggests that DTB is more liquid at the margin than LIFFE, marginal all-in trading costs (including access, liquidity, and administrative costs) may be comparable, leading to a stable equilibrium allocation of market shares across markets.[17]

It must be noted, moreover, that the very survival of the DTB bund contract is highly unusual. It is very rare for similar, let alone nearly identical, contracts to survive and trade on two different exchanges simultaneously. In addition, ceteris paribus, one would expect the higher volume contract to be more liquid. The survival of DTB, and the arguably superior liquidity and depth of this market despite its lower volume, strongly suggest that automated futures trading may be very liquid, and that the claims that open outcry is inherently more liquid may be incorrect.

SUMMARY AND CONCLUSIONS

This article has compared theoretically and empirically the liquidity supply mechanisms on automated futures trading systems and traditional open outcry systems. The two systems differ in so many ways that it is difficult to determine a priori which is more inherently liquid; computerized trading seems superior in some ways, but open outcry seems to dominate in others. There is little doubt that the prevailing wisdom in the futures industry is that open outcry is inherently more liquid. However, the empirical evidence reported herein does not support that view. A comparison of liquidity and depth of the Bund contracts traded on the automated DTB and the open outcry LIFFE shows that in the 1992–1993 period bid–ask spreads on the former exchange are approximately the same as on LIFFE. Moreover, volume shocks (especially positive volume shocks) have a less pronounced effect on DTB price volatility than on LIFFE volatility. This is consistent with the view that the automated system is deeper.

This analysis is preliminary, but tantalizing. It suggests that the adoption of automated futures trading may not cause reductions in market liquidity, but may in fact increase it. Since the costs of computing fall at

[17]Schmidt and Iverson (1993) document that among the three competing systems for trading German equities, the system with the lowest spreads—MATIS—had the smallest market share, and this market share fell over time. This could be due, they claim, to differences in the costs of other attributes of order execution.

a consistent rate over time, the capacity of automated systems to handle large volumes will increase and the costs of processing such volumes will fall. In contrast, the technology of open outcry is relatively static, if not completely so. Thus, if automated trading is not inherently less liquid, it seems inevitable that computerized trading will someday supplant open outcry as the standard means of transacting in futures markets.

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