

The liquidity of automated exchanges: new evidence from German Bund futures[☆]

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Abstract

Previous literature has suggested that automated exchanges such as the Deutsche Terminbörse (DTB) may be less liquid than their open-outcry counterparts such as the London International Financial Futures Exchange (LIFFE), although evidence provided on this issue has been mixed. This paper provides new evidence on the relative magnitudes of bid-ask spreads in the Bund contract traded on the DTB and LIFFE using intraday data from a period in which each exchanges share of total Bund trading was closer than previous research. The findings suggest that quoted bid-ask spreads are wider on the LIFFE than the DTB, even after controlling for their determinants. Furthermore, bid-ask spreads on the DTB increase more rapidly as price volatility increases relative to the LIFFE. Overall, this evidence implies that while automated exchanges are capable of providing more liquidity than floor traded exchanges, the relative performance of automated exchanges deteriorates during periods of higher volatility. © 1998 Elsevier Science B.V. All rights reserved.

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JEL classification: G00; G15; G20

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1. Introduction

A number of securities exchanges employ automated trading systems rather than traditional open-outcry including the Swiss Options and Financial Futures Exchange, Spains MEFF Renta-Fija and the Osaka Securities Exchange. However, open-outcry remains the trading system of choice for some of the worlds largest exchanges, notably the Chicago Board of Trade and the Chicago Mercantile Exchange (CME). One reason that these exchanges persist with open outcry is the claim that it is an inherently more liquid trading environment. There are several arguments which suggest this may be true. Automated systems do not handle periods of intense trading as well as floor-traded systems (Franke and Hess, 1995), they typically do not reveal the identity of traders resulting in a higher degree of information asymmetry (Kofman and Moser, 1997), and they deprive liquidity providers such as locals and market-makers of some of their trading advantage (Massimb and Phelps, 1994). Order cancellation procedures on automated systems may also force quote setters to offer free options of a greater value than those offered by limit orders on floor-traded systems (Copeland and Galai, 1983). These factors may discourage the submission of limit orders and impair the liquidity of automated markets.

There are, however, a number of arguments which support the decision to automate, suggesting that some of the features of an automated exchange may promote liquidity. For example, automated trading is widely recognised as more cost effective than floor trading, and there is a demonstrable link between the costs of trading and the level of volume traded (Constantinides, 1986).¹ Shyy and Lee (1995) suggest that automated systems can improve reporting practices thereby increasing market transparency and allowing market participants to manage their inventory exposure more effectively. In this way they can contribute to a reduction in adverse selection costs and bid-ask spreads. The transparency of the order book with respect to prices and volumes away from the best bid and ask may provide valuable information and assist in the provision of liquidity, particularly in periods of low trading activity (Franke and Hess, 1995). The process by which trade and quote data is disseminated is slower on a floor traded exchange than on an automated one, which may lead to a form of adverse selection where off-floor participants are discouraged from providing liquidity (Massimb and Phelps, 1994). In preventing this problem, automated exchanges can enhance market liquidity. With so many factors interacting and acting in favour of one system or the other, the question of which mechanism is more liquid becomes an empirical one, which is addressed in this study.

Prior research has examined this issue in controlled settings where two different trading mechanisms operate side-by-side for the same security. Such settings are rare, but one example is the trading of Bund futures on the London International

¹ Miss-communication errors—a common and expensive occurrence on floor-traded exchanges—are eliminated on automated exchanges. This, combined with other advantages in terms of administrative efficiency help to reduce the cost of processing orders on an automated exchange (Grody et al., 1994).

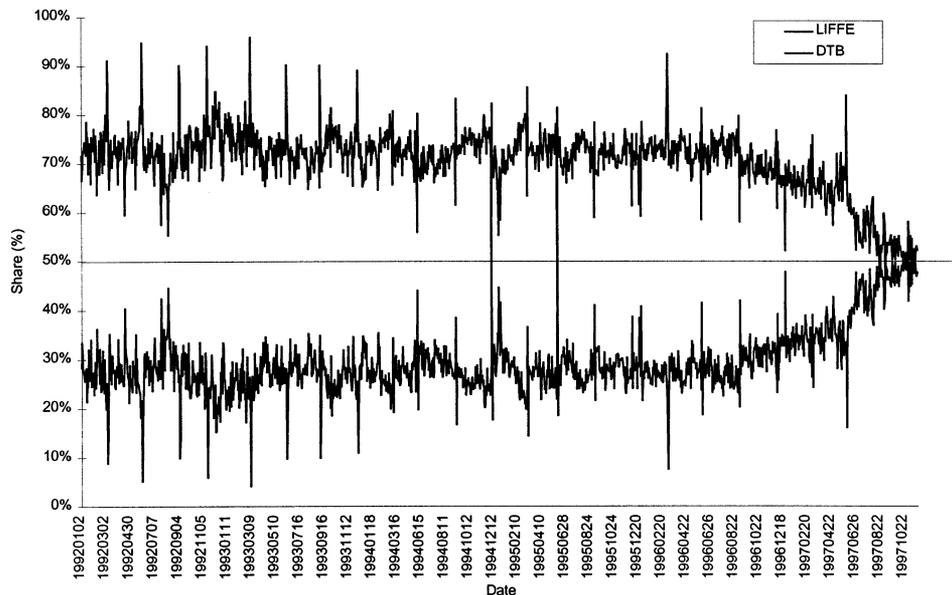


Fig. 1. Market share of volume, LIFFE (including APT) and DTB, 1992–1997.

Financial Futures Exchange (LIFFE) and the Deutsche Terminbörse (DTB). A number of papers compare the liquidity of these exchanges. Kofman and Moser (1997) examine information asymmetry, lead-lag relationships and estimated bid-ask spreads between the two markets using a small sample from 1992. Shyy and Lee (1995) examine quoted spreads on each system using data from 1993. Franke and Hess (1995) compare relative trading volume as a measure of liquidity during 1992 and 1993. Pirrong (1996) uses estimates of the effective spread to examine the amount of liquidity provided by each exchange, also using data from 1992 and 1993. A common finding from these papers is that bid-ask spreads are wider on the automated system. One of the limitations of prior research is that none of the papers control for possible systematic differences in trading volume, a well known determinant of transaction costs (see McInish and Wood, 1992), or any other determinants in conducting their analysis. However, all of these studies use data sampled prior to 1994. Fig. 1 illustrates that up to 1994 the DTBs average share of total Bund market volume was only 28%. Fig. 1 also shows that by 1997 the DTBs market share was approaching the LIFFEs.² It is clear that the impression given of the two systems may be heavily influenced by the sample analysed. This paper uses a more recent sample than previous papers to compare the cost of trading across markets.

² Note however that the daily data available for construction of this chart includes volume traded on the LIFFEs overnight trading system (APT) and hence overstates the market share of the LIFFE floor trading slightly. Our discussions with LIFFE officials suggest APT volumes in the Bund have always been less than approximately 7%. The periodic spikes in market share are related to the last trading day in DTB Bund futures which is one day later than for the LIFFE futures.

In this study, the quoted bid-ask spread on each exchange is analysed and compared as a proxy for liquidity. One possible problem associated with examining the quoted spread as a measure of the cost of trading in other floor traded markets (eg. the New York Stock Exchange) is that trades can be negotiated at prices inside the quoted spread (see Fialkowski and Peterson, 1994). Hence the quoted spread may overstate the cost of trading. This cannot occur on the LIFFE as the trading rules require all bids and offers to be announced to the floor prior to executing a trade (see LIFFE Trading Rule 4.10.3 and Rule 4.11.1). Price reporters on the floor of the LIFFE then record these bids, offers, and trade prices. As a consequence, trades may only appear to occur within the spread as a result of reporting or other data errors. Some preliminary analysis of the data indicated that a negligible number of trades occur at a price other than the prevailing bid or ask.

This paper extends prior literature in a number of ways. Firstly, data is sampled from a period in which the market shares of the LIFFE and the DTB are closer. Secondly, quote data is examined for a longer sample period than has previously been available. Thirdly, a regression approach is also used to control for any systematic differences in trading activity between the two exchanges in comparing the costs of trading on the alternative mechanisms. This also enables us to extend the analysis of Franke and Hess (1995) on market shares to bid ask spreads through a comparison of the relative performance of the two systems under different market conditions (for example, periods of high price volatility or trading volume).

The remainder of this paper proceeds as follows. Section 2 describes the institutional detail for the two exchanges. Section 3 discusses data and method. Section 4 presents the results, while Section 5 concludes and provides suggestions for future research.

2. Institutional detail

The Bund futures contract is written on notional debt of the Federal Republic of Germany with a coupon of 6% and 8.5–10 years to maturity. Trading in Bund futures on the DTB commenced on 23 November 1990—approximately 10 months after the launch of the exchange. By this time trading in the LIFFEs Bund future had been underway for approximately 2 years, having commenced on 29 September 1988.

Table 1 sets out the contract specifications for the Bund futures traded on the LIFFE and DTB. The only difference is a relatively minor one—the DTB contract trades until 2 days prior to the delivery day while trading in the LIFFE contract concludes 1 day earlier. The Exchange Delivery Settlement Price (EDSP) on the last trading day for each contract on both futures exchanges is the cash market price in Frankfurt at 11:00 (all times are expressed in local time unless otherwise stated).

There are currently more than 140 exchange participants on the DTB, covering banks, broking houses and market-making firms. Market-makers typically only trade in options. Individual traders, frequently referred to as ‘locals’ on other

Table 1
Contract specifications on LIFFE and the DTB (as at September 1997)

	LIFFE	DTB
Trading hours (local time)	7:00–16:15 (open outcry) 6:20–17:55 (APT)	7:30–19:00pm
Contract value (DM)	250 000	250 000
Minimum tick (value) (DM)	0.01 (25)	0.01 (25)
Price quotation	Per DM 100 nominal value	In percentage of the par value with two decimal places
Margins	Initial (DM 3500) and variation	Initial (1.4 points) and variation
Delivery	Tenth calendar day of delivery month	Tenth calendar day of delivery month
Method of settlement	Physical	Physical
<i>Exchange fees^a</i>		
Order matching	£0.42	DM 0.50
Notification		DM 0.50
Notification adjustment		DM 4.00
Allocation		DM 0.50
Last trading day	Three Frankfurt business days prior to delivery	Two Frankfurt business days prior to delivery

^a During the sample period examined in this paper, both exchanges were conducting ‘fee holidays’.

exchanges, are rare on the DTB. The expense involved with setting-up a trading operation on an automated exchange (relative to the cost of a local permit on LIFFE) is prohibitive for individuals (Pirrong, 1996).

The DTB commences trading in its Bund contract with a call market at 8:00.³ From 7:30 to 8:00, the DTB has a pre-trading period where orders can be submitted without the execution of overlapping orders. The algorithm used to calculate the opening price maximises the volume that can be traded at a single price and is similar to those used in other automated futures markets.⁴

During continuous trading, the DTB is an anonymous electronic limit order book. An order submitted which cannot be immediately executed is left in the order book to await execution. The ten best bid and offer prices, with associated volumes, are displayed on traders terminals. The DTB uses order ‘type’, price and then time

³ See Amihud and Mendelson (1991) for a thorough discussion of the use and impact of opening call markets.

⁴ For example, SYCOM, Project A and GLOBEX—the automated overnight trading systems of the Sydney Futures Exchange, the Chicago Board of Trade and the Chicago Mercantile Exchange (in conjunction with MATIF and Reuters), respectively—all use a similar opening mechanism.

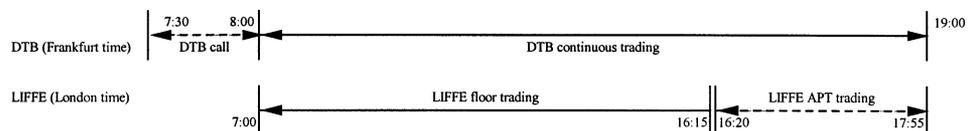
to prioritise orders for execution. Market orders are matched first, followed by all limit orders at the same price. Limit orders with the same price are prioritised for execution according to their time of arrival on a first-in-first-out basis. The DTB system allows ‘combination’ orders (for example, spread trades) to be submitted and executed as packages while also being placed in the queue in the markets for each of the component contracts. Data capture and dissemination to quote vendors on the DTB is on line in real time.

Over the sample period used in this study, there were approximately 500 locals registered on the LIFFE, participating in approximately 20% of total trading.⁵ No special opening procedure is used on the LIFFE. Trading on the floor is conducted using a continuous double auction by open-outcry. When an order is brought to the trading floor (usually by phone), it must be recorded on paper and time-stamped. Bids and offers are expressed verbally and confirmed using hand signals. An important feature of floor trading is that bids and offers are ‘good’ only ‘as long as the breath is warm’. For a trade to be executed on the LIFFE floor, a trader must first have made a bid or offer after which another trader is able to complete the trade by accepting that bid or offer (LIFFE Rules 4.10.3 and 4.11.1). Data is captured from the trading floor by pit reporters and disseminated to members by quote vendors. This process necessarily involves a small delay in the transmission of data to quote vendors.

The LIFFE floor closes at 16:15. At 16:20 trading switches to an automated trading system called APT (Automated Pit Trading). The LIFFE introduced the APT system in November 1989.⁶ The changeover between mechanisms on the LIFFE and the time difference between London and Frankfurt mean that both exchanges operate an automated trading system while APT operates until 17:55.⁷ The DTB closes 5 min later. The overlap in trading hours is depicted in Exhibit 1 below.

(Exhibit 1)

Trading hours on the LIFFE and DTB.



As illustrated, the DTB call precedes the commencement of trading on either exchange, so that continuous trading on both exchanges begins simultaneously. After 16:20, there are two automated systems trading in parallel on the two exchanges (the DTB's ordinary trading system and the LIFFE's APT system). Data

⁵ These figures are estimates provided by LIFFE officials.

⁶ The APT system attempts to mimic the conditions of floor trading by giving limit orders a maximum life of 10 s before they must be re-entered to remain valid.

⁷ Frankfurt is 1 h ahead of London.

from this period is excluded from our analysis. Due to the low trading volumes on APT, a comparison of these two systems is limited. There are only 10 min of the day where the DTB operates a continuous trading system in the absence of LIFFE trading.

At least four key differences between the exchanges trading mechanisms can be identified which may lead to a systematic difference in their provision of liquidity. First, the DTB is anonymous, the LIFFE is not. That is, a trader on the LIFFE floor knows the identity of the local or broker they are trading with. This may cause block trades to migrate towards the automated exchange and foster a higher degree of information asymmetry on the DTB, possibly leading to higher adverse selection costs and wider bid-ask spreads. Secondly, the DTB gives traders more information about price and depth away from the best bid and ask. Franke and Hess (1995) suggest that this information takes on greater value in times when there is a shortage of more fundamental information in the market. Thirdly, while the DTB enforces strict price and time priority, on the LIFFE, a new auction is deemed to have commenced after every trade, so that 'global' time priority is not maintained. Domowitz (1993) analyses spreads on an automated system (Globex) and a floor-traded system (the CME), simulating successively higher levels of volume being traded on each system. He finds that spreads on the automated system fall more rapidly as the level of trading activity rises and relates this to the enforcement of time priority. Finally, the DTB opens with a call market, while the LIFFE uses no special opening procedure. Prior literature (eg. Coppejans and Domowitz, 1996) suggested that the use of a call opening contributes to lower opening price volatility which may also have an impact on spreads (McInish and Wood, 1992). In sum there are a number of counteracting forces which may have an impact on the provision of liquidity on either exchange, leaving it an open issue.

3. Data and method

Intraday trade and quote data, as well as daily data for both the DTB and LIFFE were obtained for the period 14 October to 24 November 1997—30 trading days. The intraday data is a record of the time and price of every trade and quote revision on each exchange. Volume is attached to the trade records on the DTB, but due to the shortcomings of its price reporting system, trade volumes are not reported for the LIFFE. Trade and quote time stamps are accurate to the second for the DTB, and to the minute for the LIFFE. The daily data is a record of daily opening, high, low and closing prices as well as volume and open interest for both exchanges. Although the size of individual trades is not reported on the LIFFE, the daily data contains trade volumes sourced from settlement information.

The measure of the cost of trading used in this study is the quoted bid ask spread. A time weighting procedure identical to McInish and Wood (1992) is

employed to calculate bid ask spreads (QUOTESP) in 5-min intervals. Specifically, spreads are calculated as follows:

$$\text{QUOTESP}_t = \frac{\sum_{i=1}^n \text{BAS}_i t_i}{\sum_{i=1}^n t_i} \quad (1)$$

where BAS_i is the quoted bid ask spread in points, t_i is the amount of time the spread i exists, and n is the number of different bid ask spreads that occur during interval t .

McInish and Wood (1992) identify the main determinants of intraday bid-ask spreads. These are, in their most basic form, trading activity and price volatility. If these variables differ across the two exchanges, a simple comparison of mean spreads will give a misleading picture of relative liquidity. Hence, in previous research, spreads could have been expected to be wider on the DTB than the LIFFE because of the larger amount of trading activity occurring on the LIFFE. Although the shares in trading activity across the two markets are more comparable for the sample used in this study, the DTB now attracts a slightly greater proportion of the total market. This and other possible differences in the determinants of spreads represent sources of bias when comparing liquidity between the two mechanisms and necessitate the use of controls.

As a preliminary step, the intraday pattern in bid ask spreads, trading activity and price volatility are examined and compared across exchanges. This was done by regressing each variable on a series of time-of-day dummy variables. For example, for quoted bid-ask spreads the following model was estimated:

$$\text{QUOTESP}_t = \alpha_0 + \alpha_1 D_L + \sum_{i=1}^7 \beta_i (D_i) + \sum_{i=1}^7 \delta_i (D_L)(D_i) + \varepsilon_t \quad (2)$$

where QUOTESP_t is the average time-weighted quoted spread over the interval. D_L is an exchange dummy variable which equals one if observation t is drawn from the LIFFE and zero otherwise. D_i are time-of-day dummy variables. D_1 represents the first two 5-min of trading, with each subsequent time-of-day dummy variable representing approximately nine sequential 5-min intervals each. A similar model is estimated for the number of trades and price volatility.

A regression model similar to that suggested by McInish and Wood (1992) was then implemented to control for potential systematic differences in the determinants of bid-ask spreads across the two exchanges. The model specification used was:

$$\begin{aligned} \text{QUOTESP}_t = & \alpha_0 + \alpha_1 D_L + \alpha_2 \text{sqrt}(\text{TRADES}_t) + \alpha_3 \text{STDEV}_t \\ & + \alpha_4 (D_L) \text{sqrt}(\text{TRADES}_t) + \alpha_5 (D_L) \text{STDEV}_t \\ & + \alpha_6 \text{sqrt}(\text{MPRICE}_t) + \epsilon_t \end{aligned} \quad (3)$$

where TRADES_t is the number of trades in the interval. STDEV_t is the standard

deviation of five price observations in each interval generated by taking the mean of the bid and ask quote (midpoint) each minute. The variables associated with exchange interactive dummy variables are designed to capture the incremental effect of trading activity and price volatility on quoted spreads for the LIFFE. $MPRICE_t$ is the time weighted average price measured using the midpoint of the spread. The square root of $TRADES_t$ and $MPRICE_t$ is taken to reduce the influence of outliers, consistent with McInish and Wood (1992). While McInish and Wood (1992) also incorporate a trade size variable in their analysis, this is not possible here. The impact of this omitted variable is discussed later. A 5-min observation interval was also employed in this analysis. All t statistics are adjusted for heteroskedasticity and autocorrelation using the procedure developed by Newey and West (1987).

4. Results

Table 2 provides descriptive statistics for quoted bid-ask spreads on the DTB and LIFFE, as well as a number of possible determinants. Panel A reports each variable on a daily basis, while panel B reports each variable on a 5-min basis. The daily volatility measure reported in panel A is based on highest, lowest, opening and closing prices as described in Wiggins (1992), while Panel B reports the intraday volatility measure (STDEV) discussed above. Focusing on the 5-min data, Table 2 reports that mean and median bid-ask spreads on the DTB are narrower than on the LIFFE.

The table also reveals a number of systematic differences in the determinants of spreads. Trading activity on the DTB is higher than on the LIFFE, and volatility appears to be marginally higher on the LIFFE.

Table 3 presents regression results for the analysis of the intraday patterns in quoted spreads, number of trades and volatility. The Appendix A contains graphical representations for each of these variables on an intraday basis.

A number of findings emerge from the intraday analysis of quoted spreads. Firstly, the coefficient on the dummy variable D_L (LIFFE dummy) is positive and significant, indicating that spreads are generally wider on the LIFFE than the DTB. Secondly, the coefficients on D_1 (Morning 1), D_2 (Morning 2) and D_7 (Afternoon) are positive and significant suggesting that spreads are elevated at the open and close of trading. Furthermore, the coefficient associated with D_1D_L (LIFFE-morning 1) is negative and significant suggesting that spreads on the LIFFE are significantly lower at the open of trading relative to the DTB. This is also apparent in Fig. A1 produced in the Appendix A.

The coefficients associated with D_1 (morning 1), D_2 (morning 2), D_6 (Midday 4) and D_7 (afternoon) are positive and significant for both trading activity and volatility regressions, indicating that trading activity and volatility are significantly elevated in the morning and afternoon. Furthermore, for the trading activity

Table 2
Descriptive statistics (14 October 1997–24 November 1997)

	LIFFE					DTB				
	Mean quoted spread (points)	Volume (contracts)	Number of trades	Average trade size (contracts)	Volatility (ticks)	Mean quoted spread (points)	Volume (contracts)	Number of trades	Average trade size (contracts)	Volatility (ticks)
<i>Panel A: daily observation intervals</i>										
Mean	0.0110	105 529	2425.9	42.75	4.99	0.0100	160 634	3522	41.9	3.26
Median	0.0110	102 675	2397	42.84	3.45	0.0100	144 356	3405	42.63	2.03
Standard deviation	0.0010	38 673	745.4	3.15	5.25	0.0010	78 876	1193	4.639	4.27
Observations	30	30	30	30	30	30	30	30	30	30
<i>Panel B: 5-min observation intervals</i>										
Mean	0.0105	–	22.53	–	0.0060	0.0100	–	32.46	–	0.0058
Median	0.0103	–	21	–	0.0047	0.0100	–	28	–	0.0043
Standard deviation	0.0014	–	17.9	–	0.0078	0.0020	–	21.6	–	0.0073
Observations	3234	–	3234	–	3234	3234	–	3234	–	3234

Table 3
Regression results—intraday patterns

	Quoted spread		Number of trades		Price volatility	
	Coefficient	<i>t</i> -Statistic	Coefficient	<i>t</i> -Statistic	Coefficient	<i>t</i> -Statistic
Morning 1	0.0031	13.167*	23.556	11.043*	0.0254	26.8480*
Morning 2	0.0002	2.089*	5.698	6.304*	0.0015	3.6310*
Midday 1	Control	Control	Control	Control	Control	Control
Midday 2	0.0001	1.259	−7.492	−7.180*	−0.0006	−1.3240
Midday 3	0.0000	−0.023	−12.281	−11.600*	−0.0012	−2.5440*
Midday 4	0.0002	1.396	13.497	12.964*	0.0012	2.6490*
Afternoon	0.0003	2.449*	17.479	17.803*	0.0024	5.5260*
LIFFE dummy	0.0007	6.069*	−8.982	−8.647*	0.0001	0.2310
LIFFE-morning 1	−0.0029	−8.861*	6.499	2.154*	0.0021	1.5370
LIFFE-morning 2	−0.0002	−1.164	0.708	0.553	0.0001	0.0890
LIFFE-mid-day 1	Control	Control	Control	Control	Control	Control
LIFFE-mid-day 2	−0.0001	−0.43	4.137	2.803*	0.0000	0.0310
LIFFE-mid-day 3	0.0002	1.205	5.463	3.649*	0.0001	0.2200
LIFFE-mid-day 4	−0.0001	−0.35	−8.296	−5.634*	0.0002	0.3100
LIFFE-afternoon	−0.0003	−1.872	−9.139	−6.583*	0.0001	0.1380
<i>F</i> -Statistic	27.733*		205.59*		141.48*	
<i>R</i> -Squared	0.05		0.29		0.22	
Observations	6468		6468		6468	

* Significant at 0.05 level.

regression the coefficients for these variables associated with LIFFE interactive dummy variables are positive and significant for D_1 (LIFFE-morning 1) but significantly negative for D_6 (LIFFE-Midday 4) and D_7 (LIFFE-afternoon). This indicates that the LIFFE is more actively traded in the morning and less actively traded in the afternoon in comparison to the middle of the day relative to the DTB. None of the time of day dummy variables associated with interactive LIFFE dummy variables are significant for the volatility regression, suggesting that the intraday patterns in price volatility are similar on both the DTB and LIFFE.

The results reported in Tables 2 and 3 above indicate that there are sufficient differences between the two exchanges with respect to these three variables to warrant an examination of spreads within a regression framework. Such a framework captures the difference in spreads between the two systems after controlling for the effect of the differences in volume and volatility across the two markets.

Table 4 presents the results of a regression where the quoted bid-ask spread is modelled as a function of number of trades, volatility and exchange dummy variables.⁸

The positive and significant coefficient on the LIFFE dummy (D_L) indicates that spreads are approximately 9% (or 2.25 DM) wider on the LIFFE than on the DTB after controlling for the level of trading activity and price volatility. This is greater than the exchange fee forgone by the LIFFE (£0.42 \approx 1.3 DM) in attempts to recover its lost market share in the BUND (see Table 1).

Table 4 also reports that, consistent with prior research (McInish and Wood, 1992) and expectations, spreads are negatively related to the number of trades and positively related to price volatility.⁹ Both of these relationships are significant at the 0.01 level. The insignificant coefficient on $D_L^* \sqrt{\text{TRADES}}$ suggests that spreads on the two systems do not respond differently to given levels of trading activity. The negative and significant coefficient on $D_L \text{STDEV}$ indicates that spreads on the DTB widen at a faster rate than the LIFFE as volatility increases. This finding is consistent with Franke and Hess (1995), who find that the DTB is less liquid when the level of volatility is elevated. The authors argued that volatility is a proxy for the intensity with which information is arriving. They argue that when information intensity is low, the information contained in the DTB order book is of value and the DTB attracts traders, making it more liquid. Alternatively, when the level of information intensity is high, this information is of little incremental value and liquidity is higher on the LIFFE.

The finding that spreads deteriorate on automated systems during periods of high price volatility is also consistent with the intraday patterns observed in Table 3 and Figs. A1, A2, A3 and A4 in the Appendix A. This analysis documents an elevation in price volatility in the first interval in the morning, which is also the only interval during which spreads on the LIFFE are systematically narrower than those on the DTB.¹⁰ In light of the intraday patterns in the explanatory variables, a model of spreads was estimated which incorporated time-of-day interactive dummy variables as well as the explanatory variables above (not reported). None of the coefficients associated with these interactive dummy variables were significant, indicating that, although there are intraday patterns in spreads, trading activity and price volatility, there is no intraday pattern in the relationship between these variables. Fig. A4 in

⁸ As expected, the intercept term (not reported) is positive and significant.

⁹ To further explore the extent of the limitation imposed by the price reporting system used by the LIFFE, regressions were run using the midpoint volatility from the DTB as the proxy for 'true' price volatility. Results using this alternative produced qualitatively similar results.

¹⁰ This result may be attributable to the fact that the DTB opens with a call, while the LIFFE opens with a continuous market. Although only prices from the continuous markets of each exchange are used in this analysis, it may be that the first one or two quotes generated by the DTBs continuous market are affected by the opening algorithm used in the call. To investigate this possibility, the analysis was repeated after deleting the first two quotes on each day. Both the intraday patterns and the regression results with respect to the determinants of the spread were robust to this partition, suggesting that the opening call does not mechanically impact on these relationships.

Table 4

The determinants of the quoted bid-ask spread across the two exchanges

	Coefficient	<i>t</i> -Statistic
D_L	0.0009	4.025*
STDEV	0.1071	2.706*
Sqrt(TRADES)	-0.0001	-1.964*
Sqrt(MPRICE)	-0.0037	-4.230*
D_L^*STDEV	-0.1134	-2.811*
$D_L^*sqrt(TRADES)$	0.00004	0.572
<i>F</i> -Statistic	147.21	
<i>R</i> -Squared	0.12	
Observations	6468	

* Significant at the 0.01 level.

the Appendix A indicates that the intraday market share of the DTB increases approximately after 14:00 Frankfurt time. This time coincides with the opening of US financial markets, suggesting that a greater proportion of US-based trading activity is conducted through the DTB than the LIFFE. Hence, a natural extension to the analysis reported in Table 4 is to partition the data into morning and afternoon sessions based on 14:00 Frankfurt time and repeating the analysis of spreads. The results of this analysis are reported in Table 5.

Despite the fact that the mix of traders may be different in the period after 14:00, the results reported in Table 5 suggest the performance of the markets is substantially the same.

McInish and Wood (1992) also incorporate a trade size variable in their analysis. Given the limitations of the quote data on the LIFFE, average trade size is not

Table 5

The determinants of the quoted bid-ask spread across the two exchanges before and after 14:00 Frankfurt time

	Quoted spreads			
	Morning		Afternoon	
	Coefficient	<i>t</i> -Statistic	Coefficient	<i>t</i> -Statistic
D_L	0.001	7.650*	0.001	7.111*
Sqrt(TRADES)	0.000	-1.865	0.000	-1.219*
STDEV	0.110	2.579*	0.082	7.140*
Sqrt(MPRICE)	-0.0031	-4.30	-0.0040	-4.11
$D_L^*sqrt(TRADES)$	0.000	0.230	0.000	-0.292
D_L^*STDEV	-0.112	-2.496*	-0.107	-5.283*
<i>F</i> -Statistic	143.87		25.19	
<i>R</i> -Squared	0.13		0.08	
Observations	4918		1550	

* Significant at the 0.01 level.

available intraday. However, it is unlikely that average trade size is causing an omitted variable bias.¹¹ Furthermore, Table 2 suggests that the average trade size is similar across the two exchanges.¹²

5. Conclusions and suggestions for futures research

Intraday quoted bid-ask spreads were compared for the Bund contract traded on the (open-outcry) LIFFE and the (automated) DTB. Contrary to some suggestions in previous research, spreads on the DTB are narrower than the LIFFE both before and after controlling for differences in the determinants of bid-ask spreads. This result was documented in a comparison over a period where the two exchanges had closer market shares than periods examined in prior research. Spreads on both exchanges were found to be positively related to volatility and negatively related to trading activity. Furthermore, consistent with suggestions in prior research, the liquidity of automated systems deteriorates more rapidly than floor traded systems during periods of high volatility. Nevertheless, the general finding of this paper is that there is no evidence to support the contention that automated systems are less liquid.

There are a number of possible future research directions, both of which depend on data availability. Firstly, similar analysis can be carried out on other contracts which are similarly traded on automated and non-automated markets to determine the robustness of results reported in this paper. For example, the Nikkei 225 Stock Index future is simultaneously traded on the Osaka Securities Exchange (automated) and the Singapore International Monetary Exchange (open outcry). The institutional setting examined in this paper could also be explored further, by comparing APT and DTB trading. The APT and the DTB use different algorithms to execute trades.¹³ Such research could determine the impact of algorithm choice in automated markets on their liquidity.

¹¹ Gujarati (1995) identifies that an omitted variable problem exists when the omitted variable is highly correlated with one of the variables in the model. Where this is the case, the included variable proxies for the omitted variable and the coefficient reflects the impact of both variables. A separate regression using the DTB data suggested that average trade size was not highly correlated with either of the other explanatory variables in the model.

¹² To further explore the extent of the limitation imposed by the price reporting system used by the LIFFE, regressions were run using the average trade size on the DTB as a proxy for the average trade size on the LIFFE. The use of these variables did not effect the results reported here. Also, the sample was partitioned into days with larger average trade sizes and days with smaller average trade sizes. The results were robust to this partition, confirming that average trade size is unlikely to be a significant determinant of the difference between the two systems.

¹³ While the DTB uses time and then price precedence rules to determine the priority of limit orders in executing trades, the LIFFE allocates a market order across limit orders standing at the best price on a pro-rata basis.

Appendix A

Graphical representations of patterns in quoted spreads, number of trades, volatility and market share on an intraday basis (Figs. A1, A2, A3 and A4)

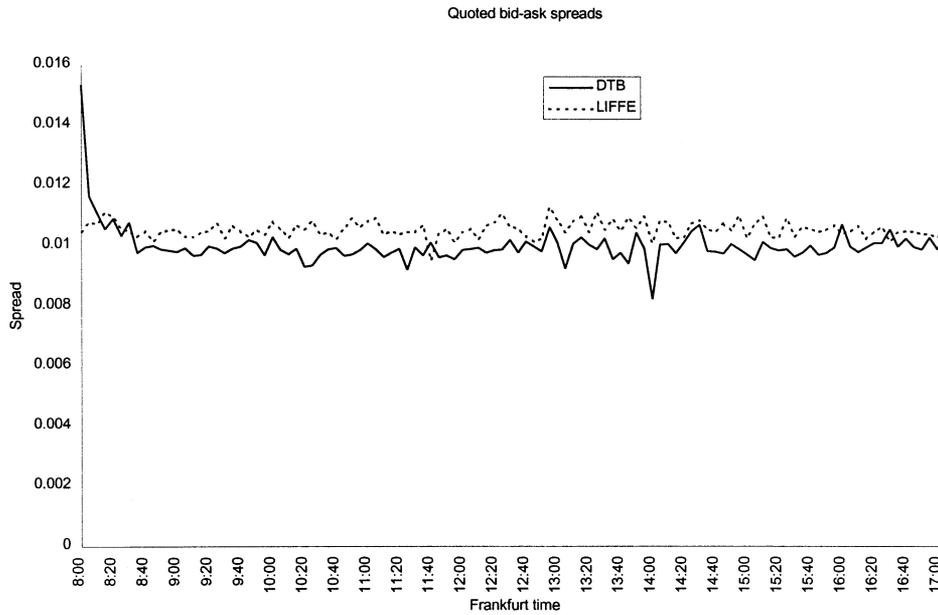


Fig. A1. Intraday pattern in quoted bid-ask spreads.

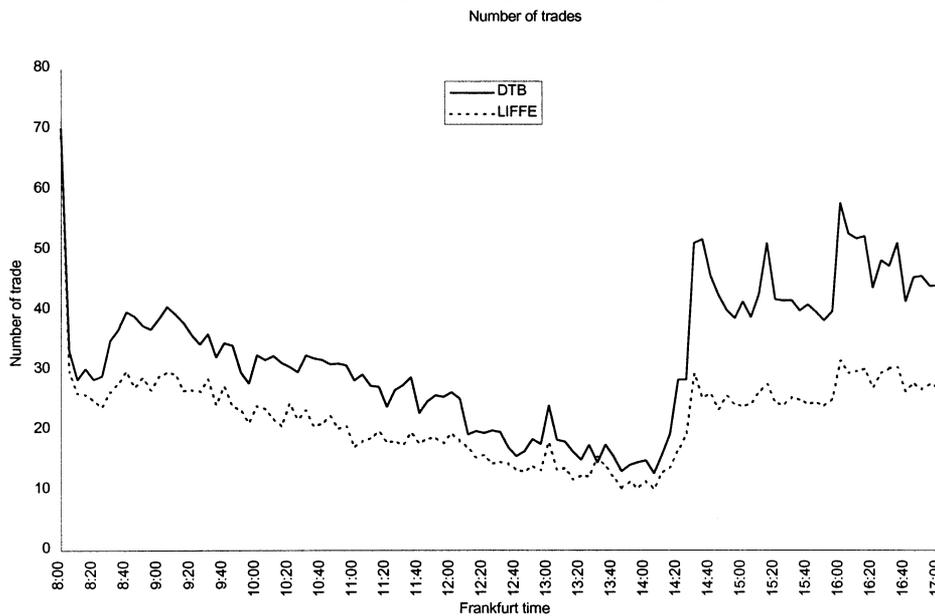


Fig. A2. Intraday pattern in trading activity.

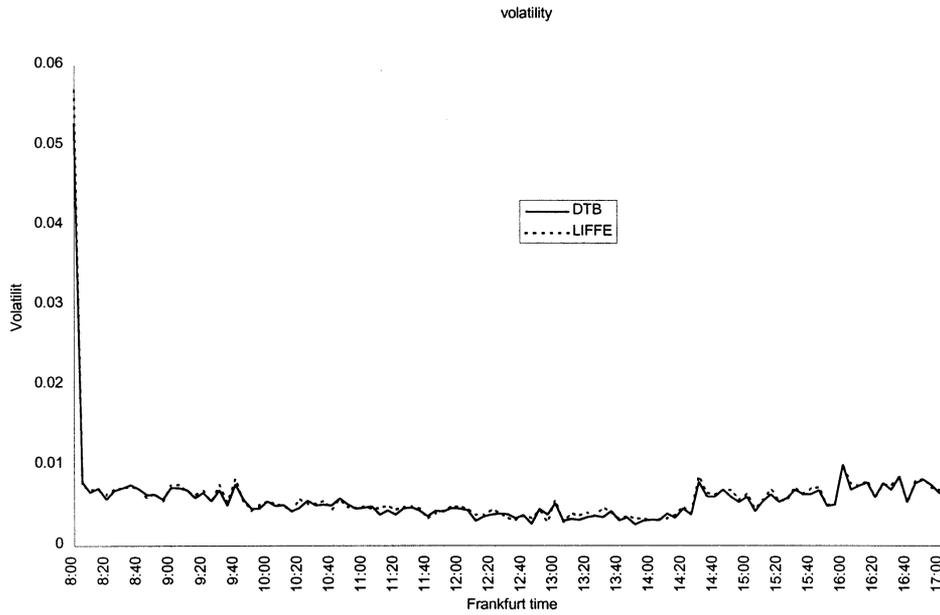


Fig. A3. Intraday pattern in price volatility.



Fig. A4. Intraday pattern in market share, based on the total number of trades.

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