

Bund for Glory, or It's a Long Way to Tip a Market

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Abstract. Theory predicts that liquidity considerations make financial markets “tippy.” In 1998, trading on Bund futures tipped from LIFFE (an open outcry exchange) to Eurex (an electronic market). Measures of spreads and depth on LIFFE and Eurex did not change markedly in the eighteen month period over which Eurex achieved dominance in Bund futures trading. The evidence suggests that trading fee differentials and operational efficiencies were the key factors in precipitating the shift in volume. The “sponsorship” of the Eurex platform by German banks narrowed liquidity cost differences sufficiently to permit Eurex to charge lower fees and thereby undercut total trading costs on LIFFE.

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1 Introduction

Theory predicts that financial markets are “tippy,” that is, that all trading volume tends to gravitate to a single trading venue (Admati and Pfleiderer, 1988, 1991; Pagano, 1989; Grossman, 1992; Glosten, 1994; Madhavan, 2000; Pirrong, 2003a-c). In the presence of informed traders, liquidity traders minimize their transactions costs by congregating in a single market. Theory predicts that liquidity considerations create network effects that make trading in a particular instrument a natural monopoly.¹

This article analyzes empirically a well-known episode of tipping—the movement of trading in Bund futures (one of the most heavily traded financial instruments in the world) from the open outcry London International Financial Futures and Options Exchange (“LIFFE”) to the electronic Eurex. At the beginning of 1997, about 65 percent of Bund futures trading took place on LIFFE. Over the next 21 months all trading volume switched to Eurex. Eurex has maintained its 100 percent market share of Bund futures trading, and also has virtually 100 percent of the trading of futures on other German government debt instruments.

I document several interesting results. First, throughout the January, 1997-June, 1998 period there were only small differences between standard measures of market quality on LIFFE and Eurex. Spreads on the two exchanges were quite similar (with the Roll spread measure being somewhat

¹Most cases of market fragmentation—the trading of a given instrument in multiple venues—are attributable to “cream skimming.” That is, most satellite markets survive only by restricting trading to the verifiably uninformed. See Pirrong (2003a, 2003b) for a formal analysis predicting this result and a discussion of the extensive empirical evidence supporting this prediction.

smaller on LIFFE). Consistent with the results of Pirrong (1996) for an earlier period, Eurex prices responded less to volume changes than LIFFE prices, which is consistent with greater depth on Eurex. Second, despite the fact that LIFFE steadily lost market share and Eurex steadily gained market share from January, 1997 to August, 1998, there were no similar trends in measures of market quality over this period. Specifically, there was no pronounced rise in spread measures on LIFFE and no pronounced fall in spread measures on Eurex. Similarly, there was no pronounced change in depth measures on LIFFE or Eurex. Measured liquidity costs on LIFFE exceeded those on Eurex only after LIFFE's share of volume had fallen to less than 18 percent. Spread and depth measures on LIFFE deteriorated substantially only in July and August, 1998, when LIFFE's share of Bund trading had fallen to less than 2 percent. Moreover, spread and depth measures on Eurex showed no pronounced improvement as its market share rose from less than 35 percent to over 99 percent.

These results suggest that the relation between futures trading volume and trading costs is very flat, steepening substantially only when volume approaches zero. Moreover, they suggest that exchange pricing decisions and cost structures are of decisive importance in determining the trading venue that prevails in a competitive contest. Starting in 1997, Eurex and LIFFE implemented a series of competitive price cuts. LIFFE's loss of market share accelerated markedly when Eurex slashed fees in January, 1998, and LIFFE did not respond immediately. In the aftermath of the Eurex price cut, the sum of exchange fees and liquidity costs was lower on the German exchange; the pace of "tipping" accelerated noticeably at this time. Furthermore, about

this time, major market participants began to reduce their floor presence on LIFFE (and not just in the Bund pit) due to the high cost of supplying brokerage services in an open outcry environment. Best available estimates suggest that the labor and equipment costs of trading on an automated exchange are approximately one-third as large as the costs of trading on an open outcry market. Thus, all in trading costs—including exchange fees and borkerage costs in addition to spread and depth related trading costs—are relevant in determining when and where trading tips. In this one particular instance, trading tipped to the market that could process trades more cheaply, and that the ultimate impact on liquidity of where trading took place was modest. This is consistent with the implications of Pirrong (2003a).

It should be noted that Eurex's operational efficiencies became decisive because liquidity cost differences between Eurex and LIFFE were sufficiently small (and the empirical evidence implies that they were quite small) by late-1997. The support of the German banks in the years 1990-1997 helped Eurex generate the trading volume necessary to narrow these liquidity cost differences. Thus, the LIFFE-Eurex Bund episode suggests that (a) controlling for volume/order flow, there are no marked differences between the liquidity costs of trading on automated and open outcry exchanges, (b) non-liquidity related trading costs are smaller on automated exchanges, but (c) the dedicated support of large sources of order flow over a considerable period of time may be required to allow a more efficient computerized entrant to prevail in competition with an open outcry incumbent exchange.

Although this article obviously has implications regarding the nature of competition between financial exchanges, it is also of interest for the study

of network industries generally. Other “new economy” industries (e.g., computer software) are widely considered to be “tippy,” but it is difficult to measure the costs and benefits of network effects, because many of these (e.g., the benefits of having more programs for a particular operating system) are difficult to quantify. In contrast, in the LIFFE-Eurex case it is possible to quantify with some precision the cost differences across “platforms” subject to network economies. The results demonstrate that very small cost differences (on the order of 3 percent of total costs) are sufficient to induce tipping in a market subject to network economies. The Eurex-LIFFE episode also highlights the importance of technology “sponsorship” in a network industry.

The remainder of this paper is organized as follows. Section 2 presents a brief history of the Bund futures market. Section 3 describes the empirical methodology. Section 4 presents the results. Section 5 summarizes the main implications of the analysis.

2 A History of Bund Futures Trading

Futures on ten-year German government bonds, “Bunds,” commenced in 1988, six years after the the formation of LIFFE. LIFFE was an open outcry futures exchange consciously modeled on the Chicago exchanges. Bund futures volume on LIFFE grew substantially from its commencement. It soon became the exchange’s largest contract.

Eurex was created by the 1998 merger of the Swiss Exchange SOFFEX and the German Deutsche Terminborse (“DTB”).² DTB was formed in 1990

²Originally, SOFFEX and DTB formed Eurex as a joint venture in 1996. The two

by a consortium of German banks. The exchange launched a Bund futures contract in competition with LIFFE. By 1993, DTB's Bund market share had grown to 24 percent. Most of this volume came from German banks, whereas most of the London and US originated order flow was directed to LIFFE.

By January, 1997, Eurex's market share had grown to 35 percent. In 1996, Eurex launched an aggressive campaign to win market share from LIFFE. Key events in the rivalry between Eurex and LIFFE include:

- March, 1996. DTB provided screen based access to its market from London.
- March, 1997. The United States futures regulator, the Commodity Futures Trading Commission, granted Eurex permission to install trading terminals in the United States. By October, 1997, ten futures commission merchants in the US had installed terminals, and accounted for 18 percent of Eurex volume.
- 1 August, 1997. Eurex extended its trading hours to match LIFFE's.
- 1 September, 1997. Eurex commenced trading fee waivers on the Bund. The fee waivers expired on 31 December, 1997. Beginning on 18 September, 1997, LIFFE also waived fees for the remainder of the year.

exchanges announced a merger in September, 1997, and the merger was completed in 1998. Hereafter, I will refer to the German exchange as "Eurex" regardless of the time to which I refer.

- 1 January, 1998. Eurex introduced a new pricing structure. It eliminated admission and annual fees for market makers and full members.³ It also reduced fixed fees for clearing members. Furthermore, Eurex introduced a new fee structure that capped the per contract charge at .50 DM (the pre-September, 1997 price) and introduced a sliding pricing scale that gave volume discounts. The resulting price schedule eliminated line fees and capped a user's total trading fees at 4500 DM (Young and Theys, 1999). This effectively set the marginal trading fee equal to zero for medium and large traders.
- 27 March, 1998. LIFFE reduced transaction fees for all of its financial futures and options. Fees for futures trades fell from 42 pence per contract to 25 pence per contract.

Eurex's efforts, and LIFFE's belated response, led to a pronounced shift in volume from LIFFE to DTB. Figure 1 depicts the Bund futures market shares of the two exchanges over the January, 1997-October, 1998 period.⁴ Over this period, LIFFE market share fell steadily. In January, 1998 Eurex volume surpassed LIFFE's. As Figure 1 makes clear, thereafter the erosion of LIFFE market share accelerated. From January to December, 1997, LIFFE market share fell about 1.1 percentage points per month; From January to October, 1998, LIFFE's market share fell an average of 5 percentage points

³These fees were substantial. A non-clearing membership required payment of a one-time DM 102,000 entry fee, a one-time line fee of DM 25,000, a monthly line fee of approximately DM 4000, and an annual fee of DM 34,000.

⁴These figures are based on data published in Eurex Monthly Statistics (1998), available at <http://www.eurexchange.com>.

per month. Indeed, the share losses were particularly acute in the first half of 1998. During this period, LIFFE's share fell almost 7 percentage points per month. By October, 1998 Eurex's market share in the Bund contract exceeded 99.9 percent. The market had tipped completely.

The acceleration in market share changes once Eurex had surpassed a 50 percent share is broadly consistent with received theories on equilibrium in network industries, and with models of liquidity in financial markets. These theories imply that, *ceteris paribus*, trading costs are lower in the market with the greater market share. This lower cost attracts additional volume to that market, which exacerbates the cost disparity, which in turn leads to further movement of trading volume to the larger exchange. This process ends when one exchange captures all the volume.

Although the market share movements are illuminating, a more direct test of these theories requires a comparison of trading costs and market quality on the two exchanges. Moreover, a more detailed analysis of the data is required to understand why the market tipped when it did. The remainder of this article utilizes data from the two exchanges to (a) document the impact of market tipping on conventional measures of trading cost and market quality, and (b) determine what caused the market to tip in January, 1998.

3 Empirical Methodology

3.1 Data

The analysis is based on tick data obtained from LIFFE and Eurex. The LIFFE data includes the time and price of each trade, as well as bid and

ask quotes (and their time). The Eurex data reports only time and price of trades; it does not report quotes. Although LIFFE data purports to report the volume of each trade, these figures are suspect. For instance, a large number of trades report a volume of 41 contracts.

3.2 Spreads

Spreads are the most commonly employed measure of trading costs. I use several well-known spread measures to estimate trading costs on LIFFE and Eurex during the 1997-1998 period. Some measures require the observation of the quoted spread, and hence I can only implement them for LIFFE. Other measures do not require knowledge of the quoted spread and can be implemented for both exchanges.

The effective spread and the realized spread require knowledge of the quoted spread. The effective spread at time t is defined as:

$$S_t^E = 2Q_t(P_t - M_t)$$

where P_t is the transaction price at t , M_t is the midpoint of the quoted bid-ask spread observed immediately prior to the transaction, and Q_t is a trade direction indicator. The realized spread at t is:

$$S_t^R = 2Q_t(P_t - M_{t+.25})$$

where $M_{t+.25}$ is the mid-point of the quoted spread 15 minutes (a quarter hour) after t .

Transactions are included in the estimates of the effective and realized spreads only if there is a bid and ask price time stamped within 15 seconds prior to the time of the transaction.

The Roll spread does not require knowledge of the quoted spread. The Roll spread is:

$$S^{Roll} = \sqrt{-2cov(\Delta P_t, \Delta P_{t-1})}$$

where $\Delta P_t = P_t - P_{t-1}$, and $t - 1$ is the time of the transaction immediately preceding the transaction at t .

Stoll's traded spread measure can also be implemented without knowledge of the quoted spread. This spread is the coefficient S_T estimated from the following regression:

$$\Delta P_t = .5S^T[Q_t + Q_{t-1}(\lambda - 1)] + \xi_t$$

In this expression, λ measures the fraction of the traded spread attributable to adverse selection and inventory costs. $1 - \lambda$ measures market maker rents. ξ_t is an error term.

The Thompson-Waller measure also does not require knowledge of the quoted spread. This measure is:

$$S^{TW} = E[|P_t - P_{t-1}|]$$

where this expectation is calculated conditional on $P_t \neq P_{t-1}$.

All spread measures except the Roll and Thompson-Waller estimators require observation of the trade direction indicator Q_t . For LIFFE, where the bid-ask is observable, I use the Lee-Ready trade direction indicator.⁵ For Eurex data, I estimate Stoll's traded spread measure using the tick test to determine Q_t ; to permit comparison, I estimate the relevant regression on

⁵The Ellis-Michaely-O'Hara (2000) trade indicator is almost always equal to the Lee-Ready indicator, and generates identical empirical results.

LIFFE data using the tick test-based trade direction measure, although I also use the Lee-Ready measure for LIFFE data. Given that Stoll shows that the possibility that broken up orders can distort the estimates of S^T and λ , I estimate the regressions on a subset of data in which trades on a zero tick are eliminated as well as on the whole data. For brevity, only the results from the former analysis are presented; the conclusions I derive do not depend on this choice.

I estimate each spread measure for each month beginning in January, 1997 and ending in August, 1998. Reported effective, realized, and Thompson-Waller spreads are sample averages of the relevant statistic within the month. The reported Roll spread is based on the within-month covariance of consecutive price changes (with overnight price changes omitted). The traded spread model is estimated month-by-month using GMM with Q_t and Q_{t-1} as instruments; overnight observations are omitted. All spread measures in a given month are based on data from the next-to-expire (i.e., “front month”) contract. Contract months are rolled at the beginning of each delivery month. Thus, for example, in March (a delivery month) spreads are estimated using June futures prices, whereas in February the March prices are used.

3.3 Depth

Market depth measures how buy-sell volume imbalances impact prices. The time and sales data available do not permit estimation of how customer order imbalances impact prices. Instead, I make inferences about depth by extending a methodology employed in Pirrong (1996) and in several subsequent studies (put in cites.)

Pirrong (1996) measures the impact of trading activity on price movements by regressing the absolute value of the price change in a given interval on several variables, including lagged trading activity, and estimates of expected and unexpected trading activity during the time interval. Pirrong (1996) estimates separate regressions for LIFFE and DTB.

What follows is in this spirit, but adapts the GARCH methodology of Chan, Chan, and Karolyi (1991). This approach allows joint estimation of the variance processes for LIFFE and Eurex, and quantification of volatility spillovers between the two exchanges.

Like Pirrong (1996) this is a three stage method. I first decompose trading activity into expected and unexpected components using OLS. Expected trading activity is posited to depend on past activity and time of the day. Specifically, for each exchange I estimate the following equation:

$$V_{X,t} = a + \sum_{j=1}^5 b_{X,j} V_{X,t-j}^e + \sum_{i=1}^{89} d_{X,i} D_i + c_X \tau + f_X \tau^2 + e_{X,t}$$

In this expression $V_{E,t}$ is the trading activity on exchange X ($X = L$ for LIFFE, $X = E$ for Eurex) in a time interval ending at time t . I use 10 minute time intervals. Moreover, since volume (in contracts) is not available for Eurex, and are of dubious quality for LIFFE, I measure volume using the number of trades in the time interval.⁶ The D_i are dummy variables taking

⁶Although LIFFE data contains a volume field, a large fraction of the volume entries are for 41 contracts. There is empirical justification for using number of trades (as opposed to the number of shares or contracts traded) as a measure of trading activity. See Jones *et al* (1994) and Geman and Ane (1996). Jones *et al* show that controlling for the number of trades, volume has no additional power to explain volatility. Geman and Ane show that a stochastic time change based on the number of trades produces normality in S& P 500 futures prices.

a value of 1 during the i th time interval in a day and zero otherwise. τ is a time trend and $e_{X,t}$ is an error term.

Based on this regression, for each exchange I create an expected trading activity variable:

$$V_{X,t}^* = a_X + \sum_{j=1}^5 b_{X,j} V_{X,t-j} + \sum_{i=1}^{89} d_{X,i} D_i + c_X \tau + f_X \tau^2$$

and an unexpected trading activity variable $U_{X,t} = e_{X,t}$. I also create a positive unexpected trading activity variable $U_{X,t}^+ = \max[e_{X,t}, 0]$.

Second, I estimate the following regressions for the mean returns:

$$r_{L,t} = m_L + \sum_{j=1}^{10} g_{L,j} r_{L,t-j} + \sum_{j=1}^{10} h_{E,j} r_{E,t-j} + q_L (\ln P_{E,t-1} - \ln P_{L,t-1}) + \eta_{L,t}$$

and

$$r_{E,t} = m_E + \sum_{j=1}^{10} g_{E,j} r_{E,t-j} + \sum_{j=1}^{10} h_{L,j} r_{L,t-j} + q_E (\ln P_{E,t-1} - \ln P_{L,t-1}) + \eta_{E,t}$$

where

$$\eta_{X,t} = (\mu_X + \psi_X Z_{X,t}) \epsilon_{X,t} \quad X = E, L.$$

In these expressions, $r_{X,t}$ is the return on exchange X in the ten minute interval ending at time t and $P_{X,t}$ is the price of the Bund futures on exchange X at time t . $Z_{X,t}$ is a dummy variable that is set to one for overnight returns, and to zero otherwise; this method of scaling to differentiate the effect of overnight and intraday returns is used by Chan *et al* (1991) and Breen *et al* (1989). The inclusion of the error correction terms in these equations reflects the fact that the Bund futures prices on the two exchanges are co-integrated. $\eta_{X,t}$ is a scaled residual return on exchange X in the time interval ending at t .

Third, and finally, I estimate the following equation system using maximum likelihood:

$$\begin{pmatrix} \epsilon_{E,t} \\ \epsilon_{L,t} \end{pmatrix} \sim N(0, \mathbf{H}_t)$$

$$\mathbf{H}_t = \begin{pmatrix} h_{E,t} & \sigma_{E,L,t} \\ \sigma_{E,L,t} & h_{L,t} \end{pmatrix}$$

$$h_{E,t} = \omega_E + \beta_E h_{E,t-1}^1 + \alpha_E \eta_{E,t-1}^2 + \nu_{E,1} V_{E,t}^* + \nu_{E,2} U_{E,t} + \nu_{E,3} U_{E,t}^+ + \sum_{i=1}^3 \gamma_{E,i} \epsilon_{L,t-i}^3$$

$$h_{L,t} = \omega_L + \beta_L h_{L,t-1}^1 + \alpha_L \eta_{L,t-1}^2 + \nu_{L,1} V_{L,t}^* + \nu_{L,2} U_{L,t} + \nu_{L,3} U_{L,t}^+ + \sum_{i=1}^3 \gamma_{L,i} \epsilon_{E,t-i}^3$$

$$\sigma_{E,L,t} = \rho \sqrt{h_{L,t} h_{E,t}}$$

This specification allows expected and unexpected trading activity on an exchange to affect return variance on that exchange. The coefficients on these variables proxy for market depth; large values of these coefficients imply that large trading activity is associated with bigger price impact, which is consistent with low depth. The specification also allows expected trading activity, unexpected trading activity, and positive unexpected trading activity shocks to have different impacts on return variance.

Moreover, this specification allows price shocks on one exchange to impact volatility on the other. Since Chan, Chan, and Karolyi (1991) volatility spillovers have been interpreted as a measure of information flow across trading venues. Volatility spillovers from one exchange to another are commonly interpreted to indicate that some price discovery is taking place on the former. Including spillover effects makes it possible to determine whether the rise to dominance of Eurex and the decline of LIFFE in Bund trading affected the locus of price discovery.

These models are estimated on ten minute returns. Moreover, I estimate the models for seven different two month time periods. These periods are: January-February, 1997 (based on prices from the March 97 contract); April-May, 1997 (June 97 contract); July-August, 1997 (September 97 contract); October-November, 1997 (December 97 contract); January-February, 1998 (March 98 contract); April-May, 1998 (June 98 contract); July-August, 1998 (September 98 contract). Estimation over multiple time periods permits determination of whether return dynamics or depth changed as trading shifted from LIFFE to Eurex. I use two month periods because (a) such a sample window gives sufficient observations for reliable estimates of the GARCH model, and (b) this avoids the problems associated with rising volume around the expiration of the prior contract and falling volume at the expiry of the contract of interest.

The mean equations and variance-covariance equations are estimated separately. Two considerations justify this approach. First, since the information matrix of the general error-correction model with time-varying volatility is block diagonal with respect to the mean and variance equation parameters, separate estimation does not reduce the efficiency of the variance estimates. Second, since the explanatory variables in the mean equations are identical, the estimated coefficients (and hence the residuals) are the same regardless of whether the equations are estimated singly or jointly. The two-step approach is computationally pragmatic due to the large number of parameters and the large number of data points.

4 Results

4.1 Spreads

Tables 1 and 2 present the results for the spread analysis. Table 1 presents results on the traded spread, Thompson-Waller, and Roll spread measures which can be compared across exchanges. Table 2 presents results on the spread measures that are available only for LIFFE due to the absence of bid-ask quotes on Eurex. In each table, the first column denotes the contract month.⁷ The second column denotes the calendar month.

Several regularities stand out in Table 1:

- With respect to the traded spread (estimated using the Stoll-Huang method with price repeats eliminated and the tick test to estimate trade direction) the LIFFE spread measure is slightly smaller than its Eurex counterpart from January, 1997 through April, 1998. Starting in May, 1998, the Eurex traded spread is smaller than the LIFFE traded spread, and the disparity widens through August, 1998, at which time the LIFFE traded spread is more than double the Eurex traded spread.⁸
- The Thompson-Waller spread measure exhibits similar behavior, with

⁷*H*, *M*, *U*, and *Z* are standard futures industry delivery month codes for March, June, September, and December, respectively.

⁸When price repeats (i.e., zero tick trades) are not eliminated, the estimated traded spread on Eurex ranges from .0115 to .0134, and the LIFFE traded spread ranges from .0126 to .0137 prior to June, 1998. The LIFFE spread ballooned to .019 in June, 1998, and to .03 in August, 1998. With price repeats included, from January, 1997-May, 1998, the Eurex spread averaged .0005 less than the LIFFE traded spread. There was no pronounced spread in either the Eurex or LIFFE spreads during the January, 1997-May, 1998 period, nor was there a trend in the Eurex spread post-August, 1998.

small advantages in favor of LIFFE prior to May, 1998, and a widening advantage in favor of Eurex from May, 1998 to the demise of the LIFFE Bund trading in August, 1998.

- The Roll spread measure shows a similar pattern, with Eurex exhibiting a lower spread only beginning in May, 1998. The disparities between LIFFE and Eurex spreads prior to that time are somewhat larger than the disparities across exchanges between the traded and Thompson-Waller spread measures; at times, the Roll spread is more than 20 percent lower on LIFFE.
- The Eurex spread measures are quite stable, and exhibit no pronounced decline during the period in which LIFFE spread measures widened.
- LIFFE spread measures are also quite stable, exhibiting no pronounced increase during the period of the exchange's market share erosion until the very end of the tipping process, by which time LIFFE market share had fallen below 20 percent.
- Eurex spread measures in the post-August, 1998 period (in which Eurex monopolized the Bund futures trade) are slightly larger than the LIFFE spread measures in the January, 1997-May, 1997 period in which LIFFE had the largest market share in the sample period. This suggests that the open outcry market offers very slightly greater maximum potential liquidity than the electronic market.

The results in Table 2 are broadly consistent with those in Table 1. The traded spread (estimated using the Stoll-Huang methodology and the Lee-

Ready trade direction estimator) and the total spread (the sum of the realized and effective spreads) fluctuate within a narrow range until the decline in LIFFE volume and market share became pronounced. Indeed, during the April-June, 1998 period, these spreads were slightly smaller than those observed in 1997.

These results suggest that conventional measures of liquidity costs cannot explain the tipping of the Bund market from LIFFE to Eurex. Eurex did not exhibit lower liquidity costs prior to the beginning of the pronounced shift of business from London to Frankfurt. Indeed, Eurex liquidity costs exceeded those on LIFFE until the tipping process was almost complete.⁹

This further suggests that other determinants of trading costs—such as fees—were important factors in determining the allocation of trading volume. Looking at measured spreads alone, it is difficult to understand how Eurex could have attracted even 35 percent of trading volume; however, Eurex’s lower exchange fees of about \$.33 per contract (in 1997) and \$.17 (in 1998) as compared to LIFFE’s \$.66 (in 1997) and \$.33 (after March, 1998) (Mehta, 1999) tended to reduce the former exchange’s cost disadvantage.

Indeed, these differences in trading costs are approximately equal to the differences in trading costs implied by the figures in Tables 1 and 2. Based on both the traded spread and realized spread estimates, the per contract liquidity cost on Eurex was approximately \$.24 higher on Eurex than LIFFE on average during the December, 1997-April, 1998 period (during which the market tipped). This was smaller than the trading fee differential during

⁹Pirrong (1996) and Kofman and Moser (1997) present evidence that differences in liquidity between LIFFE and DTB were very small as early as 1992.

this period. Thus, taking both spreads and fees into account, trading was about \$.09 cheaper on Eurex prior to the price cuts of January, 1998. This cost advantage widened to about \$.25 after Eurex's price cut.¹⁰ The acceleration of Eurex's market share gains coincided with this widening of the cost differential.

These differences are very small relative to total trading costs. Over the December, 1997-March, 1998 period, trading cost (spread plus fee) was between 3 and 4 percent lower on Eurex than LIFFE (depending on whether the traded or TW spread is used). Thus, the market tipped despite the small cost differentials documented here.

Other factors may have exacerbated these cost differentials. Although brokerage cost figures are not available, Price-Waterhouse estimated that the cost of contract execution on an open outcry exchange (including labor and equipment costs) was about three times that incurred on an electronic exchange (Price-Waterhouse, 1997). Given that brokerage fees (as distinct from exchange fees) must cover the cost of contract execution, *ceteris paribus* this cost differential inflated brokerage costs on LIFFE relative to those on Eurex, and contributed further to Eurex's operational cost advantage.¹¹

Thus, the data support the inference that out-of-pocket costs (exchange and brokerage fees) were important determinants of the allocation of trading volume across exchanges. Moreover, inasmuch as volume shifted to the ex-

¹⁰This may understate the impact of the price cuts for medium and large traders. Fees were capped so that the marginal fee for trading on Eurex was zero for firms trading more than 9000 contracts in a month. The fee cuts also sharply reduced the fixed cost of trading on Eurex.

¹¹Kofman and Moser claim that commissions were higher on LIFFE.

change with lower non-liquidity related costs, the results are consistent with the implications of the model of Pirrong (2003c). That paper presents a static model in which the lower cost exchange has a competitive advantage, and can undercut its rivals' fees as a result. In equilibrium, the low cost exchange captures 100 percent of the trading volume. In the model, liquidity costs do not depend on which exchange prevails (as is effectively the case here), but total costs are minimized in equilibrium.

The results also suggest that the relation between trading cost and trading volume is very flat. Large declines in trading volume on LIFFE and large increases in trading volume on Eurex (note the large drop in the number of observations on the former and the concomitant rise in the number of observations on the latter) were not associated with large changes in measured trading costs. This implies that, at least for Bund futures, fragmentation does not markedly increase trading costs.

4.2 Trading Activity, Depth, and Spillovers

Table 3 presents the results from the estimation of the relevant variance and covariance equations. In addition, the Table 4 reports the correlation coefficient ρ and the coefficients on the lagged log spread and the R^2 's from the mean equations.

Several results stand out:

- Trading activity typically had a smaller impact on variance on Eurex than on LIFFE. Note in particular, that unexpected positive trading activity shocks have a smaller impact on Eurex variance than on LIFFE variance: for each contract month, $\nu_{E2} + \nu_{E3} < \nu_{L2} + \nu_{L3}$. This is

consistent with findings first documented by Pirrong (1996) using a different methodology.

- There was no pronounced trend in the trading activity coefficients for either LIFFE or Eurex corresponding to the pronounced trends in volume and market share. That is, there is no evidence that the shift in volume from London to Frankfurt affected the relationship between volume and variance.
- There were typically two-way variance spillovers. That is, lagged squared return shocks on LIFFE typically affect variance on Eurex, and *vice versa*. The most common result is for the coefficient on the first lagged squared Eurex shock (in the LIFFE variance equation) to exceed the coefficient on the first lagged LIFFE shock (in the Eurex variance equation), but this is not uniformly the case. There is no pronounced trend in the spillover coefficients corresponding to the volume and market share trends.
- The correlation between LIFFE and Eurex returns was substantially lower in the last two contract months studied (June and September, 1998 contracts) than in the earlier contract months.
- Although most of the adjustment to price differences between Eurex and LIFFE (as measured by the relative magnitude of the absolute value of the coefficients on the lagged log price difference) occurred on Eurex in the last half of 1997, during 1998 most of the adjustment occurred on LIFFE. This suggests a shift in price leadership to Eurex.

In sum, the shift in Bund futures trading from LIFFE to Eurex had no marked impact on the return variance-covariance processes. Trading activity shocks had smaller effects on volatility on Eurex than LIFFE during the 1997-1998 period, but the effect of trading activity on volatility did not change as the market tipped.

4.3 Remarks

The most striking result from the foregoing analysis is how little market quality depended on the allocation of trading volume between the two exchanges. In particular, the tipping process had only small impacts on relative liquidity costs across exchanges. It also had little impact on trading activity-volatility relations (the proxy for depth). With regards to these results, one caveat should be kept in mind. Due to the lack of volume information, it is impossible to determine whether volume-price relations changed as a result of the tipping process. Relatedly, given that the spread statistics measure the cost of average trades, due to the lack of trade size data it is impossible to determine whether (a) market share differences impacted the cost of trading large orders, and (b) differences in the cost of executing large orders induced the tipping. That is, it is possible (but not testable given the data) that large orders became more (less) expensive to execute on LIFFE (Eurex) as it lost (gained) market share in early-1998, and that this drove the tipping process once it began.

5 Summary and Conclusions

This article analyzes a notable example of “tipping” of a market—the shift in Bund futures trading from LIFFE to Eurex during the course of 1997-1998. Prior to the shift in trading volume, conventional spread measures indicate that liquidity-related trading costs (as measured by conventional spread measures) were slightly lower on the open outcry LIFFE until that exchange’s market share had fallen to less than 20 percent of overall Bund futures trading volume. Only as LIFFE volume fell to effectively nothing did liquidity-related trading costs there rise substantially absolutely and relative to the comparable costs on the computerized Eurex. Moreover, market volatility processes did not change markedly as the tipping process occurred.

The tipping process began in earnest precisely at the time when the computerized Eurex dramatically cut per trade and fixed fees absolutely and relative to LIFFE’s. This suggests that the price cuts were the key factor that accelerated the shift in volume. LIFFE trading cost measures were actually smaller than those on Eurex until well after the tipping process had almost completely run its course, but the Eurex price cuts widened Eurex’s previously slight advantage in all-in trading costs.

This analysis draws attention to the importance of non-liquidity related costs in determining the victorious trading venue. Academics and market practitioners tend to focus on liquidity as the key element of trading cost. The data from LIFFE and Eurex suggest that liquidity costs (as measured by spreads) are the largest single component of trading costs, but they also suggest that liquidity cost differences across trading venues may be quite

small when each exchange has substantial trading volume. Under these circumstances, small differences in non-liquidity-related costs can be decisive. This is consistent with the predictions of Pirrong (2003a-c).

That said, it must be recognized that the Eurex-LIFFE episode should be evaluated carefully when attempting to draw broader lessons about competition between exchanges (or competition in other network industries). The statistical analysis presented herein does not start at the beginning—it starts at the beginning of the end. Eurex had grown prior to 1997 due primarily to the patronage of German banks that just happened to be the owners of the exchange. These banks provided sufficient volume to permit Eurex to survive and provide liquidity-related trading costs that were at worst only slightly higher than those on LIFFE. This put Eurex within striking range of LIFFE. With the liquidity-related cost differential sufficiently narrow, Eurex was able to price its services to exploit operational efficiencies and thereby tip the market from the incumbent.

This is consistent with the view expressed by a former Chairman of the Chicago Mercantile Exchange:

Critical mass goes this way. The competitive market has 20 percent market share, that's okay. When it has 30 percent, one starts to take notice At 45 percent you've already lost. *The reason it has moved from 30 to 45 percent is because of cost efficiencies being recognized.* Before you know it, in no time it goes to 70 percent. Game over.¹²

¹²Emphasis added. Quote from Barret and Scott, who interviewed numerous exchange

That is, operational efficiencies can induce market tipping when the more operationally efficient exchange's volume approaches, but is still smaller than, that of the putatively less operationally efficient incumbent.

This begs the question of how the more efficient entrant can generate sufficient trading volume so that its operating cost advantages can off-set higher liquidity costs. The Eurex experience provides one answer to this question—strong patrons who direct considerable order flow to the exchange. Absent such support, it is by no means clear how a more operationally efficient entrant exchange (that is, an entrant that would, if all trading activity took place there, offer lower total trading costs) can generate the volume necessary for liquidity cost differences to fall below the entrant's operating cost advantage.

This is consistent with Pirrong (2003c), who argues that the structure of the industry that exerts control over order flow can be the decisive factor in determining the victor in a winner-take-all competition between exchanges. The existence of large brokerage or trading firms that control large order flows, and which can coordinate their activities, increases the likelihood that an entrant can wrest a market from a well-established incumbent. The German banks played this role in their support of DTB/Eurex.

This is also consistent with the importance accorded technology sponsorship in the literature on network industries. The German banks effectively sponsored the Eurex platform. Without this sponsorship, it is highly doubt-

representatives in London and Chicago in 1998 and 1999. The quote is anonymous, but is attributed to an "ex-Chairman CME," and is therefore most likely Leo Melamed, Jack Sander, or Brian Monieson.

ful whether Eurex would have achieved the critical mass necessary to permit it to reach rough parity in liquidity cost with LIFFE. Once Eurex's liquidity costs were only slightly higher than LIFFE's, it could exploit its operational efficiencies through price cutting.

The finding that trading cost measures show little variation despite large fluctuations in volume has interesting implications. It suggests that there are effectively constant returns to scale in liquidity costs over large ranges of volume (at least for financial futures). This implies that multiple exchanges may survive in trading a given instrument if there are sources of decreasing returns to scale in non-liquidity related costs (e.g., systems, clearing, or labor costs). The fact that heretofore there have been no prominent examples of multiple exchanges trading the same instrument over long periods of time is consistent with the existence of constant (or increasing) returns to scale in non-liquidity-related costs. The results also imply that fragmentation does not necessarily inflate trading costs as is often claimed by those that decry it.¹³

¹³Doelde (1965) presents evidence of increasing returns to scale on exchanges. Pirrong (1999) presents a model in which economies to scale in non-liquidity-related costs leads to an equilibrium in which only a single exchange survives.

Table 1 Panel A Eurex Spread Measures						
Contract	Month	N	Traded	λ	TW	Roll
H97	Jan	35759	.0223	.9736	.0113	.0097
H97	Feb	23434	.0215	.9814	.0109	.0100
M97	Mar	28792	.0223	.9774	.0113	.0096
M97	Apr	33791	.0214	.9748	.0109	.0099
M97	May	26272	.0216	.9769	.0110	.0097
U97	Jun	31126	.0215	.9789	.0109	.0099
U97	Jul	37382	.0209	.9758	.0107	.0104
U97	Aug	36897	.0216	.9757	.0109	.0098
Z97	Sep	28568	.0212	.9868	.0107	.0105
Z97	Oct	48782	.0215	.9750	.0110	.0101
Z97	Nov	24086	.0213	.9868	.0108	.0105
H98	Dec	15807	.0214	.9933	.0108	.0098
H98	Jan	37997	.0214	.9955	.0107	.0103
H98	Feb	37987	.0212	.9883	.0107	.0113
M98	Mar	27892	.0223	.9774	.0113	.0096
M98	Apr	48473	.0214	.9943	.0108	.0120
M98	May	37200	.0211	.9948	.0106	.0120
U98	Jun	39376	.0212	.9966	.0107	.0121
U98	Jul	43597	.0214	.9989	.0107	.0126
U98	Aug	70205	.0222	.9893	.0111	.0124
Z98	Sep	94832	.0218	.9922	.0111	.0100
Z98	Oct	129416	.0223	.9874	.0116	.0108
Z98	Nov	66497	.0215	.9934	.0109	.0101
H99	Dec	36015	.0220	.9932	.0112	.0099
H99	Jan	84838	.0215	.9884	.0110	.0103
H99	Feb	99143	.0216	.9941	.0109	.0102

Note: This panel reports spread measures for Eurex based on the tick test for trade direction identification. “Contract” is the contract month (contract month code and year). “Month” is the calendar month in which the spread is estimated. “ N ” is the number of trades included (only trades at

non-zero ticks included). “Traded” is the Stoll traded spread. “ λ ” is the Stoll lambda. “TW” is the Thompson-Waller spread. “Roll” is the Roll spread.

Table 1 Panel B LIFFE Spread Measures						
Contract	Month	N	Traded	λ	TW	Roll
H97	Jan	42230	.0211	.9977	.0105	.0091
H97	Feb	30948	.0207	.9989	.0104	.0091
M97	Mar	31585	.0211	.9999	.0105	.0080
M97	Apr	35052	.0207	.9945	.0104	.0082
M97	May	31460	.0209	.9973	.0105	.0079
U97	Jun	31197	.0210	.9998	.0105	.0086
U97	Jul	36897	.0206	.9998	.0103	.0085
U97	Aug	31472	.0201	.9997	.0104	.0076
Z97	Sep	25501	.0209	.9982	.0104	.0076
Z97	Oct	42161	.0210	.9950	.0105	.0099
Z97	Nov	23299	.0206	.9986	.0103	.0088
H98	Dec	16387	.0214	.9988	.0107	.0093
H98	Jan	37573	.0209	.9962	.0104	.0086
H98	Feb	37920	.0205	.9927	.0103	.0096
M98	Mar	15443	.0215	.9889	.0108	.0094
M98	Apr	18673	.0211	.9982	.0106	.0073
M98	May	15443	.0215	.9889	.0108	.0138
U98	Jun	8118	.0240	.9985	.0121	.0122
U98	Jul	3707	.0275	.9703	.0138	.0149
U98	Aug	3319	.0494	.9824	.0274	.0133

Note: This panel reports spread measures for LIFFE based on the tick test for trade direction identification. “Contract” is the contract month (contract month code and year). “Month” is the calendar month in which the spread is estimated. “ N ” is the number of trades included (only trades at non-zero ticks included). “Traded” is the Stoll traded spread. “ λ ” is the Stoll lambda. “TW” is the Thompson-Waller spread. “Roll” is the Roll spread.

Table 2 LIFFE Spread Measures						
Contract	Month	N	Traded	λ	TW	Roll
H97	Jan	16250	.0138	.8876	.0108	.0052
H97	Feb	13132	.0139	.8926	.0109	.0051
M97	Mar	12088	.0139	.9306	.0105	.0041
M97	Apr	13419	.0138	.9037	.0109	.0057
M97	May	12126	.0139	.8877	.0110	.0027
U97	Jun	12333	.0134	.9077	.0108	.0054
U97	Jul	13194	.0139	.9410	.0107	.0043
U97	Aug	12816	.0141	.9646	.0107	.0037
Z97	Sep	9592	.0128	.9005	.0104	.0052
Z97	Oct	5291	.0142	.9286	.0105	.0045
Z97	Nov	8336	.0127	.8485	.0107	.0058
H98	Dec	5291	.0128	.8930	.0107	.0035
H98	Jan	14865	.0136	.9755	.0107	.0046
H98	Feb	11096	.0135	.9755	.0107	.0039
M98	Mar	10309	.0135	.8932	.0107	.0038
M98	Apr	6959	.0129	.9227	.0106	.0042
M98	May	4894	.0127	.9363	.0107	.0041
U98	Jun	1769	.0106	.8929	.0109	.0015
U98	Jul	473	.0137	.9812	.0109	.0063
U98	Aug	694	.0259	.9998	.0120	.0011

Note: This table reports the spread measures for LIFFE based on bid-ask quotes. “Contract” is the contract month (contract month code and year). “Month” is the calendar month in which the spread is estimated. “ N ” is the number of trades included (only trades at non-zero ticks included). “Traded” is the Stoll traded spread. “ λ ” is the Stoll lambda. “TW” is the Thompson-Waller spread. “Roll” is the Roll spread.

Table 3 Panel A Depth Analysis–Trading Activity Coefficients						
Contract	ν_{E1}	ν_{L1}	ν_{E2}	ν_{L2}	ν_{E3}	ν_{L3}
H97	.000554 (.000054)	.000770 (.000085)	.000783 (.000072)	.000996 (.000164)	-.000244 (.000099)	.001383 (.000218)
M97	.000689 (.000071)	.001224 (.000092)	.000640 (.000093)	.001181 (.000169)	.001568 (.000214)	.004141 (.000370)
U97	.000133 (.000030)	.000499 (.000078)	.000378 (.000048)	.001223 (.000096)	-.000067 (.000064)	-.000235 (.000159)
Z97	-.000004 (.000010)	-.000036 (.000018)	.000099 (.000028)	.000226 (.000037)	.000029 (.000036)	.000296 (.000057)
H98	.000124 (.000058)	.000223 (.000001)	.000262 (.000009)	.000653 (.000020)	-.000164 (.000011)	-.000124 (.000040)
M98	.000284 (.000015)	.000700 (.000001)	.000292 (.000023)	.000832 (.000034)	.000357 (.000043)	.000464 (.000058)
U98	-.000008 (.000006)	-.000569 (.000121)	.000034 (.000014)	-.000385 (.000212)	.000063 (.000024)	.001410 (.000297)

Note: This panel presents the coefficients on the trading activity variables in the depth GARCH equations. ν_{X1} is the coefficient on expected volume for exchange $X = E, L$; ν_{X2} is the coefficient on unexpected volume for exchange X ; ν_{X3} is the coefficient on unexpected positive volume for exchange X . Standard errors in parentheses.

Table 3 Panel A Depth Analysis–Spillover Coefficients						
Contract	γ_{E1}	γ_{L1}	γ_{E2}	γ_{L2}	γ_{E3}	γ_{L3}
H97	.033333 (.029059)	-.023014 (.033028)	.046639 (.009393)	.036950 (.013709)	.003359 (.006376)	-.008531 (.007251)
M97	.014042 (.011215)	.067505 (.020653)	.046144 (.011563)	.041414 (.014528)	.048795 (.010752)	.021138 (.011919)
U97	.000594 (.026940)	.058419 (.024429)	.016506 (.009595)	.026994 (.010496)	.015379 (.010774)	.021327 (.010119)
Z97	.032636 (.023774)	.057442 (.027176)	-.003310 (.013978)	.003839 (.017894)	.022385 (.012075)	.023953 (.011203)
H98	.000168 (.016489)	.000141 (.016955)	.000104 (.010220)	.000190 (.010784)	.000230 (.008317)	.000103 (.008184)
M98	.006980 (.015793)	-.116251 (.004569)	-.001099 (.007338)	.003053 (.005353)	.030314 (.009768)	.034161 (.005496)
U98	.106553 (.019759)	.164160 (.018768)	-.042072 (.025124)	-.036822 (.021260)	-.001947 (.021276)	-.026645 (.014368)

Note: This panel presents the coefficients on the spillover variables in the depth GARCH equations. γ_{X1} is the coefficient on $\eta_{Y,t-1}^2$ $X = E, L, Y = L, E$ (i.e., it is the lagged squared return shock from the other exchange); γ_{X2} is the coefficient on $\epsilon_{Y,t-2}^2$; γ_{X3} is the coefficient on $\epsilon_{Y,t-2}^2$. Standard errors in parentheses.

Table 4 Depth Analysis–Correlation and Selected Mean Equation Coefficients					
Contract	ρ	q_L	q_E	R_E^2	R_L^2
H97	.9594 (.0015)	.03526 (.24320)	.98340 (.24612)	.03319	.04944
M97	.9534 (.0060)	-.02623 (.01996)	.04114 (.02133)	.03562	.02025
U97	.9602 (.0013)	-.87139 (.19202)	-.05160 (.19351)	.04006	.03379
Z97	.9567 (.0014)	-.53510 (.20201)	.25581 (.20545)	.04901	.02621
H98	.9611 (.0009)	-.27488 (.21557)	.60964 (.21624)	.00922	.02456
M98	.9329 (.0002)	-.23780 (.12626)	.36915 (.12406)	.01354	.05627
M98	.7915 (.0064)	-.08109 (.06552)	.50848 (.06462)	.02393	.20694

Note: ρ is the correlation between the LIFFE and Eurex shocks. q_L is the coefficient on the difference between the lagged log of the Eurex price and the log of the LIFFE price in the LIFFE equation; q_E is the coefficient on the difference between the lagged log of the Eurex price and the log of the LIFFE price in the Eurex equation; R_X^2 is the R^2 in the mean return equation for exchange X . Standard errors in parentheses.

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Figure 1
LIFFE and Eurex
Bund Futures Volume Shares

