Competition between Exchanges: Lessons from the Battle of the Bund*

Estelle Cantillon† and Pai-Ling Yin‡

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Abstract

Are exchanges natural monopolies? How much does liquidity, differentiation, intermediation, and multi-homing matter to exchange competition? We answer these questions by studying competition between two exchanges over the Bund contract. The competition lasted for eight years, until the market eventually tipped in favor of the entrant. Specifically, we study the determinants of traders' exchange membership, using a novel panel dataset that contains traders' membership status at each exchange together with other trader characteristics and pricing, marketing and product portfolio strategies by each exchange. We find that horizontally differentiation was more important to membership decisions than liquidity preferences, a phenomenon we explain by the existence of intermediation in these markets, and which makes coexistence of different exchanges trading the same products more likely. We also find that this differentiation decreased over time, together with a change in the population of traders more favorable to the entrant. These developments may have explained why the market eventually tipped to the entrant, despite our surprising finding that dual-homing helped the incumbent membership more than the entrant.

Keywords: Tipping, platform competition, network effects, intermediation, multi-homing.

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†FNRS, Université Libre de Bruxelles (ECARES) and CEPR. Email: Estelle.Cantillon@ulb.ac.be

‡MIT Sloan School of Management, pyin@mit.edu.

1 Introduction

Are financial exchanges natural monopolies? This issue has become increasingly salient as many exchanges have recently switched from user-owned to for-profit structures and consolidated.[1] Exchanges exhibit particularly strong network effects: traders value liquidity in financial markets and this creates a tendency for trading to concentrate on a single exchange. As a result, exchanges have been viewed as natural monopolies (Demsetz, 1968), and entry in a particular market is extremely difficult when an incumbent exchange already hosts trading for a financial instrument.

Even in this setting of extremely strong network effects, different exchanges trading the same products do exist and theory has suggested some countervailing forces to explain coexistence: traders may value liquidity differently, offering the possibility for vertical differentiation where one exchange offers greater liquidity and charges more (Pagano, 1989), or exchanges might be horizontally differentiated (Economides and Siow, 1989). In addition, several aspects of the organization of this industry, such as the possibility to trade without being a member of an exchange (intermediation) and the possibility to be a member of several exchanges (dual-homing) have been shown in other contexts to reduce the importance of network effects and favor equilibria when several "platforms" coexist.

Although all these mechanisms represent important dimensions of competition, very little is empirically known about the quantitative importance of these countervailing forces. How much does liquidity, differentiation, intermediation, and multi-homing matter to exchange competition? Understanding the demand for exchanges is the necessary first step for analyzing optimal market structure and market power in this industry. Beyond exchanges, the relative importance of dimensions of competition in the presence of network effects is of interest for industries ranging from credit card processing and the media to many technology products.

We study membership on two derivatives exchanges who competed fiercely for the market for the future on the German Bund between 1991 and 1999: London International Financial Futures and Options Exchange (LIFFE) and Deutsche Terminbörse (DTB), two derivatives exchanges. Recently, a few papers in the 2-sided markets theory literature have analyzed the distinction between membership and usage (Rochet & Tirole, 2006, Bedre & Calvano, 2008, Evans & Schmalensee, 2009). We are the first empirical paper to focus on membership as separate from usage in platform competition. There are several advantages to studying membership. First, membership, unlike individual trading, is observable. Second, membership is driven by many other factors beyond the benefits from trading the Bund on a particular exchange. This allows for a broader picture of the determinants of the demand for exchanges. Third, the economics of membership differs from the economics of trading and alleviates some of the econometric challenges usually created by the presence of network effects: only members can use the platform, but traders actually only care about market liquidity, not members per se. We exploit a component of network competition (membership) that is highly correlated with the

[1] Witness the recent merger wave in the industry and a recent review of regulatory structure of the industry by the US Department of Justice (United States Department of Justice, 2007).

component generating network effects (usage) but less subject to network effects. Figure 1 shows the relationship between the market shares of membership and of trading. Fourth, and most importantly, the focus on membership allow us to empirically analyze the role of trader heterogeneity, multi-homing and intermediation (brokerage) in network competition. We believe we are the first empirical model of network/platform competition to integrate intermediation. Our focus on membership leads to a surprising finding: dual-homing may help the incumbent preserve membership more than the entrant. We find that the market might have tipped to the entrant sooner in the absence of dual homing.

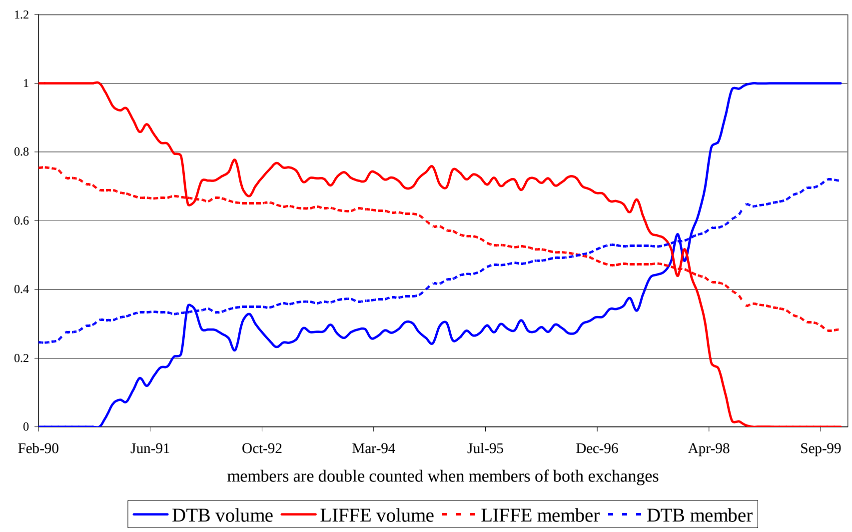

Figure 1: Market share of members and of Bund trading volume

We first propose a model of membership choice that integrates the salient features of the industry. After briefly describing the events and actions that took place during the Battle of the Bund, we measure different forms of vertical and horizontal differentiation. Each corresponds to a different source of trader heterogeneity. To estimate the quantitative importance of these sources of heterogeneity, we have collected a detailed and novel dataset of exchange members and exchange characteristics over a ten-year period. Our dataset contains all the establishments that were members of DTB or LIFFE at any point of time between January 1990 to December 1999. For each of these establishments, we have tracked their location, their inception and exit dates, their historical group affiliation, their business lines and the products they traded. This allows us to match establishments from different locations at their group level and to distinguish between groups holding memberships at both exchanges and groups holding a single membership. We also constructed a dataset of exchange characteristics over the same period. For each exchange, we have their fee structures, the value of the deposits required to guarantee trades on that exchange, measures of liquidity, the products traded, and a record of all events that could affect the decisions by traders to trade on them. We produce a panel dataset with financial groups' monthly membership status as a function of group and exchange characteristics.

Our empirical model of exchange membership incorporates the salient features of the environment. Every period, traders reconsider their membership status. Traders can be members of one exchange, both or none. When they re-optimize they select the membership status that yields the highest current period expected profit. The model accounts for the fact that trading does not require a membership (intermediation through a broker) and that traders can become members of both exchanges (dual-homing). Adoption costs of membership are geographically determined and vary with the state of access deregulation. The rest of the payoff to membership includes a component that is specific to the Bund and one that consists of all the costs and benefits of membership unrelated to the Bund. We allow for trader heterogeneity in the variable and fixed profit component.

Empirical analysis confirms that the countervailing factors to monopoly exchanges (trader heterogeneity, horizontal and vertical differentiation, intermediation and dual homing) are important and make possible coexistence of several exchanges that offer some overlapping products. We find evidence of traders' heterogeneity in how they value liquidity. The transaction fee discount needed to compensate a trader for DTB's initial lower liquidity is large relative to transaction fee levels, and about twice as large for a high-liquidity valuer as for a low-liquidity valuer. However, the level of trader heterogeneity on this dimension is dwarfed by the level of trader heterogeneity on the horizontal dimension: the non-Bund component of profits represents about 83-90% of the extra profit from membership and there is ample heterogeneity on this dimension. In contrast, deregulation allowing international access did not help DTB much. While deregulation did reduce adoption costs to DTB, its effects on membership were marginal, and certainly smaller than the effect of a hypothetical admission fee waiver or the imposition of exclusive membership. When we combine these results with the fact that 10-17% of the profits from membership are driven by trading in the Bund and that DTB attracted a larger number of newcomers (previously untapped demand in the form of traders who were not members of any exchange, but now found the lower costs of DTB membership affordable) than LIFFE, the following story emerges to explain the Battle of the Bund. The backing of German banks helped DTB garner initial volume. DTB then attracted traders who were relatively less sensitive to liquidity and/or valued their product offering more. The fact that DTB attracted more new members than LIFFE contributed to DTB's increasing market share. The relative importance of horizontal over vertical differentiation is consistent with our finding that intermediation and dual-homing reduced the exclusivity of liquidity benefits, to the benefit of the entrant at the beginning, but to the benefit of the incumbent later. Because members generate extra volume, dual-homing can both foster coexistence equilibria and also preserve incumbent liquidity. Dual-homing actually delayed market-tipping to DTB by a few years. This result contrasts with standard antitrust concerns about exclusive membership as a means to foreclose a market, but is consistent with recent findings by Lee (2009). We also did not find evidence that nationalism favored DTB during the Battle of the Bund.

Related literature. This paper is related to the finance literature on multiple trading venues and the industrial organization literature on network effects and platform competition. The finance literature has long recognized the tendency for trades in an asset to aggregate into a single trading venue due to liquidity effects (Admati and Pfleiderer, 1988, Pagano, 1989). It has also long acknowledged that trading for many securities occur in different trading venues (Hasbrouck, 1995). Some recent papers use tick data on trading venue choices to uncover informational motives for self-selection into different trading venues that have different trading rules (Barclay, Hendershott and McCormick, 2003, Reiss and Werner, 2005). With our emphasis on membership and on the regulatory and institutional drivers of this membership, this paper is in the spirit of Caskey (2004) and Biais and Green (2007) who provide membership-based explanations for, respectively, the success of the Philadelphia exchange for NYSE-listed stocks in the sixties and seventies, and the demise of the NYSE for bonds in the thirties. Both explain the success of the "new platform" by its ability to serve a different set of traders. Unlike them however, we have detailed information on traders and on both trading venues which enables a quantitative assessment of the different drivers of membership.

Farrell and Klemperer (2007) provide an excellent survey of the rich theoretical literature on network effects and their implications for platform competition. The literature has emphasized aspects such as the benefits of incumbency in the presence of network effects, the importance of beliefs and coordination, the dynamic incentives for aggressive pricing early on to build up barriers to entry through network effects, and so on. We highlight the literature on two specific features of our environment: intermediation and multi-homing.

The possibility of intermediation dramatically changes the economics of the problem. Galetovic and Zurita (2002) is the only paper we are aware of that emphasizes this point. In their model, traders have to use brokers to access exchanges. Brokers can be members of several exchanges and a transaction takes place between a seller and a buyer only when their respective brokers have a membership in a common exchange. As a result, liquidity is not about trades being executed on the same exchange but about the degree of connectedness among brokers. At the extreme, they argue that if all brokers are interconnected and the brokerage market is competitive, then there is no more network externality at the exchange level and the optimal market structure for exchanges should be solely driven by their cost structure. Likewise, in our empirical model, intermediation makes the liquidity of an exchange (almost) accessible to all. This reduces the network benefit component from membership. However, in contrast to Galetovic and Zurita (2002), traders in our model have the possibility to become members of an exchange. Membership gives them access to trade opportunities that are not profitable with a broker. Thus, some network benefits conferred by membership remain. In that sense, intermediation acts as partial compatibility does in the traditional network effects literature. In particular, Farrell and Saloner (1992) show that partial compatibility reduces users' incentives to coordinate on a single platform and it provides a rationale for the equilibrium coexistence of several platforms.

A second specific feature of our environment is that traders can be members of several exchanges. When platforms are not sufficiently compatible, multi-homing acts as a (user-controlled) substitute for compatibility. For this reason, it can restore stable equilibria where both platforms are active (De Palma et al., 1999) and further reduce the importance of network externalities. In our environment, multi-homing additionally reduces the opportunity costs of becoming a member of the new exchange, namely DTB, and thus reduced the barriers to entry for DTB (a mechanism first pointed out in the context of two-sided markets by Caillaud and Jullien, 2003).

Two econometric challenges have confronted the empirical research on network effects: the endogeneity of the network size as an explanatory variable and the possibility of multiple equilibria. Researchers have dealt with endogeneity through extensive controls for unobservables (Goolsbee and Klenow, 2002), instrumental variables (e.g. Tucker, 2008), data selection (Gowrisankaran and Stavins, 2004), non-parametric two stage approaches (Karaca-Mandic, 2007), and behavioral and informational assumptions (Augereau et al., 2006). While we have argued that the organization of financial markets and our focus on membership rather than trading reduce the importance of network effects in our application, we cannot rule them out entirely. In particular, we allow for liquidity as an explanatory variable for membership. We circumvent the potential endogeneity problem in two ways. First, our long panel dataset on individual decisions allows for extensive controls for unobservables. Second, we assume that traders best respond to past play and we leverage the delay between the membership decision and the actual membership to argue that past liquidity is exogenous.

Researchers dealt with the possibility of multiple equilibria differently (e.g., Ackerberg and Gowrisankaran, 2006 and Tucker, 2005). Our focus on a single market with network effects limited by intermediation and multi-homing reduces this concern. Additionally, unlike the trading data, the membership data do not display any structural break (Figure 1). This suggests that, even if there are multiple equilibria in the "membership game", our data likely consist of a unique selection.

Recent papers have gone beyond estimating demand by modelling and estimating the competition between platform suppliers (Jenkins et al., 2004, Dubé et al., 2007). Their approach allows answers to many interesting policy questions. Our field interviews make us skeptical about the appropriateness of the assumption of maximizing behavior by the exchanges during the Battle of the Bund. For this reason, our counterfactual analyses are based on one-sided "non-equilibrium" deviations.

2 A stylized model of membership choice

In this section we introduce our model of membership choice. We think of the exchanges as being horizontally and vertically differentiated. Vertical differentiation is either intrinsic because one exchange provides better service or endogenous because one exchange attracts more trades and thus offers greater liquidity. Liquidity reduces transaction costs and thus makes an exchange membership more attractive for traders in a way which we will make more precise below.[2] This is the source of network effects in our setting. In addition, the model allows for intermediation and dual membership.

2.1 Membership status and trading volumes

Denote the two exchanges between which traders choose by D and L (D stands for DTB and L stands for LIFFE). Let $\text{vol}_D(D)$ and $\text{vol}_L(D)$ stand for a trader's trading volume on D and L respectively,

[2] Transaction costs tend to be higher in illiquid markets than in liquid markets because, in an illiquid market, large transactions can move prices significantly. This is referred to as the price impact in the finance literature.

when he is a member of D. The utility from being a member of D is given by:

$$U_D = F_D + \text{vol}_D(D)\pi_D + \text{vol}_L(D)(\pi_L - \text{fee}), \tag{1}$$

where F_D stands for the fixed component of profit (i.e. independent of the trader's trading volume in the Bund) , π_D and π_L stand for the average per-unit profit on D and L, and fee corresponds to broker fees. We will describe in detail in Section 5.1 how we measure per-unit trading profits.

The novel aspect of equation (1) lies in the last term. Because a trader does not need to be a member of an exchange to send trades to that exchange when brokers are available, part of his profits derives from his trading on the exchange of which he is not a member. The cost of trading is higher, however, because brokers charge a fee.

Similarly, the utility a trader derives when he is not a member of any exchange is given by:

$$U_0 = F_0 + \text{vol}_D(0)(\pi_D - \text{fee}) + \text{vol}_L(0)(\pi_L - \text{fee}), \tag{2}$$

where again the expression accounts for intermediation. Differentiating the two expressions (i.e., normalizing utility from not being a member to zero), we get

$$\Delta U_D = \Delta F_D + \underbrace{(\text{vol}_D(D) - \text{vol}_D(0))}_{\text{extra volume}}\pi_D + \underbrace{(\text{vol}_L(D) - \text{vol}_L(0))}_{\text{substitution}}(\pi_L - \text{fee}) + \text{vol}_D(0)\text{fee}. \tag{3}$$

Becoming a member of an exchange changes the relative costs of trading at both exchanges. As a result, we expect a trader to channel relatively more trades to the exchange on which he is a member (extra volume effect) and relatively less trades to the other exchange (substitution effect). Equation (3) highlights these two effects and pins down the trade-offs that a trader faces when he decides to become a member: membership entails a fixed cost (captured by ΔF_D), but membership also allows a trader to forego broker fees (the $\text{vol}_D(0)$fee term) and to take advantage of additional profit opportunities (captured by the extra volume effect and the substitution effect).

The magnitude of these extra volume and substitution effects depends on the trading motive. We can broadly distinguish between four trading motives in derivatives: hedging, speculation, arbitrage, and brokerage. Derivatives trading was initially set up to hedge risk. A trader with a commitment to deliver or buy a product or money in the future can lock in the cost of this transaction today by buying or selling a future contract. Speculators trade on the basis of their forecasts about the future movements of prices: they take positions, hoping that prices will move in a direction favorable to them. Arbitrageurs are traders who speculate on the basis of price co-movements between similar securities. For example, an arbitrageur might simultaneously buy a future on a 10-year bond (like the Bund) and sell a future on a 5-year bond, hoping to derive a profit from the variation in relative interest rates. Finally, brokers are intermediaries that help traders connect to the exchange.

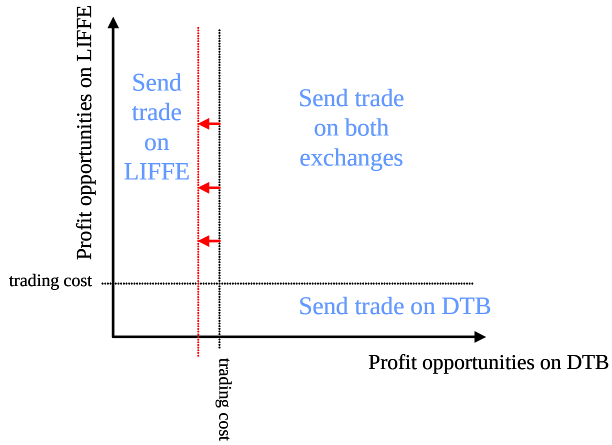

Figure 5: A speculator's decision rule for where to send trades

Consider first an arbitrageur or a speculator. Trading profit opportunities arise at all times on both exchanges and, because Bund prices may differ slightly between the two exchanges at any point in time, some profit opportunities can occur on one exchange and not the other. Speculators and arbitrageurs take advantage of any trade opportunity as soon as it generates an expected return higher than the total costs of transaction. Such a decision rule is represented in Figure 5. Membership at an exchange decreases trading costs at that exchange because it eliminates broker fees. In Figure 5, this is represented by a shift to the left in the level of trading costs on DTB. This increases trading volume on DTB but, importantly, does not affect trading volume on LIFFE. Thus there is no substitution effect and only an extra volume effect. Note also that the *extra* volume effect depends on the distribution of profit opportunities on both exchanges, not on the cost of transacting.

At the other extreme, consider a hedger. His trading needs are determined largely by positions he takes outside of the derivatives exchange in the underlying instrument. They are thus independent of his membership status. This trader will send his trades wherever it is cheapest to execute them. Membership reduces the cost of executing trades on the exchange to which he is a member. The trader will channel a larger proportion of the trades to that exchange. The total trading volume does not depend on membership status: the extra volume effect and the substitution effect cancel out.

Brokered trades lie in-between. An exchange membership allows a broker to lower his commission for executing trades on that exchange. This attracts new customers interested in trading the Bund on that exchange (extra volume effect) but also attracts existing customers who would have sent their order on the other exchange (substitution effect). Optimal pricing by the broker means that the extra volume effect must be positive.

Now that we have described how trading depends on membership status, we next introduce the possibility of being a member at both exchanges. The utility from dual membership is given by:

$$U_B = F_B + \text{vol}_D(B)\pi_D + \text{vol}_L(B)\pi_L \tag{4}$$

which, after normalization, gives:

$$\Delta U_B = \Delta F_B + (\text{vol}_D(B) - \text{vol}_D(0))\,\pi_D + (\text{vol}_L(B) - \text{vol}_L(0))\,\pi_L + (\text{vol}_D(0) + \text{vol}_L(0))\,\text{fee} \qquad (5)$$

Note that the normalized utility from membership on both involves two extra volume effects.

2.2 Economics of exchange membership

Equation (3), its equivalent for LIFFE, and equation (5) describe our model of exchange membership and form the basis of the equations we will bring to the data. (Anticipating the discussion in Section 5.1, we observe explanatory variables for π_D, π_L, ΔF_D, ΔF_L and ΔF_B and estimate the extra volume and substitution effects as coefficients.). The model incorporates several key features that capture the economics of exchange membership.

First, the model implies a two-way relationship between membership and trading. First, trading influences the liquidity of a market and increases the attractiveness of an exchange membership. In that sense, *trading drives membership.* Second, membership influences trading on an exchange because traders trade more upon becoming members. Thus, *membership also drives trading.*

While this is reminiscent of the economics found in any setting with network effects, intermediation makes the economics of the "membership game" very different from the economics of the "trading game". In particular, network effects at the trading level (i.e. liquidity) are relevant at the membership level only to the extent that membership induces more trading. If a trader does not trade more upon becoming a member, then liquidity should not affect membership decisions. From an economics perspective, this means that network effects are less important in the "membership game".[3] From an estimation perspective, this leads to a different structural interpretation of the coefficients on per-unit profits relative to the interpretation in a model without intermediation. Instead of being trading volumes, these coefficients are proportional to the extra volume effect (or the substitution effect). This has two advantages. First, extra volumes and substitution effects are likely to be more stable over time than individual trading volume (total trading volumes grew tenfold over our sample period). Second, we have argued that extra trading volumes depend on the distribution of profit opportunities and not directly on transaction costs drivers such as transaction fees. Absolute trading volumes depend on these cost drivers. We exploit these facts and the timing of membership decisions in our analysis.

The second feature of exchange competition integrated into the model is the possibility of vertical differentiation. This is built into the model in two ways. For fixed levels of π_L and π_D, the extra volume and substitution coefficients and how they vary with traders create the first dimension of vertical differentiation. Clearly, all traders value higher levels of per-unit profits (π_L, π_D). However, traders are still likely differ in their choice of exchange membership as soon as they differ in the size of their extra trading volumes and substitution effect . The second dimension of vertical differentiation comes from the fact that, in practice, per-unit profits are a function of the trading revenues and the

[3] However, as long as membership induces a trader to trade more, network effects remain present. In Galetovic and Zurita (2002), traders *must* go through a broker to access an exchange (there is no membership).

costs of trading on the exchange. As soon as different traders value the revenue and cost drivers differently, an opportunity for vertical differentiation arises.

The third feature of exchange competition integrated into the model is the possibility of horizontal differentiation. This is captured by the ΔF_D, ΔF_L and ΔF_B terms. The model allows for membership at the two exchanges to be complements or substitutes in case $\Delta F_D + \Delta F_L \neq \Delta F_B$.

Finally, dual membership means that traders have an additional option to being a member of LIFFE or DTB, captured in equation (5), that affects traders' incentives to join one exchange or the other. A well-known consequence of dual membership is that it makes it easier, relative to a situation when membership is exclusive, for an entrant to attract members (REFERENCES). Indeed, a trader becomes a member of DTB as soon as $\max\{\Delta u_D, \Delta u_B\} \geq \max\{\Delta u_L, 0\}$, which is a less stringent than the condition for a trader to become a member of DTB when membership is exclusive, $\max\{\Delta u_D\} \geq \max\{\Delta u_L, 0\}$. Of course, the symmetric argument applies: LIFFE will also attract more members if dual membership is allowed. The net effect on membership share will depend on the size of these two effects. In particular, if Δu_D tends to be lower than Δu_L on average, then dual membership will tend to increase the membership share of DTB because the option of dual membership will affect the membership decision rule for DTB more. This forms the basis for the argument that dual membership is pro-competitive and exclusive membership anti-competitive (REFERENCES).

3 The Battle of the Bund

This section summarizes the relevant aspects of the competition between LIFFE and DTB. It motivates the choice of data we collected, the hypotheses we consider for explaining the events, and our econometric model. Appendix B summarizes the basics of futures trading for readers not familiar with the workings of derivatives markets.

3.1 LIFFE and DTB

The London International Financial Futures and Options Exchange (LIFFE) was established in 1982 as a member-owned derivatives exchange. The exchange attracted international membership, with a third of members coming from abroad at launch time.[4] LIFFE initially organized markets for currency and interest rate contracts but later expanded into equities and commodities following mergers with the London Traded Options Market in 1992 and the London Commodity Market in 1996. In 1988, they launched the Bund contract. The Bund was their second biggest contract within 6 months of its launch and became their top contract less than a year later. German banks used the contract from the very beginning, providing up to a sixth of the volume.[5]

Trading was initially organized exclusively by open outcry. In 1989, LIFFE introduced electronic trading for trading outside the regular hours. In 1999, after the loss of the Bund, the exchange switched

[4] Kynaston (1997), p. 71.

[5] According to an informal LIFFE survey. Kynaston (1997), pp. 218-219.

entirely from open outcry to electronic trading.

Deutsche Terminbörse (DTB) was established in January 1990 as a for-profit company by seventeen leading German banks. Trading was conducted electronically from the very beginning. Unlike LIFFE, members did not own shares or voting rights in DTB. At launch time, 80% of members were German institutions. DTB first organized markets in equity derivatives and launched a Bund contract on November 23, 1990. In October 1998, DTB merged with the Swiss equity derivatives exchange, SOFFEX, and became known as Eurex.

3.2 The Bund

The Bund is a future on the long-term German government bond contract. Contracts have quarterly maturities, meaning that traders trade promises to buy or sell at four specific times in the year: March, June, September and December. At the time of the transaction, no monetary transfer takes place between the buyer and the seller. Instead, traders must deposit some money, representing approximately 1-2% of the contract, at the clearing house associated with the exchange. These deposits, which are called margins, are used to prevent default at maturity. They are updated daily to account for the difference between the agreed price at maturity and the current price of the underlying security, making traders indifferent between defaulting (and losing the margins) or not. When a trader has both short and long open positions, the clearing house nets these positions and only requests margins for the net open position. DTB and LIFFE used different clearing houses so that no netting was available between open positions in the Bund on LIFFE and on DTB. The contract specifications on LIFFE and on DTB were essentially the same.[6]

During the 1990s, trading in the Bund grew more than tenfold. Several macroeconomic factors contributed to this. First, German reunification in 1990 increased Germany's borrowing needs. The resulting increase in the public debt fueled interest in the future contract. Second, interest rates in the eurozone progressively converged as monetary union took shape (the euro, introduced on 1 January 1999, fixed exchange rates among participating countries). As a result, the Bund contract, which was the biggest future on a government bond in Europe, progressively attracted traders from other government bond futures. Third, futures went from exotic financial instruments to instruments used routinely by banks, asset management firms and corporations. The ensuing pool of liquidity attracted speculators and arbitrageurs of all kinds. Today, the Bund remains one of the most heavily traded derivative contracts in the world.

3.3 Dimensions of competition

While LIFFE was the incumbent, the two exchanges competed fiercely for the Bund contract over 8 years. Historical accounts and interviews reveal that competition took place on at least 5 dimensions: coordination, transaction fees, product scope, trading technology, and access. Some of these dimen-

[6] Breedon (1996) studies the differences between the two contracts in details and their likely impact on prices.

sions, namely product scope, trading technology and access, induce horizontal differentiation between the two exchanges, while transaction fees induce vertical differentiation. Coordination suggests the presence of network effects. We briefly describe these dimensions of competition here.

Coordination. In light of the early disappointing trading volumes on DTB, leading German banks with a stake in DTB signed a gentlemen's agreement in July 1991 whereby they committed to support liquidity on DTB by acting as market makers for the Bund.[7] The gentlemen's agreement was effective, and DTB's market share climbed to almost 20% by mid-July. In November 1991, the German banks that were part of this gentleman's agreement further committed to specific volume targets.

Competition in the product space. The battleground between LIFFE and DTB quickly moved to the product space. While the Bund was clearly the key product, each exchange tried to reinforce the contract by offering complementary products, such as futures on short-term and medium-term German government bonds, and complementary services that made trading in the Bund more attractive.

Transaction fees. DTB initially charged a higher transaction fee than LIFFE but then undercut LIFFE for most of the decade. There was a price war at the end of 1997 when the two exchanges were head-to-head in terms of market share. There were also several other periods when one of the two exchanges unilaterally waived their fees.

Trading technology. For most of the decade, LIFFE was an open outcry exchange and DTB was an electronic exchange. There was a fair amount of discussion in the industry at the time on the relative advantages of each technology. Open outcry markets were, at the time, better at aggregating information in periods of high volatility and allowed for more complex strategies than electronic trading. Electronic trading was significantly cheaper: a single broker could be in contact with clients and input orders in the market whereas open outcry required a floor-broker on top of the broker in contact with clients and manual handling of transactions.

Access. DTB's electronic market did not require members to be based in Germany. However, futures traders and exchanges were regulated by their national supervisory authorities. DTB had to be recognized as an exchange in other countries for traders in these countries to be allowed to trade on DTB; likewise, traders had to be recognized as investment firms in Germany to become members of DTB. Thus, initially, only firms with an office in Germany could become members of DTB.

This changed significantly over the decade as different countries deregulated access to DTB. The French and the Dutch were first in September 1994. In January 1996, the Investment Services Directive deregulated access entirely across the EU by making any exchange and investment firm authorized in one country authorized in all the other countries. Access to DTB for US-based traders was originally granted in February 1996 (and withheld for some part of 1998 and 1999). Switzerland had its own timing. We exploit these time and geographic variations in our empirical analysis.

As an open outcry exchange for most of 1990s, LIFFE members were essentially forced to have

[7] Market makers are financial intermediaries that stand ready to buy or sell at any time, thereby providing liquidity.

staff in London. Consequently, foreign access and regulatory approval were less relevant for LIFFE. Nevertheless, financial regulations in other countries did affect trading on LIFFE because Bund trading took place electronically after-hours until August 1998 and was entirely electronic after that.

4 Data

4.1 Exchange data

Exchanges charge three types of fees. First, they charge a fee for every transaction and collect margins (deposits) for every new open position. Second, they charge annual fees for membership. Third, exchanges, and DTB in particular, charged new members a one-time admission fee. Membership gives a trader a direct access to the market to trade any product listed on the exchange.

For both exchanges, we collected the following monthly data: (1) admission fee, (2) annual membership fee, (3) transaction and clearing fee per contract, (4) margins, (5) product launches and delistings, and (6) trading volume in the Bund contract. Fees, margins and product launches and delistings were collected from exchange notices to members, and volume data come from Datastream.

As a measure of the attractiveness of the Bund future, we collected data on the daily yield for the underlying Bund contract and constructed a monthly measure of volatility of the underlying Bund contract (the monthly standard deviation of the yield).

Finally, we combined internal sources of information (press releases, notices and circulars to members, records of changes in the rules of the market) and external sources of information (search on Factiva) to identify events of potential consequence for Bund traders. Specifically, we tracked the following events: (1) regulatory changes concerning access and approval in other countries, (2) marketing campaigns not reflected in the fee structure such as free hardware or free installation, and (3) technological changes such as the opening of access points.

The conversion to the euro takes place during our sample period (1 January 1999) and both exchanges introduced a Euro-denominated Bund contract towards the end of 1998. We use the Deutsche Mark (DM) as the currency for all the data. Fees are converted into DM using the monthly average exchange rate for the Pound/DM, and the fixed conversion rate for the euro/DM. The size of the Bund contract changed slightly following the conversion to the Euro, from 250,000 DM to 100,000 euros (195,583 DM equivalent). Trading volumes, margins and transaction fees were all scaled accordingly. Maturities for the Bund are quarterly and generate three-month cycles. We smooth out these cycles by considering moving three-month averages for monthly volumes.

Table 1 provides descriptive statistics for our exchange variables for the period between 1 February 1990 and 31 December 1999.

Table 1: Exchange data, 2/90-12/99 (all monetary values in DM; N = 119)

	LIFFE				DTB			
	Mean	Std.Dev.	Min	Max	Mean	Std.Dev.	Min	Max
admission fee	0	0	0	0	81,429	41,101	0	102,000
fixed fee	9,403.44	961.70	7,707	11,007	27,143	13,700	0	34,000
volatility	0.083	0.046	0.021	0.393	0.083	0.046	0.021	0.393
transaction fee[a,b]	0.90	0.35	0	1.30	0.52	0.34	0	1.50
margins[b]	3,132	943	1,500	6,250	3,601	893	2,000	5,000
volume	$1.87\ 10^6$	$1.29\ 10^6$	0	$4.11\ 10^6$	$2.37\ 10^6$	$3.22\ 10^6$	0	$1.11\ 10^7$
log(vol)	5.67	1.73	0	6.61	5.55	1.79	0	7.04
# interest rate products	19.41	4.58	14	38	6.38	5.75	0	25
# equity products	49.80	25.96	0	71	22.24	11.35	14	56
# other products	10.63	10.54	0	33	4.23	3.55	0	15

[a] This includes the clearing fee.

[b] Numbers for DTB are from 11/90 onwards because DTB did not organize a market for the Bund before that.

4.2 Trader data

We obtained from each exchange a list of past and current members, with their names, mnemonic code, and start and end dates of membership. In addition, the DTB data contain the members' country and city location and the LIFFE data contain the instrument class (equities, commodities or interest rates) that each member can trade. For current members, we also have the establishment's address.

The original dataset from DTB contains information on 493 individual establishments that held a membership any time between 1 January 1990 - 31 December 1999 period. The original dataset from LIFFE contains information on 305 individual establishments that held a membership allowing them to trade interest rate instruments (including the Bund) any time over the same period. Sixty-six individual establishments appear in both datasets, so our data cover 732 individual establishments.

For each member (establishment), we have collected additional information on (1) their (historical) group affiliations including mergers and acquisitions, (2) the establishment inception date and, if applicable, its closing date, (3) the group inception date and, if applicable, its bankruptcy date, (4) the activities of the establishment, and (5) whether the establishment trades the Bund or any other interest rate derivatives. Appendix A describes how this information was collected.

This process allowed us to track the needed information on most but not all establishments. Inception dates are missing for 110 (15.0%) of the individual establishments and 59 groups (10.15%). We could establish whether individual establishments traded the Bund contract or any other interest rate product in 78.3% of the cases. We assign the month prior to joining any of the two exchanges as the default establishment and group inception dates when these are missing, and we set the default for an establishment as trading the Bund when we do not know. We consider different default values in our robustness checks (Table 5, specification 1).

Groups versus individual establishments. We face two issues when defining the proper unit of observation in our environment. First, membership decisions of individual establishments that belong to the same group are not independent, and largely depend on the group's internal organization. Some groups are organized along geographical lines, with trading desks in each country. Others are organized along business lines with a single trading division. In the first case, all geographical trading divisions could, in principle, be members of a given exchange. In the second case, we would observe only one membership for that group. Second, mergers and acquisitions can lead to membership resignations because the resulting entity rationalizes its membership and not because the resigning establishment no longer values the membership. We address both issues by defining the group as the unit of observation and use the collected information on group ownership and mergers and acquisitions to match establishments to groups. With this convention, our dataset covers 578 groups, for which we use the generic term "trader". We drop the 25 traders for which we do not have any information, and the 35 traders who never trade interest rate products.[8] This leaves 518 traders. On average, 363.04 groups are present in any given month (min = 318, max = 433, std. deviation = 32.50).

Business models. We partitioned the traders in our dataset into seven business categories: universal bank, investment bank, retail bank, specialized trading firm, asset management, brokerage, and proprietary trading firm (details for how we partitioned traders are given in Appendix A). We distinguished banks by the customers they serve. Retail banks serve primarily individual customers as well as small and medium enterprises. Investment banks serve corporate clients as well as wealthy individuals. Universal banks serve all types of customers. Specialized trading firms are financial firms that make markets, offer execution and/or clearing for institutional clients, and trade on their own account. Proprietary trading firms are firms that focus on trading on their own account (speculation or arbitrage). Asset management firms and brokerages are self-explanatory.

Business types proxy for three things in our dataset. They proxy for size, because universal banks tend to be larger than retail banks and investment banks, and investment banks tend to be bigger than specialized firms. Some proprietary trading firms are one or two people operations. Business types also proxy for trading motives and sources of revenue, and thus eventually for traders' value for liquidity and other cost drivers. Finally, business types proxy for the scope of products traded.

Evaluated at the time a trader first appears in our dataset, our data contain 64 universal banks, 28 retail banks, 99 investment banks, 46 asset management firms, 82 specialized trading firms, 95 brokerages and 104 proprietary trading firms.

Geographical presence. Geographical presence affected adoption costs depending on the state of access deregulation. In our sample, 113 traders have their headquarters (HQ) in Germany, 32 in Switzerland, 104 in the UK, 136 in the rest of Europe, 91 in the US and 42 in the rest of the world (ROW). We also constructed a variable that records a trader's geographical presence in any given month based on the location of its headquarters and its known subsidiaries.

[8] One additional trader only traded interest rate products during a subset of the time period. We only include him in the analysis of that period.

Table 2: Member characteristics, 2/90-12/99 (N = 119)[a]

	LIFFE				DTB			
	Mean	Std.Dev.	Min	Max	Mean	Std.Dev.	Min	Max
Individual members[b]	145.60	5.34	131	158	128.66	82.48	51	367
Group members[b]	124.24	5.05	112	143	108.35	57.28	49	272
Percentage of dual members	30.83	16.71	9.79	70.17	34.85	2.59	28.57	39.67
Characteristics of membership (% of group members)								
Business type								
Universal banks	16.14	1.29	13.95	18.49	22.47	4.49	14.50	30.61
Retail banks	2.68	0.84	1.60	4.25	5.92	1.40	3.25	8.16
Investment banks	37.90	4.14	25.42	42.40	34.25	9.70	13.24	45.00
Brokerage	13.87	2.09	10.94	21.19	4.65	4.77	0	17.28
Specialized	17.97	1.76	14.62	22.60	14.02	6.15	2.04	22.39
Proprietary	11.01	1.79	7.94	15.60	9.27	6.11	2.74	20.45
Asset Management	0.43	0.41	0	0.89	9.41	2.39	5.97	14.81
Location of headquarters (HQ)								
HQ in the UK	33.28	2.82	29.17	39.42	9.27	1.74	5.94	14.03
HQ in Germany	4.52	8.07	3.17	6.36	50.97	10.94	34.27	76.59
HQ in Switzerland	2.28	0.43	0.85	3.17	6.31	2.01	3.12	12.02
HQ in rest of EU	18.43	1.94	13.14	22.12	20.17	6.11	6.38	33.47
HQ in the US	21.95	1.46	19.17	25.20	13.58	5.37	5.66	22.04
HQ in the ROW	21.82	2.91	12.39	25.42	6.01	1.74	2.42	9.72

[a] By convention, a trader is a member in a given month if it is a member in the first 15 days of that month.

[b] Excluding members for which we have no information or who never traded interest rate products.

Table 2 provides descriptive statistics on the membership of both exchanges. It confirms that LIFFE was an established exchange by the early 1990s, with a relatively stable membership, unlike the newly established DTB. Members' characteristics vary somewhat across the two exchanges: universal banks, retail banks and asset managers represent a larger fraction of members on DTB relative to LIFFE; the reverse holds for investment banks and brokerages. UK, US and ROW-headquartered traders represent a bigger fraction of LIFFE's membership while German and Swiss-headquartered traders represent a bigger fraction of the membership of DTB.

Table 2 hides the variation over time in the entire population of traders and members of each exchange. Figure 2 plots the number of traders that were members of LIFFE, DTB, both or no exchange over time. Figure 2 shows the limited degree of dual membership until the mid-1990s. About a third of DTB members are also members of LIFFE and this fraction is stable over time. In contrast, the proportion of LIFFE members holding a membership at DTB steadily increases over time, reaching 70% at the end of the decade.

Analysis of new memberships reveals a common pattern for both exchanges. Among the 331 new members of DTB over this period, 245 (74%) were not members of any exchange at the time of joining. The rest were members of LIFFE. LIFFE gained 98 new members, including 71 (72.5%) newcomers. In other words, new members tended to be traders who were not members of any exchanges.

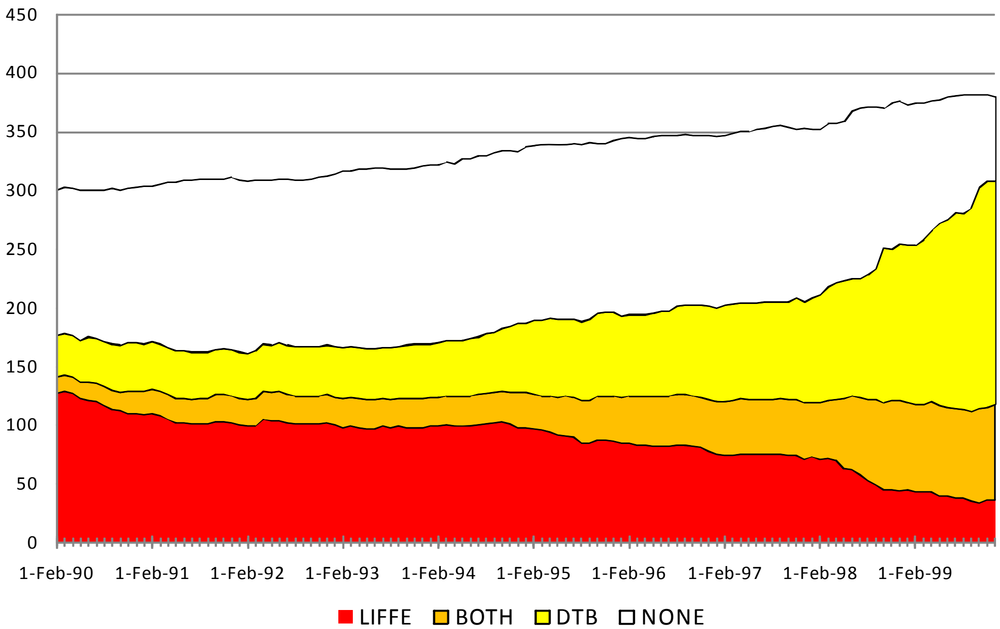

Figure 2: Exchange members and non members over time

Figure 2 also shows an increase in the population of potential exchange members over time.[9] This increase was accompanied by changes in the *composition* of traders population. There was a relative increase in the proportion of specialized trading firms and proprietary trading firms over the decade, mainly at the expense of retail banks, investment banks and asset management firms. The geographic composition of the traders population also changed, with a big increase in the number of German headquartered traders (and continental European traders more generally), at the expense of UK-headquartered traders and traders headquartered in the rest of the world (the proportion of US-headquartered traders remained more or less constant).

Finally, we note that the total number of transitions (i.e. the total number of changes in membership status) is 546. Given that our dataset controls for group ownership and group entries and exits, these transitions can be exclusively attributed to changes in firms' valuation of exchange membership.[10] Among the 518 groups present in our data, 90 never change membership status over the entire period during which they are present, 333 change status once, 78 change status twice, 11 change

[9] Given the way the data is contructed, censoring is more likely to affect the total number of groups at the end of the period, so the increase in the population of potential members is underestimated.

[10] Membership resignations due to bankruptcies or membership rationalization following a merger are not counted in this number. Likewise, decisions by groups to add another membership from another location in addition to their existing membership are not counted. As a benchmark, the number of transitions would be equal to 812 if we did not correct for those cases and instead took establishment memberships as our unit of observation.

status three times and 6 change status four times. Approximately 18 % of groups undergo at least two changes of status. This is not a trivial number. It motivates our empirical model where membership decisions are reversible.

5 Econometric model

The econometric model we employ is a close empirical analogue of the model in Section 2. The unit of observation is a trader's choice of membership in a given month. Traders are indexed by i and months by t. We think this is the relevant unit of observation for two reasons. First, the data show that membership is reversible and that a significant fraction of traders change membership status more than once. Thus, we want an empirical model where traders reoptimize on a regular basis. Second, both exchanges report trading information on a monthly basis (in addition to a daily basis), and DTB released information on membership on a monthly basis. The monthly frequency thus corresponds to the release of new information on which to base a membership decision. We explore alternative decision frequencies in our robustness checks in Section 6.

5.1 Baseline specifications

Let $\omega_{it} \in \{D,\ L,\ B,\ 0\}$ describe the membership status of trader i at time t (D stands for DTB, L stands for LIFFE, B stands for BOTH and 0 stands for no membership). Each month, traders reconsider their membership status. We assume that they play a best response to the previous period observed payoff and do not account for the possibility that the environment might be changing. We observe

$$\omega_{it} = \arg \max_{k\in\{D,L,B,0\}} \{\theta_i X_{ikt} - A_{ikt}(\omega_{it-1}) + \varepsilon_{ikt}\} \tag{6}$$

where $\theta_i X_{ikt}$ gathers the fixed and variable components of profits (see equations (3) and (5)), $A_{it}(k, \omega_{it-1})$ accounts for the adoption costs for a new membership and ε_{ikt} captures an unobservable shock to preferences. Normalization means that $\theta_i X_{i0t} = 0$.

The adoption cost represents one departure relative to the simple theoretical model of Section 2. It accounts for the fact that joining an exchange as a member is costly. In addition to the admission fee charged by the exchange (or the purchase of LIFFE shares for a membership at LIFFE), joining a membership involves training costs for the trader's personnel, equipment costs and possibly the cost of opening a new office. These costs are only borne once, when the trader becomes a member. For this reason, the adoption cost in (6) depends on the trader's membership status in the previous period. The adoption cost also varies with the trader's identity, the exchange and time (cf. the ikt index) because access deregulation affected exchanges and traders (due to their location) differently over time. By assumption, $A_{i0t}(\omega_{it-1}) = 0$ (there is no adoption cost for being a member of nothing).[11]

[11] Specifically, adoption costs are estimated using dummies that are turned on only for those choices that entail joining a new exchange. For traders with multiple locations, we take the *a priori* most favorable location and check ex-post

We distinguish between variables that affect the profits from membership independently of the trader's trading activities in the Bund and the variable component of profits. For the fixed component of profits, the baseline regressions control for the fixed fees charged by the exchanges, the number of products traded in each category, exchange fixed effects and exchange specific time trends.[12]

We assume that the per-unit trading profits (the analogue of π_D and π_L in Section 2) depend linearly on the volatility of the underlying Bund contract, the transaction fees, the margins and a measure of the liquidity of the market:

$$\pi_{ikt} = \alpha_{1i}\text{volatility}_t + \alpha_2\text{fee}_{kt} + \alpha_{3i}\text{margins}_{kt} + \alpha_{4i}\text{vol}_{kt} \tag{7}$$

Volatility is a proxy for traders' revenue opportunities. Higher volatilities increase the value of trading the Bund for hedging purposes and, given the link between the price of the Bund future and the underlying Bund contract, increase speculation and arbitrage opportunities. Volatility in the underlying Bund contract varies over time but is common to both exchanges. In principle, the impact of volatility on trading revenues depends on traders' trading motives. For this reason, the coefficient is allowed to vary with the trader's identity.

The variable "fee" in (7) controls for the transaction fees on the exchange (including clearing). It varies across exchange and time. In principle, we do not expect transaction fees to affect per-unit profits of different traders differently.

Margins record the required deposit traders need to make every time they open a new position. Margins are computed daily by the exchanges to remove the risk of default inherent to futures.[13] Each exchange sets their own margin depending on their own assessment of risk. In practice, margins vary a lot across time and tend to covary across exchanges (correlation coefficient of 0.74) because they are connected to the intrinsic volatility of the Bund contract (the correlation coefficients between the standard deviation of Bund yields and margins at DTB and LIFFE are 0.32 and 0.27, respectively). In principle, different traders may have different opportunity costs of money so that the coefficient on margins may vary across traders.

Finally, we use the lagged 3-month average trading volume (vol_{kt}) as our proxy for the liquidity (and impact cost of trading) of an exchange.[14] Different traders value liquidity differently, depending

that the estimation results are consistent with that assumption (see appendix A for details). To avoid an endogeneity bias due to the possibility that firms open an establishment at the same time as they join an exchange, we consider the geographical presence of firms at $t-3$ to construct the adoption dummies.

[12] Product counts are likely to better capture the *extra* advantage from membership because this advantage is related to the product offering and not so much to absolute levels of trading in those products. We distinguish between products of different categories because trading volumes vary a lot across asset classes.

[13] In the regressions, we only account for the initial deposit and do not account for additional margin calls that may happen during the life of the contract.

[14] Our measure of liquidity is coarser than the established measures of liquidity in the microstructure finance literature. This is largely due to data limitations. Liquidity is multidimensional and is best measured by tick data which are not available for such a long period. The closest measure of liquidity that is available is the daily bid-ask spread. However, realized spreads capture only one dimension of liquidity (e.g. it fails to capture market depth) and is largely endogenous.

on their trading behavior (in particular, the size of their transactions) suggesting that the coefficient on "vol" should vary across traders.

Recall that with intermediation, the profit derived from a membership on an exchange depends both on the per-unit trading profits on that exchange (via the extra volume effect) and the per-unit profit on the other exchange (via the substitution effect). This has two consequences. First, it implies that we should control for the per-unit revenue and cost drivers of *both* exchanges in *each* equation. Second, these drivers are multiplied in the regression by the extra volume effect and the substitution effect, which affects their structural interpretation. In our baseline specifications, we assume for simplicity that the extra trading volume and the substitution effect are constant over time and that they are equal on LIFFE and DTB; i.e. in the notations of Section 2, $\text{vol}_D(D) - \text{vol}_D(0) = \text{vol}_L(L) - \text{vol}_L(0)$, and $\text{vol}_D(L) - \text{vol}_D(0) = \text{vol}_L(D) - \text{vol}_L(0)$ (for the option "BOTH", we assume that the extra trading volume is the same on both exchanges: $\text{vol}_D(B) - \text{vol}_D(0) = \text{vol}_L(B) - \text{vol}_L(0)$).

Denote the (individual exchange) extra volume effect by Δvol_i and the substitution effect by $\Delta\text{volsubst}_i$. The coefficients we estimate on the volatility, fees, margins and trading volumes on exchange k in the equation for the payoff from a membership at exchange k are respectively $\Delta\text{vol}_i\alpha_{i1}$, $\Delta\text{vol}_i\alpha_2$, $\Delta\text{vol}_i\alpha_{3i}$, $\Delta\text{vol}_i\alpha_{4i}$. Likewise, the coefficients on the volatility, fees, margins and trading volume on the other exchange in that same equation are respectively $\Delta\text{volsubst}_i\alpha_{i1}$, $\Delta\text{volsubst}_i\alpha_2$, $\Delta\text{volsubst}_i\alpha_{3i}$, $\Delta\text{volsubst}_i\alpha_{4i}$. Because the extra volume effect is expected to be positive and the substitution effect is expected to be negative, these coefficients should have opposite signs.[15] Note also that the coefficients on the profit drivers for an exchange should be equal to zero when there is no trading in the Bund on the exchange that a trader joins. Likewise the coefficients on the profit drivers for the other exchange, which in principle are proportional to the substitution effect, are set equal to zero, when there is no trade in the Bund on the other exchange.

Before we discuss the sources of identification and our distributional assumptions, we comment briefly on the behavioral assumption imbedded in our econometric model. Our assumption that traders best-respond to the environment (instead of playing according to the equilibrium) is in the spirit of Arthur's (1989) seminal work on technology adoption with network externalities. Among subsequent papers applying evolutionary methods to the study of platform competition, Cabral (1990) and Gerber and Bettzuge (2007) are closest to our setting. They study the competition between two horizontally and vertically (due to liquidity) differentiated platforms where agents reoptimize every period by best-responding to past play. Both papers show that under some conditions, adaptive play converges to a Nash equilibrium.[16] Adaptive play is also consistent with the descriptive evidence. Because adaptive

Breedon and Holland (1998) have shown that realized bid-ask spreads for the Bund were similar in 1995 on both exchanges but that transaction sizes on LIFFE were more than double the size of transactions on DTB, suggesting that LIFFE was more liquid. Our measure captures the simple idea that liquidity increases with trading volumes.

[15] Note also that because volatility does not vary across exchanges, the estimated coefficient on volatility is proportional to the net volume effect, $(\Delta\text{vol}_i + \Delta\text{volsubst}_i)\alpha_{i1}$.

[16] Cabral (1990) shows that adaptive play converges to the minimum coordination equilibrium. Similarly, Gerber and Bettzuge (2007) find that, as the market grows large, splintering is the most likely outcome.

play ignores strategic interactions, it generically delivers a unique best response. This is consistent with the smooth path for membership market shares displayed in Figure 1. Figure 2 shows an acceleration in the number of new members for DTB just *after* tipping occurred. An interpretation of this pattern is that those trading firms were more reactive in their choices of an exchange than forward-looking. The main advantage of assuming best-response behavior is computational: we do not need to look for a fixed point in a membership game that involves more than 500 players as part of the estimation. The argument above suggests that the cost of doing so may not be too big.

5.2 Distributional assumptions

We assume that the unobserved profit shock in equation (6) is independently distributed from the explanatory variables. This may seem strong for transaction fees, margins and liquidity. Transaction fees could be correlated with the error term if exchanges set fees in response to demand and the error term contains common and unobserved demand aggregate shocks. The panel structure of our data alleviates this problem. In the baseline regressions, common demand aggregate shocks are captured by exchange fixed effects, exchange-specific time trends and measures of product scope. In our robustness checks, we include controls for marketing initiatives, technological innovations and changes in market rules, thus arguably leaving no common demand aggregate shocks in the error term.

There are two reasons why trading volumes could be correlated with the error term. The first reason is similar to the reason why fees might be correlated with the error term: unaccounted demand shocks could both influence the demand for trading and the demand for membership. We deal with this in the same way as we deal with the potential endogeneity of fees: extensive controls. The second reason is the causal relationship between membership and increased trading volume. Our assumed timing of these decisions, which is meant to replicate the observed delay between membership applications and actual membership, eliminates this potential problem. In our model, membership decisions for period t are taken in period $t-1$, on the basis of period $t-1$ data.[17] A trader's *additional* contribution to liquidity is thus not taken into account when he takes his decision to join an exchange.

The main driver for margins is the volatility in the price for the Bund future, which itself is driven by the price of the underlying Bund contract. Thus, margins are correlated with the error term if increased volatility in the Bund also increases the demand for exchange membership in a way that is currently not taken into account. In practice, volatility increases trading profit opportunities and trading volumes, and thus its effect on demand for exchange membership is already accounted for in the regressions when we control for trading volumes and volatility of the underlying Bund contract.

Any remaining correlation between the explanatory variables and the error term would lead to biased estimates. After discussing the results, we compare actual and predicted membership at both exchanges to assess the existence and extent of such bias.

[17] In practice, one month is actually a lower bound on the delay between the decision to apply for membership and actual membership.

5.3 Identification

Adoption costs and profit levels are separately identified because adoption costs affect the probability of adding a membership but do not affect the probability of resigning from a membership, whereas profit levels affect both. We exploit geographical variation in the timing of deregulation to estimate exchange, location and time-specific adoption costs for traders in a given location during the period corresponding to a fixed regulatory regime.

The coefficients on the profit drivers are identified from variation in these drivers. As discussed above, volatility does not vary across exchanges and thus we can only identify the net effect on profits. Because we do not observe individual volumes or brokers fees, the last terms in expressions (3) and (5) are estimated jointly with the fixed profit component from membership (most likely through the time trends). Consequently, the estimation can only partially identify the profit component due to trading in the Bund from the rest.

Finally a natural question that arises is whether we can separately identify whether dual membership is caused by complementarities between the two exchanges (for example through their respective product scope) or because unobserved trader-specific profit shocks for each exchange are correlated. Gentzkow (2007) has recently nicely summarized the empirical challenge. He suggests that both effects can be distinguished in a panel data like ours, with alternative-specific covariates. Correlation can be identified if we decompose the unobserved profit shock into a trader-exchange-specific shock that is invariant through time and an idiosyncratic time-trader-exchange-specific shock that is independently and identically distributed. The time-invariant trader-exchange-specific shocks can be estimated as fixed effects or random effects (in which case we must allow them to be correlated across exchanges). They soak up the correlation. Alternative-specific covariates then help identify complementarities. We adopt an approach in this spirit when we estimate the model.

5.4 Estimation

Under the further assumption that the error term is i.i.d. extreme value across time, exchanges and traders, the probability of observing $\omega_{it} = k$ conditional on ω_{it-1} is given by

$$\Pr(\omega_{it} = k|\omega_{it-1}, \theta_i) = \frac{\exp(\theta_i X_{ikt})}{1 + \sum_{l=\mathrm{D,L,BOTH}} \exp(\theta_i X_{ilt})}. \tag{8}$$

Index with 0 the first period observation for firm i. The probability of observing sequence $\omega_{i1}, ..., \omega_{iT_i}$ of membership status for firm i is given by

$$S(\{\omega_{it}\}_{t=1}^{T_i}|\theta_i, \omega_{i0}) = \prod_{t=1}^{T_i} \Pr(\omega_{it}|\omega_{it-1}, \theta_i). \tag{9}$$

Trader heterogeneity plays an important role in our model because we expect revenue and cost drivers to affect traders differently depending on their trading behavior (and specifically the typical size of their transactions) and their trading motives (speculation, arbitrage, hedging and brokerage). Additionally, we expect traders to value different aspects of each exchange's offering. In the baseline specification, this is reflected in the fact that several coefficients in θ_i are trader-specific. Estimating more than 500 values for each of these coefficients is obviously unreasonable for computational reasons and because some traders are present in our data for a limited number of periods only, creating a potential incidental parameter problem (Lancaster, 2000). We address this issue in two ways. As a first approach, we group traders by business types and force the coefficients to be the same within this class. As a second approach, we assume that the trader-specific coefficients in θ_i are independently distributed from the variables in X_{ikt} and the error term, and estimate a mixed logit model (Revelt and Train, 1998, McFadden and Train, 2000). Mixed logit models allow us to estimate the parameters of the distribution of θ_i once we have assumed the functional form for its distribution. We estimate our econometric model using maximum likelihood (ML) estimation for the case of business-type specific coefficients and simulated maximum likelihood estimation (SML) for the mixed logit. The ML estimator is consistent and asymptotically normal under our assumptions. The SML estimator is asymptotically normal and it is consistent when the number of simulations goes to infinity.

6 Results

Table 3 reports our baseline regression results. All specifications control for adoption costs and variable and fixed components of profits as described in Section 5.1. To account for any remaining trader heterogeneity in the fixed component of profit or any correlation in trader-specific unobserved demand for exchanges, exchange fixed effects are replaced by exchange-business-type-HQ fixed effects in specification (4) (the HQ locations are US, UK, Germany, Switzerland, EU except for Germany and UK, and ROW, yielding 126 dummies). Random coefficients are estimated in specifications (5) and (6).

[INSERT TABLE 3 ABOUT HERE]

6.1 Variable profits coefficients

The top panel of Table 3 reports the coefficients on variable profit drivers. Each combines the effect of the specific revenue or cost driver and the change in traded volume (extra volume or substitution effect) as a consequence of membership. In specifications (1) and (2) where they are imposed to be the same for all traders, all coefficients have the expected sign, except for margins.[18] In particular, the coefficients on "own" profit drivers and "other" profit drivers have opposite signs which is consistent with a positive extra volume effect and a negative substitution effect. Own fees, own liquidity and own margins in specification (2) are all significant at the 5% level. Only other margins is significant, suggesting that the substitution effect, even if present, is likely to be small.

Specifications (3) and (4) allow coefficients on variable profit drivers to be business-type specific. For each variable, we report four numbers: in the top row, we report the mean of those coefficients

[18] The reason might be that margins are determined on the basis of the underlying volatility of the Bund contract so that it also proxies for revenue opportunities.

that are significant at the 10% level and the mean of the standard deviation on these coefficients; the bottom row reports the means of the standard errors of the estimated coefficients and of the associated standard deviations in parentheses for those coefficients that are significant at the 10% level. The difference between specification (3) and (4) is that specification (4) includes exchange-headquarter-business-type fixed effects. A larger difference between point estimates of different business-types (measured by their standard deviation) than the standard deviation on each of these point estimates (comparison between the bottom left number and the top right number for each variable) suggest that there is trader heterogeneity captured by business types. This is the case for margins in specification (5). When the point estimates do not vary much by business types, it suggests, either that there is no heterogeneity across traders on this dimension, or that business types are not a good proxy for this heterogeneity. This is for example the case for the coefficients on liquidity.

Specifications (5) and (6) investigate this hypothesis. In specification (5), coefficients on variable profit drivers are estimated as random coefficients. In specification (6), exchange effects are also estimated as random coefficients. Table 3 reports the mean and standard deviation of the coefficients in the population. Table 4 reports the estimates for the exchange fixed effects in specification (6).

Table 4: Random Coefficients (specification (6), Table 3)

Variable	Distribution	b		w	
		Est.	Std. Err.	Est.	Std. Err.
DTB fixed effect	$Normal(b, w)$	7.907**	0.685	0.501**	0.192
LIFFE fixed effect	$Normal(b, w)$	4.129**	1.107	0.473**	0.322
BOTH fixed effect	$Normal(b, w)$	11.373**	1.185	1.031**	0.320

** indicates significance at 5%

The estimated coefficients are consistent with those in specification (2). Standard deviations on random coefficients are statistically significant for fees, margins and liquidity in specification (5) and for fees and liquidity in specification (6), suggesting heterogeneity on those dimensions.

6.2 Fixed profits components

The component of profit that does not depend on Bund trading activity is captured by exchange fixed effects, exchange-specific time trends, exchange fixed fees and product scope variables.

Once we control for exchange specific effects and time trends, controlling for product scope adds little explanatory power and does not affect the coefficients on the other variables much (compare specification (1) and specification (2) in Table 3). The coefficients on the time trend, on the other hand, are highly significant and their inclusion or exclusion affects the coefficients on variable profits. We interpret this as evidence that our scope measures might be too imperfect and that fixed effects and time trends are better suited to capture the exchange-specific and time-varying components of fixed profits. As an additional check, we run specification (4) of Table 3 adding extra dummies for all the other events reported in Table 9 in Appendix A. The results are reported as specification (2) in

Table 5. Two of these six dummies are significant but the results otherwise barely change.

Overall, the Bund-related component of profits represents from 10 to 17% of the total profits from membership, depending on the exchange. These numbers are based on specification (2) and are obtained by dividing the variable component of profits by the sum of the variable and fixed components, all evaluated at their point estimate (adoption costs are ignored).[19] These numbers are fairly stable over time. The relative importance of Bund-related variable profits is highest for DTB, with an average over time and traders equal to 16.72% and lowest for LIFFE, with an average over time and traders equal to 10.45%.

Using specification (4) (where exchange fixed effects are also business type and HQ location specific) or specification (6) (with random coefficients), we can also assess the presence of synergies between the two exchanges by comparing the sum of the fixed component of profits for DTB and LIFFE with the estimated fixed component of profits for the option BOTH. There is no statistical significance so we cannot reject the hypothesis that the two exchanges are either substitutes or complements.[20]

[INSERT TABLE 5 ABOUT HERE]

6.3 Adoption costs and access deregulation

Adoption costs to DTB consist of an explicit admission fee charged by the exchange (102,000 DM until December 1997) and all other costs incurred by a new member and captured by time-geography specific adoption dummies. LIFFE did not charge any explicit adoption fee during the period; thus the adoption costs are entirely captured by the adoption dummies. All the estimates are statistically significant and negative as expected and stable across specifications.

Within a geography, access costs vary as expected. DTB adoption costs for Swiss or EU-based traders declined as deregulation progressed. Access from an EU-based country was most affected by implementation of the Investment Services Directive (ISD) in January 1996. Access from Switzerland became significantly easier after the merger with SOFFEX in September 1998. For the US series, the increase in adoption costs between October 1998 and July 1999 corresponds to the reversal of regulations that allowed remote access to DTB from the US. Adoption costs for LIFFE and firms with a EU presence but no presence in the UK were not affected much by the ISD. This is expected because full electronic trading, which was implemented in August 1998, was not technically accessible from outside the UK. Migration to full electronic trading only happened in May 1999. Adoption costs for US-based firms drop in September 1999 when US regulators allow remote access.

Across geographies and for DTB, the relative ranking of access cost coefficients is broadly consistent

[19] These are lower bounds on the relative importance of variable profits because, as argued in section 5.3, the benefits from avoiding brokers fees are not separately identified from the fixed profits component.

[20] Both approaches involve a slight departure from the identification arguments in Gentzkow since specification (4) groups all traders with the same HQ location and business type in together (instead of estimating a fixed effect for each trader individually), and specification (6) as it currently stands forces the random fixed effects to be independent across exchanges (thereby biasing the results towards finding complementarities).

with the way we constructed the dummies for groups with geographical presence in several countries. Swiss access costs are comparable to those from the EU except after September 1998, when Swiss access costs are smaller. They are comparable to adoption costs from the US. For the first part of the decade, access for firms with a presence in Germany was cheapest. Later Swiss and US adoption costs are lower than from Germany. This suggests that costs may have declined over time for reasons other than regulation, and that the estimate for German adoption costs may be an underestimate of costs at the beginning of the period and an overestimate of costs later in the decade.

Across geographies and for LIFFE, our estimates confirm that traders who already had a presence in the UK did incur lower set-up costs.

Finally, we compare access costs across exchanges. Total adoption costs for DTB must include the admission fee for the period until December 1997. When we take this admission fee into account, adoption costs for DTB were not smaller than for LIFFE until December 1997. They became smaller afterwards. The coefficient on the admission fee helps us calibrate total adoption costs. For instance, total adoption costs for DTB in early 1996 for a US-based firm was around 430,000 DM (approx. 285,000 USD) based on specification (1).[21]

6.4 Goodness of fit and further robustness checks

In all specifications, the pseudo R^2 is very high. However, the level of the R^2 itself is not very informative for our data. With only 518 transitions out of $39,844$ observations, a high R^2 could be explained by setting high adoption costs: high adoption costs together with stable profits would result in a low number of transitions (in fact, a simple regression with time and geography varying adoption dummies and exchange fixed effects yields a pseudo R^2 of 94.97 already). The fact that the coefficients on time-varying explanatory variables are positive is encouraging. We do three further checks. First, we restrict attention to the group-month observations where the group changed membership status and we estimate a conditional logit model (conditional on changing status, which of the three other options did the trader choose?). In such a specification, adoption costs are barely identified: differences in adoption costs across exchanges are identified from transitions where a trader adds a membership and levels are only identified from transitions where a trader drops a membership. Most of the coefficients on the other explanatory variables are no longer significant either. Nevertheless, the pseudo R^2 reaches 0.70 in the simplest specification, suggesting that our explanatory variables for profits capture some relevant dimensions of traders' decision making.[22]

Second, we check whether our high R^2 and high significance levels for many variables are driven by the way we structured our data. Specifically, we might be worried that the high and significant adoption costs are driven by our assumption of monthly decision-making. To investigate this hypothesis, we extend the behavioral model to allow for different periodicities in decision-making. Specifically, we

[21] $102{,}000 + \frac{10.19}{3.09} \times 100,000$. Estimates of set-up costs reported in the press at that time were one million USD.

[22] The simplest specification corresponds to specification (1) in Table 3 where we have additionally pooled some of the admission dummies to ensure convergence.

assume that, at every period, traders reoptimize their membership status with probability λ. Thus, conditional on λ, ω_{it-1} and θ_i, the probability that trader i chooses k in period t is equal to

$$\Pr(\omega_{it} = k|\omega_{it-1}, \theta_i) = \begin{cases} \lambda \frac{\exp(\theta_i X_{ikt})}{1+\sum_{l=\text{D,L,BOTH}} \exp(\theta_i X_{ilt})} & \text{if } k \neq \omega_{it-1} \\ \lambda \frac{\exp(\theta_i X_{ikt})}{1+\sum_{l=\text{D,L,BOTH}} \exp(\theta_i X_{ilt})} + (1-\lambda) & \text{if } k = \omega_{it-1} \end{cases}. \tag{10}$$

When $\lambda = 1$, expression (10) reduces to (8). When $\lambda < 1$, a trader can keep the same membership status because he did not reconsider his membership status this period or because he reconsidered it but decided that his current membership status is optimal. Although both high adoption costs and a low value for the λ parameter could explain the relatively low number of status changes in the data, the two parameters are separately identified. Specifically, a decrease in adoption costs has two effects: (1) an increase in the number of adoption spells, and (2) longer spells during which a trader is a member of an exchange because it is profitable earlier to join an exchange. An increase in the frequency of decision-making also increases the number of adoption spells but, unlike lower adoption costs, it can both lengthen or shorten membership spells. In numerical simulations, both parameters were well identified. Specification (3) in Table 5 reports the results for the same specification of the profit function as in specification (1), Table 3. The estimated λ is equal to 1.[23]

Finally, we simulated the number of exchange members on the basis of the estimated coefficients for specification (1) in Table 3 and compared them to the actual exchange members. The simulated number of exchange members is based on 100 draws of the error term for each group-month observation. In Figure 6, the red squares correspond to the data, the full line corresponds to the median model prediction. The dotted lines correspond to the 5 and 95 percentiles.

7 The economics of exchange membership revisited

With these demand estimates, we now revisit the economics of exchange membership. Our findings are as follows: First, the results provide support for the hypothesis that exchanges are both horizontally and vertically differentiated, with trader heterogeneity on the horizontal dimension being much more important than trader heterogeneity on the vertical dimension. Second, access deregulation did reduce adoption costs but these policy measures are quantitatively less important than exchange-controlled admission fees. In other words, both exchanges would have been able to compensate for the regulatory barriers put by access regulation using lower admission fees. Third, dual membership slowed down DTB's membership growth. We describe each of these findings in greater detail in this section.

[23] Interestingly, the estimated λ is below one for coarser models that do not include time-varying explanatory variables for profit levels. It converges to 1 as soon as we add a time trend or product scope variables.

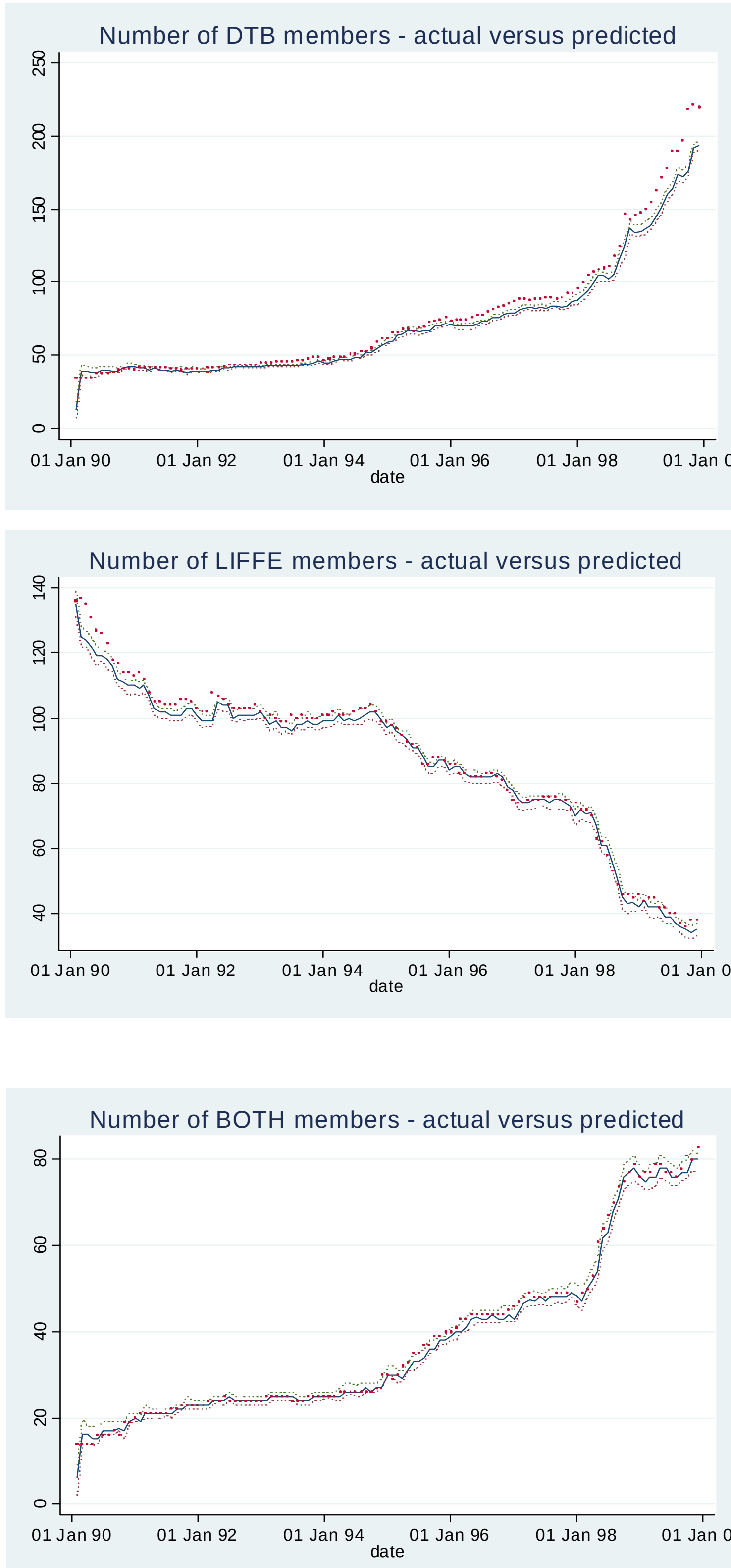

Figure 6: Goodness of fit

7.1 Evidence of vertical heterogeneity

There is scope for vertical differentiation in the exchange industry if (1) liquidity matters (i.e. the coefficients on volume is significant) and (2) traders care about liquidity differently. Our regression results show that liquidity matters in the membership game. Table 4 suggests the presence of trader heterogeneity on that dimension.

To quantify this dimension of heterogeneity, we compute by how much DTB should have decreased their transaction fees to compensate for their lower liquidity. Specifically, let $\theta_{\text{LIQ},i}$ and $\theta_{\text{FEE},i}$ be trader i's coefficient on volume and on fees respectively, and let Δvol describe the difference in trading volume between the two exchanges. To compensate trader i for his lower liquidity level, DTB would need to cut fees by $\Delta\text{fee} = \theta_{\text{LIQ},i}\Delta\text{vol}/\theta_{\text{FEE},i}$.

Table 7 reports the results at different points in time and for each quartile of the distribution of the liquidity coefficient (the coefficient on fees is set to its median value), based on specification (6). Table 7 quantifies trader heterogeneity in terms of liquidity: attracting a high-liquidity valuer requires a discount approximately twice as big as for a low-liquidity valuer. Table 7 also suggests that early in the decade, when the absolute difference in trading volumes was not big, DTB could have compensated the low-liquidity valuer with a 0.20 DM transaction fee discount (a 40% reduction). As volumes and the absolute difference in volumes grew, the required reduction increased.

Table 7: Decrease in DTB fee (in DM) required to compensate for the liquidity differential

	$\theta_{\text{LIQ},0.25}$	$\theta_{\text{LIQ},0.5}$	$\theta_{\text{LIQ},0.75}$
Jan 91	-0.18	-0.24	-0.32
Jan 92	-0.14	-0.19	-0.26
Jan 93	-0.21	-0.29	-0.39
Jan 94	-0.37	-0.50	-0.68
Jan 95	-0.52	-0.71	-0.96
Jan 96	-0.47	-0.64	-0.86
Jan 97	-0.52	-0.71	-0.96
Jan 98	-0.03	-0.04	-0.05
Jan 99	2.44	3.30	4.47

7.2 Evidence of horizontal heterogeneity

To quantify the level of horizontal heterogeneity, we run the following experiment. Using specification (6), we set all coefficients, except for the coefficient on liquidity and the trader exchange fixed effect, equal to their point estimates or their median values in case of random coefficients. The payoff from an exchange membership at DTB and LIFFE can then be expressed as:

$$
\begin{aligned}
U_D &= \theta_{\text{LIQ},i}\text{vol}_D + \text{DTBFIXEDEFFECT}_i + \text{REST}_D \\
U_L &= \theta_{\text{LIQ},i}\text{vol}_L + \text{LIFFEFIXEDEFFECT}_i + \text{REST}_L
\end{aligned}
$$

where the terms REST gather all other variables in the traders' profit function. Given the value of the exogenous variables, the pair of trader attributes fully pins down his choice between DTB and LIFFE.

In Figure 7 we plot the locus of trader attributes ($\log \theta_{\text{LIQ},i}$, $\text{DTBFIXEDEFFECT}_i -$ DTBFIXEDEFFECT_i) that make traders indifferent between LIFFE and DTB (the $x-$axis is $\text{DTBFIXEDEFFECT}_i -$ DTBFIXEDEFFECT_i, and the $y-$axis is $\log \theta_{\text{LIQ},i}$).[24] Trader attributes are independently normally distributed and the extremes of the box on each dimension correspond to the 0.5 and 99.5 percentile respectively.

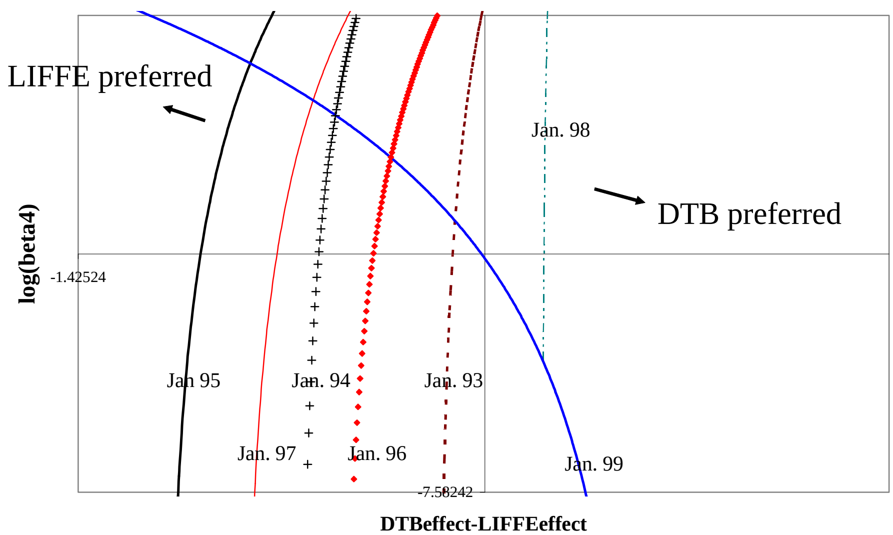

Figure 7: Preferences over DTB and LIFFE as a function of $\theta_{\text{LIQ},i}$ and individual fixed effects

What is remarkable about Figure 7 is that the indifference loci are almost vertical in most years. If we pick any point in the box (i.e. any pair of trader attributes) and shift it up or down slightly, this change in preferences for liquidity is unlikely to change the trader's choice between DTB and LIFFE. By contrast, if we move the point left or right (i.e. fix the value for liquidity but change the horizontal component), it is likely to change his choice. Put differently, the slopes of the loci quantify the relative importance of trader heterogeneity on the liquidity dimension relative to trader heterogeneity in the horizontal dimension. The fact that all slopes are very steep suggests that heterogeneity on the horizontal dimension is more important than heterogeneity on the vertical dimension. One interpretation of this result, together with the evidence in the previous section that liquidity does matter, is that it reflects the importance of intermediation in the exchange business, which makes liquidity a much less important determinant of traders' choice in the membership game than in the trading game.

7.3 Adoption costs: deregulation versus admission fees

In Section 6, we found that adoption costs are highly significant and decrease with deregulation. We now assess the actual advantage that deregulation gave DTB in attracting new members. Specifically, we run the following experiment. For each geographical zone, we set DTB's adoption costs equal to

[24] We use the log transform of $\theta_{\text{LIQ},i}$ so that the resulting variable is effectively normally distributed.

their levels at the beginning of the period. The estimates are taken from specification (1) in Table 3. So, for instance, adoption costs for EU countries are set equal to -11.51 for the entire decade. We then simulate the number of firms that are members of DTB and LIFFE in the counterfactual scenario and compare it with the predicted numbers under the true parameters. The difference underestimates the effect of deregulation because it ignores the multiplier effect that less members today imply lower trading volume tomorrow and thus less members tomorrow.

Nevertheless, the comparison is already instructive. In Figure 8, the predicted number of DTB members in the absence of deregulation is barely under the model predictions and the two numbers are not distinguishable for LIFFE. By comparison, we simulated the number of DTB and LIFFE members if DTB had not charged any admission fee from the beginning. There is no effect of admission fees on LIFFE membership but a sizable effect on DTB membership. If DTB had not charged any admission fee, they would have reached a 50% share of membership at least (given the multiplier effect) a year and a half earlier. Regulatory access is often seen by exchanges as the key to attracting new members. These results caution against this view. They suggest that the barriers to trading created by the lack of regulatory access can be compensated by a cut in admission fees.

7.4 Dual membership

The econometric results so far suggest that traders derive no positive or negative synergies from holding a dual membership. Traders who hold dual membership are simply traders who happen to value the services provided by exchanges highly. However, this does not mean that the practice of dual membership is neutral as far as the competition between exchanges. Indeed, using the estimates from specification (1) in Table 3, we simulated the number of DTB and LIFFE members in the absence of dual-homing (for instance because membership is exclusive). Figure 6 shows the result. As expected, dual-homing reduces traders' incentives to become members of DTB. More interestingly, they also reduce traders' incentives to keep a LIFFE membership. Both effects are large. With exclusive membership, DTB would have reached a 50% market share in membership almost four full years earlier (the same caveat applies as earlier: this ignores any multiplier effect).

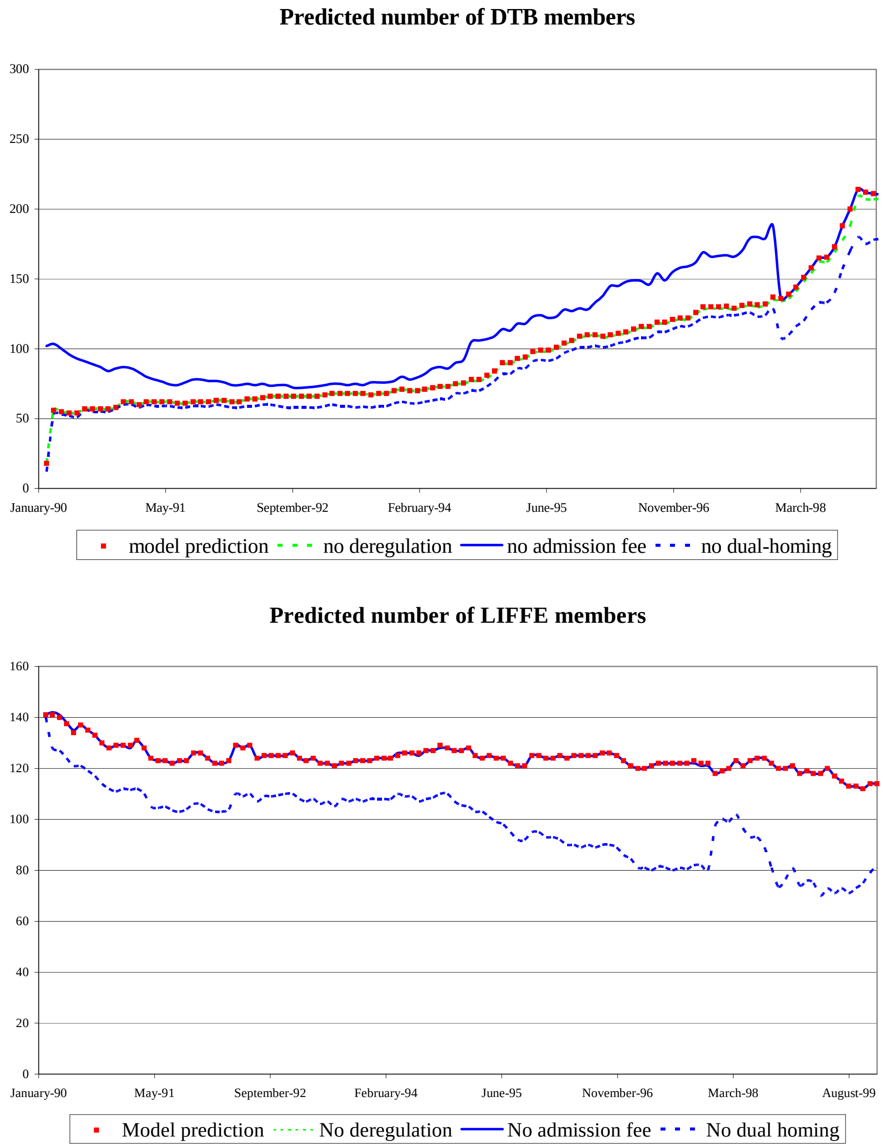

Figure 8: Predicted number of DTB and LIFFE members under different scenarios

8 Revisiting the Battle of the Bund

While the main purpose of this paper was to better understand the demand for exchanges, our analysis also sheds new light on the Battle of the Bund. First, our results rule out two popular explanations of the eventual success of DTB: access deregulation overwhelmingly favored DTB (Section 7.3 shows that the effect of access deregulation was not quantitatively important), and German traders were biased in favor of DTB (we found no evidence of such a bias when comparing the exchange-business-type-HQ specific fixed effects across headquarter locations). Second, we explore two new explanations for the observed dynamic: decreasing horizontal differentiation between the two exchanges over time and changing population of traders. Preliminary results from a model allowing random coefficients on exchange fixed effects for the early, middle, and late eras of our sample period reveal that the standard deviation in heterogeneity over preferences for DTB decreases over time and is much larger in the early period than the overall standard deviation reported in Table 4. LIFFE's standard deviaton remains constant over time. A later version will describe both findings in greater details.

9 Concluding remarks

Liquidity matters in financial markets. This creates a tendency for trading to concentrate on a single exchange and gives incumbent exchanges a first-mover advantage. However, several counteracting forces exist. First, exchanges differ on other dimensions than liquidity. National regulation, product portfolio, and user convenience all provide scope for differentiation and thus a rationale for coexistence. Second, several features of the organization of financial markets, specifically intermediation and non exclusive membership, reduce the forces towards aggregation on a single exchange.

This is the first paper that empirically evaluates the contribution of these different factors to the demand for exchanges and ultimately to the way exchanges compete. One novel aspect of our empirical model is that it allows for intermediation. We find evidence of trader heterogeneity, both on the vertical dimension (including liquidity) and on the horizontal dimension. The transaction fee discount needed to compensate a trader for DTB's initial lower liquidity is large relative to transaction fee levels, and about twice as large for a high-liquidity valuer as for a low-liquidity valuer. We believe that the existence of intermediation in this market drives the relative importance of horizontal to vertical differentiation: 83-90% of the extra profit from membership are not directly attributable to Bund trading. Our results also put access deregulation in perspective. Deregulation did lower adoption costs but had a marginal effect relative to a hypothetical admission fee waiver or the imposition of exclusive membership. We also find that dual-homing favors coexistence but, surprisingly, makes entry more difficult. Dual-homing delayed market-tipping to DTB by a few years. Preliminary analysis also suggests new explanations for why the market tipped in favor of DTB: the exchanges became less horizontally differentiated over time and the population of traders changed in favor of DTB.

We end with several venues for future research. First, heterogeneity has important welfare consequences and strategic implications for exchanges. Exchanges could charge different prices to different traders, a practice that was uncommon in the nineties but has become more routine today. Whether such strategies are effective depends on how different traders contribute to liquidity. We address this issue in Cantillon and Yin (in progress). Second, as a story about the Battle of the Bund, our paper remains of course incomplete because we explain membership and not trading (although we have argued that both are connected). In particular, we do not address timing of the market tip. Answering this question requires looking at trading volumes and, because network effects are more important for trading than for membership, allowing for multiple equilibria. Our current results can help us integrate relevant aspects of trader heterogeneity into an empirical model of aggregate trading volume.

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10 Appendix A: Description of data and variable construction

This appendix complements the main text. It describes how the firm dataset was constructed and provides definitions for the geography and time contingent adoption costs and for the exchange period dummies.

10.1 Firm dataset

The main text reports that, for each individual establishment, we collected information on (1) its historical group affiliation including mergers and acquisitions, (2) the establishment inception date and, if applicable, its closing date, (3) the group inception date and, if applicable, its bankruptcy date, (4) the activities of the establishment, and (5) whether the establishment trades the Bund or any other long-term government bond derivatives. This information was collected manually using the following procedure:

1. *Group and establishment inception dates and exit dates.* Inception dates for existing companies were taken from ORBIS, UKdata.co.uk or by contacting the establishment directly.[25] For bankrupt establishments located in Germany and Switzerland, we used the Dufa-Index and the Dun & Bradstreet (Switzerland)'s records (both available through Factiva).[26] Factiva was used to track any available information for other bankrupt firms (e.g. reports of bankruptcy filing, trading license being upheld). Some establishments still exist legally but are no longer active. Those appear in ORBIS with the mention "inactive" and we took the date of the last financial accounts as the exit date.

2. *Information on group ownership structure including mergers and acquisitions* was gathered from company websites, ORBIS, UKdata.com, Dufa-Index, Dun & Bradstreet and press articles (Factiva). We consider that an establishment belongs to a group when it is owned 100% by this group or when it is clearly managed as a wholly-owned subsidiary (for example, a common ownership structure for specialized trading firms is that the local partners own a small fraction - of the order of 5% - of the capital of the local subsidiary. In these cases, we considered that the establishment belonged to the group).

3. *Information on establishments' business activies* was taken from self-descriptions of the business

[25] ORBIS is a database of about 15 million listed and non listed companies worlwide that aggregates legal (such as legal status, inception date, structure of ownership), financial (balance sheets) and business information (www.bvdep.com/ORBIS.html). UKdata.co.uk has the same kind of information but is limited to UK companies (www.ukdata.com).

[26] The Dufa Index is published by Dumrath & Fassnacht. It contains registration information of German companies, as published in the official daily Bundesanzeiger. It includes information on legal status, change of ownership, management, liquidation, settlement and mergers & acquistions. The information is available from 8 June 1994. Dun & Bradstreet (Switzerland)'s records contain all company-related publications by the Swiss official gazette of commerce (SHAB). The information is available from 20 August 1996.

on company websites, ORBIS, and press articles during the relevant period, as well as direct phone or email contact with the company when possible. We recorded the following business activities: retail banking, investment banking, private banking,[27] asset management, proprietary trading, market making, brokerage for institutional or professional traders, brokerage for retail clients, arcade[28] and universal banking.

4. *Information on the products traded* was taken from company websites, LIFFE's product licenses, LIFFE's and DTB's notices to members, press articles during the relevant period, and phone calls to the establishment when possible.

10.2 Regulation-driven adoption costs

DTB

Initially, a trader had to have an office in Germany to be a member of DTB and only German firms could be clearing members. On 28 July 1993, there was a change in the law and EU trading firms with a German office could become clearing members. In September 1994, MATIF members could become members of DTB and the Dutch authorities recognized DTB and authorized Dutch-based firms to trade on DTB for their own account. The EU Investment Services Directive came into force in January 1996. Switzerland is not part of the EU and thus access from Switzerland followed its own timetable. Acess points were installed in Zurich in January 1996 and SOFFEX members became members of Eurex when SOFFEX and DTB merged in October 1998. Finally, the US Commodities Futures Trading Commission granted a no-action letter to DTB on 28 February 1996 which authorized US-based traders to trade on DTB. The authorization was frozen on October 30, 1998, forbidding any new membership from the US. It was reinstated in August 1999.

A single geography-time adoption dummy is turned on for each group that is not a member. For groups with geographical presence in several locations, we considered the "closest" geographical location according to the following a-priori order: Germany $\succ$ France and the Netherlands between 9/94 and 12/95 $\succ$ Switzerland $\succ$ EU except France and the Netherlands between 9/94 and 12/95 $\succ$ US. Locations included in the construction are those prevailing at $t-3$.

LIFFE

Until August 1998, LIFFE was an open-outcry exchange, requiring LIFFE members to have staff based in London. We distinguished between groups that had a presence in the UK and those that did not have a presence in the UK before they joined the exchange. For those without a UK presence but a European presence, we distinguished three periods: before the European Investment Service Directive, after the ISD but before LIFFE moved the Bund to electronic trading in August 1998, and

[27] Private banks, essentially a German-Swiss concept, offer financial advice and asset management to wealthy individuals. They also offer some corporate banking services.

[28] An arcade is a firm ofering services to independent traders, such as access to exchanges, back office support or office space.

after August 1998. For firms with a US presence only, we distinguished between the two periods before and after July 1999, when the CFTC issued a no action letter for Liffe.connect.

Table 8 summarizes the value for the resulting adoption dummies.

Table 8: Adoption dummies for DTB and LIFFE

Name	Event	Location	t between ...
DTBaccessG		Germany	1/90-12/99
DTBaccessSwiss1		Switzerland	1/90-12/95
DTBaccessSwiss2	Access points in Zurich	Switzerland	1/96-9/98
DTBaccessSwiss3	Merger with SOFFEX	Switzerland	10/98-12/99
DTBaccessEU1		EU	1/90-7/93
DTBaccessEU2	EU-based institutions can be clearing members	EU	8/93-12/95
DTBaccessEU3	Investment Service Directive	EU	1/96-12/99
DTBaccessFrench	Dutch regulatory approval + link with MATIF	France and NL	9/94-12/95
DTBaccessUS1		US	1/90-2/96
DTBaccessUS2	CFTC no-action letter	US	3/96-10/98
DTBaccessUS3	CFTC no-action letter upheld	US	11/98-7/99
DTBaccessUS4	CFTC no-action letter reinstated	US	8/99-12/99
LIFFEaccessUK		UK	1/90-12/99
LIFFEaccessEU1		EU	1/90-12/95
LIFFEaccessEU2	Investment Service Directive	EU	1/96-7/98
LIFFEaccessEU3	Bund moved to electronic trading	EU	8/98-12/99
LIFFEaccessUS1		US	1/90-7/99
LIFFEaccessUS2	CFTC no-action letter	US	8/99-12/99

10.3 Other events affecting the attractiveness of DTB and LIFFE

The next table records the events that affect the attractiveness of DTB and LIFFE, beyond those already controlled for in the base specification. A dummy switches on in the specified period.

Table 9: Other events

Event	Type	t between ...
DTB		
Cut in one-time connection charges for German-based customers	adoption cost	4/95-12/99
DTB offers free computers to LIFFE members	adoption cost	4/98-10/98
LIFFE		
Launch of new Automated Trading Platform (APT)	market rules	12/93-12/99
LIFFE-CBOT link	extra trading opportunities	5/97-12/97
Top step initiative	market rules	6/97-12/99
Bund trading moved entirely to electronic trading	market rules	8/98-12/99
Demutualization voted	corp. governance	5/99-12/99

11 Appendix B: Economics of futures trading (not for publication)

This section provides a concise overview of the basics of futures trading for the purpose of determining the relevant factors we will need to take into account in our analysis. For further details, see Hull (2003) or Kim (1997).

A future (contract) is a promise to sell or to buy a specific instrument at a future date and at a given price. At the time of the agreement, the price and maturity are decided, but typically no payment is made. Delivery and payment take place at maturity.

Because economic conditions may have changed between the time of the agreement and the maturity date, the ex-ante beneficial contract is usually no longer beneficial ex-post for one of the parties. This creates an incentive to default. Futures have been used at all times and places, and various mechanisms have been used to mitigate this default risk. One of them is the use of exchanges and clearing.

11.1 Exchange-traded futures

Two key features characterize exchange-mediated futures trading. First, future contracts traded on exchanges are standardized. The exchange defines the product (size of the contract, delivery date, product that can be delivered) and its trading rules (hours, minimum tick size, etc.). Standardization pools liquidity around a limited set of contracts and makes it easier for traders to find a counterpart at the best price. Second, exchange-traded contracts are cleared by a clearing house. Clearing is the process by which a trade—initially an agreement between two traders—is transformed into a commitment by each trader vis-à-vis the clearing house. In return for acting as a central counterparty, the clearing house requires each trader to deposit margins as collateral. Margins are updated daily in a way that eliminates traders' incentives to default. Thus clearing removes counterparty (default) risk.

Market rules vary across exchanges and instruments. Broadly speaking, there are two categories of market organization: floor-based trading (also known as open outcry) and electronic trading. In floor-based trading, traders meet in a single physical venue and shout the price at which they are willing to buy or sell. All orders are channeled through traders on the floor. In electronic trading, traders can, in principle, be located anywhere in the world. They sit behind a computer connected to the exchange and input orders into the market through their computers. Orders are matched on the basis of price and some time priority rule. For most of the 1990s, LIFFE was an open outcry exchange and DTB was an electronic exchange.

Participation in futures exchanges is restricted to members. Futures exchanges impose conditions on new members to ensure that their markets function smoothly. New members must prove their financial stability and clearing arrangements must be in place (i.e. the new member must be "approved" by the exchange's clearing house, or must have an agreement with a member of the clearing house). New members must take an exam confirming their knowledge of basic finance and of the exchange's market rules and code of conduct.

Corporate governance. Traditionally, exchanges were set up as member-owned and member-managed organizations. Members owned a seat and/or shares in the exchange. Recently, there has been a worldwide move towards demutualization and thus decoupling between ownership and membership. In particular, LIFFE demutualized in May 1999. Members of DTB were not shareholders.

11.2 Market participants and trading motives

Broadly speaking, we can distinguish between three trading motives: hedging, speculation and arbitrage. Futures trading was initially set up to hedge risk. A firm or individual with a commitment to deliver or buy a product or money in the future would be able to lock in the cost of this transaction today by buying or selling a future contract. Speculators trade on the basis of their forecasts about the future movements of prices: they take positions, hoping that prices will move in a direction favorable to them. Finally, arbitrageurs are traders who speculate on the basis of price co-movements between similar securities. For example, an arbitrageur might simultaneously buy a future on a 2-year bond and sell a future on a 5-year bond, hoping to derive a profit from the variation in relative interest rates.

Today and in most futures markets, pure hedgers are in the minority. Speculators and arbitrageurs dominate, due to the way future contracts are traded. At the time of the trade, no money is transferred. Only margins, often representing less than 2-3% of the value of the contract, must be deposited with the clearing house to guarantee the trade. Thus, very large positions can be taken, without having to commit significant financial resources. This leverage is unique to derivatives markets and explains their attractiveness to asset managers, investment banks, and hedge funds.

11.3 Cost of trading

The costs of trading on an exchange fall into three categories: adoption costs, fixed costs, and variable costs incurred when trading.

Adoption costs. Traders must be members of an exchange to be able to trade on it without using a broker. New members bear the cost of training their traders to use the exchange and the cost of satisfying all the financial requirements for being a member. In addition, some exchanges charge an admission fee or require that the new member buys a seat or shares in the exchange. Finally, a new member would need to organize her back office to keep track of trade orders, current open positions, commissions and margins. Together, these adoption costs are far from trivial. A March 1996 article estimated those set-up costs for a US-based trading firm wanting to join DTB at one million dollars.[29]

Fixed costs. Fixed costs include the annual fees members pay to the exchanges, as well as a series of fees in return for some service, independently of the amount traded. Those service fees are typically priced at cost and are not a source of profit for exchanges.

Variable costs. Variable costs of trading are made of three components: transaction fees, margins, and price impact costs. First, on each contract traded, a trader pays a transaction fee to the exchange and a clearing fee to the clearing house. Second, for each new open position a trader has, margins must be deposited at the clearing house.[30] LIFFE's clearing house did remunerate margins but DTB's clearing house did not. However, even when margins accrue interest, this return may be much lower than what a trader could generate elsewhere. Thus, margins generate an opportunity cost. Third, a trader may influence the price of the future when trying to buy or sell large quantities. The impact cost of a transaction is defined as the difference between the theoretical "equilibrium price" for the contract at the time of the transaction and the realized price for the transaction. Impact costs are related to the liquidity of a market. The more liquid a market is, the less specific orders affect prices. Figure 10 represents the impact cost of a ten-unit transaction in a liquid and less liquid market. The state of the market at a particular time is captured by the unmet demand and supply (this would correspond to the order book in an electronic order-driven market). These are closer to one another in a liquid market. The equilibrium price is defined as the average of the lowest unmet ask price and

[29] "DTB receives CFTC approval to install trading screens in U.S.", Securities Week, vol. 23, No. 10, 11 March 1996.

[30] A new position is opened when a trade does not cancel an earlier open position. For example, suppose that a trader buys a future contract at time t, and sells the same future contract at time $t+1$. From the clearing house's perspective, these two transactions cancel out and there is no residual default risk after $t+1$. In this case, margins will be required only for one day.

the highest unmet bid price. The figure illustrates that impact costs are higher in less liquid markets.

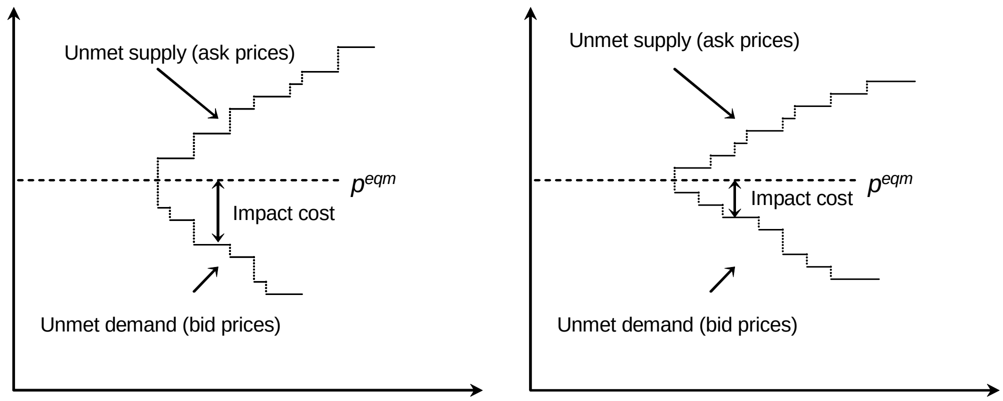

Figure 10: Impact costs in a less liquid (left panel) and liquid market (right panel)

The variable costs that a trader incurs depend on his trading behavior. First, some exchanges have different transaction fees for different classes of traders. For much of the 1990s, LIFFE had a reduced "scratch trade" transaction fee for traders trading on their own account, when they liquidated positions at the same price as the price at which they opened them, within the same day. The scratch trade fee was meant to encourage those traders to provide liquidity by reducing the penalty they bore in case they made no trading profit. Second, the opportunity cost of margins depends on the average length during which a trader keeps his position open. Day-traders for example are speculators who speculate on within day price movements. They close their positions every night, thereby foregoing margins completely. At the other extreme, hedgers will typically keep their positions open until maturity, and thus bear the opportunity cost of margins until then. Finally, impact costs depend on the size of trades a trader executes. The larger the transactions, the higher the impact costs, everything else equal.

Transaction fees, opportunity cost of margins and price impact costs were of comparable size for the Bund contract in the 1990's. Moreover, two different traders could rank the two exchanges differently on the basis of these variable costs as the following back-of-the-envelope calculation illustrates. Consider an average trader trading 10,000 contracts a month in April 1995. At that time, transaction fees were 0.45 £ on LIFFE (that is, the equivalent of 1 DM) and 0.50 DM on DTB. Initial margins were 3,500 DM on LIFFE and 5,000 DM on DTB. We consider two scenarios for the opportunity cost of margins. In the first scenario, the trader is a day trader who closes his positions at the end of the day. He does not need to deposit any margins. At the other extreme, the trader keeps on average a position open for 15 days. We assume a 3% opportunity cost of capital. Under this assumption, the opportunity cost of margin deposits for this trader were equal to $(1.03^{\frac{1}{24}} - 1) * 3500 = 4.3$ DM per contract on LIFFE and 6.2 DM on DTB. Finally, consider the impact cost. Suppose that DTB was less liquid in April 1995, meaning that 3% of the contracts were traded at one tick higher (or lower) than the best bid or ask, and that this number was only 2% on LIFFE. Given a tick size of 25 DM, this adds 0.75 DM to costs for DTB versus 0.50 DM for LIFFE. From a day-trader's perspective, the total average variable costs of trading were lower on DTB (1.25 DM per contract versus 1.5 DM). From the "long term" trader's perspective on the other hand, the cost comparison favored LIFFE (5.8DM versus 7.45 DM).

This example illustrates that the different components of variable costs are roughly in the same ball park: none dominates the others. It also illustrates that different traders may rank the exchanges differently on the basis of their trading costs. A similar example can be generated where the preference for one or the other exchange depends of traders' average transaction sizes and thus impact costs.

Table 3 – Multinomial logit for exchange choice (with substitution effect)

	(1)		(2) (product scope)		(3) (business types)		(4) (bus types + FE)		(5) (random coef)		(6) (random coef + FE)	
Variable	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Dev.	Coef.	Std. Dev.	Coef.	Std. Dev.	Coef.	Std. Dev.
Variable profits –single												
Volatility	2.27**	1.59	3.42**	1.64	14.31	5.32	None significant		2.21	0.68	2.13	1.06
					(0)	(0)			(1.92)	(2.11)	(1.92)	(2.26)
Extra-volume effect												
Own transaction fee	-0.0056**	0.0025	-0.0064**	0.0026	-0.014	0.006	-0.017	0.009	-0.0059**	0.0081**	-0.0057**	0.0080**
					(0.005)	(0.003)	(0.005)	(0.003)	(0.0029)	(0.0021)	(0.0029)	(0.0021)
Own margins	0.138	0.085	0.216**	0.091	0.370	0.130	0.612	0.156	0.217**	0.106**	0.196**	0.061
					(0.163)	(0.009)	(0.002)	(0.001)	(0.092)	(0.050)	(0.093)	(0.044)
Own liquidity	0.0015**	0.0006	0.0016**	0.0007	0.002	0.001	0.002	0.001	0.0013*	0.0008**	0.0012*	0.0009**
					(0.001)	(0.000)	(0.001)	(0.000)	(0.0007)	(0.0002)	(0.0007)	(0.0002)
Substitution effect												
Other transaction fee	0.0034	0.0021	0.0015	0.0022	0.011	0.005	0.007	0.007	0.0008	0.0003	0.0011	0.0046*
					(0.003)	(0.001)	(0.024)	(0.004)	(0.0022)	(0.0029)	(0.0023)	(0.0023)
Other margins	-0.256**	0.067	-0.264**	0.070	-0.270	0.149	-0.403	0.176	-0.166**	0.300**	-0.164**	0.268**
					(0.276)	(0.033)	(0.160)	(0.039)	(0.080)	(0.035)	(0.079)	(0.044)
Other liquidity	-0.0005	0.0007	-0.0010	0.0009	None significant		-0.002	0.001	-0.0011	0.0008	-0.0014	0.0016**
							(0.001)	0.000	(0.0010)	(0.0005)	(0.0010)	(0.0003)
Variable profits - both												
Volatility	6.64**	2.17	6.55**	2.27	9.49	5.20	None significant		1.05	2.22	1.00	1.43**
					(1.08)	(0.26)			(1.90)	(1.68)	(1.98)	(0.51)
Transaction fees	-0.0002	0.0029	-0.0032	0.0031	None significant		None significant		-0.0036	0.0013	-0.0037	0.0012
									(0.0034)	(0.0021)	(0.0034)	(0.0026)
Margins	0.0562	0.0969	0.1075	0.1015	-0.581	0.235	-0.891	0.435	0.0264	0.1323**	0.0113	0.1137**
					(0)	(0)	(0)	(0)	(0.1130)	(0.0539)	(0.1113)	(0.0402)
Liquidity	0.0010**	0.0004	0.0009	0.0005	0.002	0.001	0.003	0.001	0.0011**	0.0001	0.0009*	0.0009*
					(0)	(0)	(0.002)	(0.000)	(0.0006)	(0.0007)	(0.0006)	(0.0005)

Table 3 (continued)

	(1)		(2) (product scope)		(3) (business types)		(4) (bus types + FE)		(5) (random coef)		(6) (random coef + FE)	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Product scope – DTB												
Interest rate products			-0.087**	0.026	-0.0833**	0.0258	-0.087**	0.027	-0.090**	0.027	-0.093**	0.027
Equity			0.052**	0.023	0.0313	0.0240	0.035	0.025	0.036	0.025	0.041	0.025
Other			0.165**	0.068	0.1771**	0.0686	0.157**	0.070	0.161**	0.072	0.167**	0.073
Product scope – LIFFE												
Interest rate			0.0017	0.025	-0.0020	0.025	-0.0163	0.025	-0.0095	0.027	-0.0087	0.027
Equity			-0.0001	0.008	0.0056	0.008	0.0063	0.008	0.0006	0.008	0.0072	0.008
Other			0.0076	0.025	0.0010	0.026	-0.0007	0.026	0.0147	0.028	0.0085	0.028
Fixed fees	7.33 10^{-5}**	1.41 10^{-5}	5.23 10^{-5}**	1.63 10^{-5}	7.33 10^{-5}**	1.41 10^{-6}**	6.39 10^{-5}**	1.71 10^{-5}	5.26 10^{-5}**	1.71 10^{-5}	5.59 10^{-5}**	1.74 10^{-5}
Adoption costs – DTB												
Admission	-3.09 10^{-5}**	3.89 10^{-6}	-3.09 10^{-5}**	3.91 10^{-6}	-3.2 10^{-5}**	3.95 10^{-6}	-3.50 10^{-5}**	4.19 10^{-6}	-3.1 10^{-5}**	4.18 10^{-6}	-3.2 10^{-5}**	4.31 10^{-6}
Germany	-7.48**	0.24	-7.48**	0.24	-7.42**	0.24	-7.18**	0.27	-6.97**	0.27	-6.86**	0.29
EU 1/90-7/93	-11.51**	0.49	-11.49**	0.49	-11.40**	0.51	-11.12**	0.53	-12.13**	0.55	-12.10**	0.57
EU 8/93-12/95	-10.24**	0.53	-10.31**	0.53	-10.20**	0.54	-9.76**	0.55	-10.47**	0.57	-10.55**	0.59
EU 1/96-	-8.83**	0.22	-8.85**	0.22	-8.34**	0.23	-8.46**	0.25	-8.99**	0.27	-9.05**	0.28
France-NL 9/94-12/95	-6.61**	0.39	-6.74**	0.39	-6.69**	0.40	-6.83**	0.44	-6.77**	0.47	-6.74**	0.48
Switzerland 1/90-12/95	-10.23**	0.64	-10.22**	0.64	-10.32**	0.68	-11.00**	1.04	-11.03**	0.76	-10.83**	0.74
Switzerland 1/96-9/98	-10.62**	1.02	-10.69**	1.03	-10.26**	1.05	-12.17**	1.30	-11.41**	1.07	-11.42**	1.09
Switzerland 10/98 -	-6.19**	0.35	-6.05**	0.35	-6.66**	0.42	-7.20**	0.80	-5.34**	0.48	-5.36**	0.48
US 1/90 - 2/96	-10.19**	1.04	-10.19**	1.04	-10.00**	1.05	-9.96**	1.26	-10.96**	1.17	-10.84**	1.15
US 3/96 - 10/98	-7.26**	0.43	-7.42**	0.43	-7.17**	0.44	-6.79**	0.51	-7.49**	0.57	-7.62**	0.59
US 11/98 – 7/99	-9.17**	1.03	-8.88**	1.03	-8.93**	1.04	-8.31**	1.07	-8.90**	1.12	-8.75**	1.15
US 8/99 -	-6.07**	0.54	-6.27**	0.55	-5.88**	0.56	-5.85**	0.62	-6.30**	0.69	-6.07**	0.76

Table 3 (further continued)

	(1)		(2) (product scope)		(3) (business types)		(4) (bus types + FE)		(5) (random coef)		(6) (random coef + FE)	
Variable	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Adoption costs – LIFFE												
UK	-9.69**	0.16	-9.70**	0.16	-9.73**	0.17	-9.74**	0.18	-9.75**	0.20	-9.72**	0.20
EU 1/90 – 12/95	-13.33**	0.59	-13.33**	0.59	-13.22**	0.60	-13.59**	0.66	-14.14**	0.64	-14.33**	0.67
EU 1/96 – 7/98	-12.75**	0.60	-12.78**	0.60	-12.62**	0.60	-12.81**	0.66	-13.58**	0.68	-13.94**	0.71
EU 8/98 -	-12.19**	0.62	-12.20**	0.62	-12.05**	0.62	-12.10**	0.72	-12.83**	0.67	-13.47**	0.73
US 1/90 – 7/99	-12.13**	1.01	-12.13**	1.01	-12.22**	1.01	-12.07**	1.03	-12.96**	1.07	-13.13**	1.10
US 8/99 – 12/99	-9.74**	1.06	-9.88**	1.07	-9.83**	1.08	-10.28**	1.14	-10.50**	1.13	-11.21**	1.25
Exchange-specific time trend	Yes		Yes		Yes		Yes		Yes		Yes	
Exchange fixed effects	Yes		Yes		Yes		No		Yes		Yes	
Exchange-business-type-HQ fixed effects	No		No		No		Yes		No		No	
Loglikelihood	-2,672.76		-2,665.67		-2,597.50		-2464.86		-2615.13		-2611.10	
Pseudo R2	0.9516		0.9517		0.9530		0.9554		0.9527		0.9528	
N	39,844		39,844		39,844		39,844		39,844		39,844	

** indicates significance at 5%; * indicates significance at 10%. Liquidity is expressed in 10,000 contracts, fees in 0.01 DM and margins in 1000 DM. Time trend includes time, $time^2$ and $time^3$. Specifications (3) & (4): two numbers are reported for each variable profit component: the mean of the coefficients that turned out to be significant at the 10% level and their mean standard deviations (the terms in the parenthesis are the means of standard errors across trader types). Specification (3): For the single exchange coefficients, significant types for volatility are asset management; own fees are asset management and proprietary traders; own margins are specialized and proprietary trading; own liquidity and other fee are universal, retail and investment banks and asset management; other margins are all types but brokerage. For "both", significant types for volatility are universal banks and brokerages, margins are proprietary trading and liquidity are specialized traders. Specification (4): For the single exchange coefficients, significant types for own fees are brokerage and asset management; own margins are proprietary trading; own liquidity are universal and retail banks, brokerage and asset management; other fees are specialized trading and asset management; other margins are universal, retail and investment banks; othervol are universal and investment banks. For "both", margins are significant for brokerage and liquidity is significant for specialized trading and brokerage. Specification (5): random coefficients logit with normally distributed random coefficients for volatility, transaction fee, margins, and liquidity. Specification (6): same as specification (5) but with normally distributed random coefficients on exchange effects (estimates reported in Table 4). All random coefficients estimation based on 200 draws per month-group observation. The first row reports the estimated means and standard deviations of the coefficients in the population (the terms in the parentheses are the standard errors).

Table 5 – Multinomial logit for exchange choice (robustness)

Variable	(1) Default values		(2) Macro events		(3) Frequency of exchange choice	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
λ					1.0000**	0.1122
Adoption costs – DTB						
Admission	-2.89 10^{-5}**	5.41 10^{-6}	-3.75 10^{-5}**	5.17 10^{-6}	-3.24 10^{-5}**	3.94 10^{-6}
Germany	-8.16**	0.37	-6.59**	0.54	-7.43**	0.33
EU 1/90-7/93	-11.76**	0.57	-10.80**	0.71	-11.51**	0.51
EU 8/93-12/95	-10.69**	0.71	-9.44**	0.61	-10.06**	0.55
EU 1/96-	-9.17**	0.34	-8.52**	0.26	-8.80**	0.32
France-NL 9/94-12/95	-6.50**	0.51	-6.64**	0.49	-6.48**	0.44
Switzerland 1/90-12/95	-11.43**	0.81	-9.83**	1.05	-10.24**	0.66
Switzerland 1/96-8/98	-24.62	847.95	-11.10**	1.24	-10.48**	1.04
Switzerland 9/98 -	-7.17**	0.44	-7.41**	0.77	-6.52**	0.43
US 1/90 - 2/96	-10.95**	1.08	-9.43**	1.27	-10.19**	1.04
US 3/96 - 9/98	-7.74**	0.63	-6.68**	0.51	-7.25**	0.49
US 10/98 – 7/99	-8.76**	1.09	-8.47**	1.07	-9.08**	1.04
US 8/99 -	-8.16**	1.14	-5.99**	0.63	-6.06**	0.56
Adoption costs – LIFFE						
UK	-9.98**	0.22	-9.65**	0.17	-9.65**	0.30
EU 1/90 – 12/95	-13.50**	0.61	-13.42**	0.64	-13.31**	0.66
EU 1/96 – 7/98	-12.68**	0.62	-12.68**	0.65	-12.69**	0.65
EU 8/98 -	-12.20**	0.66	-11.97**	0.72	-12.10**	0.66
US 1/90 – 8/99	-12.25**	1.02	-11.95**	1.03	-12.08**	1.02
US 9/99 – 12/99	-26.06	3,631.51	-10.15**	1.14	-9.50**	1.06
Variable profits						
Volatility	2.74	1.70	12.49	4.36	2.20**	1.07
			(0)	(0)		
Transaction fee	-0.0062**	0.0028	-0.0110	0.0049	-0.0043*	0.0022
			(0.0005)	(0.0001)		
Margins	0.2110**	0.0965	0.3824	0.1286	0.1520**	0.0732
			(0.2586)	(0.0164)		
Liquidity	0.0019**	0.0008	0.0018	0.0008	0.0014**	0.0005
			(0.0003)	(0.0001)		

Table 5 (continued)

Variable	(1) Default values		(2) Macro events		(3) Frequency of exchange choice	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Product scope – DTB						
Interest rate products	-0.063**	0.030	-0.075**	0.024		
Equity	0.058**	0.028	0.066**	0.023		
Other	0.072	0.081	0.140**	0.064		
Product scope – LIFFE						
Interest rate	-0.019	0.031	-0.002	0.038		
Equity	-0.012	0.010	0.014	0.008		
Other	0.042	0.033	0.021	0.028		
Fixed fees	$4.81\ 10^{-5}$**	$2.06\ 10^{-5}$	$6.94\ 10^{-5}$**	1.92	$7.28\ 10^{-5}$**	$1.34\ 10^{-5}$
Exchange-specific time trend	Yes		Yes		Yes	
Event dummies	No		Yes		No	
Exchange fixed effects	Yes		No		Yes	
Exchange-business-type-HQ fixed effects	No		Yes		No	
Loglikelihood	-1,660.33		-2,501.26		-2.693.05	
Pseudo R2	0.9557		0.9547		0.9512	
N	27,063		39,844		39,844	

** indicates significance at 5%; * indicates significance at 10%. Liquidity is expressed in 10,000 contracts, fees in 0.01 DM and margins in 1000 DM. Time trend includes time, $time^2$ and $time^3$. Sample for specification (1) is restricted to firms for which we could establish that they traded interest rates products during the relevant period. Specification (2) allows for business-types specific coefficients on variable profits and for business-type and HQ specific exchange fixed effects. The reported top row numbers are the means of the coefficients and the means of their standard deviations for those coefficients that are significant at the 10% level. The bottom row numbers are the means of the standard errors on these numbers. The volatility coefficient on asset management firms is significant; the fee coefficients for brokerage and proprietary trading firms are significant; the margins coefficients are significant for investment banks and proprietary trading firms; the liquidity coefficients are significant for universal and retail banks and for brokerage and asset management firms.