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

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Abstract

This paper is an empirical investigation of the ways in which financial exchanges compete, through the lens of the competition that took place over ten years between two derivatives exchanges. We propose and bring to the data a new model of exchange membership that allows for intermediation and dual membership. Our panel dataset contains traders' membership status at each exchange together with trader characteristics, regulatory controls, and pricing, marketing and product portfolio strategies by each exchange over time. We document several dimensions of heterogeneity across traders that affect competition. We find that horizontal differentiation between the two exchanges dominates the vertical differentiation induced by liquidity effects. This phenomenon, which we interpret as the result of intermediation, reduces the importance of liquidity as a determinant of exchange competition and rationalizes the coexistence of different exchanges trading the same products.

Keywords: Platform competition, network effects, intermediation, multi-homing.

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1 Introduction

Are exchanges natural monopolies? This question has been debated at least since Demsetz (1968), who showed that transaction costs decreased with trading activity. In more modern jargon, traders value liquidity in financial markets and this creates a tendency for trading to concentrate on a single exchange (Admati and Pfleiderer, 1989, Pagano, 1989, Chowdry and Nanda, 1991). In practice however, trading of the same security on several exchanges is actually not uncommon. Theoretically, traders' heterogeneity in their value for liquidity offers the possibility for vertical differentiation where one exchange offers greater liquidity and charges more (Pagano, 1989). Horizontal differentiation and self-selection is another popular explanation for the coexistence of multiple trading venues for the same security (Economides and Siow, 1989), with support in the empirical finance literature (Barclay, Hendershott, McCormick, 2003, Reiss and Werner, 2005).

This debate has not been limited to academic circles however. In fact, the recent conversion of many exchanges from a user-owned to a for-profit structure, and the recent merger wave in the industry have reignited the policy debate on the subject. Witness, for example, the recent review of regulatory structure of the industry by the US Department of Justice (United States Department of Justice, 2007). The policy debate has taken the presence of strong network effects in trading as given and has focussed attention on aspects of the organization of the industry that can limit the anti-competitive consequences of such network effects (see e.g. Kleit and Falvey (2006)'s discussion of barriers to entry).

In this paper, we start from the simple observation that there are two ways to send trades to an exchange: to be a member of that exchange, or to go through an intermediary, i.e. a broker, who is a member. Consequently, we distinguish two levels of analysis of exchanges, the level of membership and the level of trading. We argue that these two "games" have very different economics: network effects (or, equivalently, liquidity effects), are strong in the trading game but not necessarily so in the membership game. This helps reconcile practitioners' claims that liquidity is paramount with the coexistence of trading in the same security on different exchanges.

Specifically, we argue theoretically that membership decisions are driven by liquidity *only to the extent* that traders trade more upon becoming members. At the level of membership, this reduces the importance of network effects relative to other differentiation factors. We then show empirically that horizontal differentiation factors are indeed more important than liquidity factors in explaining membership decisions at two derivatives exchanges during the 1990s. The fact that exchanges attract a different set of largely non-overlapping members explains the coexistence of trading of the same product on different exchanges.

Our analysis rests on the detailed analysis of a famous episode of financial history, the Battle of the Bund, during which two derivatives exchanges, LIFFE and DTB, competed fiercely for the market for the Bund, a future on the German long-term government bond and one of the largest derivatives contracts in the world. This is a very appropriate setting because the two exchanges competed on several dimensions during this period generating a good amount of variation in fees and other variables of interest. There was also great variation in their market shares (LIFFE, which was the incumbent, ended up losing the market entirely). Our dataset contains all the firms that were members of DTB or LIFFE at any point of time between January 1990 to December 1999, together with several characteristics of these firms. In particular, we have taken great care in tracking members' ownership structures as well as bankruptcy or any reorganization events such as mergers, so as to be able to identify occurrences of dual membership and occurrences of membership resignations and applications that are due to reorganizations, rather than due to the intrinsic value of a membership.

Our paper starts with a short description of the Battle of the Bund where we summarize the key characteristics of the two exchanges and describe the dimensions over which they competed: measures to jump start liquidity, product scope, transaction fees, trading technology and access.

Our theoretical model of membership choice, which we describe in section 3, integrates these dimensions while accounting for two structural features of the exchange industry: intermediation (the possibility to send a trade to an exchange without being a member) and non exclusive membership. We model exchanges as horizontally and vertically differentiated. Vertical differentiation may be exogenous (because one exchange provides an intrinsically better service) or endogenous (because one exchange attracts more trades and thus offer greater liquidity).

Intermediation in this setting has two consequences. First, members can continue to send some of their trades to the other exchange (and they will generally do so). As a result, the payoff from membership at one exchange also depends on trading profits made at the other exchange. Second, because traders could already send their trades to an exchange (using a broker) before becoming members, transaction fees, liquidity and other transaction-related aspects of an exchange are only relevant to the extent that traders trade more upon becoming a member. (We argue in the paper that this will generally be the case because membership allows traders to forego broker fees).

Section 4 describes the data. In addition to the trader dataset described above, we constructed a dataset of exchange characteristics over the same period. The end result is a panel dataset with traders' monthly membership status as a function of trader and exchange characteristics. This section provides preliminary evidence of horizontal differentiation: dual memberships remained limited during most of the decade and the two exchanges attracted different trader profiles.

The model we bring to the data is a close analogue of our theoretical model. It is described in section 5. We assume that traders reoptimize their membership status every month by playing a best response to past play using the previous period observed payoffs as an indication of their future payoffs. Because trader heterogeneity is an essential part of how exchanges may differentiate themselves from one another, we allow some coefficients to depend on trader characteristics.

Our findings regarding the way exchanges compete are as follows. First, we find evidence of traders' heterogeneity in how they value liquidity. Specifically, we quantify the transaction fee discount needed to compensate a trader for DTB's initial lower liquidity. It is large relative to transaction fee levels, and about twice as large for a high-liquidity valuer as for a low-liquidity valuer. Second, we find evidence that the two exchanges were also horizontally differentiated. Third, when we compare the levels of heterogeneity of traders' preferences for liquidity and for horizontal aspects of differentiation, we find that horizontal differentiation matters more: the best predictor of a trader's membership choice is his preference along the horizontal dimension, not his preferences for liquidity. We take this as evidence of the importance of intermediation in this industry: intermediation reduces the impact of transaction-related aspects in traders' membership decisions and, in particular, intermediation reduces the importance of network effects at the membership level. Finally, our results also shed light on the impact of alternative policy measures to foster competition in this industry. Access deregulation, a policy measure lauded for the success of DTB, did lower adoption costs to DTB but its pro-competitive effects were small relative to the alternative of waiving admission fees. Dual homing actually slowed down the entrant's increase in market share of members.

While our main purpose in this paper is *not* to explain why the market for the Bund actually tipped, our results do provide new perspectives on this question. First, our results cast doubt on two popular explanation for the success of DTB: access deregulation and political pressure on German traders. Neither hypothesis explains DTB's success in attracting new members. Second, we propose a new explanation for the tipping in members, and thus possibly for the tipping in trading: the population of traders changed during the 1990s in a way that favored DTB.

1.1 Related literature

Will be added at a later stage

2 The Battle of the Bund

This section summarizes the relevant aspects of the competition between LIFFE and DTB. It motivates our model, the choice of data we collected, and the hypotheses we consider for explaining the events.

2.1 The Bund

The Bund is a future (i.e. a promise to sell or buy) on the German long-term government bond contract.[1] 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 1 to 2% of the contract, at the clearing house associated with the exchange. These deposits, 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 Bund. When a trader has both short and long open positions, the clearing house only requests margins for the net open position. DTB and LIFFE used different clearing houses so that no netting was available

[1] Both the German long-term government bond and the future on the bond are referred to as the Bund in the industry. When it may not be clear which one we refer to, we will write explicitly "the Bund future" to refer to the future on the bond, and the "underlying Bund" to refer to the bond it-self.

between open positions in the Bund on LIFFE and on DTB. The contract specifications on LIFFE and on DTB were otherwise essentially the same.[2]

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 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, the biggest future on a government bond in Europe, progressively attracted traders hedging positions in 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.

2.2 LIFFE and DTB

LIFFE and DTB are two derivatives exchanges. LIFFE, which stands for the London International Financial Futures and Options Exchange, was established in 1982 as a member-owned derivatives exchange (LIFFE is now part of NYSE-Euronext). LIFFE initially organized markets for currency and interest rate contracts but later expanded into equities and commodities as well. They launched a Bund future contract in 1988. The contract became their second biggest contract within 6 months 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 (Kynaston, 1997, pp. 218-219).

Trading was initially organized exclusively by open outcry, which requires the physical presence of traders. In 1989, LIFFE introduced electronic trading for trading outside the regular hours. In 1999, after the loss of the Bund, the exchange switched 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. DTB first organized markets in equity derivatives and launched a Bund future contract on November 23, 1990. The contract immediately became their largest contract. DTB is now part of Deutsche Börse.

2.3 Dimensions of competition

The two exchanges competed fiercely for the Bund contract over 8 years. Figure 1 plots volume market shares and membership shares during this period. Accounts in the press and interviews with industry participants revealed that competition took place on at least 5 dimensions: coordination, transaction fees, product scope, trading technology, and access. Some of these dimensions, namely product scope, trading technology and access, induce horizontal differentiation between the two exchanges, while

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

transaction fees leverage vertical differentiation. Coordination suggests the presence of network effects. We briefly describe these dimensions of competition here.

Coordination. In light of the disappointing trading volumes on DTB at launch time, 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.[3] 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. While the Bund was clearly the key product for both exchanges, 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.

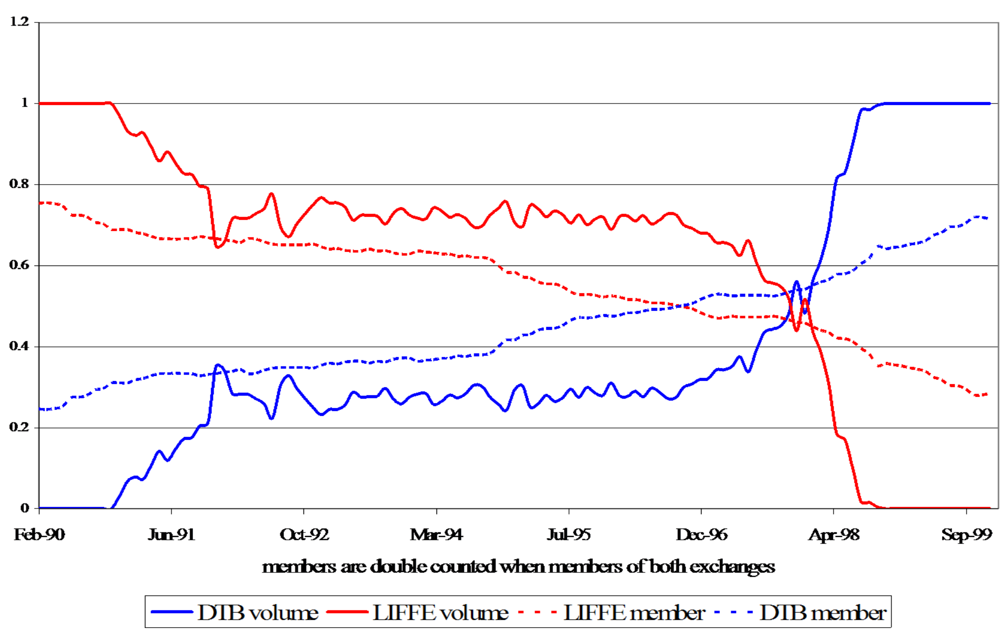

Figure 1: Market share of members and of Bund trading volume

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 shares. 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. Arguments in favor of open outcry markets were that they were better

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

at aggregating information in periods of high volatility and allowed for more complex strategies than electronic trading. Electronic trading on the other hand 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, 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: the French allowed all members of their national derivatives exchange to get remote access to DTB and the Dutch regulatory authorities allowed remote access to DTB for proprietary traders based in theNetherlands. In January 1996, the Investment Services Directive deregulated access entirely across the EU by making any exchange and investment firm authorized in one country of the EU authorized in all the other countries. This meant that a trader based in any country of the EU could access DTB remotedly. 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 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.

3 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 exogenous 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.[4] This is the source of network effects in our setting. In addition, the model allows for intermediation and dual membership, which, as we will argue, fundamentally change the economics of membership choice because these features further disconnect membership from trading.

[4] 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 (ADD REF)

3.1 Membership status, intermediation, 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, when he is a member of D. The payoff 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. the profits that do not depend on 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. Section 5.1 will describe 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, 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 payoff 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 the payoff 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 of 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 distinguish broadly between four trading motives: 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 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.

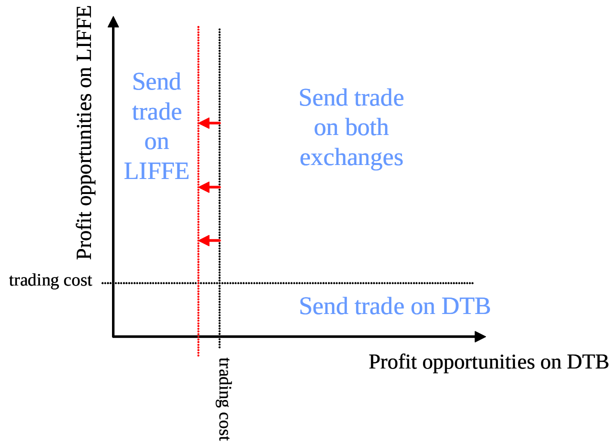

Figure 2: A speculator's decision rule for where to send trades

We now discuss how trading motives influence the magnitude of the extra volume and substitution effects. Consider first 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 take advantage of any trade opportunity as soon as it generates an expected return higher than the total cost of transaction. Such a decision rule is represented in Figure 2. Membership at an exchange decreases trading costs at that exchange because it eliminates broker fees. In Figure 2, 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 but, importantly, not on transaction costs. The argument for arbitrageurs is similar, leading to the same conclusion, except for those arbitrageurs doing arbitrage between the Bund on DTB and the Bund on LIFFE. For those, membership at one exchange may also induce more trades on the other exchange.

At the other extreme, a hedger's 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 of which he is a member. As a result, this trader will channel a larger proportion of the trades to that exchange. The total trading volume should 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 the extra volume effect and the substitution effect depend on the trading motive, 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:

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

Note that the normalized utility from membership on both involves two extra volume effects. Moreover, absent substitution effects, the extra volume effects in the dual membership equation should be equal to the extra volume effect in equation (3).[5] This property will be used when interpreting our empirical results.

3.2 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. On the one hand, trading influences the liquidity of a market which reduces transaction costs and thus raise per-unit profit, π_D or π_L. This increases the attractiveness of an exchange membership. In that sense, *trading drives membership.* On the other hand, membership influences trading on an exchange because traders trade more upon becoming members. Thus, *membership also drives trading.*

While this is reminescent 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 drops out of the membership decision in equations (3) and (5). From an economics perspective, this means that network effects are less important in the "membership game."[6] From an estimation perspective, this leads to a different structural interpretation

[5] Indeed, in the absence of substitution effect $\text{vol}_D(B) = \text{vol}_D(D)$.

[6] However, as long as membership induces a trader to trade more, network effects remain present. This is in contrast with Galetovic and Zurita (2002), where traders *must* go through a broker to access an exchange (there is thus no membership and no network effects at the exchange level).

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 (recall that total trading volumes grew tenfold over our sample period). Second, absolute individual trading volume may vary directly with transaction cost drivers such as fees. Extra trading volume depends on the distribution of profit opportunities, so it only indirectly varies with transaction cost drivers. We exploit these properties and the timing of membership decisions in our empirical 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 per-unit profit π_L and π_D, the way extra volume and substitution coefficients 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 to differ in their choice of exchange membership as soon as they differ in the size of their extra trading volume and substitution effects. 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 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 and their variation across traders.

Finally, dual membership means that traders have an additional option relative to being a member of LIFFE or of DTB. This 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 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 shares will depend on the size of these two effects. In particular, if the benefits from a single membership at DTB tend to be lower than the benefits of a single membership at LIFFE, 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 (ADD REFERENCES). Note that our model allows for membership at the two exchanges to be complements or substitutes in case $\Delta U_D + \Delta U_L \neq \Delta U_B$. When exchange memberships are substitutes, the effect of dual membership on competition will be smaller. We will revisit these questions when we discuss our empirical results.

4 Data

Our data cover the 1990-2000 period and contain exchange actions and characteristics, as well as detailed information of every firm that ever became a member of any of the two exchanges during that time period.

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. In our data, these fees and margins were the same for all traders at all times, with a single exception: on LIFFE, locals (i.e. traders on the floor, trading on their own account) could benefit from a reduced fee if they bought and sold a contract at the same price, within the same day. Second, exchanges charge annual fees for membership. Third, exchanges, and DTB in particular, charged new members a one-time admission fee.[7] Membership gives a trader a direct access to the market.

For both exchanges, we collected the following monthly data: (1) admission fee, (2) annual membership fee, (3) transaction 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 daily yields for the underlying Bund contract and constructed a monthly measure of volatility of the underlying Bund contract (the monthly standard deviation of the daily 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 regulatory changes concerning access and approval in other countries and 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 in trading volumes. We smooth out these cycles by considering three-month moving average trading volumes.

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

[INSERT TABLE 1 HERE]

[7] LIFFE did not charge an admission fee but new members needed to acquire a share of the exchange to become a member. The price of such shares varied over time but is not observed.

4.2 Trader data

We obtained from each exchange a list of members with the 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.

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%) individual establishments and 59 groups (10.2%). 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.

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, become 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" from now on. We further drop the 25 traders for which we do not have any information, and the 35 traders who never trade interest rate products. This leaves 518 traders. On average, 334.82 traders are present in any given month (min = 300, max = 382, std. deviation = 24.92).

Business types. 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, 112 traders have their headquarters (HQ) in Germany, 32 in Switzerland, 105 in the UK, 136 in the rest of Europe, 92 in the US and 41 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.

[INSERT TABLE 2 ABOUT HERE]

Initial evidence of exchange differentiation. 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 management firms represent a larger fraction of membership 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 at DTB.

Patterns of new memberships over time. Table 2 hides the variation over time in the entire population of traders and members of each exchange. Figure 3 plots the number of traders that were members of LIFFE, DTB, both or no exchange over time. Figure 3 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 282 new members of DTB over this period, 209 (74%) were not members of any exchange at the time of joining.

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 exchange.

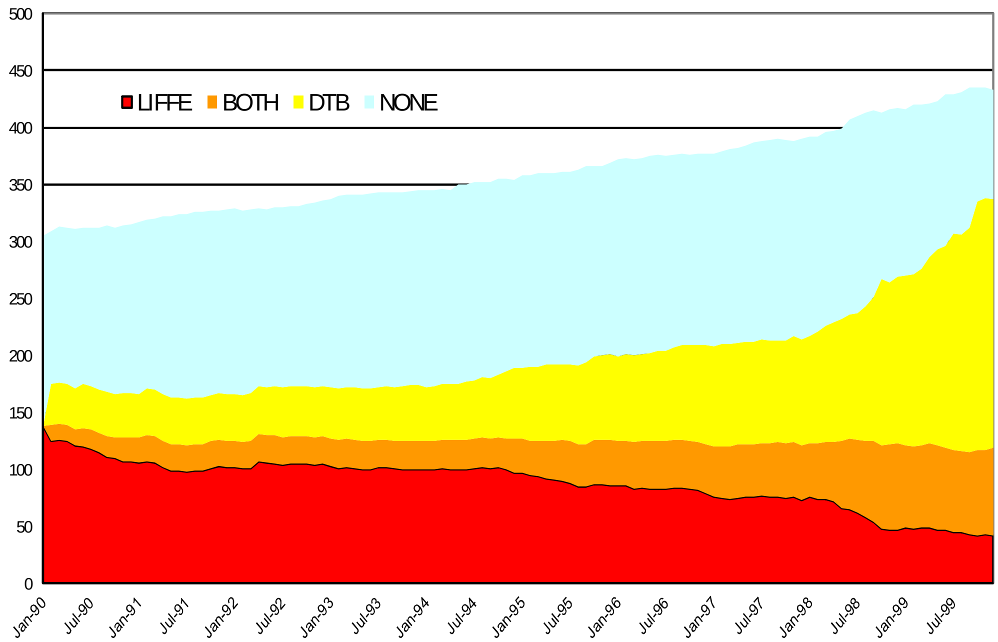

Figure 3: Membership status of traders over time

Figure 3 also shows an increase in the population of potential exchange members over time.[8] This increase was accompanied by changes in the *composition* of the trader population. There was a relative increase in the proportion of proprietary trading firms over the decade, mainly at the expense of retail banks and investment banks. The geographic composition of the trader 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 changes in membership status is 497. Given that our dataset controls for group ownership and group entries and exits, these membership status changed can be exclusively attributed to changes in traders' valuation of exchange membership.[9] Among the 518 groups present in our data, 134 never change membership status over the entire period during which they are present, 294 change status once, 73 change status twice, 11 change status three times and 6 change status four times. Approximately 17.5 % of groups undergo at least two status changes. This

[8] 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.

[9] In other words, membership resignations due to bankruptcies or membership rationalization following a merger are not counted in this number. Likewise, decisions by traders to add another membership from another location in addition to their existing membership are not counted. As a benchmark, the number of membership changes would be equal to 761 if we did not correct for those cases and instead took establishment memberships as our unit of observation.

is not a trivial number. It motivates our empirical model where membership decisions are reversible.

5 Econometric model

The econometric model that we bring to the data is a close empirical analogue of the model in Section 3. The unit of observation is a trader's choice of membership in a given month. 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 that allows traders to 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 specification

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). We observe

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

where $A_{it}(k, \omega_{it-1})$ accounts for the adoption costs for a new membership and $\theta_i X_{ikt} + \varepsilon_{ikt}$ gathers the fixed and variable components of profits.

Each month, traders reconsider their membership status. For simplicity, 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. 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.[10] Adaptive play is also consistent with the descriptive evidence. Because adaptive 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. In addition, Figure 3 shows an acceleration in the number of DTB members just *after* tipping in trading volume occurred. An interpretation of this pattern is that those traders were more reactive in their choices of an exchange than forward-looking.

The adoption cost in (6) represents one departure from the simple theoretical model of Section 3. It accounts for the fact that joining an exchange as a member is costly. In addition to the admission

[10] 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. Cabral (1990) shows that adaptive play converges to the minimum coordination equilibrium. Gerber and Bettzuge (2007) find that, as the market grows large, trading on multiple exchanges is the most likely outcome.

fee charged by the exchange (or the purchase of LIFFE shares for a membership at LIFFE), joining an exchange 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. Adoption costs are allowed to vary with the trader's identity, the exchange and time because access deregulation affected exchanges and traders (due to their location) differently over time.[11]

The terms $\theta_i X_{ikt} + \varepsilon_{ikt}$ in (6) are the empirical analogue of (3) and (5). They capture both the fixed component of profits and profits derived from the trader's trading activity in the Bund. We assume that the per-unit trading profits (the analogue of π_D and π_L) depend linearly on the volatility of the underlying Bund contract, transaction fees, margins and a measure of the liquidity of the market:

$$\pi_{ikt} = \alpha_{1i}\text{volatility}_t + \alpha_{2i}\text{fee}_{kt} + \alpha_{3i}\text{margins}_{kt} + \alpha_{4i}\text{liquidity}_{kt} \tag{7}$$

Volatility is a proxy for traders' revenue opportunities. It is defined as the standard deviation in the daily yields of the underlying Bund contract. 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, higher volatilities also 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 exchange transaction fees, which obviously represent a cost of trading. Fees vary across exchanges and time.

Margins record the required deposit traders need to make every time they open a new position. Each exchange sets their own margins depending on their own assessment of risk. 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 3-month average trading volume as our proxy for the liquidity of an exchange.[12] A higher level of liquidity reduces the impact that a single trade has on the market and thus reduces

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

[12] 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 and not available for open outcry. 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. 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. Note that we played with different functional forms of volume to allow for decreasing returns to volume, but these were rejected based on specification tests.

what traders refer to as the "impact cost." Different traders value liquidity differently, depending on their trading behavior (in particular, the size of their transactions) suggesting that the coefficient on trading volumes 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 implies that we should control for the per-unit revenue and cost drivers (volatility, fees, margins and liquidity) of *both* exchanges in *each* equation (cf. equation (3)). Another implication is that these drivers are multiplied in the regression by the extra volume effect and the substitution effect, which affects their structural interpretation. We assume that the extra trading volume and the substitution effect are constant over time and that they are equal on LIFFE and DTB and denote the (individual exchange) extra volume effect by Δvol_i and the substitution effect by $\Delta\text{volsubst}_i$.[13] Then, the coefficients we estimate on the volatility, fees, margins and liquidity on exchange k in the equation for the payoff from a membership at that exchange are respectively $\Delta\text{vol}_i\alpha_{i1}$, $\Delta\text{vol}_i\alpha_{2i}$, $\Delta\text{vol}_i\alpha_{3i}$, $\Delta\text{vol}_i\alpha_{4i}$. Likewise, the coefficients on the volatility, fees, margins and liquidity on the other exchange in that same equation are, respectively, $\Delta\text{volsubst}_i\alpha_{i1}$, $\Delta\text{volsubst}_i\alpha_{2i}$, $\Delta\text{volsubst}_i\alpha_{3i}$, $\Delta\text{volsubst}_i\alpha_{4i}$.[14] 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. 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 because $\Delta\text{vol}_i = 0$ in that case. 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 that other exchange. This restriction is imposed in the estimation.

5.2 Distributional assumptions

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

There are two reasons why trading volumes could be correlated with the error term. The first reason

[13] In the notation of Section 3, $\Delta\text{vol}_i = \text{vol}_D(D) - \text{vol}_D(0) = \text{vol}_L(L) - \text{vol}_L(0)$, and $\Delta\text{volsubst}_i = \text{vol}_D(L) - \text{vol}_D(0)$ $= \text{vol}_L(D) - \text{vol}_L(0)$ (for the option "B", we assume that the extra trading volume is the same on both exchanges: $\text{vol}_D(B) - \text{vol}_D(0) = \text{vol}_L(B) - \text{vol}_L(0)$).

[14] Because coefficients on these profit drivers for the exchange which the trader is joining are related to those for the other exchange, the ratio of estimated coefficients on volatility should be the same as the ratio of estimated coefficients on fees, ... and so on. This forms the basis of a specification test, which we exploit in the next section.

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, and our behavioral assumption, eliminate this potential problem. In our model, membership decisions for period t are taken on the basis of period $t-1$ data. A trader's future *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 an 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 as we control for trading volumes and volatility of the underlying Bund contract.

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.[15] 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 empirical model cannot however fully disentangle the variable profit from the fixed profit components because we do not observe individual trading volumes nor the broker fees. As a result, the last terms in equations (3) and (5) are estimated together with the fixed profit component in the time trend and the exchange fixed effects.

The coefficients on the variable profit drivers are identified from variation in these drivers over time and across exchanges. Of note, separate coefficients on volatility (one for the extra volume effect and one for the substitution volume effect) can be identified even though volatility does not vary across exchanges, because the Bund was traded on a single exchange during some part of the sample (in which case only the extra volume is relevant when the exchange a trader joins trades the Bund, whereas both the extra volume and the substitution volume are relevant otherwise).

Finally, a natural question that arises is whether we can separately identify if dual membership is caused by complementarities between the two exchanges or because unobserved trader-specific profit shocks for each exchange are correlated. Gentzkow (2007) has recently nicely summarized the em-

[15] The same argument can be used to argue that the fact that we do not observe the entire population of traders will cause us to *underestimate* adoption costs but will otherwise not bias profit levels estimates since we observe *all* the traders that ever became members or resigned during the sample period.

pirical challenge. He argues that both effects can be distinguished in a panel dataset 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 assumption that the error term ε_{ikt} is i.i.d. extreme value across time, exchanges and traders, the probability of observing membership choice $\omega_{it} = k$ for trader i at time t, conditional on ω_{it-1} is given by

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

Denote by $\underline{t}_i$ the first time trader i appears in our data, and by $\bar{t}_i$, the last period it appears. The probability of observing sequence $\omega_{i\underline{t}_i}, ..., \omega_{i\bar{t}_i}$ of membership status for trader i is given by

$$\textstyle\prod_{t=\underline{t}_i}^{\bar{t}_i} \Pr(\omega_{it}|\theta_i, A_{ikt}; \omega_{it-1}). \tag{9}$$

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 their trading motives. 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 type and force the coefficients to be the same within each group. As a second approach, we assume that the trader-specific coefficients in θ_i are independently distributed from the variables in X_{ikt}, A_{ikt}, $\omega_{i\underline{t}_i}$, 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 a functional form for its distribution.

To disentangle dual membership driven from complementarities across exchanges rather than correlation, we allow for exchange "fixed effects" to be correlated across exchanges. Specifically, let θ_{Di} , θ_{Li} , θ_{Bi} denote the exchange fixed effects for trader i. We assume that:

$$\begin{bmatrix} \theta_{Di} \\ \theta_{Li} \end{bmatrix} \sim N\left(\begin{bmatrix} \mu_D \\ \mu_L \end{bmatrix}, \begin{bmatrix} \sigma_{DD} & \sigma_{DL} \\ \sigma_{DL} & \sigma_{LL} \end{bmatrix} \right) \text{ and } \theta_{Bi} = \theta_{Di} + \theta_{Li} + \mu_B \tag{10}$$

This yields 6 parameters to estimate $(\mu_D, \mu_L, \mu_B, \sigma_{DD}, \sigma_{DL}, \sigma_{LL})$.

Coefficients on variable profit terms are modelled as the product of two normal random variables, one that is specific to the profit driver, and the other that is common to the four profit drivers and captures the correlation induced by the extra volume or substitution effect. Specifically, let h index the specific profit driver (i.e. volatility, fee, margins or liquidity). Focusing on the "extra volume" part of the payoffs, we model $\theta_{hi} = \alpha_i \beta_{hi}$ where $\alpha_i \sim N(1, \sigma_\alpha)$ and $\beta_{hi} \sim N(\mu_{\beta_h}, \sigma_{\beta_h})$. The parameter σ_α measures the degree of correlation between the different profit coefficients.

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 (ADD REFERENCES)

6 Results

We now describe our regression results and discuss their implications for the economics of exchanges. The results lend support to our model of exchange choice with intermediation and confirm the presence of trader heterogeneity in their value for trading the Bund and other exchange services, as well as in adoption costs. Intermediation reduces the relative importance of network effects - through liquitity - at the level of exchanges. In addition, when we quantify trqder heterogeneity along these different dimensions, we find that heterogeneity in dimensions that induce *horizontal differentiation* dominates heterogeneity in dimensions that induce *vertical differentiation*.

To recall, our unit of observation, which we call a trader, is the monthly membership status of all active trading groups that (1) were members of any of the two exchanges during any period between 1990 and 2000 and (2) traded interest rate products during that time. Table 3 reports the results from four specifications. The first two specifications impose common coefficients on all variables for all traders, except for adoption costs which vary by location and the state of access regulation. The other two specifications allow for heterogeneity in traders' value for trading the Bund and value for other exchanges services. All specifications include an exchange-specific time trend and control for adoption costs, the fixed fees charged by the exchanges, and the number of products traded in each category (interest rate, individual stock options, others).[16]

Before describing the results in details, some introductory comments on the overall fit of the model are in order. 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 497 changes in membership out of $39,844$ observations, a high R^2 can be explained by setting high adoption costs: high adoption costs together with stable profits would result in a low number of status changes. To better assess the fit of the model, we

[16] These variables are meant to capture the attractiveness of the exchange due to their product scope. We use product counts rather than trading volumes in these other products to better capture the *extra* advantage from membership (recall that payoffs from non membership is normalized to zero). We distinguish between products of different categories because trading volumes vary a lot across asset classes.

consider alternative measures that focus more specifically on the way the model predicts changes in membership status.

The first set of alternative measures assess, *conditional on traders changing membership status*, how well the model predicts the actual choice. The conditional pseudo-R2 measures how well, conditional on traders changing membership status, the model predicts the chosen alternative, relative to a purely random choice among the three remaining alternatives.[17] The conditional pseudo-R2 ranges from 0.675 in specification (1) to 0.707 in specification (3). This is quite high. (As a benchmark, a simple multinomial logit regression of specification (1) restricted to the 497 observations when traders change membership status yields a pseudo-R2 of 0.700.) Alternatively, we also compute the mean predicted probability (conditional on changing membership status) of the actual choice. These range from 0.790 to 0.810.

The second set of alternative measures assess how well the model predicts traders' changes of membership status. The mean predicted probability of a change of membership status in any given trader-month varies from 0.0123 to 0.0124 which is very close to the actual number in our data, 0.0125 (497/39,844). If we restrict attention to those trader-month observations where traders did change membership status, this number goes up 0.0669 in specification (1) to 0.0710 in specification (3). If, instead we restrict attention to those trader-month observations without transitions, these numbers go down to 0.0118 in specification (1) to 0.0117 in specification (3). Put differently, membership status changes are predicted to be six times more likely during the months when such change happens than outside these months. This quantifies the sense in which variations in explanatory variables explain the *timing* of membership status transitions.

[INSERT TABLE 3 ABOUT HERE]

6.1 Evidence for network effects and intermediation

We start our description of the results by discussing the estimates on variable profit drivers: volatility, fees, margins and liquidity (top panel of Table 3). As a benchmark, specification (1) assumes that there there are no substitution effects so that only the extra volume effect is estimated on these profit drivers.[18] In this specification, margins and liquidity are significant. Volatility and fees have the expected sign but are not statistically significant. The coefficient on margins is positive, suggesting that higher margins increase trading profits. This contradicts the interpretation of margins as generating an opportunity costs of money but can be rationalized by the fact that margins are related to the

[17] Formally, it is equal to $1-\frac{\log\prod_{(i,t)} p_{it}(\theta)}{n\log\frac{1}{3}}$, where n is the number of status changes, $p_{it}(\theta)$ is the predicted probability of the actual choice (given parameter θ) and the product is taken over all (i,t) pairs that correspond to a change in membership status.

[18] When there are no substitution effects, a trader's trading activity at one exchange does not depend on his membership status at the other exchange and thus the extra volume effect from joining one exchange or from dual membership is the same. They are estimated as such and the reported coefficients on the extra volume effect apply a single membership as well as a dual membership.

volatility of the underlying contract, and this volatility generates profit opportunities. Anticipating the results from the other specifications, we interpret the consistently positive coefficient on margins across specifications as the result of margins also proxying for profit opportunities. Liquidity is significant and positive as expected, suggesting that higher liquidity lowers trading costs and increases trading profits, and confirming the presence of network effects.

Adding the possibility of substitution (specification (2)) does not affect the overall fit of the model nor the coefficients on the other variables very much. Two elements suggest substitution effects are present nevertheless. First, we can reject the hypothesis that substitution effects are not present on the basis of a standard LR test. Second, coefficients on the extra volume effect become more significant and they become slightly larger, once we allow for substitution effects. This is especially the case for volatility, which does not vary across exchanges. The higher coefficient (relative to specification (1)) on volatility in the extra volume effect is compensated by a negative coefficient on volatility in the substitution effect. This is consistent with the presence of substitution effects because when substitution effects are not included in the regression, the coefficients on the extra volume effect capture the *net* volume effect of membership. (Another implication of the model with substitution effects is that the ratio of the coefficients on the extra volume effect and on the substitution effect should be equal for all profit drivers. This provides the basis of a specification test. We cannot reject this hypothesis at the 10% confidence level).

Interpreting both pieces of evidence in light of our model, we can already conclude that traders do trade more upon becoming members (significant extra volume effects) and that traders also access exchanges through intermediaries.[19].To evaluate the economic consequence of these effects, we compute the relative importance of the differential profit from membership induced by the liquidity differential between the two exchange. Specifically, we compute the ratio between $\theta_{\text{LIQ}}(\text{vol}_D - \text{vol}_L)$ and the difference between the mean flow profit at DTB and at LIFFE, for different months. Table 4 shows that liquidity differences between the two exchanges represent less than 20% of the differences in flow utilities for most of the sample period. This is consistent with liquitity being less important in the membership game, because of the presence of intermediation.

[INSERT TABLE 4 ABOUT HERE]

6.2 Trader heterogeneity

While the lower relative importance of network effects in the membership game provides a first explanation for exchange coexistence; it does not in itself explain what drives this coexistence. To do this, we next explore the nature of trader heterogeneity in our data. Specification (3) allows coefficients on the extra volume effect and on exchange fixed effects to depend on traders' business types.[20]

[19] Note also that the significant extra volume effect and the small substitution effects are consistent with speculation and brokering being the key trading motive.

[20] We keep coefficients on substitution effects and the extra volume effect for both exchanges common to all traders. We also ran regressions when business-specific effects were estimated for the substitution effect and the extra volume

For these coefficients, Table 3 reports the population means and standard deviations, as well as the standard errors on these means and standard deviations. The mean coefficients are very similar to the coefficients in specification (2), but now the results indicate the presence of statistically significant heterogeneity across business types for all extra-volume effects, and for the exchange fixed effects (significant population standard deviations).

As an alternative way of capturing trader heterogeneity (and, in particular, one that does not assume an a priori source of heterogeneity), specification (4) estimates coefficients on variable profit drivers and exchange effects as random coefficients, using the distributions described in Section 5.4. The parameter estimates for these distributions are given in Tables 4 and 5. Resulting population means and standard deviations are described in Table 3.

[INSERT TABLES 5 AND 6 HERE]

The population mean coefficients and the overall fit of the model are very similar in either specifications (3) or (4). Trader heterogeneity as captured by population standard deviations for extra volume effects are somewhat lower in specification (4) and not always statistically significant, unlike in specification (3). By contrast, trader heterogeneity captured by the population standard deviation on exchange effects are all significant and larger than in specification (3).

Both specifications indicate that traders are heterogenous in their valuations for exchange characteristics. Such heterogeneity offers an opportunity for the exchanges to differentiate themselves horizontally or vertically. Specifically, there is scope for vertical differentiation because liquidity matters (i.e. the coefficients on liquidity is significant) *and* traders care about liquidity differently. Likewise, there is scope for horizontal differentiation because adoption costs vary across geographies (which will confirm below) and traders attach different values to exchanges characteristics, as captured by the exchange fixed effects.

We now explore the *economic* significance of this heterogeneity. To quantify the importance of traders heterogeneity in their value for liquidity, we first 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 liquidity and fees respectively in the extra volume effect, and let Δvol describe the difference in trading volumes between the two exchanges at a given point in time. To compensate trader i for his lower liquidity level, DTB would need to cut fees by Δfee $= \theta_{\text{LIQ},i}\Delta\text{vol}/\theta_{\text{FEE},i}$. Table 7 reports this fee discount at different points in time and for each quartile of the distribution of the liquidity coefficient (the coefficient on fees is set to its mean value), based on specification (4). Table 6 quantifies trader heterogeneity in terms of liquidity: attracting a high-liquidity valuer requires a discount approximately 33% bigger than attracting a low-liquidity valuer. For comparison, Table 6 also reports the actual fee discount offered by DTB during this period. For

effect for dual membership, but these tended to be poorly identified and we could not reject the hypothesis that they are equal for all traders.

most of time, the fee discount offered by DTB was at least as large as the fee discount needed to attract at least the low liquidity valuers.

[INSERT TABLE 7 ABOUT HERE]

Because the ratio $\theta_{\text{LIQ},i}/\theta_{\text{FEE},i}$ is not statistically significant however, the numbers in Table 7 are only indicative of the *economic* significance of trader heterogeneity in their value for liquidity. As another perspective, we perform the following thought experiment. Using specification (4), we set all coefficients, except for the coefficient on liquidity and the trader exchange effects, equal to their point estimates (or their mean values in case of random coefficients). The payoff from an exchange membership at DTB and LIFFE can then be expressed as:

$$\begin{aligned}\Delta U_{Di} &= \theta_{\text{LIQ},i}\text{vol}_D + \theta_{Di} + \text{REST}_D \\ \Delta U_{Li} &= \theta_{\text{LIQ},i}\text{vol}_L + \theta_{Li} + \text{REST}_L\end{aligned}$$

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 ($\theta_{\text{LIQ},i}$, $\theta_{Di} - \theta_{Li}$) fully pins down his choice between DTB and LIFFE.

In Figure 4 we plot the locus of trader attributes ($\theta_{\text{LIQ},i}$, $\theta_{Di} - \theta_{Li}$) that make traders indifferent between LIFFE and DTB (the $x-$axis is $\theta_{Di} - \theta_{Li}$, and the $y-$axis is $\theta_{\text{LIQ},i}$).[21] Trader attributes are independently distributed and the extremes of the box on each dimension correspond to the 0.5 and 99.5 percentiles respectively.

[21] Formally, the locus is defined as $\theta_{\text{LIQ},i} = \frac{1}{\Delta\text{vol}}(\theta_{Di} - \theta_{Li}) + \text{REST}_D - \text{REST}_L$. The locus changes over time as Δvol, the difference in trading volumes, and the other exogenous variables gathered in $\text{REST}_D - \text{REST}_L$ change over time.

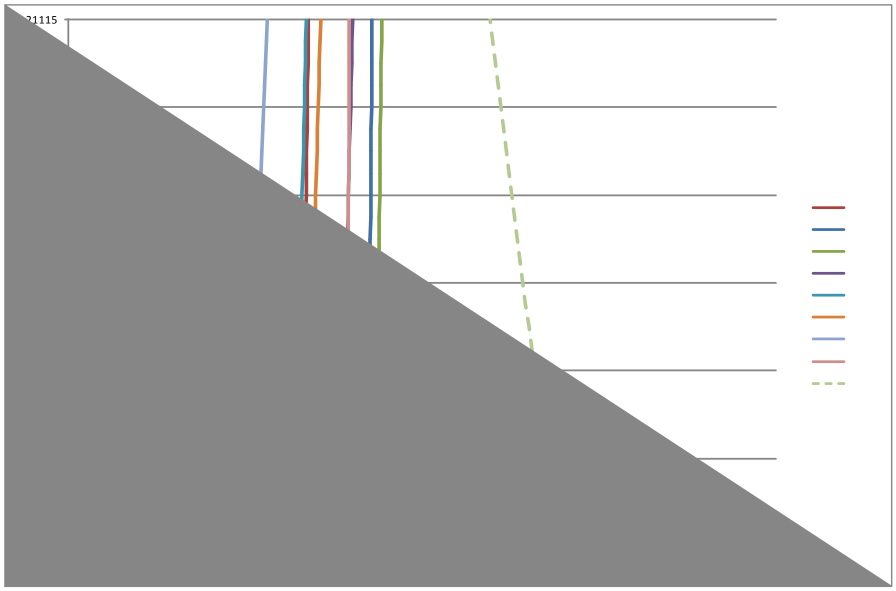

Figure 4: Trader relative heterogeneity along the vertical (liquidity) and horizontal (exchange fixed effects) dimensions.

What is remarkable about Figure 4 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, tfigure 5 quantifies the relative importance of trader heterogeneity on the liquidity (i.e. vertical) 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.

6.3 Adoption costs

We now turn to the adoption costs estimates (second half of Table 3). They are all negative as expected, highly significant, and very stable across specifications. They also vary across geography and time as expected. Specifically, adoption costs for DTB are lower for traders with a presence in Germany and, likewise, adoption costs for LIFFE are lower for traders with a presence in the UK. Within a geography, adoption costs decline as access deregulation progress. For example, adoption costs to DTB for traders with a presence in the EU (but not in Germany) drop significantly after the implementation of the Investment Services Directive on 1 January 1996 (comparison of the coefficients on EU 1/90 - 7/93, EU 8/93-12/95 with those of EU 1/96 -). Likewise, adoption costs for DTB decrease for traders based in the US (and without a European presence) when remote access is authorized in

April 1996. They go up again when this authorisation is upheld in November 1998 (comparison of the coefficients on US 1/90-3/96, US 4/96-10/98, US 11/98-7/99 and US 8/99).

Until November 1997, total adoption costs to DTB are not significantly different from adoption costs to LIFFE, except for traders with a presence in Germany, and traders with a presence in France or the Netherlands during the 9/94 - 12/95 period.[22] Starting in November 1997, when DTB eliminated its admission fee, total adoption costs to DTB become lower from all locations. This may explain the acceleration of new memberships to DTB after November.

Access deregulation, combined with the fact that DTB was an electronic exchange, has been heralded as one of the key factors that explain DTB's success during the Battle of the Bund (see Bessler et al. 1996). We can 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 their levels at the beginning of the period. The estimates are taken from specification (3) in Table 3. So, for instance, adoption costs for EU countries are set equal to -11.606, the coefficient on "EU 1/90 - 7/93" 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.

[numbers and graphs must be updated: the earlier results showed a small economic impact of access deregulation]

6.4 Dual membership

Because traders can choose to be a member of both exchanges, a natural question that arises concerns the competitive consequences of dual membership. Specification (3) allows us a first investigation into this question. Let γ be the difference between the fixed effect for dual membership and the fixed effects for LIFFE and DTB. γ measures the level of complementarity and substitution between LIFFE and DTB. A positive γ means that membership at both exchanges is complementary. A negative γ means the two exchanges are substitutes. Computing the value of γ for each business type, we find that γ is positive and significant for universal banks. It is not significant for any other business types.

Specification (4) provides an alternative measure of complementary between exchanges. [describe the results]

7 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

[22] Recall that, until November 1997, DTB charged an admission fee which must be added to time and geographic specific adoption costs

of the eventual success of DTB: access deregulation overwhelmingly favored DTB (Section 6.4 shows that the effects of access deregulation were 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. A later version will describe both findings in greater details.

8 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 relative contribution of these different factors to the demand for exchanges and ultimately to the way exchanges compete. One novel aspect of our analysis is the distinction between the economics of trading and the economics of membership. Intermediation makes these two facets in which exchanges compete very different. In particular, we find that trader horizontal heterogeneity is much more important than traders' heterogeneity in terms of value for liquidity in explaining their membership choice. This certainly helps explain the coexistence of exchanges but also suggests new ways of looking at the welfare impact of mergers in this industry.

We end with two 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 rare 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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9 Appendix A: Description of data and variable construction

9.1 Trader data collection

For each individual establishment, we manually 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 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.[23] For bankrupt establishments located in Germany and Switzerland, we used the Dufa-Index and the Dun & Bradstreet (Switzerland)'s records (both available through Factiva).[24] 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 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,[25] asset management, proprietary

[23] 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).

[24] 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.

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

trading, market making, brokerage for institutional or professional traders, brokerage for retail clients, arcade[26] 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.

9.2 Business types

We partitioned the groups in our dataset into seven categories: universal bank, investment bank, retail bank, specialized trading firm, asset management, brokerage, and proprietary trading firm. We distinguished banks by the type of customers they serve. Retail banks serve primarily individual customers as well as small and medium enterprises. Investment banks serve corporate clients as well as, often, wealthy individuals. Universal banks serve all types of customers.

For most of their activities, investment banks compete with more focused financial firms. Table A1 summarizes the main activities of an investment bank (IB): underwriting and mergers & acquisitions, market making, brokerage services, asset management and proprietary trading. Specialized trading firms compete with investment banks by making markets, offering execution and/or clearing for institutional clients, and trading on their own account. Asset management firms sometimes offer brokerage services to a retail clientele and trade on their own account on top of their core asset management activity. Brokerages offer execution services and sometimes also offer some funds. Proprietary trading firms are firms that focus on trading on their own account. Table A1 compares the activities covered by these firms. In categorizing our firms, we have assigned the smallest encompassing category for each group. Thus a group active in market making, proprietary trading and asset management would be classified as an IB, but a group active in asset management and proprietary trading would be classified as an asset management firm and a group active in proprietary trading and market making would be classified as a specialized trading firm.

Table A1: Investment banks and their competitors

Activities \ Business types	IB	Specialized	Asset Mgt	Brokerage	Proprietary
Underwriting, M&A	$\surd$				
Market making	$\surd$	$\surd$			
Retail brokerage	$\surd$			$\surd$	
Institutional brokerage	$\surd$	$\surd$		$\surd$	
Asset Management	$\surd$		$\surd$	($\surd$)	
Proprietary trading	$\surd$	$\surd$	($\surd$)		$\surd$

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

9.3 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 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.

[INSERT TABLE 7 HERE]

Table 1: Exchange data, 2/90-12/99 (monthly basis, 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	82,286	40,447	0	102,000
fixed fee	9,394	951	7,707	10,839	27,429	13,482	0	34,000
volatility	0.083	0.046	0.021	0.393	0.083	0.046	0.021	0.393
transaction fee[a,b]	0.91	0.34	0	1.30	0.52	0.34	0	1.50
margins[b]	3,122	954	1,500	6,250	3,601	893	2,000	5,000
Volume[c]	1.88	1.30	0	4.11	2.38	3.22	0	11.1
log(vol)	5.78	1.87	0	6.70	5.57	1.79	0	7.11
# interest rate prod.	19.41	4.58	14	38	6.27	5.75	0	25
# equity products	49.20	26.28	0	71	21.76	11.09	14	56
# other products	10.41	10.34	0	33	4.10	3.43	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.
[c] Three month moving average, in millions of Bund future contracts

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

	LIFFE				DTB			
	Mean	Std.Dev.	Min	Max	Mean	Std.Dev.	Min	Max
Individual members[b]	145.08	5.01	131	157	128.34	82.48	51	367
Traders (Group members)[b]	124.24	5.05	112	143	108.35	57.28	49	272
% of dual members	30.83	16.71	9.79	70.17	34.85	2.59	28.57	39.67
Characteristics of membership (% of traders)								
<u>Business type</u>								
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	33.37	2.82	29.17	39.42	9.44	1.68	5.88	14.03
HQ in Germany	4.45	8.27	3.01	6.36	50.85	10.81	33.74	74.47
HQ in Switzerland	2.31	0.43	0.84	3.17	6.38	1.99	3.08	12.02
HQ in rest of EU	18.49	1.96	13.14	22.12	20.19	6.11	6.38	33.47
HQ in the US	21.81	1.55	18.40	25.41	13.48	5.34	5.66	21.69
HQ in the ROW	21.87	2.91	13.14	22.12	6.05	1.73	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 3: Baseline Regressions

	(1) (no substitution)		(2) (substitution)		(3) (business types)		(4) (random coefficients)	
Variable	Coef.	Std Err	Coef.	Std Err	Coef.	Std. Err	Coef.	Std Err.
Extra-volume effect								
(Pop mean) volatility	1.988	1.345	5.088**	2.394	4.336**	2.128	4.156**	1.942
Pop standard deviation	-	-	-	-	4.040**	1.077	2.374**	1.304
(Pop mean) fees	-0.214	0.239	-0.370	0.269	-0.365	0.272	-0.463	0.2829
Pop standard deviation	-	-	-	-	0.563**	0.185	0.399	0.381
(Pop mean) margins	0.145*	0.074	0.151*	0.087	0.133	0.086	0.161*	0.803
Pop standard deviation	-	-	-	-	0.196**	0.046	0.113**	0.053
(Pop mean) liquidity	0.146**	0.068	0.156**	0.077	0.156**	0.077	0.147*	0.081
Pop standard deviation	-	-	-	-	0.062**	0.014	0.031	0.023
Substitution effect								
Volatility			-4.046	3.042	-2.144	2.894	-3.036	2.7355
Fees			-0.562**	0.220	-0.519**	0.221	-0.544**	0.216
Margins			0.074	0.087	0.053	0.086	0.074	0.085
Liquidity			0.022	0.046	0.012	0.047	-0.001	0.048
Extra-volume effect – dual membership								
Volatility			0.414	1.735	0.888	1.775	0.231	1.772
Fees			-0.479	0.323	-0.324	0.329	-0.482	0.337
Margins			0.235**	0.099	0.238**	0.099	0.237**	0.102
Liquidity			0.282**	0.123	0.294**	0.126	0.303**	0.130
Adoption costs – DTB								
Admission	-2.918**	0.371	-2.918**	0.373	-3.081**	0.381	-3.192**	0.402
Germany	-7.495**	0.244	-7.519**	0.245	-7.440**	0.251	-7.203**	0.282
EU 1/90-7/93	-11.586**	0.514	-11.606**	0.516	-11.775**	0.529	-10.594**	0.556
EU 8/93-12/95	-10.503**	0.530	-10.570**	0.533	-10.626**	0.539	-10.626**	0.554
EU 1/96-	-8.821**	0.230	-8.851**	0.231	-8.824**	0.235	-8.895**	0.255
FR-NL 9/94-12/95	-6.928**	0.390	-7.037**	0.393	-7.225**	0.403	-7.219**	0.441
Swiss 1/90-12/95	-9.507**	0.647	-9.535**	0.647	-9.469**	0.705	-9.806**	0.691
Swiss 1/96-9/98	-10.478**	1.028	-10.453**	1.028	-10.520**	1.045	-10.909**	1.058
Swiss 10/98 -	-7.999**	0.634	-8.037**	0.634	-8.195**	0.679	-8.441**	0.770
US 1/90 –3/96	-9.639**	1.041	-9.677**	1.041	-9.809**	1.052	-9.987**	1.091
US 4/96 - 10/98	-7.269**	0.534	-7.248**	0.434	-7.164**	0.447	-7.283**	0.533
US 11/98 – 7/99	-8.832**	1.036	-8.895**	1.037	-8.789**	1.044	-9.071**	1.124
US 8/99 -	-6.334**	0.547	-6.343**	0.549	-6.281**	0.567	-6.565**	0.709

Table 3: Baseline Regressions (continued)

Adoption costs – LIFFE								
UK	-9.656**	0.158	-9.696**	0.160	-9.687**	0.167	-9.812**	0.211
EU 1/90 – 12/95	-13.331**	0.593	-13.375**	0.594	-13.320**	0.602	-14.775**	0.684
EU 1/96 – 7/98	-12.736**	0.601	-12.728**	0.601	-12.632**	0.604	-14.090**	0.699
EU 8/98 -	-12.069**	0.618	-12.099**	0.618	-11.932**	0.622	-13.255**	0.717
US 1/90 – 7/99	-12.072**	1.007	-12.117**	1.008	-12.216**	1.015	-13.497**	1.148
US 8/99 – 12/99	-9.578**	1.064	-9.605**	1.063	-9.919**	1.080	-10.747**	1.285
Mean DTB fixed effect	4.280**	0.636	4.936**	0.691	4.863**	0.694	4.576**	0.700
Pop standard deviation	-	-	-	-	0.581**	0.156	0.810**	0.239
LIFFE fixed effect	3.150**	0.835	2.974**	0.981	2.956**	0.961	3.748**	0.983
Pop standard deviation	-	-	-	-	0.555**	0.138	1.348**	0.557
Mean BOTH fixed effect	8.534**	1.103	8.800**	1.324	8.466**	1.335	8.614**	2.135
Pop standard deviation					0.843**	0.124	2.146*	1.146
Loglikelihood	-2,533.4399		-2,525.3344		-2,471.9112		-2,475.8	
Pseudo R2	0.9541		0.9543		0.9552		0.9552	
Conditional pseudo-R2	0.6749		0.6795		0.7072			
Predicted probability of actual choice during transitions:								
	0.7898		0.7918		0.8104			
Predicted probability of a change in membership status in any given trader-month:								
	0.0124		0.0123		0.0124			
Predicted probability of a change in membership status in a trader-month with a transition:								
	0.0669		0.0670		0.0710			
Predicted probability of a change in membership status outside of a trade-month with a transition:								
	0.0118		0.0116		0.0117			

Notes: The number of trader-month observations is 39,844 for all specifications. ** indicates significance at 5%; * indicates significance at 10%. All specifications control for exchange-specific time trends (trend, squared and cubed), exchange fixed fees, and product scope variables. Admission fees are expressed in 100,000 DM, fixed fees and margins in 1,000 DM and volumes in 1,000,000 contracts. Specification (3): two numbers are reported for each variable profit component and exchange effect: the population mean of the business-specific point estimates and the population standard deviation of these point estimates. (the right hand-side numbers give the standard errors of these population means and standard deviations, using the delta method). Specification (4): two numbers are reported for each variable profit component and exchange effect: the mean and the standard deviation of the population distribution of coefficients, together with their standard errors.

Table 4: Fraction of flow utility differential from being a member that is due to the liquidity differential between the two exchanges

	Fraction due to liquidity differential	Standard Err.
Jan 91	0.07	0.04
Jan 92	0.21	0.12
Jan 93	0.19	0.10
Jan 94	0.20	0.11
Jan 95	0.12	0.07
Jan 96	0.16	0.09
Jan 97	0.15	0.09
Jan 98	0.04	0.02
Jan 99	0.79	0.44

Notes: Computations are based on specification (4) with all coefficients estimated at their mean values.

Table 5: Random Coefficients for variable profit drivers

Variable	Param	Extra volume effect Est.	Std.Err.
A	σ_α	0.163	0.130
$\beta_{volatility}$	$\mu_{volatility}$	4.156**	1.942
	$\sigma_{volatility}$	2.247*	1.340
β_{fee}	μ_{fee}	-0.463	0.283
	σ_{fee}	0.386	0.383
$\beta_{margins}$	$\mu_{margins}$	0.168*	0.083
	$\sigma_{margins}$	0.108**	0.054
$\beta_{liquidity}$	$\mu_{liquidity}$	0.147*	0.081
	$\sigma_{liquidity}$	0.019	0.031

Notes: All variables are normally distributed. The coefficients on profit drivers, as reported in Table 3, are equal to $\alpha\beta_{volatility}$, $\alpha\beta_{fee}$, $\alpha\beta_{margins}$ and $\alpha\beta_{liquidity}$. * indicates significance at 10% level, ** indicates significance at 5% level.

Table 6: Covariance of individual exchange effects

	DTB	LIFFE	BOTH
DTB	0.656**	1.063**	1.718**
LIFFE		1.818**	2.881**
BOTH			4.599**

Notes: * indicates significance at 10% level, ** indicates significance at 5% level (standard errors computed using the delta method).

Table 7: Required DTB fee discount relative to LIFFE fee (in DM) to compensate for the liquidity differential, and actual fee discount

	Bottom quartile liquidity valuer	Median liquidity valuer	Top quartile liquidity valuer	Actual fee discount
Jan 91	0.19	0.22	0.25	-0.34
Jan 92	0.22	0.25	0.29	1.15
Jan 93	0.19	0.22	0.25	0.46
Jan 94	0.47	0.54	0.62	0.55
Jan 95	0.40	0.46	0.53	0.46
Jan 96	0.60	0.70	0.80	0.40
Jan 97	0.54	0.63	0.71	0.60
Jan 98	-0.34	-0.39	-0.45	0.75
Jan 99	-2.38	-2.77	-3.16	-0.50

Notes: Fee discount is computed based on specification (4) with coefficient on fee set to its mean, and the coefficient on liquidity taking its quartile values. Grey areas correspond to liquidity valuers for which DTB's fee discount was sufficient.

Table 7: Definition of 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 the Netherlands	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