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

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Abstract

In a famous episode of financial history which lasted over eight years, the market for the future on the Bund moved entirely from LIFFE, the incumbent London-based derivatives exchange, to DTB, the entering Frankfurt-based exchange. This paper studies the determinants of traders' exchange choice, using a novel panel dataset that contains individual trading firms' membership status at each exchange together with other firms characteristics and pricing, marketing and product portfolio strategies by each exchange. Our data allows us to evaluate different sources of heterogeneity among trading firms and thus distinguish between different explanations for the observed phenomenon. The story the data tells is one of horizontal differentiation and vertical differentiation through liquidity. As a result, DTB attracted a different set of traders than LIFFE, and those traders contributed to the market share reversal.

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

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1 Introduction

Traders value liquidity in financial markets. This creates a tendency for trading to concentrate on a single exchange and gives incumbent exchanges an advantage. However, in a famous episode of financial history known as "The Battle of the Bund" that lasted over eight years, the market for the future on the German long-term government bond, the Bund, moved entirely from LIFFE, a derivatives exchange based in London, to DTB, a Frankfurt-based exchange (Figure 1 illustrates the market shares of the traded volumes and members). While the Battle of the Bund is a particularly dramatic example, it is not an exception. In practice and contrary to the often-held "exchange-as-a-natural-monopoly" view, different exchanges trading the same products do co-exist.

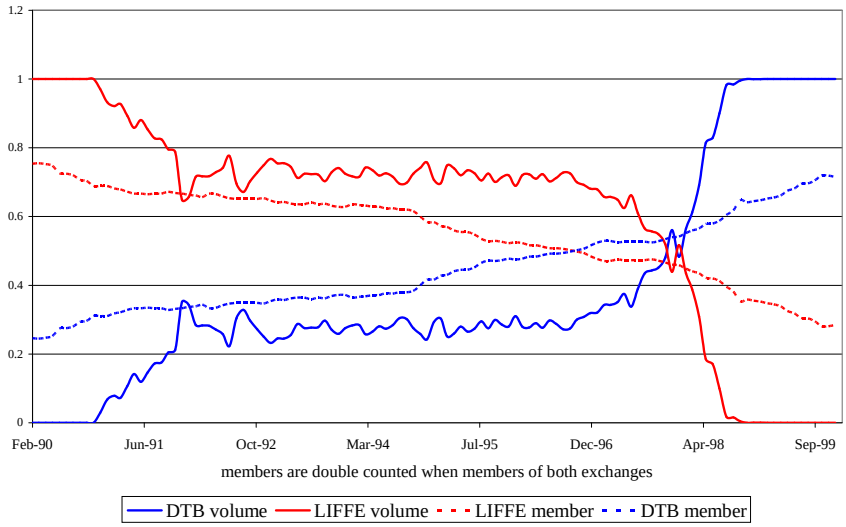


Figure 1: Market share of members and of Bund trading volume

The goal of this paper is twofold. First, we want to understand why DTB was able to garner a critical mass of trading early on, and why it was able to tip the market in its favor despite LIFFE's first-mover advantage. Answering this question is important because the Battle of the Bund is often cited as an example where an exchange successfully enters the market for a product already traded on another exchange. However, no exchange has ever been able to reproduce the complete tipping of the Battle of the Bund, and most attempts have resulted in failure. Beyond exchanges, the question of how competition plays out in the presence of network effects is of interest for industries ranging from credit card processing and the media to many technology products. Our analysis of the Battle of the Bund sheds light on many issues present in those industries such as user heterogeneity and network differentiation.

Second, we want to understand the different ways in which exchanges compete and thus ultimately on the drivers of the demand for exchanges. This issue has become increasingly salient as many

exchanges have recently switched from user-owned to for-profit structures and consolidated.[1] Understanding the demand for exchanges is the necessary first step for analyzing optimal market structure and market power in this industry. The Battle of the Bund is an excellent setting to study these questions because there was a lot of variation in the environment during this ten-year period and the Bund was a key product for both exchanges.[2]

To answer these questions, we study membership at both exchanges over this ten-year period. A trader must be a member of an exchange to be able to send an order directly to the exchange. Otherwise, he must use a broker who charges a fee for the service. Thus, while any trader can access most of the liquidity of an exchange at any time, membership confers exclusive access to "liquidity at the margin", that is, trades that are only profitable absent brokers fees. For this reason, membership and trading are driven by some common factors. Figure 1 shows the relationship between the market shares of membership and of trading.

While studying membership only provides a partial explanation for the observed trading, it has three advantages. First, membership, unlike individual trading, is observable, and Figure 1 suggests a role for traders' heterogeneity in explaining the observed trading pattern: clearly, some traders found it advantageous to trade the Bund on DTB earlier than others. Likewise, some traders joined DTB as members earlier than others. Second, membership is driven by many other factors beyond the benefits from trading the Bund on a particular exchange. This allows for a broader picture of the determinants of the demand for exchanges. Third, we will argue that the economics of membership differs from the economics of trading and that this alleviates some of the econometric challenges usually created by the presence of network effects.

After briefly describing the events and actions that took place during the Battle of the Bund, we propose four non-exclusive explanations for the observed outcome. Each corresponds to a different source of trader heterogeneity: (1) If traders value liquidity differently, DTB may have attracted early on those traders who did not care as much about liquidity by charging them lower transaction fees. As more traders joined DTB, those who cared more about liquidity followed. (2) Figure 1 can also be explained if traders saw the exchanges as horizontally differentiated. One dimension of horizontal differentiation is product scope. Exchanges are multiproduct firms. Even if the Bund was the main product for both exchanges during this period, each exchange organized markets for other products. DTB could have won the battle because its product offering attracted those traders that also happened to trade the Bund. (3) A second dimension of horizontal differentiation is geography. At the beginning of the decade, traders had to have an office in London to trade on LIFFE and they had to have an office in Germany to trade on DTB. Because DTB was an electronic exchange, remote access from other countries became possible as access deregulation progressed. This helped DTB attract new members.

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

[2] During the period, the Bund consistently ranked among DTB and LIFFE's top 3 products and it often ranked first at both exchanges.

(4) Finally, we consider the conjecture that DTB's success was the result of political pressure on German traders.

To evaluate these different stories, we have collected a detailed and novel dataset of exchange members and exchange characteristics over a ten-year period. Our dataset contains all the establishments that were members of DTB or LIFFE at any point of time between January 1990 to December 1999. For each of these establishments, we have tracked their location, their inception and exit dates, their historical group affiliation, their business lines and the products they traded. This allows us to match establishments from different locations at their group level and to distinguish between groups holding memberships at both exchanges and groups holding a single membership. We have also constructed a dataset of exchange characteristics over the same period. For each exchange, we have their fee structures, the value of the deposits required to guarantee the trades on that exchange, measures of liquidity, the products traded, and a record of all events that could affect the decisions by traders to trade on them. The end result is a panel dataset with financial groups' monthly membership status as a function of group and exchange characteristics.

Our empirical model of exchange membership incorporates the salient features of the environment. Every period, traders reconsider their membership status. Traders can be members of one exchange, both or none. When they reoptimize they select the membership status that yields the highest current period expected profit. The model accounts for the fact that trading does not require a membership and that traders can become members of both exchanges. Joining an exchange entails adoption costs that are geographically determined and vary with the state of access deregulation. The rest of the payoff to membership includes a component that is specific to the Bund and one that consists of all the costs and benefits conferred to membership outside of the Bund. We allow for trader heterogeneity in the variable profit component and in the fixed profit component.

Our findings are as follows. 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. We also find evidence that the two exchanges were horizontally differentiated: the non-Bund component of profits represents about 83-90% of the extra profit from membership and there is ample heterogeneity on this dimension. In contrast, deregulation did not help DTB much. Access deregulation did reduce adoption costs to DTB but its effects on membership were marginal, and certainly smaller than the effect of a hypothetical admission fee waiver or the imposition of exclusive membership. We also did not find evidence that nationalism favored DTB during the Battle of the Bund.

When we combine these results with the fact that 10-17% of the profits from membership are driven by trading in the Bund and that DTB primarily attracted newcomers (traders who were not members of any exchange), the following story emerges to explain the Battle of the Bund. The backing of German banks helped DTB garner initial volume. DTB then attracted traders who were relatively less sensitive to liquidity and/or valued their product offering more. The fact that many of these new

members were not members of LIFFE contributed to DTB's increasing market share.

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

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

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

and Saloner (1992) show that partial compatibility reduces users' incentives to coordinate on a single platform and it provides a rationale for the equilibrium coexistence of several platforms.

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

The empirical research on network effects has had to confront two econometric challenges: the endogeneity of the network size as an explanatory variable and the possibility of multiple equilibria. In both cases, researchers have proposed different solutions depending on their question and data. Thus, researchers have dealt with endogeneity through extensive controls for unobservables (Goolsbee and Klenow, 2002), instrumental variables (e.g. Tucker, 2008), data selection (Gowrisankaran and Stavins, 2004), non-parametric two stage approaches (Karaca-Mandic, 2007), behavioral and informational assumptions (Augereau et al., 2006) and so on. Some of these solutions are specific to the network effects literature while others are borrowed from the demand estimation literature. While we have argued above that the organization of financial markets and our focus on membership rather than trading reduce the importance of network effects in our application, we cannot rule them out entirely. In particular, we allow for liquidity as an explanatory variable for membership. We circumvent the potential endogeneity problem in two ways. First, our long panel dataset on individual decisions allows for extensive controls for unobservables. Second, we assume that traders best respond to past play and we leverage the delay between the membership decision and the actual membership to argue that past liquidity is exogenous.

Likewise, authors have used different solutions to deal with the possibility of multiple equilibria (for two examples, see Ackerberg and Gowrisankaran, 2006 and Tucker, 2005). Our focus on a single market with network effects limited by intermediation and multi-homing reduces this concern. Additionally, unlike the trading data, the membership data do not display any structural break (Figure 1). This suggests that, even if there are multiple equilibria in the "membership game", our data likely consist of a unique selection.

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

2 The Battle of the Bund

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

The London International Financial Futures and Options Exchange (LIFFE) was established in 1982 as a member-owned derivatives exchange. Two hundred sixty one members joined at launch time, a good third of them coming from outside the UK.[3] Trading was initially organized exclusively by open outcry. LIFFE's first products were currency contracts, two short term interest rate contracts, and one future on the British long term government bond. Their debut was relatively modest, but trading grew after the exchange lowered transaction fees and negotiated lower margins with their clearing house.[4] LIFFE introduced an automated trading platform (APT) in 1989 for electronic trading outside the pit hours.

New products were progressively added, among them the Bund future contract in September 1988. The Bund launch was controversial. There was clearly a need for such a contract: the underlying cash market was one of the biggest in the world, yet it did not have a proper hedging instrument. However, German financial institutions were keen on developing such a market in Germany and they were pushing for new laws that would make it possible to set up a derivatives exchange in Germany.

The Bund contract was an instant success on LIFFE. It was their second biggest contract within 6 months of its launch and became their top contract less than a year later. German banks used the contract from the very beginning, providing up to a sixth of the volume according to an informal LIFFE survey.[5]

Deutsche Terminbörse (DTB) was established in January 1990 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. Fifty members had joined at launch time, of which 80% were German institutions. Their first products were an equity index future and stock options. DTB launched a Bund contract on November 23, 1990. The contract was essentially identical to the LIFFE contract.[6] Clearing was provided by DKV, a German company.

The beginnings. Shortly before DTB's launch of the Bund contract, LIFFE geared up for competition and trading was moved one hour earlier in order to match DTB's hours. Grand declarations were made in the press about where volume would go. In practice, volumes were low and participation seemed limited to German banks in the first few days. It became clear that much would depend on whether German banks would really be willing to trade on DTB even if it were less liquid. By

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

[4] Every time a trader opens a new position, he must deposit margins with the clearing house to guarantee his trade. These margins generate an opportunity cost for traders.

[5] Kynaston (1997), pp. 218-219.

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

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

Competition in the product space. The battleground between LIFFE and DTB quickly moved to the product space. While the Bund was clearly the key product, each exchange tried to reinforce the contract by offering complementary products and services. Thus, DTB launched an option on the Bund in August 1991, and it started a Bobl contract, a future on the medium-term German government bond, in October 1991. In January 1993, LIFFE launched its own version of the Bobl and DTB launched an option on the Bobl. Finally, DTB launched the Schatz contract, a future on the short-term German government bond in March 1997. Each of these product launches was accompanied by statements from the exchanges suggesting that Bund traders would be interested in these products. DTB's Bobl turned out to be a hit in its own right (LIFFE's version was a failure). However, the Bund remained the dominant contract and it is not clear to what extent these products attracted new traders on the exchanges, instead of simply benefitting from the positive spillovers from the Bund contract.

New services were also offered to boost trading in the Bund. LIFFE launched a basis-trade facility where traders could trade simultaneously the Bund future and its cash equivalent in July 1995, followed by DTB in October of the same year. LIFFE launched a spread facility where traders could buy a Bobl and sell a Bund (or the other way round) simultaneously in February 1994, followed by DTB in May 1997.

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

DTB seemed to have realized early on that access was critical.[8] In December 1993, it signed an agreement with the French derivatives exchange MATIF whereby MATIF members would be able to trade the Bund and Bobl on DTB. The agreement came into force in September 1994, at the same time as Dutch regulatory authorities authorized proprietary traders based in the Netherlands to trade on DTB. DTB also actively lobbied US and British regulatory authorities to allow remote access from the US and the UK. Those efforts resulted in a no-action letter issued on 29 February 1996 by the CFTC allowing US-based traders to trade on DTB. DTB's efforts with the British authorities were

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

[8] "DTB may put screens outside Germany", *Financial Times*, 23 January 1991.

unsuccessful. In the meantime, the European Union approved the Investment Services Directive. The Directive, which came into force in January 1996, implied that any exchange and investment firm authorized and regulated in one of the European Union countries would be recognized and authorized in all the other countries. From then on, EU-based trading firms could have remote access to DTB.

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 not as meaningful for lowering costs of trading on LIFFE. Nevertheless, financial regulations in other countries did also affect trading on LIFFE because trading in the Bund took place on an electronic platform after-hours until August 1998 and was entirely electronic after that.

Electronic trading versus open outcry. There was a fair amount of discussion in the industry at the time on the relative advantages of open outcry versus electronic trading. It was argued that open outcry markets were better at aggregating information in periods of high volatility and that they allowed for more complex strategies than electronic markets. Electronic trading, it was argued, 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, electronic transactions were automatically processed through clearing, and so on.

Breedon and Holland (1998) summarize the evidence on the relative quality of the Bund market at both exchanges. Using different measures of spreads (the difference between the buy price and the sell price) and transaction prices, they find that "realized" liquidity was similar in both markets around 1995. However, transaction sizes on LIFFE were more than double the size of transactions at DTB, suggesting DTB might have been less liquid.

Macroeconomic developments. Trading volumes of the Bund grew more than tenfold during the 1990s. Several factors contributed to this. First, German reunification in 1990 increased Germany's borrowing needs. The resulting increase in the public debt fueled interest in the future contract. Second, interest rates in the eurozone progressively converged as monetary union took shape (the euro - which fixed exchange rates among participating countries - was introduced on 1 January 1999). As a result, the Bund contract, which was the biggest future on a government bond in Europe progressively attracted traders from other government bond futures. Third, futures went from exotic financial instruments to instruments used routinely by banks, asset management funds and corporations. The ensuing pool of liquidity attracted speculators and arbitrageurs of all kinds.[9]

Mergers. Both exchanges underwent mergers during the 1990s. LIFFE merged with the London Traded Options Market (LTOM), an equity option exchange, in March 1992. It merged with the London Commodity Exchange in May 1996. DTB became part of Deutsche Börse, the Frankfurt-based stock exchange, in August 1994. It merged with the Swiss derivatives exchange SOFFEX in

[9]Speculators trade on the basis of their forecasts about future movements of prices: they take positions, hoping that prices will move in a direction favorable to them. Arbitrageurs speculate on the basis of price co-movements between similar securities.

September 1998. The new entity took the name of Eurex.

The loss of the Bund. Between 1992 and 1996, DTB's share of the Bund trading remained virtually unchanged at 30% (Figure 1). Things started to change at the end of 1996. The Investment Services Directive had come into force and, during 1996, DTB installed access points in Amsterdam, Chicago and Zurich for easy access to its market. In August 1997, DTB extended its trading hours to match those of LIFFE and in September 1997, a price war broke out with both exchanges waiving transaction fees on the Bund. A sixth of DTB's members were now based in London and DTB opened an office there to facilitate contacts and new traders training.

The exchanges were head-to-head by the last quarter of 1997: LIFFE was still ahead in September, but DTB took the lead and they finished the year with an almost equal market share. Things went very fast afterwards. LIFFE completely restructured its fee structure in March 1998 in the hope of boosting its appeal. During that time, DTB maintained the pressure: it wrote a letter to LIFFE's members offering a computer and DTB's trading software to any members willing to trade on DTB. DTB also ran an advertising campaign in all major newspapers offering its trading system to LIFFE for free. By mid-July, it was clear that LIFFE had lost the Bund. LIFFE underwent a complete restructuring following the loss of the Bund. It demutualized in February 1999 and became an all-electronic exchange.

3 Four stories

We think of the two exchanges as being horizontally and vertically differentiated (e.g. Economides and Siow, 1988). Vertical differentiation is either intrinsic because one exchange provides a better quality of service or endogenous because one exchange attracts more trades and thus offers greater liquidity. As described in the introduction, trading and membership decisions are causally related because membership offers increased trading opportunities that would not be available if traders had to incur brokers fees. This suggests several explanations for the observed tipping based on membership decisions by traders. These explanations are not exclusive. One purpose of the empirical analysis is to identify their respective roles.

Story 1: Vertical differentiation. According to this story, the main source of differentiation between the two exchanges was liquidity. LIFFE, being the incumbent, offered a larger liquidity pool to traders. However, it was also intrinsically more expensive, both due to its fee structure and its market organization. When selecting an exchange, traders traded off the higher liquidity of LIFFE with DTB's lower costs. Traders with low liquidity needs were predominently attracted to DTB (Pagano, 1989). The resulting increase of DTB's liquidity eventually triggered a snowball effect, leading to the complete reversal in market share.

Story 2: Access and adoption costs. According to this story, the main source of differentiation between the two exchanges was their geographically determined access costs. Access deregulation in

the EU combined with the fact that DTB was an electronic exchange lowered the cost of access to DTB and increased the market for potential exchange members. Traders who originally used brokers to trade the Bund could now afford a membership at DTB. This increased trading volumes on DTB. Bessler, Book and Preuß (2006) make an argument along these lines. They argue that scalability of electronic trading, enhanced by access deregulation, is what gave DTB a definite advantage in the Battle of the Bund.

Story 3: Product scope. According to this story, the main source of differentiation between the two exchanges was their product portfolio and DTB was more dynamic and successful than LIFFE in trading products that also attracted Bund traders. Section 2 suggests that both exchanges attempted strategies motivated by this story.

Story 4: Non economic factors. Several industry participants have suggested that political forces rather than economic forces led to the market share reversal. In the words of one of the traders we interviewed, "German banks had a gun to their heads to trade on DTB."

Two remarks are in order. First, none of the stories above assumes that exchanges acted optimally as the dynamics played out. In fact, it is likely that some stories require some level of non-optimal behavior by the incumbent exchange.

Second, a tempting explanation for the pattern of membership at DTB is the traditional technology diffusion story (Griliches, 1957). According to this story, the electronic trading platform provided by DTB was a new, better technology which would replace open-outcry floor exchanges. Heterogeneous adoption costs and benefits among traders generated the observed pattern as adoption costs went down or benefits increased over time. The four stories presented above largely nest the traditional diffusion story. To the extent that access deregulation decreased adoption costs over time, it can equally be interpreted as a technology diffusion story. In addition, evidence of increased benefits over time would provide additional support to the technology story. Story 1 and story 3 explain increased benefits over time by increased liquidity and more attractive product portfolio on DTB.

There are three reasons why we do not emphasize the technology diffusion story here. The main reason is that the traditional technology diffusion story is best suited to settings where a clearly superior technology appears which will eventually replace the old one. In our case, technology was a choice of the exchanges (and indeed LIFFE switched to electronic trading in 1998). The second reason is that technology adoption is seen as irreversible in the technology diffusion literature, whereas membership decisions are reversible, a fact that is borne out in our data. The third and final reason is more a question of emphasis. Instead of studying how adoption costs or benefits varied over time, we want to study the individual factors that affected those adoption costs and benefits.

4 Data

4.1 Firm data

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

The original dataset from DTB contains information on 493 individual establishments that held a membership any time during the 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. This means that 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. This information was collected manually following the procedure described in Appendix A.

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

Groups versus individual establishments. We face two issues when defining the proper unit of observation in our environment. First, membership decisions of individual establishments that belong to the same group are not independent, and largely depend on the group's internal organization. Some groups are organized along geographical lines, with trading desks in each country. Others are organized along business lines with a single trading division. In the first case, all geographical trading divisions could, in principle, be members of a given exchange. In the second case, we would observe only one membership for that group. Second, mergers and acquisitions can lead to membership resignations because the resulting entity rationalizes its membership and not because the resigning establishment no longer values the membership. We address both issues by defining the group as the unit of observation and use the collected information on group ownership and mergers and acquisitions to match establishments to groups. With this convention, our dataset covers 578 groups. On average,

362.64 groups are present in any given month (min = 315, max = 433, std deviation = 32.66).

Business models. 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 1 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 1 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 1: Investment banks and their competitors

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

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 on average, and investment banks tend to be bigger than more specialized financial 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 opportunity cost of margins. Finally, business types proxy for the scope of products traded.

Evaluated at the time a group first appears in our dataset, our data contain 64 universal banks, 28 retail banks, 102 investment banks, 48 asset management firms, 95 specialized trading firms, 110 brokerages and 131 proprietary trading firms.

Geographical presence. Geographical presence affected adoption costs depending on the state of access deregulation. In our sample, 127 groups have their headquarters (HQ) in Germany, 37 have their HQ in Switzerland, 116 in the UK, 149 in the rest of Europe, 108 in the US and 41 in the rest of the world. We have also constructed a variable that records a group's geographical presence in any given month based on the locations of its headquarters and its known subsidiaries in that month.

4.2 Exchange data

For both exchanges, we collected the following monthly data: (1) admission fee to the exchange, (2) annual membership fee, (3) transaction and clearing fee per contract, (4) margins, (5) membership, (6) product launches and delisting, and (7) trading volume in the Bund contract. Fees, margins and product launches and delisting were collected from exchange notices to members, membership was constructed on the basis of the information provided to us by both exchanges, and volume data come from Datastream.

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

Table 2: Descriptive statistics for the exchange dataset (all monetary values in DM)

	LIFFE				DTB			
	Mean	Std.Dev.	Min	Max	Mean	Std.Dev.	Min	Max
admission fee	0	0	0	0	81,600	40,971.07	0	102,000
fixed fee	9,407.77	958.82	7,707	11,006.8	27,200	13,657.02	0	34,000
transaction fee[a]	0.91	0.36	0	1.34	0.52	0.34	0	1.50
margins[a,b]	2,983.34	858.13	1,500	6,250	3,600.83	892.62	2,000	5,000
volume	$1.87\ 10^6$	$1.29\ 10^6$	0	$4.11\ 10^6$	$2.36\ 10^6$	$3.22\ 10^6$	0	$1.11\ 10^7$
log(vol)	5.67	1.72	0	6.61	5.51	1.85	0	7.04
# interest rate products	19.37	4.58	14	38	6.33	5.76	0	25
# equity products	49.38	26.25	0	71	22.05	11.48	0	56
# other products	10.60	10.50	0	33	4.19	3.55	0	15
members[c]	148.22	5.69	134	166	134.13	90.33	0	400
group members	126.89	6.33	115	151	113.66	64.51	0	303

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

[b] Margins refer to initial margins

[c] LIFFE membership numbers are restricted to those allowed to trade interest rate instruments.

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 averages for volumes instead of monthly volumes.

Table 2 provides descriptive statistics for our exchange variables for the period between 1 January 1990 and 31 December 1999. The number of month observations is 120. It distinguishes between individual memberships and memberships held by establishments under the same ownership, which is the data we used in our econometric analysis. Both numbers display the same pattern. They confirm that LIFFE was an established exchange by the early 1990s, with a stable membership, unlike the newly established DTB.

Finally, as a measure of attractiveness of the Bund future, we collected data on the daily yield for the underlying Bund contract (the government bond on which the future is based) and constructed a monthly variable to capture its volatility. We define volatility of the underlying Bund contract as the monthly standard deviation of the yield. It has mean 0.083, standard deviation 0.046 (min = 0.021, max = 0.393)

5 Descriptive evidence

In this section, we provide descriptive evidence on the importance of newcomers (firms that were not members of any exchange) among DTB's membership relative to switchers, and on geography as a determinant of the timing at which traders became members of DTB. We also provide evidence that membership decisions are reversible and that indeed traders reoptimized their membership status several times over the period, an aspect that the econometric model will integrate.

5.1 Switchers versus newcomers and evidence of lock-in

Table 2 already suggested that DTB experienced an increase in membership whereas membership at LIFFE remained almost constant during the 1990s. A first question we can answer on the basis of our data (since we have tracked group ownership and can thus distinguish between members that hold dual and single memberships) is to what extent the increase in DTB membership was driven by traders switching from DTB to LIFFE (or, more plausibly given Table 2, joining DTB on top of LIFFE), rather than by newcomers choosing predominantly DTB. Figure 2, which plots the number of groups that were members of LIFFE, BOTH, DTB or no exchange over time, offers a first perspective on this question.

Figure 2 shows the increase in the population of potential exchange members.[10] Figure 2 also

[10] 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 actually an underestimate.

shows the limited overlap in membership between the two exchanges until the mid-1990s. Most of DTB members were newcomers.

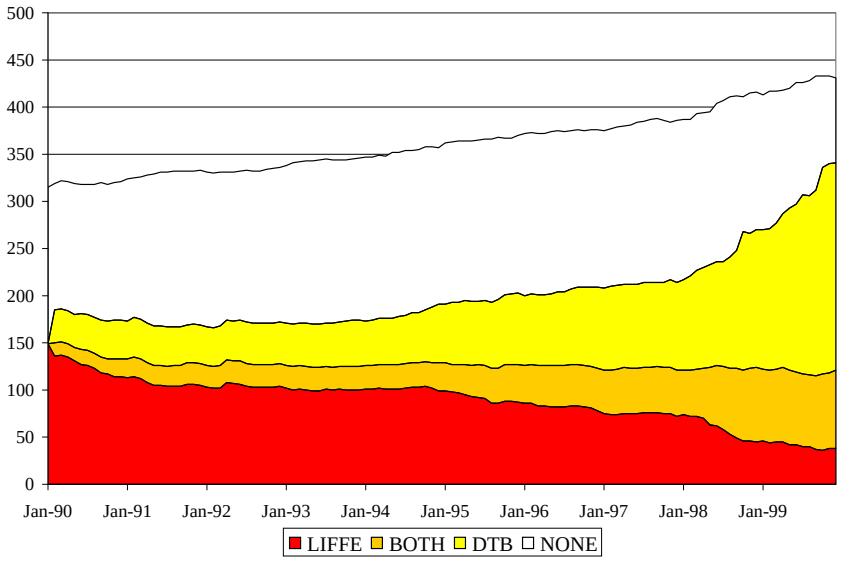


Figure 2: Exchange members and non-members over time

As further evidence of the predominance of newcomers among DTB's membership, we build a panel dataset of groups' membership status over the 120 month period between 1 January 1990 till 31 December 99.[11] Thus, an observation is a group-month observation. For each group-month observation, we record the group's membership status in the previous month and the current membership status. The fact that a large fraction of DTB members were not members of LIFFE provides a first explanation for the market share reversal.

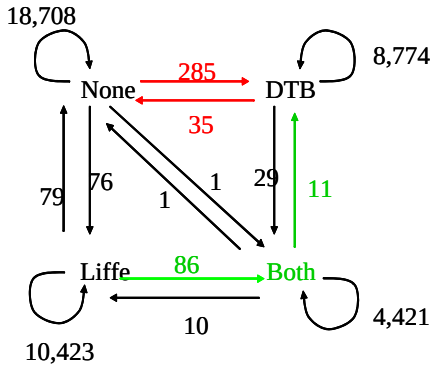


Figure 3: Transitions in full dataset

(2/99 - 12/99)

[11] A group is present in the data from its inception date until its exit date (acquisition, merger or bankruptcy). A group is a member of an exchange as soon as one establishment belonging to the group is a member

Figure 3 summarizes the resulting transition matrix. Newcomers predominantly chose DTB: Out of the 361 newcomers that joined an exchange during the period, 285 chose DTB. There were at most 11 "switchers" from LIFFE to DTB (a switcher would have first joined DTB generating a LIFFE-Both transition, and then resigned from LIFFE, generating a Both-DTB transition). If we also consider those groups that added a DTB membership to their LIFFE membership, the number of "switchers" is at most 86.

The total number of transitions is 613. Given that our dataset controls for group ownership and group entries and exits, these transitions can be exclusively attributed to changes in the value that the firms assign to the exchanges.[12] Among the 578 groups present in our data, 97 never change membership status over the entire period during which they are present, 372 change status once, 92 change status twice, 11 change status three times and 6 change status four times. Approximately 18 % of groups undergo at least two changes of status. This is not a trivial number. It motivates our empirical model where membership decisions are reversible.

5.2 Sources of trader heterogeneity

Section 3 suggested several sources of trader heterogeneity in our environment: different traders have different adoption costs, different traders value the exchanges' product portfolios differently, and traders also differ in trading behavior, opportunity costs of margins and value of liquidity.

In practice, our measures of groups' characteristics are their headquarter location, their geographical presence and their business type. Because of the way deregulation worked, geographical presence clearly captures differential adoption costs. Figure 4 plots the cumulative distribution function of the time at which groups joined DTB as a function of their "closest" geographical presence three months before joining.[13] We focus on DTB given that it is the exchange that experienced the biggest growth in membership. In defining "closest" geographical presence, we considered Germany to be closest, followed by France and the Netherlands, followed by Switzerland, followed by the UK, followed by other EU countries, followed by the US and finally by the rest of the world. Thus, for example, the closest geographical presence of a group with establishments in the UK, France and the rest of the world will be France.

Figure 4 shows that geographical presence captures one important aspect by which groups differ. Geographical presence affects both the volume of early DTB members (30% of groups with a German presence had joined by January 1990 whereas it took a year for groups without an initial German presence to join DTB) as well as the dynamics of the timing of adoption (many groups with a French or Dutch presence join after the deregulation of access from the Netherlands and France in September

[12] Put differently, membership resignations due to bankruptcies or membership rationalization following a merger are not counted in this number. Likewise, decisions by groups to add another membership from another location in addition to their existing membership are also not counted. As a benchmark, the number of transitions would be equal to 1,019 if we did not correct for those cases and took establishment memberships as our unit of observation.

[13] We consider their geographical presence three months before joining to ensure it is exogenous to the decision to join.

1994; likewise, membership from groups based in Switzerland jumps around the time of the merger with SOFFEX). However, it is also clear that geographical presence does not entirely capture the timing of adoption. Figure 4 shows that groups with a UK presence but no German, French or Dutch presence came in earlier than groups with a European presence outside of Germany, France, Holland and the UK despite the fact that those groups were in principle affected equally by deregulation.

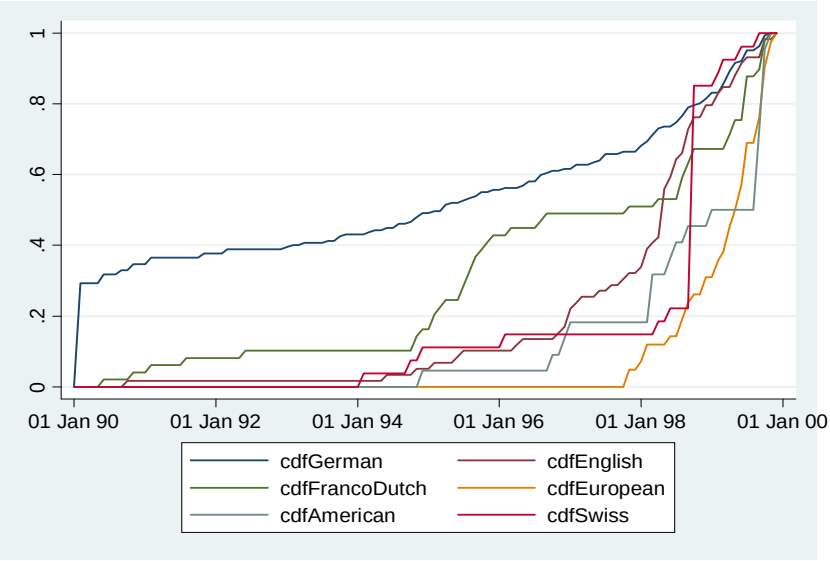


Figure 4: DTB joining time according to closest geographical presence

6 Econometric model

In this section, we introduce our baseline econometric model. Let i index a particular trader and t index time. Traders can be members of DTB, LIFFE, both exchanges or none. We let $\omega_{it} \in \{D, L, B, 0\}$ describe the membership status of trader i at time t, where D stands for DTB, L stands for LIFFE, B stands for both and 0 stands for none. Expected profits from each alternative consist of a fixed component that does not vary with firms' trading in the Bund (thus capturing the profits from trading in the other products and the fixed costs of trading), a variable component that varies with trading in the Bund and, depending on membership status in the previous period, an adoption cost. Thus we let firm i's expected profits from being a member of exchange k at time t be:

$$\widetilde{\pi}_{it}(k, \omega_{it-1}) = F_{it}(k) + \text{VAR}_{it}(k) - A_{it}(k, \omega_{it-1}) \tag{1}$$

where $F_{it}(k)$ and $\text{VAR}_{it}(k)$ are firm i's fixed and variable components of profits due to its membership at exchange k and $A_{it}(k, \omega_{it-1})$ stands for firm i's adoption cost for exchange k at time t given their membership status ω_{it-1} in the previous period. There is a positive adoption cost whenever firm i becomes a new member of an exchange.

6.1 Trading profits

Because trading on one exchange does not require a membership on that exchange, $\text{VAR}_{it}(k)$ contains trading profits from trades on both exchanges. To examine this issue, we decompose variable profits into average profits per contract and trading volumes.

Profits per contract. Suppose trader i generates an average revenue of ρ_{it} on each Bund contract traded (depending on the trader's business, revenue can be speculative profits or commissions). To do so he incurs several costs. First, he pays a transaction fee to the exchange (FEE_{kt}). Second, for each new open position, margins must be deposited at the clearing house to guarantee the trade. Margins generate an opportunity cost (MARGINS_{ikt}). Third, trader i may influence the price of the contract when trying to buy or sell large quantities. The impact cost of a transaction is defined as the difference between the theoretical "equilibrium price" for the contract at the time of the transaction and the realized price for the transaction (IMPACT_{ikt}). Impact costs are related to the liquidity of a market. The more liquid a market is, the less specific orders affect prices. Fourth, trader i must pay a broker's fee for trades on exchanges of which he is not a member (BROKERFEE_t).

Traded volumes. Denote $\text{vol}_{iDt}(k)$ the trading volume in the Bund by trader i on exchange D in period t when he is a member of exchange k. Define $\text{vol}_{iLt}(k)$ similarly. Trader i's variable profits from being a member of DTB is given by:

$$\begin{aligned} \text{VAR}_{it}(D) &= \text{vol}_{iDt}(D)(\rho_{it} - \text{FEE}_{Dt} - \text{MARGINS}_{iDt} - \text{IMPACT}_{iDt}) \\ &\quad + \text{vol}_{iLt}(D)(\rho_{it} - \text{FEE}_{Lt} - \text{MARGINS}_{iLt} - \text{IMPACT}_{iLt} - \text{BROKERFEE}_t) \end{aligned} \tag{2}$$

Trading volumes may depend on membership status for two reasons: membership generates an extra volume effect (because traders avoid brokers fees) and a potential substitution effect. The balance between these two effects depend on the trading motive.

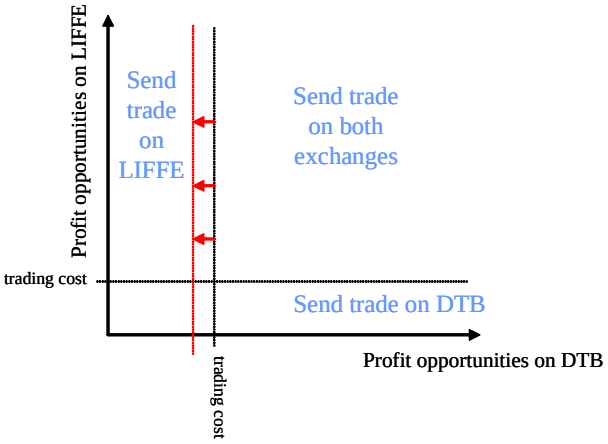


Figure 5: A speculator's decision rule for where to send trades

Consider first speculation-motivated trades.[14] Trading profit opportunities arise at all times on both exchanges and, because prices may differ slightly across 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 costs of transaction. Such a decision rule is represented in Figure 5. Membership at an exchange decreases trading costs at that exchange because it eliminates brokers fees. In Figure 5 this is represented by a shift to the left in the level of trading costs on DTB. This increases trading volume on DTB but, importantly, does not affect trading volume on LIFFE. Thus $\text{vol}_{iLt}(D) = \text{vol}_{iLt}(0)$, $\text{vol}_{iLt}(B) = \text{vol}_{iLt}(L)$ and $\text{vol}_{iDt}(D) - \text{vol}_{iDt}(0) = \text{vol}_{iDt}(B) - \text{vol}_{iDt}(L) > 0$ for example. There is only an extra volume effect for speculation-motivated trades.

At the other extreme, consider hedging-motivated trades.[15] For those trades, trading needs are determined by positions the trader takes in the underlying instrument and are thus exogenous to membership status. As a result, the trader will send his trades wherever it is cheapest to execute them. Membership reduces the variable costs of executing trades on the exchange to which he is a member. Thus the trader will channel a larger proportion of the trades to that exchange (substitution effect). Thus, for a hedger we have that $\text{vol}_{iDt}(k) + \text{vol}_{iLt}(k)$ does not depend on membership status, $\text{vol}_{iLt}(D) - \text{vol}_{iLt}(0) < 0$ (substitution effect) and $\text{vol}_{iDt}(D) - \text{vol}_{iDt}(0) > 0$ (extra volume effect).

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.

In practice, speculation-motivated trades represent the bulk of volume. Moreover, there are no traders (among the member firms) that only trades for hedging purposes. For this reason, we simplify and consider that the substitution effect of membership is negligible.[16]

Normalized profits. We now revisit (1) when we normalize $\pi_{it}(0, \omega_{it-1}) = 0$ and use the discussion above to evaluate the resulting normalized variable profits:

$$\pi_{it}(k, \omega_{it-1}) = \Delta F_{it}(k) + \Delta \text{VAR}_{it}(k) - A_{it}(k, \omega_{it-1}) \tag{3}$$

[14] Recall that a speculator is a trader who trades on the basis of his forecast about future price movements. He takes positions, hoping that prices will move in a direction favorable to him.

[15] A hedger is a trader who trades to lock-in the price of a future commitment.

[16] Doing so simplifies the exposition and estimation greatly without changing the economics of the problem. We allow for substitution effects in the regressions when we do our robustness checks in section 7.

where $\Delta F_{it}(k) = F_{it}(k) - F_{it}(0)$ and, for $k = D, L$,

$$\begin{aligned}
\Delta\text{VAR}_{it}(k) &= \text{VAR}_{it}(k) - \text{VAR}_{it}(0) \\
&= (\text{vol}_{ikt}(k) - \text{vol}_{ikt}(0))(\rho_{it} - \text{FEE}_{kt} - \text{MARGINS}_{ikt} - \text{IMPACT}_{ikt}) \\
&\quad +\text{vol}_{ikt}(0)\text{BROKERFEE}_t \\
&= \Delta\text{vol}_{ik}(\rho_{it} - \text{FEE}_{kt} - \text{MARGINS}_{ikt} - \text{IMPACT}_{ikt}) + \text{vol}_{ikt}(0)\text{BROKERFEE}_t
\end{aligned}$$

where, in the last line, we have assumed that the extra volume effect, $\text{vol}_{ikt}(k) - \text{vol}_{ikt}(0) = \Delta\text{vol}_{ik}$, is not a function of time. Similarly, normalized variable profits from being a member of both exchanges are given by:

$$\begin{aligned}
\Delta\text{VAR}_{it}(B) &= \Delta\text{vol}_{iD}(\rho_{it} - \text{FEE}_{Dt} - \text{MARGINS}_{iDt} - \text{IMPACT}_{iDt}) \\
&\quad \Delta\text{vol}_{iL}(\rho_{it} - \text{FEE}_{Lt} - \text{MARGINS}_{iLt} - \text{IMPACT}_{iLt}) \\
&\quad +(\text{vol}_{iDt}(0) + \text{vol}_{iLt}(0))\text{BROKERFEE}_t
\end{aligned} \tag{4}$$

The assumption that substitution effects from membership are negligible ensures that normalized variable profits for an individual exchange are only a function of the transaction costs on that exchange, and not of the transaction costs on the other exchange.

If we further assume that the extra trading volume induced by membership does not depend on the exchange and consider that trading profits are linear in the volatility of the underlying Bund contract, and that the cost of margins and the impact costs are linear in margins and a measure of liquidity respectively, we can further simplify normalized variable profits to

$$\Delta\text{VAR}_{it}(k) = \beta_{1i}\text{VOLAT}_t + \beta_{2i}\text{FEE}_{kt} + \beta_{3i}\text{MARGINS}_{kt} + \beta_{4i}\text{LIQUIDITY}_{kt} + \eta_{ikt},\ k = D, L \tag{5}$$

$$\Delta\text{VAR}_{it}(B) = 2\beta_{1i}\text{VOLAT}_t + \beta_{2i}\text{FEE}_{Bt} + \beta_{3i}\text{MARGINS}_{Bt} + \beta_{4i}\text{LIQUIDITY}_{Bt} + \eta_{iBt} \tag{6}$$

where $\text{FEE}_{Bt} = \text{FEE}_{Dt} + \text{FEE}_{Lt}$, $\text{MARGINS}_{Bt} = \text{MARGINS}_{Dt} + \text{MARGINS}_{Lt}$, $\eta_{ikt} = \text{vol}_{ikt}(0)\text{BROKERFEE}_t$ for $k = D, L$ and $\eta_{iBt} = (\text{vol}_{iDt}(0) + \text{vol}_{iLt}(0))\text{BROKERFEE}_t$. Equations (5) and (6) correspond to the specification of normalized variable profits we bring to the data. Note that the coefficients on volatility, fees, margins and impact costs combine the extra volume effect with the impact of the specific variable on profits.

6.2 Behavioral model

At every period t, traders reconsider their membership status. In doing so, 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, either following exogenous events or following membership decisions by other firms. We observe

$$\omega_{it} = k \text{ if } k = \arg\max_{k' \in \{D,L,B,0\}} \pi_{it}(k', \omega_{it-1}) \tag{7}$$

We now discuss four econometric and / or conceptual issues that our econometric model raises:

Best-response versus equilibrium behavior. Our assumption that traders are best-responding to the environment they are facing is in the spirit of Arthur (1989)'s seminal work on technology adoption with network externalities. Among the follow-up papers applying evolutionary methods to the study of platform competition, Cabral (1990) and Gerber and Bettzuge (2007) are closest to our setting in that 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. Interestingly, they both show that, under some conditions, adaptive play converges to a Nash equilibrium.[17] Thus, the tension between best-response behavior and Nash equilibrium is not as acute as it may at first seem. Adaptive play is also consistent with the descriptive evidence. First, 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. Second, Figure 3 shows an acceleration in the number of new members for DTB just *after* tipping occured. An interpretation of this pattern is that those trading firms were more reactive in their choices of an exchange than forward-looking. The main advantage of assuming best-response behavior, of course, is computational: we do not need to look for a fixed point in a membership game that involves more than 500 players as part of the estimation. The argument above suggests that the cost of doing so may not be too big.

Multi-homing and identification of synergies generated from dual membership. Because traders can become members of both exchanges, a natural question that arises is whether we can separately identify whether dual membership is caused by complementarities between the two exchanges (for example through their respective product scope) or because unobserved trader-specific taste for each exchange are correlated. Gentzkow (2007) has recently nicely summarized the issue. He suggests that both effects can be distinguished in a panel data with alternative-specific covariates. Correlation can be identified if we decompose the unobserved demand shock into a trader and exchange-specific shock that is invariant through time, and an idiosyncratic time, trader and exchange specific shock that is independently and identically distributed. The time-invariant trader and exchange-specific shocks can be estimated as fixed effects or random effects and soak up the correlation. Alternative-specific covariates then help identify complementarities. This is essentially our approach here.

Identification of adoption costs versus profit levels. Adoption costs and profit levels are separately identified because adoption costs affect the probability of joining a new exchange but they do not affect the probability of resigning from a membership, whereas profit levels affect both.

Bund-specific versus non Bund-specific profits. Our model can only partially distinguish the profit component due to trading in the Bund from the rest. Specifically, we can control for trading profit opportunities, fees, margins and impact costs in (5) but not for the η_{ikt} term, which will therefore be estimated together with the time-varying component of $\Delta F_{it}(k)$.

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

6.3 Estimation

Rewrite $\Delta F_{it}(k)+ \Delta \text{VAR}_{it}(k) - A_{it}(k, \omega_{it-1}) = \theta_i X_{ikt} + \varepsilon_{ikt}$. Traders' profit functions become:

$$\begin{aligned} \pi_{it}(k, \omega_{it-1}) &= \theta_i X_{ikt} + \varepsilon_{ikt}, \quad k \in \{D, L, B\} \\ \pi_{it}(0, \omega_{it-1}) &= 0 \end{aligned} \tag{8}$$

Our maintained assumption, which we justify in the next section, is that the variables in X_{ikt} are uncorrelated with the error term ε_{ikt}. Under the further assumption that the error term is i.i.d. extreme value across time, exchanges and traders, the probability of observing $\omega_{it} = k$ conditional on ω_{it-1} is given by:

$$\Pr(\omega_{it} = k | \omega_{it-1}, \theta_i) = \frac{\exp(\theta_i X_{ikt})}{1 + \sum_{l=\text{D,L,BOTH}} \exp(\theta_i X_{ilt})} \tag{9}$$

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

$$S(\{\omega_{it}\}_{t=1}^{T_i} | \theta_i, \omega_{i0}) = \prod_{t=1}^{T_i} \Pr(\omega_{it} | \omega_{it-1}, \theta_i) \tag{10}$$

Trader heterogeneity plays an important role in several of the four stories. It 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 as well as because some groups are present in our data for a limited number of periods only, creating a potential incidental parameter problem (Lancaster, 2000). We address this issue in two ways. As a first approach, we group traders by business types and force the coefficients to be the same within this class. As a second approach, we assume that the trader-specific coefficients in θ_i are independently distributed from the variables in X_{ikt} and the error term, and estimate a mixed logit model (Revelt and Train, 1998, McFadden and Train, 2000). Mixed logit models allow us to estimate the parameters of the distribution of θ_i once we have assumed the functional form for its distribution. We estimate our econometric model using maximum likelihood estimation for the case of business-type specific coefficients and simulated maximum likelihood estimation 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.

7 Results

For the estimation, we dropped the 25 groups for which we could not get any information and the 36 group-month observations for which we could establish that the groups did not trade the Bund during that period. DTB traded the Bund from November 1990 onwards, whereas no more Bund trades took place on LIFFE after 1 January 1999. For the periods where exchanges do not trade the Bund, all components of variable profits are set equal to zero because there is no extra volume from membership in these cases. DTB starts operations at the end of January 1990 and in our coding a firm is a member

in a given month if it is a member in the 15 first days of that month. Thus we focus on membership from February 1990 till December 1999. This leaves us with 39,844 group-month observations and 518 groups.

7.1 Baseline regressions

Table 3 reports the results from our baseline regressions. All specifications control for adoption costs, and variable and fixed components of profits. Adoption costs are made of admission fees and exchange-specific and geography and regulation dependent adoption cost dummies. Admission fees and adoption cost dummies 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 firms open an establishment at the same time as they join an exchange, we consider the geographical presence of firms at $t-3$ to construct the adoption dummies.

Following (5) and (6), volatility of the underlying Bund contract, transaction fees, margins and liquidity make up the variable component of profits. Volatility is defined as the standard deviation of the yield of the underlying Bund contract. Liquidity at exchange k at time t (LIQUIDITY_{kt}) is defined as the 3-month average of traded volume at exchange k over periods $t-3$ to $t-1$ in 10,000s of contracts.[18] To help with the estimation, transaction fees are expressed in Pfennig (0.01 DM) and margins are expressed in thousands of DM.

The fixed component of profits consists of the exchanges' fixed fees, measures of product scope, exchange fixed-effects and exchange-specific time trends. Our measures for product scope are counts of products by product category (interest rate, individual equity, other). Product counts are likely to better capture the *extra* advantage from membership because this advantage is related to the product offering and not so much to absolute levels of trading in those products. Products are organized in classes of similar products because trading volumes vary a lot across asset classes. To account for any remaining trader heterogeneity in the fixed component of profit or any correlation in trader-specific unobserved demand for exchanges, exchange fixed effects are replaced by exchange-business-type-headquarter fixed effects in specification (4) (the headquarter locations are US, UK, Germany, Switzerland, EU except for Germany and UK, ROW, yielding 126 dummies). They are estimated as random coefficients in specifications (5) and (6).

[18] Our measure of liquidity is clearly coarser than the established measures of liquidity studied in the microfinance literature. This is largely dictated by data limitations. Liquidity is multidimensional and is best measured on tick data which are not available for such a long period. The closest measure of liquidity that is available is daily bid-ask spread. However, realized spreads capture only one dimension of liquidity (e.g. it fails to capture market depth) and it is largely endogenous. For example, Breedon and Holland (1998) have shown that realized bid-ask spreads for the Bund were similar in 1995 on both exchanges, but they noted that transaction sizes on LIFFE were more than double the size of transactions at DTB, suggesting that LIFFE was more liquid. Our measure captures the simple idea that liquidity increases with trading volumes.

7.2 Sources of variation

Before discussing our results, we summarize the sources of variation present in our data. Traders vary by geographical presence, headquarter locations and business models. There are three sources of variations over exchanges and time: (1) access deregulation affects countries and exchanges differently across time. In principle, it affects all firms with a geographical presence in a country equally, (2) exchange fees, margins, liquidity and volatility in the underlying Bund contract vary over time (exchange fees, margins and liquidity are also exchange specific). They may affect traders differently because the coefficient on these variables captures both the extra trading volume induced by membership and how those cost drivers affect profits. There are a few short term variations and a downward trend in transaction fees. Margins vary a lot across time but tend to covary across exchanges (correlation coefficient of 0.74) because they are connected to the intrinsic volatility of the Bund contract (the correlation coefficients between the standard deviation of Bund yields and margins at DTB and LIFFE are 0.32 and 0.27 respectively). Overall trading volumes grew tenfold over the ten year period, (3) product scope varies over time and across exchanges as each exchange developed new products or acquired new products through mergers. These sources of variation help identify the effect of the underlying variables.

7.3 Discussion of distributional assumptions

As mentioned in section 6.3, we assume that the logit error term is independently distributed from the explanatory variables. This may seem a strong assumption for transaction fees, margins and liquidity. Specifically, transaction fees could be correlated with the error term if exchanges set fees in response to demand for their services and the error term contains common and unobserved demand aggregate shocks. The panel structure of our data alleviates this problem. In the baseline regressions, common demand aggregate shocks are captured by exchange fixed effects, exchange-specific time trends and measures of product scope. As part of our robustness checks, we include controls for marketing initiatives, technological innovations and changes in the rules of the market, thus arguably leaving no common demand aggregate shocks in the error term.

There are two reasons why liquidity could be correlated with the error term. The first reason is similar to the reason why fees might be correlated with the error term: unaccounted demand shocks could both influence the demand for trading and the demand for membership. We deal with this in the same way as we deal with the potential endogeneity of fees: extensive controls. The second reason is the causal relationship between membership and increased trading volume. The timing of these decisions eliminates this potential problem. In our model, membership decisions for period t are taken in period $t-1$, on the basis of period $t-1$ data.[19] A trader's contribution to liquidity is thus not taken into account. Moreover, an average member represents less than 2% of trading volume in the

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

Bund at all times. The extra trading volume that his membership entails represents even less. So even if a trader took his future impact on liquidity into account that effect would be small.

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

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

[INSERT TABLE 3 ABOUT HERE]

7.4 Adoption costs and access deregulation

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

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

Across geographies and for DTB, the relative ranking of access cost coefficients is broadly consistent with the way we constructed the dummies for groups with geographical presence in several countries. Access costs from Switzerland are comparable to those from the EU except after September 1998 when access costs from Switzerland are smaller. They are comparable to adoption costs from the US. For the first part of the decade, access for firms with a presence in Germany was cheapest. Adoption costs later from Switzerland and the US are lower than from Germany. This suggests that costs may have declined over time for reasons other than regulation, and that the estimate for adoption costs from

Germany may be an underestimate of costs at the beginning of the period and an overestimate of costs later in the decade.

Across geographies and for LIFFE, our estimates confirm that traders with a presence in the UK did incur lower set-up costs than traders without a UK presence.

Finally, we compare access costs across exchanges. Total adoption costs for DTB must include the admission fee for the period until December 1997. When we take this admission fee into account, adoption costs for DTB were not smaller than for LIFFE until December 1997. They became smaller afterwards. The coefficient on the admission fee helps us calibrate total adoption costs. For instance, total adoption costs for DTB in early 1996 for a US-based firm was around 420,000 DM (approx. 280,000 USD) based on specification (1).[20]

7.5 Variable profits coefficients

The second part of table 3 reports the coefficients on variable profits. Each combines the effect of the variable on variable profits and the extra volume traded as a consequence of membership. In specifications (1) and (2) where they are imposed to be the same for all traders, all coefficients have the expected sign, except for margins. Fees, margins and liquidity are all significant at the 5% level.

Specifications (3) and (4) allow coefficients on variable profits to be business-type specific. For each variable, we report four numbers: in the top row, we report the mean of those coefficients that are significant at the 10% level and the mean of the standard deviation on these coefficients; the bottom row reports in parenthesis, the standard deviations of the estimated coefficients and of the associated standard deviations, again for those coefficients that are significant at the 10% level. The difference between specification (3) and (4) is that specification (4) includes, in addition, exchange, headquarter and business-type fixed effects. The difference of point estimates across business-types is less than the standard deviation on these point estimates (comparison between the bottom left number and the top right number for each variable). This suggests that, either business-types are not be a good proxy for trader heterogeneity as far as their trading behavior is concerned, or that trader heterogeneity on this dimension is not important practically. Specifications (5) and (6) investigate this hypothesis. In specification (5), coefficients on variable profits (volatility, transaction fees, margins and liquidity) are estimated as random coefficients. In specification (6), exchange effects are also estimated as random coefficients. Table 3 reports the mean and standard deviation of the coefficients in the population (Table 4 reports the parameter estimates of the distributions).

[20] 102,000 + $\frac{10.19}{3.21} \times 100,000$. This is to be compared with estimates of set-up costs reported in the press at that time of one million US dollars.

Table 4: Random Coefficients (specifications (5) and (6), Table 3)

		Specification (5)				Specification (6)			
Variable	Distribution	b		w		b		w	
		Est.	Stdev.	Est.	Stdev.	Est.	Stdev.	Est.	Stdev.
DTB fixed effect	$N(b,w)$					6.5495	0.5168	0.9208	0.1403
LIFFE fixed effect	$N(b,w)$					4.0213	0.4713	1.2227	0.1637
BOTH fixed effect	$N(b,w)$					10.3458	0.7627	0.8389	0.3697
Volatility	$e^{N(b,w)}$	0.6982	0.6536	0.0000	1.0000	0.5357	0.8317	0.0000	1.0000
Fee	$-10^{-2}e^{N(b,w)}$	-0.6328	0.4296	0.7320	0.2039	-0.8069	0.6892	0.0000	1.0000
Margins	$N(b,w)$	0.1977	0.0758	0.2166	0.0300	0.1743	0.0703	0.1510	0.0430
Liquidity	$10^{-2}e^{N(b,w)}$	-1.9225	0.4120	0.3376	0.2473	-1.8171	0.3855	0.4504	0.2204

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

7.6 Fixed profits components

The component of profit that does not depend on trading activity in the Bund is captured by several variables in the specifications. Of particular interest are the coefficients on product scope variables. They are significant for DTB but are not significant for LIFFE. One reason might be the way our membership data is constructed. Our data for LIFFE members include traders with a license to trade interest rate products. Some of them also have a license to trade other product categories such as equities or commodities, but they for sure trade interest rate products and thus presumably the Bund. For DTB members, we had to track that information, and we included groups for which we could not establish whether they traded interest rate products or not. Thus the set of members for DTB arguably represents a more varied lot, more likely to care about other products. To check this hypothesis, we rerun specification (2) on the subsample of the 341 firms for which we could establish that they trade interest rate products. The results are reported as specification (1) in Table 5. The results are very similar to the results in Table 3, except for the fact that two of the adoption dummies become essentially unidentified due to lack of observations and that the scope coefficients for DTB on "other products" becomes insignificant.

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

dummies for all the other events reported in Table 9 in Appendix A. The results are reported as specification (2) in Table 5. Two of these six dummies are significant but the results otherwise barely change.

Overall, the Bund-related component of profits represents from 10 to 17% of the total extra profits from membership, depending on the exchange. These numbers are based on specification (2) and are obtained by dividing the variable component of extra profits by the sum of the variable and fixed components (adoption costs are ignored). They are lower bounds on the relative importance of variable profits because, as argued in section 6.2, the benefits from avoiding brokers fees are not separately identified from the fixed profits component. The relative importance of Bund-related variable profits is highest for DTB, with an average over time and traders equal to 16.72% and lowest for LIFFE, with an average over time and traders equal to 10.45%.

[INSERT TABLE 5 ABOUT HERE]

7.7 Allowing for substitution effects

A simplifying assumption in the baseline regressions is that membership to one exchange does not reduce trading activity on the other exchange. Without this assumption, the variable profit component takes the following form for $k = D$ (the expression for L is symmetric):

$$\begin{aligned}
\Delta\text{VAR}_{it}(D) &= \text{VAR}_{it}(D) - \text{VAR}_{it}(0) \\
&= (\text{vol}_{iDt}(D) - \text{vol}_{iDt}(0))(\rho_{it} - \text{FEE}_{Dt} - \text{MARGINS}_{iDt} - \text{IMPACT}_{iDt}) \\
&\quad +(\text{vol}_{iLt}(D) - \text{vol}_{iLt}(0))(\rho_{it} - \text{FEE}_{Lt} - \text{MARGINS}_{iLt} - \text{IMPACT}_{iLt}) \\
&\quad +(\text{vol}_{iDt}(0) + \text{vol}_{iLt}(0) - \text{vol}_{iLt}(D))\text{BROKERFEE}_t
\end{aligned}$$

where $(\text{vol}_{iDt}(D) - \text{vol}_{iDt}(0))$ captures as before the extra volume effect and $(\text{vol}_{iLt}(D) - \text{vol}_{iLt}(0))$ now captures the substitution effect. The derivation for the choice $k = B$ yields:

$$\begin{aligned}
\Delta\text{VAR}_{it}(B) &= \text{VAR}_{it}(B) - \text{VAR}_{it}(0) \\
&= (\text{vol}_{iDt}(B) - \text{vol}_{iDt}(0))(\rho_{it} - \text{FEE}_{Dt} - \text{MARGINS}_{iDt} - \text{IMPACT}_{iDt}) \\
&\quad +(\text{vol}_{iLt}(B) - \text{vol}_{iLt}(0))(\rho_{it} - \text{FEE}_{Lt} - \text{MARGINS}_{iLt} - \text{IMPACT}_{iLt}) \\
&\quad +(\text{vol}_{iLt}(0) + \text{vol}_{iDt}(0))\text{BROKERFEE}_t
\end{aligned}$$

The only difference with (4) is that $(\text{vol}_{iDt}(B) - \text{vol}_{iDt}(0))$ is no longer equal to $(\text{vol}_{iDt}(D) - \text{vol}_{iDt}(0))$. Thus the specification we bring to the data is (the equivalent of equations (5) and (6)):

$$\begin{aligned}
\Delta\text{VAR}_{it}(k) &= \beta_{1i}\text{VOLAT}_t + \beta_{2i}\text{FEE}_{kt} + \beta_{3i}\text{MARGINS}_{kt} + \beta_{4i}\text{LIQUIDITY}_{kt} \\
&\quad +\beta_{5i}\text{FEE}_{k't} + \beta_{6i}\text{MARGINS}_{k't} + \beta_{7i}\text{LIQUIDITY}_{k't} + \eta_{ikt} \\
\text{for } k, k' &\in \{D, L\} \text{ and } k \neq k' \\
\Delta\text{VAR}_{it}(B) &= \beta_{8i}\text{VOLAT}_t + \beta_{9i}\text{FEE}_{Bt} + \beta_{10i}\text{MARGINS}_{Bt} + \beta_{11i}\text{LIQUIDITY}_{Bt} + \eta_{iBt}
\end{aligned}$$

We run the equivalent of specifications (1)-(3) from Table 3 with this adjusted specification. The results are reported in Table 6. As predicted, the coefficients on "other transaction fee" (β_{5i}), "other margins" (β_{6i}) and "other liquidity" (β_{7i}) have the opposite sign as the coefficients on "own transaction fee", "own margins" and "own liquidity". In some cases, they are also significant suggesting the presence of substitution effects. Nevertheless, the rest of the coefficients are similar to those obtained under the assumption of no substitution effects, and the explanatory power, measured by the pseudo-R^2, is barely improved from the baseline regressions.

[INSERT TABLE 6 ABOUT HERE]

7.8 Goodness of fit and further robustness checks

In all specifications, the pseudo R^2 is very high. However, the level of the R^2 itself is not very informative for our data. With only 546 transitions out of 39,844 observations, a high R^2 could be explained by setting high adoption costs: high adoption costs together with stable profits would result in a low number of transitions (in fact, a simple regression with time and geography varying adoption dummies and exchange fixed effects yields a pseudo R^2 of 94.97 already). The fact that the coefficients on time-varying explanatory variables are positive is encouraging. We do three further checks. First, we restrict attention to the group-month observations where the group changed membership status and we estimate a conditional logit model (conditional on changing status, which of the three other options did the trader choose?). In such a specification, adoption costs are barely identified: differences in adoption costs across exchanges are identified from transition where a trader adds a membership and levels are only identified from transitions where a trader drops a membership. Most of the coefficients on the other explanatory variables are no longer significant either. Nevertheless, the pseudo R^2 reaches 0.70 in the simplest specification, suggesting that our explanatory variables for profits capture some relevant dimensions of traders' decision making.[21]

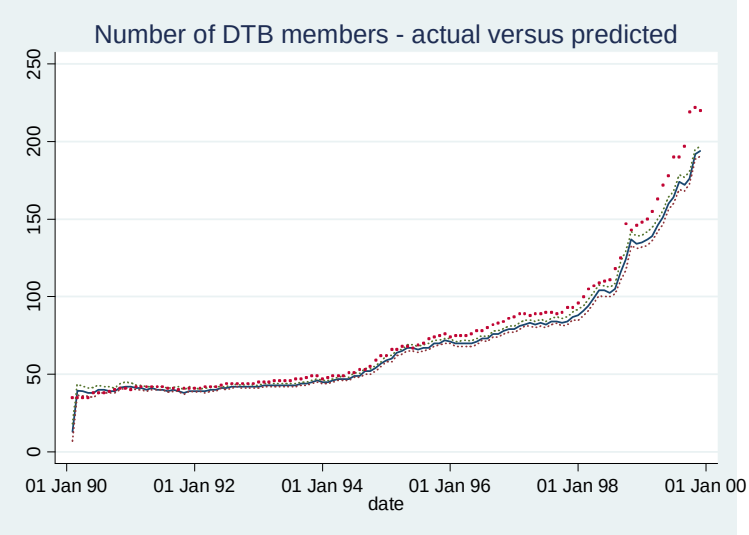
Second, we check whether our high R^2 and high significance levels for many variables are driven by the way we structured our data. Specifically, we might be worried that the high and significant adoption costs are driven by our assumption of monthly decision-making. To investigate this hypothesis, we extend the behavioral model to allow for different periodicities in decision-making. Specifically, we assume that, at every period, traders reoptimize their membership status with probability λ. Thus, conditional on λ, ω_{it-1} and θ_i, the probability that trader i chooses k in period t is equal to:

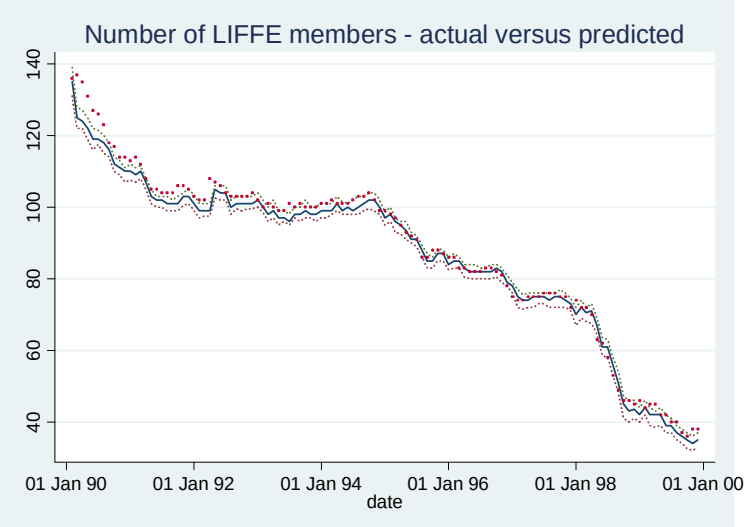
$$\Pr(\omega_{it}=k|\omega_{it-1},\theta_i)=\begin{cases}\lambda\frac{\exp(\theta_i X_{ikt})}{1+\sum_{l=\mathrm{D,L,BOTH}}\exp(\theta_i X_{ilt})} & \text{if } k\neq\omega_{it-1}\\ \lambda\frac{\exp(\theta_i X_{ikt})}{1+\sum_{l=\mathrm{D,L,BOTH}}\exp(\theta_i X_{ilt})}+(1-\lambda) & \text{if } k=\omega_{it-1}\end{cases} \tag{11}$$

When $\lambda=1$, expression (11) reduces to (9). When $\lambda<1$, a trader can keep the same membership status because he did not reconsider his membership status this period or because he reconsidered

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

it but decided that his current membership status is optimal. Although both high adoption costs and a low value for the λ parameter could explain the relatively low number of status changes in the data, the two parameters are separately identified. Specifically, a decrease in adoption costs has two effects: (1) an increase in the number of adoption spells, and (2) longer spells during which a trader is a member of an exchange because it is profitable earlier to join an exchange. An increase in the frequency of decision-making also increases the number of adoption spells but, unlike lower adoption costs, it can both lengthen or shorten membership spells. In numerical simulations, both parameters were well identified. Specification (3) in Table 5 reports the results for the same specification of the profit function as in specification (1), Table 3. The estimated λ is equal to 1.[22]





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

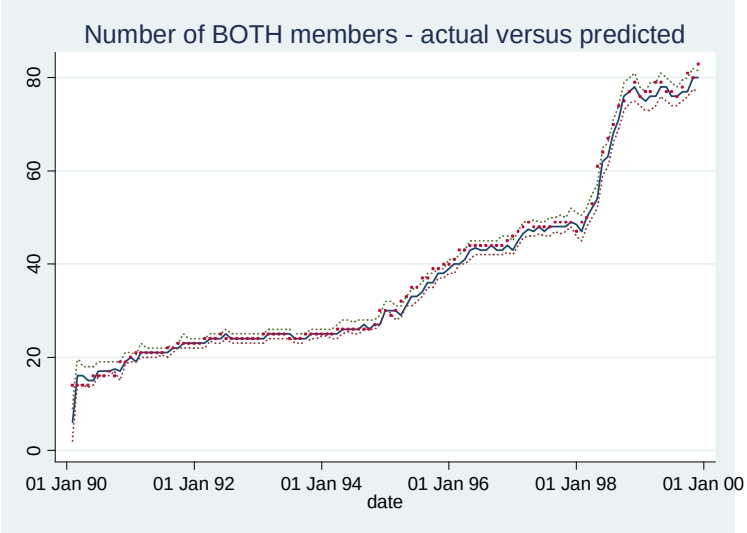


Figure 6

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

8 The four stories revisited

We now revisit the four stories that have been proposed to explain the Battle of the Bund in light of our empirical results. The results provide support for the vertical and horizontal differentiation stories but do not lend support to the idea that access deregulation or political pressures on German traders gave DTB a definite advantage during the Battle. Putting this together with the descriptive evidence in section 5 that a large part of DTB members were not members of LIFFE helps explain the market share reversal.

8.1 Evidence for vertical differentiation

For the vertical differentiation story to hold, we need evidence that liquidity matters and that traders care about liquidity differently. Our regression results show that traders did take liquidity into account when selecting their membership status and that heterogeneity matters on that dimension. We now

quantify this dimension of heterogeneity.

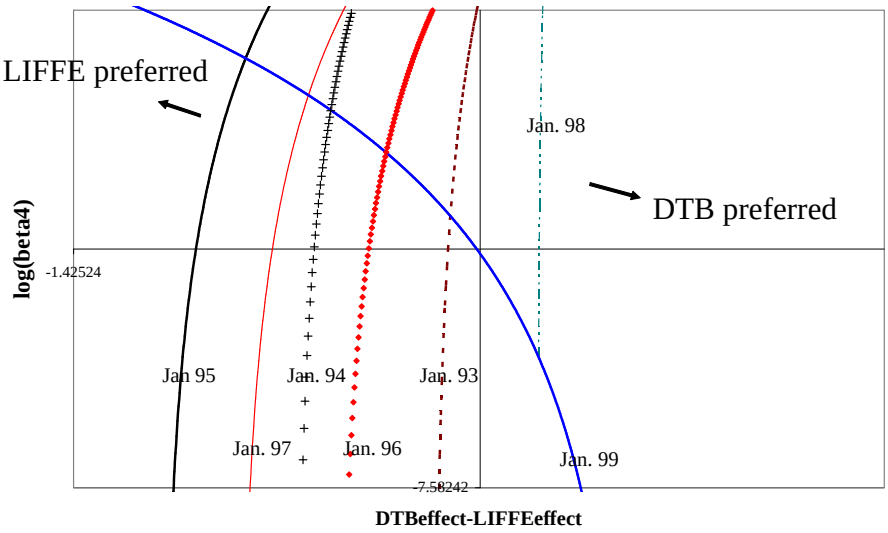


Figure 7: Preferences over DTB and LIFFE as a function of β_{4i} and individual fixed effects

Figure 7 plots the combination of trader liquidity preferences (β_{4i}) and exchange effects that makes a trader indifferent between DTB and LIFFE at different points in time. It is constructed on the basis of specification (6) where we set the other random coefficients (margins, fees, volatility) at their mean. The $x-$axis corresponds to the difference between the individual DTB and LIFFE effects. It is normally distributed and the extremes of the box on that dimension correspond to the 0.5 and 99.5 percentile respectively. The $y-$axis corresponds to the log of the liquidity coefficient (β_{4i}). It is also normally distributed and the extremes of the box on that dimension correspond to the 0.5 and 99.5 percentile.

The slope of the loci quantifies the relative importance of trader heterogeneity on the liquidity dimension relative to trader heterogeneity in terms of the fixed component of profits. The steeper the locus, the smaller the relative importance of trader heterogeneity in terms of liquidity. The loci shift a lot over time suggesting that the preferences of a trader of a given liquidity and exchange effect type varies a lot over time. These shifts are driven by changes in the rest of the profit function (time trends, product scope, margins, volatility and fees).

As another perspective, we ask by how much DTB should have decreased their transaction fees to compensate for their lower liquidity. Table 7 reports the results of this exercise at different points in time and for each quartile of the distribution of the liquidity coefficient. It is based on specification (6). Table 7 helps us quantify trader heterogeneity in terms of liquidity: attracting the high-liquidity valuer requires a discount that is approximately twice as big as the required discount for a low-liquidity valuer. Table 7 also suggests that, early in the decade when the absolute difference in trading volumes

was not too big, DTB could have compensated the low-liquidity valuer with a 0.20 DM transaction fee reduction (a 40% reduction). As trading volumes and the absolute difference in trading volumes grew, the required reduction increased.

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

	$\beta_{4,0.25}$	$\beta_{4,0.5}$	$\beta_{4,0.75}$
Jan 91	-0.18	-0.24	-0.32
Jan 92	-0.14	-0.19	-0.26
Jan 93	-0.21	-0.29	-0.39
Jan 94	-0.37	-0.50	-0.68
Jan 95	-0.52	-0.71	-0.96
Jan 96	-0.47	-0.64	-0.86
Jan 97	-0.52	-0.71	-0.96
Jan 98	-0.03	-0.04	-0.05
Jan 99	2.44	3.30	4.47

8.2 Deregulation and adoption costs

In Section 7, we found that adoption costs were highly significant and evolved as expected with deregulation. We now assess the actual advantage 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 (1) in Table 3. So, for instance, adoption costs for EU countries are set equal to -11.51 for the entire decade. We then simulate the number of firms that are members of DTB and LIFFE in the counterfactual scenario and compare it with the predicted numbers under the true parameters. The difference underestimates the effect of deregulation because it ignores the multiplier effect that less members today imply lower trading volume tomorrow and thus less members tomorrow.

Nevertheless, the comparison is already instructive. In Figure 8, the predicted number of DTB members in the absence of deregulation is barely under the model predictions and the two numbers are not distinguishable for LIFFE. By comparison, we simulated the number of DTB and LIFFE members if DTB had not charged any admission fee from the beginning. There is no effect of admission fees on LIFFE membership but a sizable effect on DTB membership. If DTB had not charged any admission fee, they would have reached a 50% share of membership at least (given the multiplier effect) a year and a half earlier. As a second point of comparison, we simulated the number of DTB and LIFFE members in the absence of dual-homing (for instance because membership is exclusive). As expected, dual-homing reduces traders incentives to become members of DTB. More interestingly, they also reduce traders' incentives to keep a LIFFE membership. Both effects are large. With exclusive membership, DTB would have reached a 50% market share in membership almost four full years

earlier (the same caveat applies as earlier: this ignores any multiplier effect).

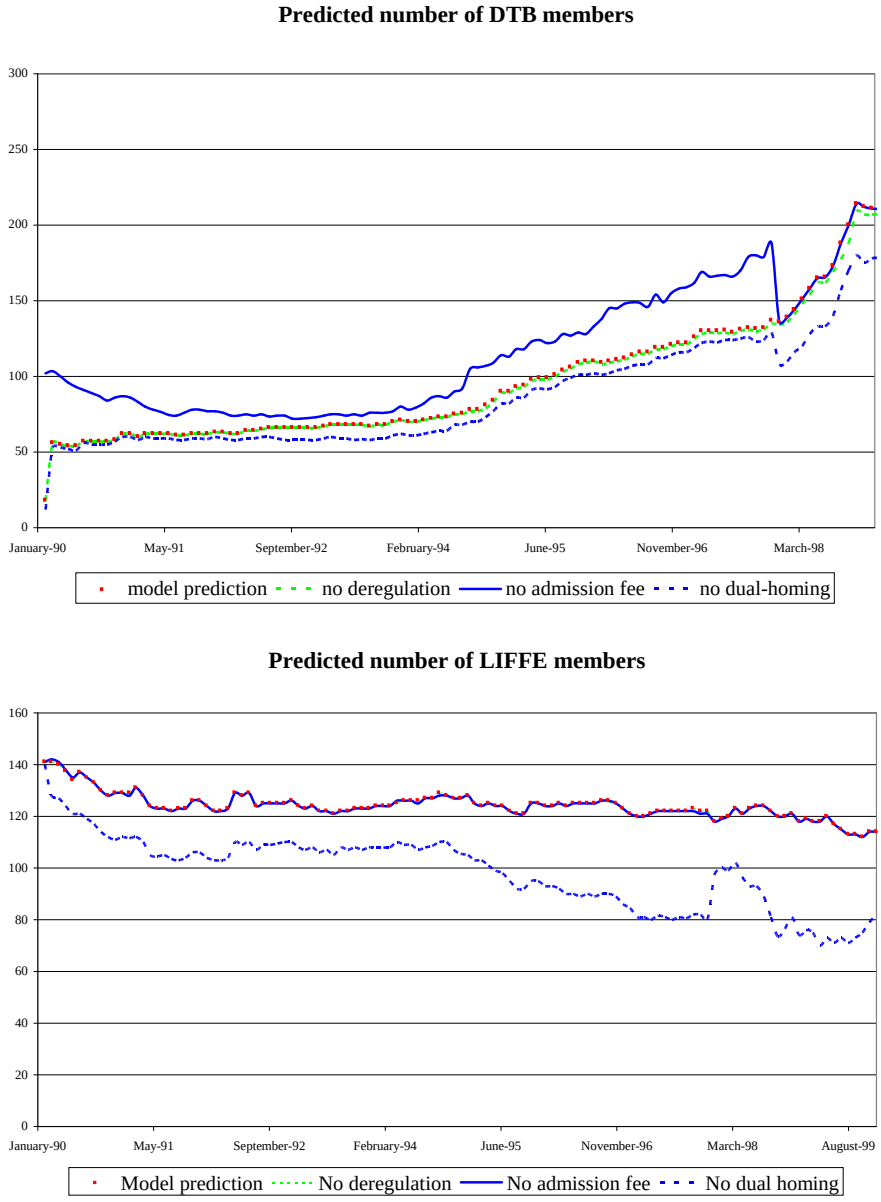


Figure 8: Predicted number of DTB and LIFFE members under different scenarios

8.3 The role of product scope and other non Bund-related aspects

We now turn to the conjecture that product portfolio choices made the difference for DTB. The evidence from Table 3 is mixed and certainly does not support the conjecture that DTB's product development in interest rate products helped attract new members. However, our measures of product scope may be too imperfect to capture the whole story. For this reason we take a broader view and now ask to what extent differences in the component of profits that does not vary with trading in the Bund affected DTB. From Figure 7, we already know that the two exchanges were horizontally differentiated (indeed, one way to read Figure 7 is that heterogeneity on the horizontal dimension was

more important than heterogeneity in terms of preferences for liquidity). As an alternative perspective, Figure 9 plots the evolution over time of the (mean) fixed component of profits for DTB and LIFFE. It includes the mean exchange fixed effects, the time trend, the fixed fees and the product scope variables, using the coefficients from specification (6) in Table 3. Recall that the normalization here is with respect to not being a member of any exchange. Figure 9 shows DTB and LIFFE head to head for most of the period.

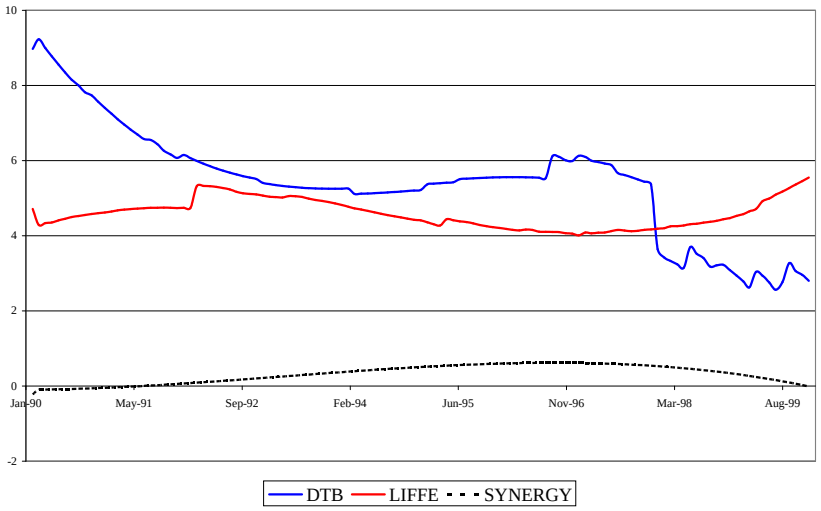


Figure 9: Estimated mean fixed component of profits for DTB and LIFFE and estimated synergy over time

Because exchange effects are estimated as random coefficients, specification (6) also allows us to assess the presence of synergies between the two exchanges (Gentzkow, 2007). The dotted line in Figure 9 traces the value of $\Delta F_{it}(B) - \Delta F_{it}(D) - \Delta F_{it}(L)$. It is stable and around zero over the entire period suggesting that memberships at the two exchanges were neither complements nor substitutes. The same exercise based on specification (4) shows synergy stable around -2, suggesting that the two exchanges were partial substitutes.

8.4 Nationalism

Several industry participants have suggested that political pressure on German traders played a role in DTB's success. To investigate this hypothesis, specification (4) in Table 3 controls for exchange effects that are headquarter and business-type specific.[23] Many of these dummies are significant, suggesting that trader-exchange unobservable may be important. The value of some of these fixed effects is reported in Table 8 (n/a indicates that the dummy is not identified). The omitted category is the NONE choice within each business-type-HQ-location, thus the interpretation for each of these variables should be the preference of a given trader for an exchange relative to not being a member

[23] Heaquarter locations are different from geographical presence. They capture the nationality of the firms.

of any exchange. In addition, because specification (4) also includes time trends that are exchange specific, only *within exchange* comparisons are meaningful.

Table 8: Evidence of HQ location - business type effect

		DTB	LIFFE	BOTH
IB	UK HQ	7.23	4.29	10.79
		(0.69)	(1.02)	(1.21)
	US HQ	8.07	3.98	12.00
		(0.74)	(0.97)	(1.14)
	German HQ	8.20	5.59	11.62
		(0.53)	(1.17)	(1.24)
Specialized	UK HQ	5.13	3.55	11.27
		(1.00)	(0.98)	(1.31)
	US HQ	6.80	3.22	11.39
		(0.69)	(0.99)	(1.29)
	German HQ	7.38	N/A	12.76
		(0.71)		(1.66)
Proprietary	UK HQ	3.99	2.82	7.70
		(0.88)	(0.96)	(1.35)
	US HQ	5.58	2.92	8.94
		(0.77)	(1.06)	(1.48)
	German HQ	5.89	N/A	N/A
		(0.68)		

We use the US-headquartered firms as a benchmark for unbiasedness and compare the fixed effects across headquarter locations, for a given exchange and a given business type. For DTB, the US HQ dummy is always between the UK and the German dummy, consistent with a positive bias towards DTB for German hearquartered traders and a negative bias for UK headquartered traders. This difference is significant only for the UK and US headquartered specialized trading firms and proprietary firms.[24] This suggests the existence of a *negative* bias by these UK-headquartered firms against DTB, rather than a positive bias by German firms. For LIFFE, the numbers indicate that German headquartered investment banks are more favorable to LIFFE than the US headquartered banks and the difference is significant. Overall, we find no evidence that German firms were biased in favor of DTB. Rather, we find that some UK headquartered firms were biased against DTB and that German IBs were biased in favor of LIFFE.

[24] The unreported tests are one-sided t-tests based on the full variance-covariance matrix.

9 Concluding remarks

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

This is the first paper that evaluates the contribution of these different factors to the attractiveness of exchanges and ultimately to the way exchanges compete. This is done through the detailed study of the Battle of the Bund, a famous episode in European financial history. The paper documents the role of trader heterogeneity in explaining DTB and LIFFE's coexistence and DTB's eventual success, and identifies two specific sources of such heterogenity: differences in preferences over liquidity and differences in preferences over product scope (or more generally, horizontal differentiation). Our results also put access deregulation in perspective. Deregulation did lower adoption costs for DTB but had a marginal effect relative to a hypothetical admission fee waiver or the imposition of exclusive membership. All in all, these results suggest a richer view of exchanges than the established "exchanges as natural monopolies" view.

We end with several venues for future research. First, heterogeneity has important welfare consequences and strategic implications for exchanges. In particular, it suggests a scope for exchanges to charge different prices to different traders, a practice that was uncommon in the nineties but has become more routine these days. Whether such strategies are effective depends on how different traders contribute to liquidity. This is a question we take on in Cantillon and Yin (in progresss). 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, the paper does not tell why the market tip when it did. Answering this question requires that we look at trading volumes and because network effects are more important for trading than for membership, that we allow for multiple equilibria. Our current results can help us integrate relevant aspects of trader heterogeneity into an empirical model of aggregate trading volume.

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10 Appendix A: Description of data and variable construction

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

10.1 Firm dataset

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

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

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

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

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

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

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

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

10.2 Regulation-driven adoption costs

DTB

Initially, a trader had to have an office in Germany to be a member of DTB and only German firms could be clearing members. On 28 July 1993, there was a change in the law and EU trading firms with a German office could become clearing members. In September 1994, MATIF members could become members of DTB and the Dutch authorities recognized DTB and authorized Dutch-based firms to trade on DTB for their own account. The EU Investment Services Directive came into force in January 1996. Switzerland is not part of the EU and thus access from Switzerland followed its own timetable. Acess points were installed in Zurich in January 1996 and SOFFEX members became members of Eurex when SOFFEX and DTB merged in September 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 in October 1998, forbidding any new membership from the US. It was reinstated in August 1999.

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

LIFFE

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

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

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

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

Table 8 summarizes the value for the resulting adoption dummies.

Table 8: Adoption dummies for DTB and LIFFE

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

10.3 Other events affecting the attractiveness of DTB and LIFFE

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

Table 9: Other events

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

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

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

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

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

11.1 Exchange-traded futures

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

Market rules vary across exchanges and instruments. Broadly speaking, there are two cate-

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

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

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

11.2 Market participants and trading motives

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

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

11.3 Cost of trading

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

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

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

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

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

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

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

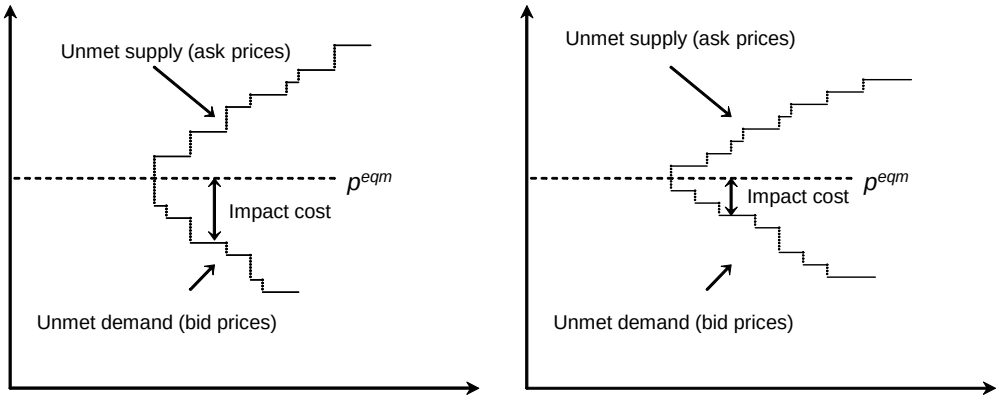

Figure 10: Impact costs in a less liquid (left panel) and liquid market (right panel)

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

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

average variable costs of trading were lower on DTB (1.25 DM per contract versus 1.5 DM). From the "long term" trader's perspective on the other hand, the cost comparison favored LIFFE (5.8DM versus 7.45 DM).

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

Table 3 – Multinomial logit for exchange choice (baseline regressions)

			With product scope		Business-type specific coef. on var. profits		Business-type specific coef. on var profits and exchange effetcs		Random coefficients on var profits		Random coefficients on var profits and exchange effects	
	(1)		(2)		(3)		(4)		(5)		(6)	
Variable	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err.	Coef.	Std. Err.
Adoption costs – DTB												
Admission	-3.21 10^{-5}**	3.93 10^{-6}	-3.20 10^{-5}**	3.95 10^{-6}	-3.3 10^{-5}**	4.01 10^{-6}	-3.49 10^{-5}**	4.13 10^{-6}	-3.60 10^{-5}**	4.18 10^{-6}	-3.38 10^{-5}**	5.94 10^{-6}
Germany	-7.43**	0.24	-7.45**	0.24	-7.40**	0.24	-7.12**	0.26	-7.06**	0.26	-6.64**	0.31
EU 1/90-7/93	-11.51**	0.49	-11.51**	0.49	-11.46**	0.49	-12.33**	0.53	-11.23**	0.51	-11.71**	0.87
EU 8/93-12/95	-10.06**	0.53	-10.13**	0.53	-10.08**	0.53	-9.69**	0.55	-10.11**	0.55	-10.47**	0.86
EU 1/96-	-8.80**	0.22	-8.83**	0.22	-8.86**	0.23	-8.39**	0.25	-8.90**	0.25	-8.96**	0.31
France-NL 9/94-12/95	-6.48**	0.39	-6.57**	0.39	-6.64**	0.40	-6.81**	0.43	-6.66**	0.44	-6.72**	0.74
Switzerland 1/90-12/95	-10.24**	0.64	-10.24**	0.64	-10.11**	0.65	-10.37**	0.94	-10.19**	0.66	-10.33**	0.96
Switzerland 1/96-8/98	-10.48**	1.03	-10.55**	1.03	-10.60**	1.04	-11.11**	1.24	-10.87**	1.00	-10.84**	1.00
Switzerland 9/98 -	-6.52**	0.34	-6.46**	0.34	-6.97**	0.40	-7.45**	0.76	-6.24**	0.43	-6.10**	0.50
US 1/90 - 2/96	-10.19**	1.04	-10.19**	1.04	-10.17**	1.04	-9.90**	1.20	-10.14**	1.01	-10.29**	1.00
US 3/96 - 9/98	-7.25**	0.43	-7.32**	0.43	-7.28**	0.44	-6.64**	0.51	-7.39**	0.99	-7.24**	0.89
US 10/98 – 7/99	-9.08**	1.03	-8.97**	1.03	-9.00**	1.04	-8.43**	1.07	-9.04**	0.99	-8.97**	1.00
US 8/99 -	-6.06**	0.54	-6.31**	0.55	-6.36**	0.56	-5.93**	0.62	-6.35**	0.69	-6.30**	0.99
Adoption costs – LIFFE												
UK	-9.65**	0.16	-9.66**	0.16	-9.64**	0.16	-9.62**	0.17	-9.73**	0.18	-9.68**	0.21
EU 1/90 – 12/95	-13.31**	0.59	-13.34**	0.59	-13.12**	0.60	-13.37**	0.64	-13.89**	0.62	-14.24**	0.99
EU 1/96 – 7/98	-12.10**	0.62	-12.69**	0.60	-12.64**	0.60	-12.62**	0.65	-13.32**	0.63	-13.70**	0.98
EU 8/98 -	-12.12**	0.62	-12.12**	0.62	-12.15**	0.62	-12.13**	0.72	-12.25**	0.62	-12.94**	0.96
US 1/90 – 8/99	-12.08**	1.01	-12.08**	1.01	-12.03**	1.01	-11.94**	1.03	-12.63**	1.00	-12.97**	1.00
US 9/99 – 12/99	-9.50**	1.05	-9.61**	1.06	-9.63**	1.06	-10.14**	1.14	-9.60**	1.01	-10.51**	1.00
Variable profits					Mean coefficient	Mean std. dev.	Mean coefficient	Mean std. dev.	Mean and standard deviation of coefficients in population		Mean and standard deviation of coefficients in population	
Volatility	2.1996*	1.2633	2.0003	1.3182	12.07	4.18	11.65	4.41	2.0102	0.0000	1.7087	0.0000
					(0)	(0)	(0)	(0)				
Transaction fee	-0.0043**	0.0022	-0.0050**	0.0023	-0.0142	0.0057	-0.0125	0.0066	-0.0069	0.0058	-0.0045	0.0000

					(0.0085)	(0.0019)	(0.0040)	(0.0030)				
Margins	0.1520**	0.0732	0.1927**	0.0779	0.3371	0.1096	0.5766	0.1394	0.1981	0.2166	0.1749	0.1512
					(0.0727)	(0.0032)	(0)	(0)				
Liquidity	0.0014**	0.0005	0.0016**	0.0006	0.0023	0.0273	0.0023	0.0008	0.0015	0.0005	0.0018	0.0008
					(0.0004)	(0.0531)	(0.0003)	(0.0001)				
Product scope – DTB												
Interest rate products			-0.072**	0.023	-0.073**	0.024	-0.075**	0.024	-0.086**	0.022	-0.081**	0.010
Equity			0.048**	0.022	0.053**	0.023	0.054**	0.023	0.062**	0.021	0.062**	0.010
Other			0.164**	0.063	0.144**	0.064	0.142**	0.064	0.157**	0.058	0.124**	0.010
Product scope – LIFFE												
Interest rate			0.001	0.024	-0.0035	0.0245	-0.0048	0.0244	-0.005	0.010	-0.003	0.011
Equity			0.010	0.007	0.0102	0.0073	0.0112	0.0073	0.012	0.008	0.012	0.072
Other			0.013	0.025	0.0070	0.0258	0.0069	0.0258	0.011	0.010	0.010	0.013
Fixed fees	$7.28\ 10^{-5}$**	$1.37\ 10^{-5}$	$5.34\ 10^{-5}$**	$1.57\ 10^{-5}$	$5.73\ 10^{-5}$**	$1.61\ 10^{-5}$	$5.9\ 10^{-5}$**	$1.61\ 10^{-5}$	$6.62\ 10^{-5}$**	$1.92\ 10^{-5}$	$5.77\ 10^{-5}$**	$1.99\ 10^{-5}$
Exchange-specific time trend	Yes		Yes		Yes		Yes		Yes		Yes	
Exchange fixed effects	Yes		Yes		Yes		No		Yes			
Exchange-business-type-HQ fixed effects	No		No		No		Yes		No		Random coefficients	
Loglikelihood	-2,693.05		-2,685.35		-2,650.64		-2,509.04		-2,657.29		-2,630.91	
Pseudo R2	0.9512		0.9514		0.9520		0.9546		0.9519		0.9524	
N	39,844		39,844		39,844		39,844		39,844		39,844	

** indicates significance at 5%; * indicates significance at 10%. Time trend includes time, time^2 and time^3. Specifications (1)-(4): fixed coefficients multinomial logit. Specifications (3) and (4): two numbers are reported for each variable profit component: the mean of the coefficients that turned out to be significant at the 10% level and their mean standard deviations (the terms in parenthesis are the standard deviation across trader types). For specification (3), volatility is significant for asset management firms; fees are significant for specialized trading firms, asset management and proprietary firms; margins are significant for specialized trading firms and proprietary trading firms; liquidity is significant for universal and retail banks, brokerages and asset management firms. For specification (4), volatility is significant for asset management firms, fees are significant for brokerages, asset management firms and proprietary trading firms; margins are significant for proprietary trading firms, liquidity is significant for universal and retail banks, and for asset management and proprietary trading firms. Specification (5): random coefficients logit with random coefficients for volatility (lognormal), transaction fee (lognormal), margins (normal), liquidity (lognormal). Specification (6): same as specification (5) but with RCs on exchange effects (normal). Based on 200 draws per month-group observation. The table reports the means and standard deviations of the coefficients in the population implied by the estimated distribution. Table 4 reports the estimates of the coefficients.

Table 5 – Multinomial logit for exchange choice (robustness)

Variable	Different default values		Additional checks		Freq of decision-making	
	(1)		(2)		(3)	
	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
λ					1.0000**	0.1122
Adoption costs – DTB						
Admission	-2.89 10^{-5}**	5.41 10^{-6}	-3.75 10^{-5}**	5.17 10^{-6}	-3.24 10^{-5}**	3.94 10^{-6}
Germany	-8.16**	0.37	-6.59**	0.54	-7.43**	0.33
EU 1/90-7/93	-11.76**	0.57	-10.80**	0.71	-11.51**	0.51
EU 8/93-12/95	-10.69**	0.71	-9.44**	0.61	-10.06**	0.55
EU 1/96-	-9.17**	0.34	-8.52**	0.26	-8.80**	0.32
France-NL 9/94-12/95	-6.50**	0.51	-6.64**	0.49	-6.48**	0.44
Switzerland 1/90-12/95	-11.43**	0.81	-9.83**	1.05	-10.24**	0.66
Switzerland 1/96-8/98	-24.62	847.95	-11.10**	1.24	-10.48**	1.04
Switzerland 9/98 -	-7.17**	0.44	-7.41**	0.77	-6.52**	0.43
US 1/90 - 2/96	-10.95**	1.08	-9.43**	1.27	-10.19**	1.04
US 3/96 - 9/98	-7.74**	0.63	-6.68**	0.51	-7.25**	0.49
US 10/98 – 7/99	-8.76**	1.09	-8.47**	1.07	-9.08**	1.04
US 8/99 -	-8.16**	1.14	-5.99**	0.63	-6.06**	0.56
Adoption costs – LIFFE						
UK	-9.98**	0.22	-9.65**	0.17	-9.65**	0.30
EU 1/90 – 12/95	-13.50**	0.61	-13.42**	0.64	-13.31**	0.66
EU 1/96 – 7/98	-12.68**	0.62	-12.68**	0.65	-12.69**	0.65
EU 8/98 -	-12.20**	0.66	-11.97**	0.72	-12.10**	0.66
US 1/90 – 8/99	-12.25**	1.02	-11.95**	1.03	-12.08**	1.02
US 9/99 – 12/99	-26.06	3,631.51	-10.15**	1.14	-9.50**	1.06
Variable profits						
Volatility	2.74	1.70	12.49	4.36	2.1996**	1.0692
			(0)	(0)		
Transaction fee	-0.0062**	0.0028	-0.0110	0.0049	-0.0043*	0.0022
			(0.0005)	(0.0001)		
Margins	0.2110**	0.0965	0.3824	0.1286	0.1520**	0.0732
			(0.2586)	(0.0164)		
Liquidity	0.0019**	0.0008	0.0018	0.0008	0.0014**	0.0005
			(0.0003)	(0.0001)		
Product scope – DTB						
Interest rate products	-0.063**	0.030	-0.075**	0.024		
Equity	0.058**	0.028	0.066**	0.023		
Other	0.072	0.081	0.140**	0.064		
Product scope – LIFFE						
Interest rate	-0.019	0.031	-0.002	0.038		
Equity	-0.012	0.010	0.014	0.008		
Other	0.042	0.033	0.021	0.028		
Fixed fees	4.81 10^{-5}**	2.06 10^{-5}	6.94 10^{-5}**	1.92	7.28 10^{-5}**	1.34 10^{-5}
Exchange-specific time trend	Yes		Yes		Yes	
Event dummies	No		Yes		No	
Exchange fixed effects	Yes		No		Yes	

Exchange-business-type-HQ fixed effects	No	Yes	No
Loglikelihood	-1,660.33	-2,501.26	-2.693.05
Pseudo R2	0.9557	0.9547	0.9512
N	27,063	39,844	39,844

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

Table 6 – Multinomial logit for exchange choice (with substitution effect)

	(1)		(2)		(3)	
Variable	Coef.	Std. Err	Coef.	Std. Err	Coef.	Std. Err
Adoption costs – DTB						
Admission	-3.10 10^{-5}**	3.89 10^{-6}	-3. 09**	3.89 10^{-6}	-3.17 10^{-5}**	3.97 10^{-6}
Germany	-7.48**	0.24	-7.48**	0.24	-7.46**	0.25
EU 1/90-7/93	-11.50**	0.49	-11.48**	0.49	-11.34**	0.51
EU 8/93-12/95	-10.30**	0.53	-10.35**	0.53	-10.35**	0.54
EU 1/96-	-8.83**	0.22	-8.83**	0.22	-8.88**	0.23
France-NL 9/94-12/95	-6.63**	0.39	-6.76**	0.39	-6.87**	0.40
Switzerland 1/90-12/95	-10.23**	0.64	-10.21**	0.64	-10.11**	0.68
Switzerland 1/96-12/99	-10.48**	1.03	-10.53**	1.03	-10.83**	1.05
Switzerland 9/98 -	-6.56**	0.34	-6.46**	0.34	-7.11**	0.42
US 1/90 - 2/96	-10.19**	1.04	-10.18**	1.04	-9.94**	1.05
US 3/96 - 9/98	-7.26**	0.43	-7.30**	0.43	-7.21**	0.45
US 10/98 – 7/99	-9.17**	1.03	-9.05**	1.03	-9.01**	1.04
US 8/99 -	-6.07**	0.54	-6.28**	0.55	-6.22**	0.57
Adoption costs – LIFFE						
UK	-9.68**	0.16	-9.69**	0.16	-9.82**	0.17
EU 1/90 – 12/95	-13.33**	0.59	-13.33**	0.59	-13.22**	0.60
EU 1/96 – 7/98	-12.74**	0.60	-12.77**	0.60	-12.71**	0.61
EU 8/98 -	-12.12**	0.62	-12.12**	0.62	-12.39**	0.64
US 1/90 – 8/99	-12.11**	1.01	-12.11**	1.01	-12.30**	1.02
US 9/99 – 12/99	-9.64**	1.06	-9.72**	1.07	-10.94**	1.10
Variable costs – single exchange						
Volatility	2.10*	1.45	2.57*	1.51	11.66	4.81
					(0)	(0)
Own transaction fee	-0.0053**	0.0025	-0.0061**	0.0026	-0.1134	0.0064
					(0.1421)	(0.0031)
Own margins	0.1406*	0.0812	0.2044**	0.0877	0.4694	0.1344
					(0.1636)	(0.0081)
Own liquidity	0.0018**	0.0007	0.0018**	0.0007	0.0026	0.0009
					(0.0005)	(0.0001)
Other transaction fee	0.0034*	0.0020	0.0015	0.0021	0.0104	0.0054
					(0.0013)	(0.0007)
Other margins	-0.2614**	0.0644	-0.2780**	0.0681	-0.4256	0.1534
					(0.1136)	(0.0324)
Other liquidity	-0.0004	0.0008	-0.0010	0.0010	-0.0021	0.0011
					(0)	(0)
Variable profits - both						
Volatility	5.8911**	2.0385	5.7642**	2.1257	6.1995	3.3479
					(2.3335)	(1.0945)
Transaction fees	0.0006	0.0030	-0.0021	0.0032	0.0168	0.0083
					(0)	(0)
Margins	0.0013	0.0912	0.0430	0.0955	-0.6325	0.2613
					(0.1991)	(0.0034)
Liquidity	0.0020*	0.0012	0.0018	0.0013	0.0058	0.0016

					(0)	(0)
Product scope – DTB						
Interest rate products			-0.0874**	0.0256	-0.946**	0.0259
Equity			0.0521**	0.0226	0.0613**	0.0229
Other			0.1647**	0.0678	0.1555**	0.0681
Product scope – LIFFE						
Interest rate			0.0022	0.0248	0.0040	0.245
Equity			-0.0007	0.0080	0.0024	0.0258
Other			0.0040	0.0253	0.0047	0.0258
Fixed fees	$7.17\ 10^{-5}$**	$1.39\ 10^{-5}$	$4.61\ 10^{-5}$**	$1.61\ 10^{-5}$	$4.45\ 10^{-5}$*	$1.63\ 10^{-5}$
Exchange-specific time trend	Yes		Yes		Yes	
Exchange fixed effects	Yes		Yes		Yes	
Loglikelihood	-2,680.04		-2,672.73		-2,591.65	
Pseudo R2	0.9515		0.9516		0.9531	
N	39,844		39,844		39,844	

** indicates significance at 5%; * indicates significance at 10%. Time trend includes time, time^2 and time^3. Specification (3): two numbers are reported for each variable profit component: the mean of the coefficients that turned out to be significant at the 10% level and their mean standard deviations (the terms in the parenthesis are the standard deviation across trader types). For the single exchange coefficients, own volatility is significant for asset management firms; own fees are significant for asset management and proprietary firms; own margins are significant for specialized trading firms and proprietary trading firms; own liquidity is significant for universal and retail banks, brokerages and asset management firms; other fee is significant for retail and universal banks and asset management firms, other margins is significant for retail and universal bank and for asset management and proprietary trading firms; other liquidity is significant for investment banks. For the option "both", volatility is significant for retail banks and proprietary trading firms; fees are significant for brokerages, margins are significant for brokerage and proprietary trading firms; liquidity is significant for brokerages.