How and When do Markets Tip?
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, a London-based derivatives exchange, to DTB, a Frankfurt-based exchange. This paper studies the causes of the observed dynamics, 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. In particular, we assess the relative importance of exogenous factors such as access deregulation and the rapid growth in the market versus firms' strategies in explaining tipping.

VERY PRELIMINARY AND INCOMPLETE

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1 Introduction

In a famous episode of financial history 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). Since then, the "Battle of the Bund", as this episode became known, has served to illustrate that financial markets can tip and thus, implicitly, that competition is feasible and that there is a role for firms' strategies.

In this paper, we exploit a new panel dataset to study the determinants of the observed tipping. Individual trading volumes are not observed, so we focus on the observable traders' choice of an exchange instead (the dotted lines in Figure 1 represent the membership shares of both exchanges). When studying their choice, we distinguish between the factors that were outside of the control of the exchanges and those factors that were under their control such as the fees they charge, their market rules and their product portfolio. The exogenous factors we consider are (i) the progressive access deregulation that affected the access costs from different locations, (ii) the rapid growth in the Bund market driven by monetary convergence in Europe and the popularization of derivatives, and (iii) the resulting increase in the number and types of trading firms. The main question we ask is: to what extent was the observed tipping driven by the exchanges' strategies rather than exogenous factors?

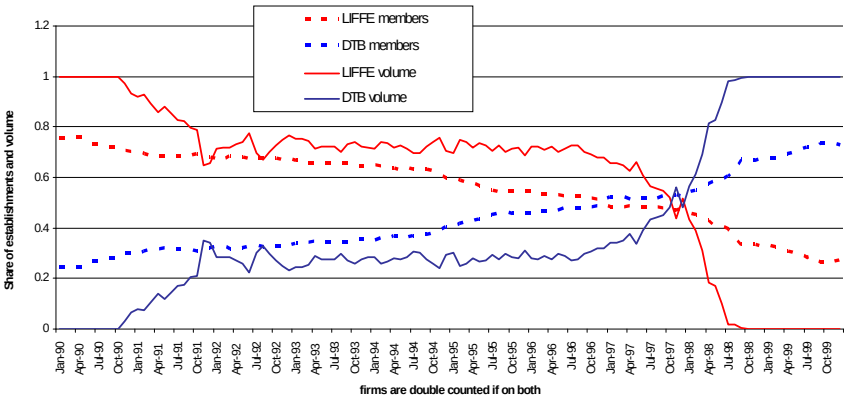


Figure 1: Market share of members and of Bund trading volume

To answer this question, we have constructed a dataset of all the firms that were members of DTB or LIFFE at any point of time between January 1990 to December 1999 (a firm needs to be a member to trade directly on these exchanges). For each of these firms, we know their location and

collected various information including their business lines and the products they traded. 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 firms' monthly membership status as a function of firms and exchange characteristics.

Our empirical model has three main ingredients: trader heterogeneity, exchange differentiation, and networks effects. Trader heterogeneity comes in four guises: different traders care about liquidity differently, different traders have different values for the other products that the exchanges trade, different traders have different opportunity costs of money and different traders have different access costs to these exchanges due to their geographical locations. The exchanges differed in their market rules, fee structure, product portfolio, location and liquidity. Finally, the source of network effects in exchanges is liquidity: traders care about where other traders trade because large markets are more liquid, implying better transaction prices.

Existing theories suggest several ways in which markets can tip in our environment, depending on the extent of trader heterogeneity and on the relative importance of newcomers (new traders) versus switchers (see Farrell and Klemperer, 2004, for a recent review). Tipping is "easier" in growing markets where newcomers dominate switchers. With heterogenous traders, this happens because the entrant differentiates itself (vertically or horizontally) from the incumbent exchange and attracts some of the new traders as a result. As new traders join, liquidity on the new exchange increases and the new exchange eventually attracts traders from the other exchange. With homogenous traders, tipping can happen as the result of self-confirming rational expectations: new traders join the new exchange because they expect future newcomers to also choose the new exchange. In stable markets, i.e. in markets where switchers dominate, tipping requires traders to coordinate on a new equilibrium (if such an equilibrium exists, which is not obvious if there are some switching costs). Expectations play again an important role.

In our data, newcomers dominate and our analysis of the industry suggests that trader heterogeneity is likely to be important. For this reason, we focus on that aspect of the problem, and abstract from the role of expectations about the future. Our behavioral assumption is that, every period, traders choose the membership status (be a member of LIFFE, DTB, both or none) that maximizes their expected profit for that period (myopic behavior). Costs are made of "adoption costs" if the trader was not a member of the exchange in the previous period, fixed costs, and variable costs. Variable costs consist of the exchange transaction fee, the opportunity cost of the deposits, and the impact cost. Trader heterogeneity comes in the adoption costs (which vary according to geography and the state of regulation) and the different components of variable costs.

Network effects enter through the impact cost, which is related to liquidity and depends on the number of traders and trading volumes at the exchange. We consider several models for traders' expectations about impact costs. We make use of the panel structure of our dataset to control for unobserved trader-exchange preferences and exchange-period unobservables.

Our preliminary findings are as follows. Access deregulation played a very important role in helping DTB attract newcomers. "Implicit" adoption costs, that is, the cost for new members to join an exchange, beyond the explicit admission fees charged by the exchanges, were of the order of ten times larger than admission fees. Access deregulation reduced them significantly and, depending on the original location of the traders and on the exchange, deregulation was equivalent to the exchange charging negative admission fees. Turning to exchanges strategies, we find evidence that some new products and services increased the attractiveness of the exchanges that launched them. When significant, the size of these effects are comparable to admission fees. By contrast, we did not find evidence that pricing strategies affected adoption. This may be due to the fact that trading firms do not take short-term fee variations into account when contemplating joining an exchange, or simply because there is little variation in fees in our data. Because of either the lack of variation in the sources of variable costs or because of correlation in these variables across exchanges, coefficients on these variables are largely insignificant and cannot be used to evaluate the importance of trader heterogeneity on these dimensions. However, in an alternative specification where we control for fixed trader type - exchange effects, we find evidence that traders' observables affect the intrinsic value they attach to each exchange.

Related literature. This paper is related to the literature on technology adoption, the literature on competition between networks and the finance literature on multiple trading venues. [**to be completed**]

The rest of the paper is organized as follows. In the next section, we cover some of the basics of futures trading. In section 3, we summarize how competition between LIFFE and DTB played out. Section 4 discusses how existing theories about tipping apply to our environment. We use these three sections to motivate our empirical model and the data we collected. Section 5 describes the data we collected. Section 6 introduces our empirical model and discusses how we address the various econometric issues that the model together with the data raise. Section 7 describes our results. Section 8 concludes.

2 Economics of futures trading

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.

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.

2.1 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, ...). The advantage of standardization is that it pools liquidity around a limited set of contracts, making 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 put up margins as collateral. Margins are updated daily in a way that eliminates traders' incentives to default. Thus clearing removes counterparty (default) risk, thereby increasing traders' willingness to trade.

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

Participation in futures exchanges is restricted to members. Futures exchanges impose conditions on new members to ensure the well functioning of their markets. 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 February 1999. Members of DTB were not shareholders.

2.2 Market participants and trading motives

Broadly speaking, traders fall into three categories: hedgers, speculators and arbitrageurs. 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 movement 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. The reason has to do with 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 success with asset managers, investment banks and hedge funds.

2.3 Cost of trading

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

Adoption costs. Traders must be members of an exchange to be able to trade on it. 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 his 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.[1]

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.[2] Some clearing houses pay interests on margins but many do not. In particular, LIFFE's clearing house did remunerate margins but DTB's clearing house did not. However, even when margins accrue interests, 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.

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 price movements only during the day. 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

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

[2] A new position is opened when a trade does not invert 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.

transactions, the higher the impact costs, everything else equal.

In the data section, we illustrate that 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.

3 The Battle of the Bund

The London International Financial Futures and Options Exchange (LIFFE) was established in 1982 as a member-owned exchange. Two hundred sixty one members were signed up 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. Its debuts were relatively modest, but trading progressively garnered pace after the exchange lowered transaction fees, negotiated a lowering of margins costs with the clearing house, and encouraged participation by locals - individuals trading on their own account. 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 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 its second biggest contract within 6 months of its launch and became its 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.[4] An option on the Bund was added in April 1989.

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. Its first products were an equity index future and 14 stock option contracts. After some technical delays, DTB launched a Bund contract on November 23, 1990. The contract was essentially identical to the LIFFE contract.[5] Clearing was done by DKV, a German

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

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

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

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, the first days of trading on DTB were very disappointing: volumes were low and participation seemed limited to German banks. 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 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. The Gentlemen's agreement was effective and DTB's market share climbed to almost 20% by mid-July. The commitment by the German banks was strengthened in November when they 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 were accompanied by statements by 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 (e.g. the Securities and Futures Authority in the UK or the Commodity Futures Trading Commission in the US). 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. Thus, initially, only firms with an office in Germany could trade on DTB.

DTB seemed to have realized early on that access was critical.[6] 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, two important sources of trading volumes. Those efforts resulted in a no-action letter issued in February 1996 by the CFTC allowing US-based traders to trade on DTB. DTB's efforts with the British authorities were 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 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 making access and regulatory approval a lower priority for LIFFE. Yet, financial regulations in other countries did also affect trading on LIFFE. First, trading in the Bund took place on an electronic platform after-hours until August 1998 and was entirely electronic after that. Second, brokers in other countries could offer LIFFE's products to their clients only to the extent that LIFFE was recognized as a financial exchange in those countries. In practice, remote access to APT was not physically possible outside the London area and LIFFE's recognition in other European countries followed from the European Investment Service Directive.[7]

During the 1990s LIFFE entered several agreements with other exchanges. None of these agreements seemed to have been very successful nor conducive to higher trading volumes in the Bund at LIFFE. For example, in March 1997, the Chicago Board of Trade (CBOT) started trading the Bund in its pits and LIFFE started trading the long term T-bill, one of CBOT's key products. The idea was to offer longer overall trading hours for the Bund and the T-bills. However, traders could also trade those products on the exchanges' respective after-hour electronic trading platforms and trading volumes in the pits were low. The link was abandoned in December 1997.

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

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

[7] French authorities recognized LIFFE as an exchange in March 1995 allowing brokers in France to market LIFFE's products to their clients a full nine months before the ISD came into force.

in the market whereas open outcry required a floor-broker on top of the broker in contact with clients, transactions were automatically processed through clearing, and so on.

Breedon and Holland (1998) summarize the evidence on the relative quality of the Bund market in 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, had transaction sizes been as large as on LIFFE. They also found that volumes tended to migrate to LIFFE in periods of high volatility.

Macroeconomic developments. Trading volumes of the Bund grew fifteen-fold 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 common investment and hedging instruments used routinely by banks, asset management funds and corporations. The ensuing pool of liquidity attracted speculators and arbitrageurs of all kinds. Increased volumes may have played in favor of DTB by decreasing the relative difference in liquidity between the two markets.

Mergers. Both exchanges underwent mergers during the 1990s. LIFFE merged with the London Traded Options Market (LTOM), an equity option exchange, in 1992. It merged with the London Commodity Exchange in 1996. DTB became part of Deutsche Börse, the Frankfurt-based stock exchange, in January 1993. It merged with the Swiss derivatives exchange SOFFEX in September 1998. The SOFFEX merger, which was announced at the end of 1997, brought about 40 new members instantaneously to DTB. 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). Trading volumes were exploding and LIFFE celebrated its 15^{th} birthday in fanfare: it controlled Europe's most liquid money market product, the three-month DM contract, and had a firm grip on Europe's most liquid long term bond future, the Bund.

Things started to change at the end of 1996. The Investment Service 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 to boost its appeal, and called on an extraordinary general assembly. 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. Late 1998, LIFFE unveiled a new contract, the DM-denominated Libor-Financed-Bond aimed at challenging the Bund's dominance of the long term part of the yield curve. The new contract never took off. LIFFE underwent a complete restructuring following the loss of the Bund. It demutualized in February 1999 and became an all-electronic exchange.

4 Factors favoring inertia and factors favoring tipping

Factors favoring the incumbent. Two factors favor inertia and thus the incumbent exchange in our environment. The first factor is a classic network effect: traders prefer to trade where the market is most liquid, that is, usually, where most of the other traders trade.

The second factor is specific to derivatives exchanges and the fact that LIFFE and DTB used different clearing houses. Consider a trader who has bought a Bund contract on LIFFE. He thus has margins deposited at the London Clearing House to guarantee that transaction. Suppose the market has moved and he now wants to *sell* a Bund contract. All things equal, he will prefer to sell the contract on LIFFE because a contract on DTB would open a new position vis-à-vis DTB's clearing house, resulting in the trader having margins deposited at two different clearing houses. If, instead, the trader sold the contract on LIFFE, the London Clearing House would recognize that there is no more residual default risk and net the positions, removing the margins requirement. As we argue in section 5, the opportunity cost of margins relative to the other cost of trading could be substantial for the Bund. Thus, the economics of clearing generated a bias in favor of LIFFE, independently of network effects.[8]

[8] This statement must be somewhat substantiated. The Bund was traded with quarterly maturities (March, June, September and December), with the front month (the closest maturity) gathering the bulk of trading. As a result, even traders with longer investment horizons would typically open positions in the front month contract. At or just before the maturity date, they would first close their position in the front month contract, and reopen a new position in the next maturity, in a process called "roll-over". Roll-over periods provide an opportunity for traders to coordinate on a new exchange because most traders are free from over-hanging margin deposits at that stage.

Factors favoring tipping. Environments with network effects typically have several equilibria, and are thus, in principle, subject to tipping. Existing theories suggest several mechanisms for tipping in our environment.

The first class of mechanisms relies on some heterogeneity across users of the exchanges and on the arrival of new users. Let i denote a particular trader and let k index exchanges. Trader i's utility from exchange k is given by $d_{ik} + \alpha_i n_k$ where n_k is the number of users of exchange k. The term d_{ik} captures the intrinsic value that trader i attaches to exchange k and is the source of horizontal differentiation. In our case, differential adoption costs, differential margins requirements and differential product portfolio play that role. Indeed, traders faced very different adoption costs for LIFFE and DTB and this varied over time depending on the state of access deregulation in Europe and in the US and on the cost of trading technologies at DTB and LIFFE. Moreover, both exchanges offered a different mix of instruments for trading and traders are likely to value these different product portfolios differently. The term α_i captures the value trader i attaches to the size of the network. In our case, traders may have different liquidity needs. A trader who trades only a couple of contracts at a time will find even a small market liquid enough for his needs, whereas large traders will attach greater value to liquidity.

In Arthur (1989)'s classic paper, new users arrive stochastically and decide which exchange to join based on the utility they derive from this exchange. New users are myopic. Tipping occurs in this model if the realized sequence of new users arrivals favors the new exchange because the new users attach a high intrinsic value to the new exchange. Once the new exchange has garnered a critical mass, even users with a higher intrinsic value for the other exchange might prefer the new exchange because of its higher liquidity.[9] Other papers in that class include Auriol and Benaim (2000).

The second class of mechanisms relies on users to somehow coordinate on the new exchange, and thus on their ability to coordinate on a new equilibrium. Farrell and Saloner (1986) suggest two ways in which this can happen. In environments of rapid growth, i.e. with a high rate of new users arrival, new users could coordinate of the new exchange if (i) they expect future new users to do the same, (ii) high switching costs guarantee that exchange choices are one and for all, and (iii) the short run loss of using a smaller exchange are more than compensated by the long run benefit of using a superior and large exchange. In Farrell and Saloner's second model, users have exogenous and stochastic opportunities to reoptimize their choice of an exchange. The resulting coordination game can generate tipping. Note that trader heterogeneity does not play any role in these theories. Other papers in that class include

[9] In Arthur's model, users are backward-looking but he shows that tipping is even easier with forward-looking users because of the self-fullfilling property of expectations.

Sponsored versus unsponsored networks. All the theories so far are theories of "unsponsored networks" and it is unclear whether tipping remains an equilibrium phenomenon once we let exchanges decide on their product portfolio, pricing and so on. In this paper, we do not take a stance on whether LIFFE and DTB were behaving optimally. Christensen (1997) provides a behavioral explanation for why tipping could occur in the presence of user heterogeneity when we endogenize firm strategies. The incumbent exchange listens to its current set of customers when deciding on its pricing, product characteristics and market rules. As a result, the new exchange might be able to serve a niche of customers whose needs are not currently met by the incumbent (in the model above, these customers have different d_{ik}'s or lower values for liquidity, α_i). As the new exchange garners volume, a virtuous cycle kicks in where liquidity increases, eventually attracting the users of the incumbent (see also Christensen and Bower, 1996). Certainly, this theory seems relevant for understanding LIFFE's slow switch to electronic trading.

In addition, "non economic forces" might have helped DTB reach the critical mass of trading volume necessary to trigger tipping.[10] The banks that owned DTB had an incentive to "make it work", even if it took Rolf Breuer, then on the board of Deutsche Bank and chairman of DTB, to coordinate them, resulting in the July 1991 Gentlemen's agreement to support liquidity on DTB. There were also rumors that the German government put pressure on German firms to direct their trades to DTB.

Exogenous versus competitive factors. From the description above we can distinguish between exogenous and competitive explanations for the observed tipping. Competitive explanations are the result of decisions by the two exchanges, such as their pricing strategy, their product portfolio strategy and their market rules. Exogenous explanations are the result of factors that helped the tipping but are outside of the control of exchanges. Rapid growth in trading volumes (partly fueled by the introduction of the euro), entry of new financial market participants into derivatives trading, the deregulation of access across Europe and the US, and the potential national bias of German firms belong to this category.[11] Whether the "Battle of the Bund" tells us anything about the effectiveness of competition and firm strategies in financial markets depends on which factors dominate. If exogenous factors dominate, we should be cautious when using the Battle of the Bund as an example showing that markets can tip because the conditions under which it happened may

[10] Without it, only an extreme high level of horizontal differentiation, or a very low value for liquidty - both of which seem implausible in our environment - could have generated the observed complete reversal of market shares.

[11] Access deregulation and entry of new market participants might have also been affected by exchange strategies. DTB actively lobbied regulatory authorities in the UK and in the US to guarantee access from these countries and DTB's relatively low adoption cost led to the entry of a lot of small proprietary trading firms that would not have entered the business otherwise.

be hard to reproduce.

Table 1: Competitive and exogenous factors explaining tipping in the Bund market

Competitive factors	Exogenous factors
Pricing policy	Rapid growth in market
Product portfolio	Access deregulation
Market rules	Nationalism

5 Data

An important premise for our analysis is that membership decisions are largely driven by an interest in trading the Bund. In principle, membership is neither a necessary nor a sufficient condition for trading the Bund on an exchange: one can always go through a broker who is a member, and both exchanges listed other products than the Bund. We think these issues are mitigated in our environment because large traders are likely to prefer membership over going through a broker, and the Bund was the largest or one of the largest product on both exchanges during that period. Moreover, in our empirical analysis we focus on the members with an interest in the Bund. Finally, market share and membership are highly correlated in our data (Figure 1).

The rest of this section describes the dataset we collected and reports on preliminary evidence concerning the likely factors driving tipping in our environment.

5.1 Exchange data

For both exchanges and for the period between 1 November 1990 until 31 December 1999, we collected the following monthly data: (1) admission fee to the exchange, (2) annual membership fee (for the different categories of memberships if applicable), (3) transaction and clearing fee per contract, (4) minimum transaction fee, (5) initial and maintenance margins,[12] (6) membership, (7) product launches and delisting, and (8) traded volume in the Bund contract. The exact sources for each of these variables are described in Appendix A.

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) change in trading hours for the Bund contract, (2) introduction

[12] Initial margins are those margins required at the opening of the position. As time passes, the clearing house credits or debits the initial margin depending on the evolution of the future contract. If margins go below the level of maintenance margins, the clearing house calls on the trader to deposit additional margins.

and termination of potentially complementary or substitute products such as futures on other parts of the yield curve (Schatz and Bobl) or futures on other fixed income securities, (3) regulatory changes concerning access and recognition in other countries, (4) marketing campaigns not reflected in the price information such as free hardware or free installation, (5) changes in the Bund contract specification, (6) changes in the trading rules, for instance the introduction of new trading functionality allowing more sophisticated trades, (7) technological changes such as the opening of access points.

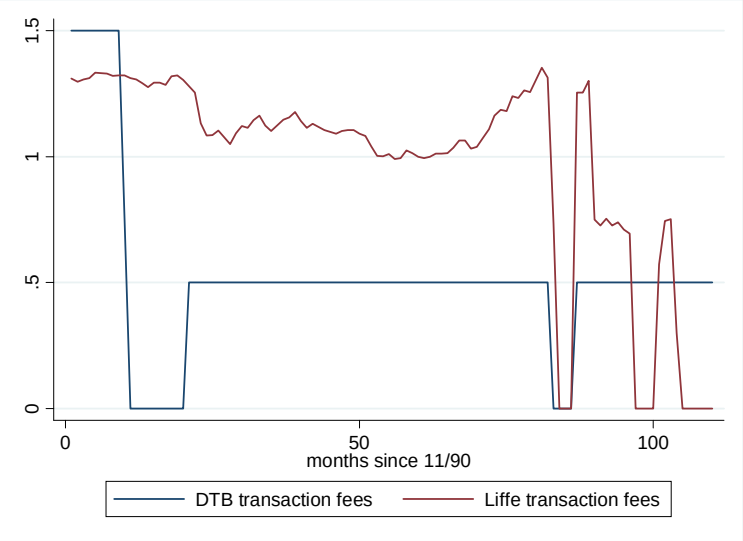
The conversion to the euro takes place during our sample period (1 January 1999) and both exchanges introduced a Euro-denominated Bund contract towards the end of 1998. We use the Deutsche Mark as the currency for all the data. Fees are converted into DM using the monthly average exchange rate for the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

Exchanges have control over their admission fees, their annual fees and their transaction fees. Margins are driven by objective risk analysis and are largely outside of their control (moreover they are set by the clearing house, not the exchange). The only extent to which exchanges have control over margins is through their product portfolio choice. Indeed, the clearing house aggregates products with similar risk patterns, and margins are netted across those.

In practice, neither exchange seemed to have used admission and fixed fees to lure new members. LIFFE did not charge an admission fee (but members had to buy a share in the exchange) and annual fees were constant during the entire sample period. DTB charged a 102,000 DM admission fee and a 34,000 DM fixed fee until December 1997, after which both fees were waived.

There was more activity on the transaction fee front. Figure 2 illustrates the transaction fee pattern in both exchanges (recall that fees are expressed in DM, even though they were set in Pounds at LIFFE. This explains the small month-to-month variation in the LIFFE fee). Although transaction fees were originally higher on DTB, DTB quickly undercut LIFFE. When the market was tipping at the end of 1997, a price war broke down and both exchanges waived transaction fees

entirely. LIFFE waived again its fees several times afterwards.



5.2 Firm data

We have obtained from each exchange a list of past and current members, with their names, mnemonic code, clearing status and start and end dates of membership. In addition, the DTB data contain the country and city location of these members. For current Eurex members, we also have their exact address and information on whether they offer brokerage services. The LIFFE data contain in addition the instrument class (equities, commodities or financials) that the member can trade, and information on whether the member can accept orders from the public. For current members, we also have the address of the establishment.

The original data from DTB contain information on 493 individual establishments that held a membership any time during the 1 January 1990 - 31 December 1999 period. The original data from LIFFE contain information on 288 individual establishments that held a membership allowing them to trade financial instruments (including the Bund) any time during the 1 January 1990 - 31 December 1999 period. Seventy-five individual establishments appear in both datasets. This means our data cover 706 individual establishments.

For each member (establishment), we have collected additional information on (1) their (historical) group affiliation including mergers and acquisition, (2) the establishment inception, and possibly its closing date, (3) the group inception date, and possibly its bankruptcy date, (4) the business type of the establishment, (5) whether the establishment can trade on third party accounts, (6) whether the establishment trades the Bund. 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 114 (16.2%) of the individual establishments and 62 groups (for some of these we have the inception year but not the month). We could establish whether individual establishments traded the Bund contract in 62.5% 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 consider that the establishment trades 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, establishments can be endogenous to the decision to join an exchange. Prior to September 1994, traders had to have an office in Germany to be able to trade on DTB. Second, 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. We address both issues by defining the group as the proper 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 559 individual groups, including 204 groups with a single establishment.[13]

Business models. We partitioned the establishments and the groups in our dataset into seven business model categories: universal bank, investment bank, retail bank, private banking / asset management, brokerage, specialized trading firm 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. Private banks, essentially a German-Swiss concept, offer financial advice and asset management for wealthy individuals. They also tend to have limited corporate finance activities. On top of asset management and corporate finance advising, investment banks also offer brokerage services, act as market makers for various instruments and have proprietary trading activities.

Within each of these activities, investment banks compete with more specialized financial firms: brokerage firms, proprietary trading firms and specialized trading firms. Figure 3 illustrates how we categorized each of the establishments and groups in our dataset. At the bottom of the figure lie

[13] This does not mean that the group is present in only a single location, it only means that it held a membership in either exchange from a single location

the individual activities firms engage in. For example, specialized trading firms make markets and engage in proprietary trading. For each establishment and group, we assigned the business category that consisted in the smallest containing set. Thus a firm only doing proprietary trading would be considered a proprietary trading firm, but a firm doing both proprietary trading and offering brokerage services would be considered an investment bank. Figure 3 suggests that we might have up to 11 business categories. In practice, we grouped retail and professional brokers and arcades together.[14] Moreover, all market making firms in our dataset were involved in proprietary trading.

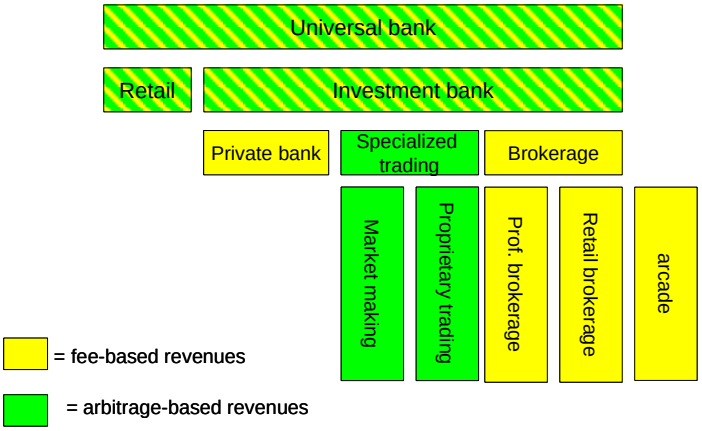


Figure 3: Categories of business models and their relationship with one another

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. Brokerages trade on behalf of third party investors and receive a fee in return. Their value added lies in providing access to exchanges and they will thus be interested in exchanges that organize markets in the instruments their clients need. At the other extreme, proprietary trading firms are only interested that the exchange offers the product(s) they speculate on. Relatedly, business types proxy for the scope of products traded. Finally, business types are likely to proxy for traders' transaction sizes and thus value for liquidity.

Our dataset contains 61 universal banks, 26 retail banks, 107 investment banks, 46 private banks / asset management firms, 69 specialized trading firms, 121 brokerages and 129 proprietary

[14] An arcade is a firm offering services to independent traders, such as access to exchanges, back office support or renting of office space.

trading firms.

Geographical presence. Geographical presence affected adoption costs depending on the state of access deregulation. For each group, we constructed a geographical presence variable based on its headquarter location and the location of each of its establishments. In our sample, 126 groups have their headquarters (HQ) in Germany, 35 have their HQ in Switzerland, 107 in the UK, 64 in France or Holland, 78 in the rest of Europe, 103 in the US and 45 in the rest of the world. The corresponding numbers for locations are 184 for Germany, 45 for Switzerland, 269 for the UK, 72 for France and Holland, 81 for the rest of Europe, 105 for the US and 45 for the rest of the world.

5.3 Evidence on the sources of trader heterogeneity

Section 4 suggested four sources of trader heterogeneity in our environment: different traders have different adoption costs, different traders trade different sets of products and thus value the exchanges' product portfolios differently, different traders care about margins costs differently because they have different trading behaviors, and some traders care more about liquidity than others. The description of our firm dataset makes it clear that traders were impacted differently by national regulations on remote access and exchange recognition. Our data on traded products are only partial, so we postpone a discussion of product portfolio effects until the results section where we infer them indirectly. Instead, we focus here how margins and liquidity affected traders differently.

The following back-of-the-envelope calculation provides some perspective on the variable costs of trading on DTB and LIFFE. 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 all 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 Eurex 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 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.

5.4 Switchers versus newcomers, and evidence of lock-in

Existing theories on tipping differ in the role switchers versus newcomers play. A first question we can answer on the basis of our data is to what extent tipping was driven by traders switching from one exchange to the other rather than by newcomers choosing predominantly DTB. To answer this question, we build a panel data of groups' membership status (a group is a member of an exchange as soon as one establishment belonging to the group is a member) over the 120 month period between 1 January 1990 till 31 December 99 (a group is present in the data from its inception date till its exit date (acquisition, merger or bankruptcy) if applicable. 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. Figure 4 summarizes the resulting transition matrix. DTB's success seems largely due to newcomers. Newcomers predominantly chose DTB at a ratio of 3.5 to 1: Out of the 353 groups that were not members of either exchange at the beginning of the sample, 275 chose DTB.[15] There were at most 24 "switchers" (a switcher would have first joined DTB generating a LIFFE-Both transition, and then resigned from LIFFE,

[15] This number is somewhat exaggerated because we consider the period 1/90 till 9/99 and DTB was set up in January 1990. This boosts the number of newcomers by about 50 right there independently of the Bund. We should recompute this matrix to take this into account.

generating a Both-DTB transition).

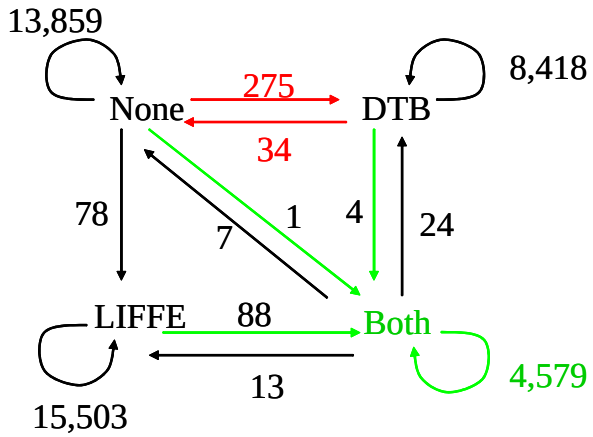


Figure 4: Membership status transition matrix
(an observation is a group-month observation)

The transition matrix suggests that changes of membership status are not frequent suggesting some kind of lock-in.[16] Among the 559 groups present in our data, 85 never change status over the entire period during which they are present, 419 change status once, 52 change status twice and 3 change status three times.

6 An empirical model of exchange choice

This section introduces our empirical model and discusses how we address the econometric issues that the model and the data raise.

6.1 Benchmark model

In the benchmark model, we assume that trading firms are myopic and that they become members of the exchange(s) that deliver(s) the highest expected profit from trading the Bund in the next period. Alternative interpretations of the coefficients when traders are forward-looking and extensions to account for the multi-product nature of exchanges are discussed below.

Let $i \in \mathcal{I} = \{1, ..., I\}$ denote a trading firm, $s \in \mathcal{S}$ denotes the type of business it does, and t denotes time. Let ω_{it} describe the membership status of firm i at time t, $\omega_{it} \in \{D, L, B, 0\}$

[16] An alternative explanation is that the environment is not changing very much so that reoptimization is rarely necessary. We revisit this hypothesis when we consider the choice of frequency for decisions.

standing for DTB, LIFFE, BOTH and none respectively. The vector of membership status is denoted $\boldsymbol{\omega}_t = (\omega_{1t}, ..., \omega_{it}, ..., \omega_{It})$ ($\boldsymbol{\omega}_{-it}$ refers to the subvector of membership status in $\boldsymbol{\omega}_t$ but for firm i).

At any point of time, firm i's cost of trading at exchange $k \in \{D, L, B, 0\}$ is a function of the fixed costs and variable costs at exchange k and of adoption costs (in case firm i was not a member of exchange k in the previous period). Thus we let firm i's expected profit from being a member of exchange k at time t be:

$$\pi_{it}(k) = R_{it}(k) - A_{it}(k, \omega_{it-1}) - F_t(k) - VAR_{it}(k) \tag{1}$$

where $R_{it}(k)$ stands from firm i's revenue from trading the Bund at exchange k, $A_{it}(k, \omega_{it-1})$ stands for firm i's adoption cost for exchange k given that it was a member of exchange ω_{it-1} in the previous period, $F_t(k)$ is the fixed cost of being a member of exchange k, and $VAR_{it}(k)$ is firm i's expected total variable costs of trading at exchange k. Variable costs consist of the observed transaction fee, the opportunity cost of margin requirements and the impact cost, defined as the absolute value of the difference between the theoretical "equilibrium price" for the Bund contract and the realized price for the transaction. Transaction fees, the opportunity cost of margins and impact costs are all functions of the kind of trading a trader does. Let $\text{vol}_{it}(k)$ and $c_{it}(k)$ denote firm i's total trading volume and average cost per trade at time t and exchange k. Thus

$$VAR_{it}(k) = \text{vol}_{it}(k) c_{it}(k)$$

We assume that trading firms that conduct the same type of business have similar trading patterns and thus impose the following structure on average variable costs:

$$\begin{aligned}
c_{st}(k) &= \alpha_{1s}\text{fee}_t(k) + \alpha_{2s}\text{margin}_t(k) + \alpha_{3s}\text{impact}_t(k) \quad k = D, L && (2)\\
c_{st}(B) &= \alpha_{4s}\text{fee}_t(D) + \alpha_{5s}\text{margin}_t(D) + \alpha_{6s}\text{impact}_t(D) && (3)\\
&\quad + \alpha_{7s}\text{fee}_t(L) + \alpha_{8s}\text{margin}_t(L) + \alpha_{9s}\text{impact}_t(L) \\
c_{st}(0) &= \alpha_0 && (4)
\end{aligned}$$

where $\text{fee}_t(k)$ is the observed transaction fee at exchange k at time t, $\text{margin}_t(k)$ is the margin requirement for the Bund contract at time t and exchange k, and $\text{impact}_t(k)$ is a measure of the impact cost at exchange k. Coefficients on cost drivers are a function of traders' types. Fees and margins are published ahead of time by exchanges so they are known at the time traders make their decisions. Impact costs are a function of trading volumes and are thus not known at the time of the decision. We describe our assumptions about the way traders make their forecasts in section 6.4.

The structure of costs for dual membership requires some comments. Dual membership allows traders to optimize across exchange at every point in time.[17] In particular, margin costs and impact costs are transaction specific, and they are likely to vary over time during period t. Suppose a member of both exchanges executes fraction λ of his trades at exchange D. Theory imposes the following restriction on the coefficients in (3): $\alpha_{4s} = \lambda\alpha_{1s}$, $\alpha_{7s} = (1-\lambda)\alpha_{1s}$, that is, $\alpha_{4s}+\alpha_{7s} = \alpha_{1s}$. This relationship does not hold for the margins and the impact costs because those are transaction specific. A trader with a dual membership may be interested in opening a position on one exchange and closing it in another, generating $\alpha_{5s} + \alpha_{8s} \geq \alpha_{2s}$. In addition, we expect $\alpha_{6s} < \lambda\alpha_{3s}$ and $\alpha_{9s} < (1-\lambda)\alpha_{3s}$. The ability to select the cheapest exchange at all points in time provides a motivation for dual membership in the benchmark model. We simplify $c_{st}(0) = \alpha_0$.

In period $t-1$, trading firms simultaneously decide on their membership for period t. We observe

$$\omega_{it} = k \text{ if } k = \arg \max_{k' \in \{D,L,B,0\}} \pi_{it}(k') \tag{5}$$

Equations (2)-(4) raise several issues for estimation, namely, the fact that we do not perfectly observe $vol_{it}(k)$, the structure and identification of unobservables and the presence of network effects. We deal with each of them in turn in the next subsections.

6.2 Measurement error for $vol_{it}(k)$

We do not observe firm i's expected trading volume, $vol_{it}(k)$. Instead, our dataset contains aggregate monthly trading volume and membership at each exchange, as well as various macro variables that affects trading volume. We use these to construct $\overline{vol}_t(k)$, the expected average per member trading volume at exchange k. Then

$$vol_{it}(k) = \overline{vol}_t(k) + \varepsilon_{ikt}$$

where ε_{ikt} is observed by i but not by the econometrician. We assume that measurement errors are uncorrelated across firms and that they are uncorrelated with the average trading volume $\overline{vol}_t(k)$, and any other explanatory variables in X (we use the symbol X to denote a generic set of explanatory variables). By contrast, firms that trade more than the average trader in one period are likely to trade more than the average trader in other periods. Thus measurement errors are likely to be correlated across time for the same trader. We capture this aspect by letting

$$\varepsilon_{ikt} = \mu_i + \mu_{ikt}, \qquad E[\mu_{ikt}|X] = 0, \text{VAR}[\mu_{ikt}] = \sigma^2 I$$

[17] Dual membership is not the only way to do this. An alternative is to go through a broker. However, presumably, the broker charges a higher variable cost reducing or even eliminating any incentives to do so.

Thus (1) becomes

$$\pi_{it}(k) = R_{it}(k) - A_{it}(k, \omega_{it-1}) - F_t(k) - \overline{vol}_t(k)c_{st}(k) - \mu_i c_{st}(k) - \mu_{ikt}c_{st}(k) \tag{6}$$

The term $c_{st}(k)$ can be seen as a new explanatory variable, with firm-specific coefficients. The advantage of assuming this structure on measurement errors is that $\mu_{ikt}c_{st}(k)$ is uncorrelated across time, across exchange and across firms, conditional on X. However, measurement errors do introduce heteroskedasticity because the variance of $\mu_{ikt}c_{st}(k)$ varies across firm type, time and exchange. Finally, note that $\text{Cov}[\overline{vol}_t(k)c_{st}(k), \mu_{ikt}c_{st}(k)] = 0$. Thus, measurement errors per se do not introduce an endogeneity problem in our setting.

6.3 Structure and identification of non observables

Equation (1) contains several unobserved explanatory variables. $R_{it}(k)$ is not observed and from the discussion in Appendix B, we assume it takes the form[18]

$$R_{it}(k) = \beta_{ik} + \nu_{it} \tag{7}$$

where ν_{it} is observed by trader i but not by the econometrician. The term β_{ik} captures any special ability by firm i to generate revenue at exchange k, or any special "taste" for exchange k. Any volume-related effect on revenues will be confounded with the effect of volume on costs, via the impact costs, and is thus ignored in (7).

Adoption costs are made of observed and non observed components. Based on the discussion in section 3, we assume that unobserved components are location specific and vary with the progressive deregulation of access (see Appendix A for details). Thus

$$A_{it}(k, \omega_{it-1}) = \left(\gamma_1 \text{ADM}_{kt} + \sum_{\text{location}} \text{D(location},k,t_o,t_1) 1_{\{i \text{ is in location}, t \in [t_o,t_1]\}} \right) 1_{\{k \neq \omega_{it-1},\ k \neq 0, \text{ and } \omega_{it-1} \neq B\}} \tag{8}$$

where D(location,k, t_o, t_1) is a location, exchange and period specific fixed effect. For instance, for a trader with a UK presence and DTB, we distinguish three periods: before August 1993 when EU-based firms with an office in Germany could become clearing members of DTB, between August 1993 and 1 January 1996 when the EU Investment Service came into force, and after 1 January 1996.[19] The index function $1_{\{k \neq \omega_{it-1},\ k \neq 0, \text{ and } \omega_{it-1} \neq B\}}$ ensures that the adoption cost variable is

[18] Trading firms' sources of revenue are commissions, trading gains or both. Appendix B describes how the various business models generate a profit function of the form (1) and (7).

[19] For traders with multiple locations, we take the location with the a priori lowest adoption costs as described in Appendix B, and check expost that the estimation adoption costs are consistent with that assumption.

only turned on when a trader becomes a member of an exchange to which it was not a member of in the previous period.

Fixed fees are made of the exchange annual fees as well as various unobserved costs. We let the unobserved fixed costs depend on time through a time trend that will capture the trend in wages and technology costs.

$$F_t(k) = \delta_1 \text{FIXEDFEES}_{kt} + \delta_{2k} + \delta_{3k} t \tag{9}$$

Gathering all the "unobserved" terms in (6)-(9) we get

$$-\mu_{ikt} c_{st}(k) + \beta_{ik} + \nu_{it} - 1_{\{k \neq \omega_{it-1},\ k \neq 0,\ \text{and}\ \omega_{it-1} \neq B\}} \sum_{\text{location}} \text{D(location},k,t_o,t_1) 1_{\{i \text{ is in location}, t \in [t_o,t_1]\}} - \delta_{2k} \tag{10}$$

This motivates the following structure for the unobservables in the estimation:

$$d_k + d_{ik} - 1_{\{k \neq \omega_{it-1} \text{and}\ \omega_{it-1} \neq B\}} \sum_{\text{location}} \text{D(location},k,t_o,t_1) 1_{\{i \text{ is in location}, t \in [t_o,t_1]\}} + \xi_{ikt} \tag{11}$$

where d_k is an exchange fixed effect, d_{ik} is a trader-exchange fixed effect and ξ_{ikt} is a mean zero error term.

We first discuss the interpretation of the fixed effects in equation (11) before describing the structure that our discussion imposes on ξ_{ikt}. The term d_k is the profit boost from being a member of exchange k relative to not being a member of any exchange (we normalize $d_k = 0$ for $k = 0$), absent any switching behavior. It captures δ_{2k} and any trader invariant part of β_{ik}. The term d_{ik} is the mean profit deviation of firm i at exchange k relative to the average firm at that exchange, absent any switching behavior (again, we normalize $d_{ik} = 0$ for $k = 0$). It captures the part of β_{ik} not captured by d_k.

Comparing (10) and (11), it is clear that D(location,k, t_o, t_1) is identified, but β_{ik} and δ_{2k} are only jointly identified from d_k and d_{ik}. The term ν_{it} does not affect firm choice and is thus not identified. What remains in ξ_{ikt} is $\mu_{ikt} c_{st}(k)$. Our discussion suggests the following structure on ξ_{ikt}

$$\begin{aligned} \text{Cov}(\xi_{ikt}, \xi_{jk't'}) &= 0 \text{ for } i \neq j, \text{ for all } k, k', t, t' \\ \text{Cov}(\xi_{ikt}, \xi_{ik't'}) &= \begin{cases} \sigma^2_{skt} & \text{if } k = k',\ t = t' \text{ and } i \text{ is of type } s \\ 0 & \text{otherwise} \end{cases} \end{aligned} \tag{12}$$

For practical purpose and because fees, margins and impact costs either do not vary much or are highly correlated across exchanges, we impose the constraint that $\sigma_{skt} = \sigma_s$ for all k, t. Thus our empirical model reduces to

$$\begin{aligned} \omega_{it} &= k \text{ if } k = \arg \max_{k \in \{D,L,B,0\}} \pi_{it}(k), \text{ where} \\ \pi_{it}(k) &= \theta_i X_{ikt} + \xi_{ikt}, \text{ and } \xi_{ikt} \text{ is independently distributed with covariance } \sigma^2_s \end{aligned} \tag{13}$$

Note that the set of dummies contributes to ensuring that the error term is uncorrelated across time and across exchange, even if the data is not exactly generated by (6)-(9). However we might worry that factors beyond fees, liquidity, margins and access regulation affect the attractiveness of an exchange at a given time, inducing correlation across firms. We construct exchange-period dummies based on official exchange information and press articles documenting changes or events likely to affect the attractiveness of each exchange. In an alternative specification, we add exchange-time fixed effects, d_{kt} (and drop ADM_{kt} and FIXEDFEES_{kt} as a result since they would be perfectly collinear) and check that the coefficients on the other variables do not change too much.

6.4 Network effects

Network effects enter our model through the variable $\text{impact}_t(k)$, which we construct to capture the expected average impact cost of trading at exchange k. Impact cost is one measure of liquidity. The more liquid a market, the lower the impact cost of a given transaction in that market. In turn, liquidity increases with trading volume (up to a point: we expect the marginal increase in liquidity to be decreasing with trading volume), and thus also with membership. Formally, we let $\text{impact}_t(k) = E_{t-1} \log vol_{kt}(\frac{n_{kt}}{n_{Dt}+n_{Lt}}, Z_{kt})$ where n_{kt} is the number of members of exchange k at time t, and Z_{kt} collects other variables that influence $vol_t(k)$.

Network effects traditionally raise three distinct issues for empirical work. First, there is the question of internal consistency and identification of the model (Manski, 1993). The dependent variable consists of a decision by a firm to join or not an exchange, whereas the independent variables contain firms' collective decisions to join an exchange. Under rational expectations, internal consistency may require that a fixed point exists so that the aggregation of the individual decisions is consistent with the value of the right hand side collective decision variable.[20] In addition, Manski (1993) pointed out in the context of a linear model that identification was not always guaranteed. Brock and Durlauf (2001) suggest that this argument does not extend to non linear models. In particular, they derive conditions under which discrete choice models with network effects are identified. Second, simultaneous-move games with positive network effects may have multiple equilibria which is problematic for estimation. Finally, we might worry that traders' choice is driven by some unobserved factor in which case $\text{impact}_t(k)$ is correlated with the error term.

In this version of the paper, we assume that traders predict future volumes accurately and thus simply let $\text{impact}_t(k) = \log vol_t(k)$. We plan to estimate a model for $E_{t-1} \log vol_{kt}(\frac{n_{kt}}{n_{Dt}+n_{Lt}}, Z_{kt})$ in the future, and deal with the issue of multiplicity explicitly then. For now, simply note that

[20] We write "may require" and not "requires" because agents may not have the same information as the econometrician when they form their expectations over the other agents' decisions.

the average trader represented less than 1% of trading volume so that the network externality generated by an additional trader is likely to be smaller than the precision level of any forecast. The fact that it is so small is suggesting that multiplicity of equilibria might not be such an issue in our set-up. To deal with the potential endogeneity of the impact cost generated from unobserved heterogeneity, we make use of our panel structure by adding exchange-time dummies when we perform our robustness checks.

6.5 Estimation

For exposition purposes, we rewrite the model in (13) by separating the firm-exchange effect d_{ik} from the other covariates. Let $\overline{X}_{ikt}$ denote the vector of covariates but for d_{ik}. We have

$$\pi_{it}(k) = \theta_i \overline{X}_{ikt} + d_{ik} + \xi_{ikt} \tag{14}$$

where, in the baseline model, $\overline{X}_{ikt}$ contains exchange-time specific variables (admission, fixed, and transaction fees, margins, trading volume and impact costs), an exchange-location-time specific variable (access cost), and a time trend, and ξ_{ikt} is an independently distributed heteroskedastic error term. Thus, ignoring the d_{ik}'s the baseline model consists of about 650 coefficients to estimate (including 550 coefficients for the μ_i's).

We assume that the error terms are distributed extreme value. We deal with the heteroskedascity by dividing all the coefficients in (14) by σ_s, the business-type specific standard deviation, and accounting for it when we write the log-likelihood function. We adopt two approaches to deal with the d_{ik}'s when we estimate this model. In our first approach, we treat the d_{ik}'s as "fixed effects" and use Chamberlain (1980)'s Conditional Maximum Likelihood Estimator (CMLE). Define T_{ik} as the number of periods during which firm i is a member of exchange k. Let $(\omega_{i1}, ..., \omega_{iT_i})$ the vector of firm i's choice in our sample and let $\Omega(\omega_{i1}, ..., \omega_{iT_i})$ describe the set of other vector of T_i observation resulting in the same number of periods T_{ik} for $k \in \{0, D, L, B\}$. Then

$$\Pr(\omega_{i1}, ..., \omega_{iT_i} | T_{i0}, T_{iD}, T_{iL}, T_{iB}, \overline{X}, \theta_i, \sigma_s) = \frac{\prod_{k \in \{0,D,L,B\}} \prod_{t \text{ s.t. } \omega_{it}=k} \exp(\widetilde{\theta}_i \overline{X}_{ikt})}{\sum_{(\omega'_{i1},...,\omega'_{iT_i}) \in \Omega(\omega_{i1},...,\omega_{iT_i})} \left(\prod_{k \in \{0,D,L,B\}} \prod_{t \text{ s.t. } \omega'_{it}=k} \exp(\widetilde{\theta}_i \overline{X}_{ikt}) \right)} \tag{15}$$

where $\widetilde{\theta}_i = \frac{\theta_i}{\sigma_s}$ to account for the heteroskedasiticty. The CMLE maximizes the conditional maximum likelihood function, $\prod_i \Pr(\omega_{i1}, ..., \omega_{iT_i} | T_{i0}, T_{iD}, T_{iL}, T_{iB}, X)$. It is consistent. Moreover, under the null hypothesis that d_{ik} is not equal to zero for all i and k, it is efficient (Chamberlain, 1980).[21]

[21] The CMLE was originally proposed to solve the incidental parameter problem arising from the fact that, with

The difficulty with the CMLE in our application is that $\Omega(\omega_{i1}, ..., \omega_{iT_i})$ can be vary large for a typical observed sequence $(\omega_{i1}, ..., \omega_{iT_i})$.

The second approach we adopt is to treat d_{ik} as a random variable, independently distributed from the variables in $\overline{X}_{ikt}$ (in addition to being independently distributed from ξ_{ikt}), and with density $f(.|\kappa)$. Under this assumption,

$$\Pr(\omega_{i1}, ..., \omega_{iT_i}|\overline{X}, \theta_i, \sigma_s, \kappa) = \int \Pr(\omega_{i1}, ..., \omega_{iT_i}|\overline{X}, \theta_i, \sigma_s, d_{iD}, d_{iL}, d_{iB}) f(d_{iD}, d_{iL}, d_{iB}|\kappa) d(d_{iD}, d_{iL}, d_{iB}) \tag{16}$$

The mixed multinomial logit estimator maximizes $\prod_i \Pr(\omega_{i1}, ..., \omega_{iT_i}|X, \theta_i, \sigma_s, \kappa)$ over $((\theta_i)_i, (\sigma_s)_s, \kappa)$. The expression in (16) involves a triple integral which we approximate using simulations.

6.6 Extensions

Cross product effects. Both exchanges listed other products than the Bund during our sample period, including some which were thought to be complementary to the Bund. We control for this by adding product dummies that turn on when an exchange list a particular complementary product (Appendix A provides a list of the complementary products we consider). These dummies capture the overall increased attractiveness of DTB or LIFFE from listing these products. Some types of traders - specifically brokerages and investment banks - are likely to benefit more from an increased product range. We will account for this by constructing a product scope variable for which we will allow business type specific coefficients in a later version. None of these extensions affect the estimation.

Forward-looking traders. Our analysis assumes that traders are myopic when they make their decisions. Our model continues to be consistently estimated if traders are forward-looking and current variables capture future expectations. This will be the case if traders expect future profits to grow at a constant rate. The model will also be consistently estimated if changes in continuation values coincide with the product launches and other events for which we control use exchange-period dummies and if these changes affect traders' continuation values equally. The only implication of forward-looking traders in these two cases is in terms of interpretation of these coefficients. If traders are forward-looking and neither condition holds, the model is mispecified and the coefficients are inconsistently estimated.

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the standard maximum likelihood estimator, the d_{ik}'s are estimated from only T_i observations which is small in a typical panel dataset. In non linear models such as the logit model, the poor estimation of the d_{ik}'s implies that the estimates of the other coefficients are inconsistent (Lancaster, 2000).

7 Results

7.1 Benchmark model

The next tables report our results for the benchmark model when we constrain $\mu_i = \mu_s$ for all i of type s, and d_{ki} to take the same values for all traders that have the same business type and the same location for their headquarters. The normalized choice is "none" implying $d_0 = 0$ and $d_{0i} = 0$ for all i.

Table 1 reports our estimates for the admission and fixed fees, the exchange fixed effects, the time trend, the implicit adoption costs D(location, k, t_0, t_1), and the exchange-period fixed effects, for three different specifications. In specification (1), we do not control for exchange events and trader-exchange fixed effects. These effects are added in specification (2). In specifications (1) and (2), we constrain the coefficients on the variable costs to be the same across business types. In specification (3), we use an alternative measure of variable cost and allow the coefficients to vary across business types.

Admissions fees were statistically significant in all three specifications and negative as expected. Given that LIFFE never charged an admission fee during the sample period and that DTB charged 102,000 DM until 1 January 1998 and then zero afterwards, we will be using this coefficient to give a DM interpretation to the other coefficients. Fixedfees were significant in specifications (2) and (3) but with the wrong sign. The time trend was only marginally significant for the choice "both".

Implicit adoption cost and access deregulation. The next set of estimates, from DTBaccessG through LIFFEaccess3, are the regulation and geography related dummy variables for adoption costs (see Appendix A). They capture the implicit costs of adoption, i.e. those costs incurred by a new member beyond the admission fee charged by the exchanges. All of these estimates are statistically significant and negative as expected, indicating that explicit admission costs were only one part of the costs borne by new members. The coefficients are stable across specifications. If we use the explicit admission fee coefficient as a benchmark, taking into account that admission fees were equal to 102,000 DM, we get that implicit adoption costs were of the order of 10 times larger than explicit admission fees.

Within a geography, access costs evolve as expected. Implicit adoption costs for a EU-based trader or a Swiss-based trader declined as deregulation progressed. For the DTBaccessUS series, the rise in magnitude of DTBaccessUS3 relative to the other US coefficients is expected, since this event was a reversal or previous regulations that allowed more US access to DTB. Smaller magnitude changes between DTBaccessEU1 and DTBaccessEU2 versus DTBaccessEU3 and DTBaccessSwiss1 and DTBaccessSwiss2 versus DTBaccessSwiss3 indicate that clearing status and access points were

less critical changes than full access to DTB. The impact of the European Investment Service directive is estimated to be worth 300,000 DM approximately.

Across geographies and for DTB, access costs compare as we expect (and as consistent with the way we constructed the dummies for groups with several geographical presences). Access costs from Switzerland were lower than from the EU, and except when remote access was authorized from the US, access from the US was more expensive than from Europe. For the first part of the decade, access for firms with a presence in Germany was cheapest. Across geographies and for LIFFE, our estimates confirm that traders with a presence in the UK did occur lower set-up costs than traders without a UK presence.

Finally, we can compare access costs across exchanges. The coefficient magnitudes indicate that access to LIFFE was more difficult than access to DTB. In addition, and as expected given that APT was not technically accessible from outside the UK, the European ISD has less impact on LIFFE than on DTB.

Table 1: Conditional Logit Estimates for Traders' choice of exchange: Access

Coefficient (variable)	**Estimate**	**st. err.**	**Estimate**	**st. err**	**Estimate**	**st. err.**
Specification	(1)		(2)		(3)	
d_{DTB}	5.40**	0.46				
d_{LIFFE}	5.23**	0.25				
d_{BOTH}	10.55**	0.65				
ADM (γ_1)	-8.9 10^{-6}**	2.3 10^{-6}	-1.3 10^{-5}**	2.7 10^{-6}	-1.0 10^{-5}**	2.5 10^{-6}
FIXEDFEES (δ_1)	-5.6 10^{-6}	8.9 10^{-6}	3.6 10^{-5}**	1.8 10^{-6}	2.9 10^{-5}*	1.7 10^{-5}
δ_{3DTB}	0.0035	0.0043	0.034	0.023	0.031	0.021
δ_{3LIFFE}	0.0019	0.0036	0.021	0.028	0.014	0.029
δ_{3BOTH}	0.013*	0.007	0.064*	0.036	0.050	0.035
DTBaccessG	-8.36**	0.20	-8.34**	0.23	-8.43**	0.23
DTBaccessEU1	-12.29**	0.55	-12.19**	0.57	-12.20**	0.57
DTBaccessEU2	-11.56**	0.42	-11.70**	0.46	-11.82**	0.46
DTBaccessEU3	-9.66**	0.20	-9.17**	0.22	-9.21**	0.22
DTBaccessFrench	-7.77**	0.32	-8.48**	0.39	-8.56**	0.39
DTBaccessSwiss1	-10.40**	0.63	-11.10**	1.04	-11.11**	1.05
DTBaccessSwiss2	-10.28**	0.61	-10.24**	0.95	-10.34**	0.94
DTBaccessSwiss3	-6.76**	0.32	-6.96**	0.78	-7.13**	078
DTBaccessUS1	-10.67**	1.03	-10.72**	1.13	-10.92**	1.13
DTBaccessUS2	-8.11**	0.40	-7.56**	0.48	-7.65**	0.48
DTBaccessUS3	-9.66**	1.03	-9.41**	1.06	-9.46**	1.06
DTBaccessUS4	-6.39**	0.43	-6.32**	0.52	-6.38**	0.52
LIFFEaccessUK	-9.70**	0.16	-9.72**	0.18	-9.69**	0.18
LIFFEaccess1	-12.85**	0.47	-13.14**	0.53	-13.11**	0.53
LIFFEaccess2	-12.32**	0.52	-12.50**	0.59	-12.44**	0.59
LIFFEaccess3	-12.11**	0.61	-12.15**	0.67	-12.01**	0.69
	see Table 3 for variable costs				alternative	
event dummies	no		yes		yes	
exchange-type dummies	no		yes		yes	
Loglikelihood	-2,785		-2,623		-2,631	
Pseudo R^2	0.9499		0.9520		0.9526	
N	40,072		40,072		40,072	

** indicates significance at 5%, * indicates significance at 10%

Exchange-period effects. In specifications (2) and (3), we included dummies for the exchange events described in Appendix A. Four DTB events have a significant impact on the attractiveness of DTB. These are the overhaul of the options on the Bund (coefficient -1.38 in specification (2) and coefficient -1.55 in specification (3)), the launch of the option on the Schatz (coefficient 1.07 in specification (2) and 1.32 in specification (3)), the launch of the block trade facility (coefficient -0.82 in specification (2) and coefficient -0.93 in specification (3)), the delisting of the JumboPfandbriefe (coefficient 0.91 in specification (2) and 0.95 in specification (3)). No LIFFE event was significant in specification (2) but two LIFFE events were in specification (3). These were the top step initiative (coefficient -1.06) and the end of the CBOT link (coefficient - 1.17). Using again admission costs as a benchmark, their quantitative importance is of the order of 1.5 times admission costs. Note that some of these coefficients do not have the expected sign. One possible reason which we will explore in detail in the future is that the effect of these changes might have a lag.

Table 2: Evidence of HQ location - business type effect

		DTB	LIFFE	BOTH
UK HQ	Universal	1.72	4.87**	9.00**
		(2.05)	(0.97)	1.46
	IB	3.35**	4.01**	7.96**
		(0.98)	(0.68)	(1.23)
	Proprietary	2.10**	4.18**	7.03**
		(1.04)	(0.61)	(1.24)
German HQ	Universal	4.65**	5.92**	10.09**
		(0.88)	(1.01)	(1.32)
	IB	4.77**	6.17**	9.52**
		(0.87)	(0.97)	(1.31)
	Proprietary	4.52**	-9.97	-7.90
		(0.86)	(2246)	(5646)
US HQ	IB	3.80**	4.61**	9.22**
		(0.90)	(0.64)	(1.17)
	Proprietary	3.83**	3.89**	7.96**
		(0.90)	(0.72)	(1.34)

Exchange-business-types-HQ-location fixed effects. As a coarser version of the d_{ik}'s, specifications (2) and (3) included 126 exchange-business-types-HQ-location dummies (the headquarter locations were US, UK, Germany, Switzerland, EU except for Germany and UK, ROW). The omitted categories are for the "none" choice, thus the interpretation for each of these variables should

be relative to the preference of a given trader for an exchange relative to not being a member of any exchange. Many of these dummies were significant indicating that trader-exchange unobservables might be important. Table 2 reports a subset of these coefficients and specification (3)

We use US-headquartered firms as a benchmark. Holding business types fixed and comparing the DTB coefficients for UK-headquartered firms, German-headquartered firms and US-headquartered firms, we find that German headquartered firms have a slight preference for DTB and that UK-headquartered firms discounted DTB. German-headquartered firms, especially universal banks and investment banks valued LIFFE at least as much as UK-based firms. Thus if anything, our results do not indicate a pro-DTB bias among German headquartered firms, rather than an anti-DTB sentiment among UK-headquartered firms.

Variable costs coefficients. Specification (2) correspond to our benchmark model but with the coefficient on cost variables forced to be the same across business types. Most coefficients were insignificant except α_1 which was positive (contrary to expectations) and α_9 which was positive as expected. We also ran a regression with coefficients allowed to vary across business types and most coefficients were insignificant. The reason for these results might be that there is little variation in transaction fees, that margins covary a lot across exchanges (and because they are driven by risk fundamentals, traders might ignore them when deciding across exchanges), and that our measure of liquidity might not differentiate exchanges very much. In specification (3) we dropped transaction fees and margins all together and used an alternative measure for impact where we divided volumes by 100,000. Thus $\text{impact}_t(k) = \log vol_t(k) - \log(100,000)$. Trading volume for both exchanges was simply the sum of the two (we also no longer multiplier $\text{impact}_t(k)$ by volume). We let the coefficients on $\text{impact}_t(k)$ vary across business types. Impact was significant for specialized trading firms only, and with a negative coefficient.

Summing up: determinants of exchange membership. Our empirical model includes four sources of variation across exchanges and time. The first source of variation is access deregulation. It is location specific and affects all trading firms with a geographical presence in a given country equally. The second source of variation is the increase in relative liquidity of DTB over time (DTB's market share remain constant for most of the sample period but because volumes grew, the liquidity differential between the two exchanges declined). This source of variation affects all traders irrespective of geography, but it potentially affects different business types differentially. The third source of variation are the period fixed effects associated with exchange product launches and so on. We have implicitly constraint them to affect all traders equally. Finally, the fourth and last source of variation is the time trend. It also affects all traders equally. While some exchange events were significant and we did find some evidence that liquidity mattered, our results suggests

that access deregulation was the dominant factor that helped DTB attract traders.

8 Conclusions

Incumbents in industries with network effects notoriously have an advantage. In this paper, we have studied the determinants of market tipping in such an industry: financial exchanges. Our panel dataset contains trader-level exchange choice decisions as well as traders and exchanges characteristics. The panel structure allows us to control for both trader and exchange unobserved heterogeneity.

The current version of this paper lays out our model for traders' choice, describes our intended empirical strategy, and reports estimates from a somewhat simpler specification.

These preliminary results indicate that exogenous factors were the main determinants of the observed dynamics. Specifically, access deregulation combined with the rapid growth in the number of traders had a significant impact on the number of members DTB attracted. Deregulation decreased adoption costs by the order of three times the magnitude of explicit admission fees on DTB and the number of traders nearly doubled in the space of 10 years. German firms were critical in helping DTB garner a critical mass of trading volume initially, without which tipping could not have happened. However, we did not find evidence of a systematic national bias in the membership decisions. The fact that the early members of DTB were predominently German can be explained by lower access costs.

Concerning firms' strategies, we found some evidence that product additions raised the attractiveness of the exchange that listed the new product or service. The magnitude of these effects are comparable to explicit admission fees. We did not find evidence that transaction fees played much role in helping the market tip but this may be due to the lack of variation on the data. The preliminary results also confirm the role of trader heterogeneity in helping DTB progressively attract members and trading volumes.

We intend to push our results in two directions. First, we intend to estimate the full model that controls for trader-exchange (instead of types-of-traders-exchange unobservables as currently reported) and plan to carry out a series of robustness checks. These will include alternative specifications to control for trader heterogeneity and cross-product effects, alternative timing for traders' decision marking and specification testing.

Second, while the fact that we do not impose that DTB and LIFFE limits what we can do in terms of counter-factuals, we can already investigate the following questions:

1. How much was access deregulation worth for DTB? (by considering the alternative admission

fee DTB should have charged to maintain adoption constant, absent deregulation)

2. Is there evidence that the exchanges optimized their fee structure? (by considering the costs of alternative fee structure that would have generated the same adoption behavior).

3. Holding the behavior of DTB fixed, what would it have taken LIFFE to keep the Bund?

[bibliography is incomplete]

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9 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.

9.1 Firm dataset

The main text reports that, for each establishment, we collected information on (1) their (historical) group affiliation including mergers and acquisition, (2) the establishment inception, and possibly its closing date, (3) the group inception date, and possibly its bankruptcy date, (4) the business type of the establishment, (5) whether the establishment can trade on third party accounts, (6) whether the establishment trades the Bund. This information was collected manually using the following procedure:

1. *Group and establishment inception dates and merger and acquisition dates* for existing companies was taken from ORBIS, UKdata.com or by contacting the establishment directly.[22] For bankrupt establishments located in Germany and Switzerland, we used the Dufa-Index and the Dun&Bradstreet (Swtizerland)'s records (both available through Factiva).[23] Factiva was used to track any available information for other bankrupt firms (e.g. reports of bankruptcy filing or trading license being upheld).

2. *Information on group ownership structure* 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.

3. *Information on establishments' business types* was taken from self-descriptions of the business on company websites, ORBIS, and press articles during the relevant period, as well as direct phone or email contract with the company when possible.

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

[23] 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.

4. *Information on whether the establishment can trade on behalf of third parties* was obtained from national regulators (for instance, a US-based establishememt must be a registered futures commission merchant to be allowed to trade for the public), LIFFE's membership status, and Eurex' website (for current members). It was completed by phone calls to individual establishments when possible.

5. *Information on the products traded* were taken from company websites, LIFFE's product licenses, LIFFE's and DTB's notices to members, press articles mentioning a trader from that establishment in relation to the Bund market, and phone calls to the establishment when possible.

9.2 Regulation-driven adoption costs

9.2.1 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 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 Service 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 geographical-time adoption dummy is turned out for each group. For groups with geographical presence in several locations, we considered that access from Switzerland was easier than from any other European country at all times, and that a firm with a presence in France or the Netherlands found it easier to connect from there from September 1994 until the Investment Service Directive came into force. Access from Europe is considered to be easier than from the US at all times. The following table summarizes the value for the $D(\text{location,DTB}, t_0, t_1)$ variable.[24]

[24] To "ensure" exogeneity of the geographical presence of the group in a given location at time t, we considered a group was present in a location if it had an establishment in that location at time $t-3$.

Name	Events	Location	t_0	t_1
DTBaccessG		Germany	11/90	12/99
DTBaccessSwiss1		Switzerland	11/90	12/95
DTBaccessSwiss2	Access points in Zurich	Switzerland	1/96	8/98
DTBaccessSwiss3	Merger with SOFFEX	Switzerland	9/98	12/99
DTBaccessEU1		EU	11/90	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 Holland	9/94	12/95
DTBaccessUS1		US	11/90	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

9.2.2 LIFFE

For most of the period, 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, we distinguished three periods: before the European Investment Service Directive, after the ISD but before LIFFE moved the Bund to electronic trading only in August 1998, and after August 1998. The resulting variables are: LIFFEaccessUK, LIFFEaccess1, LIFFEaccess2, and LIFFEaccess3.

9.3 Events affecting the attractiveness of DTB and LIFFE

The next two tables record the events that we control for in the current specification, as well as their types and likely effect. Dummies turn on from the date onwards and can thus be interpreted as the marginal impact of the event on the attractiveness of each exchange

Date	Events affecting the attractiveness of DTB	Type	Sign
7/91	Gentlemen's agreement to provide liquidity		+
8/91	Launch of option on Bund	complementary product	+
10/91	Launch of Bobl	complementary product	+
6/92	Change in the Bund contract specification	quality	+
1/93	Launch of option on Bobl	complementary product	+
12/93	Cross-margining for Bobl and Bund	complementary product	+
3/94	Launch of FIBOR and BUXL	complementary product	+
4/95	Cut in one-time connection charges	adoption cost	+
6/95	New transaction limits in place	market rules	+
10/95	Launch of basis trading facility for Bund and Bobl	complementary product	+
11/95	Overhaul of options on Bund and Bobl	complementary product	+
3/97	Launch of Schatz	complementary product	+
5/97	Launch of Spread Facility for Bund/.Bobl and Bund/Schatz	complementary product	+
2/98	Launch of option on Schatz	complementary product	+
4/98	DTB offers free computerto LIFFE members	adoption cost	+
7/98	Launch of Jumbo-Pfandbriefe	complementary product	+
9/98	Merger with SOFFEX to create Eurex		+
1/99	Launch of Block Trade Facility for options on Bund and Bobl	complementary product	+
3/99	Delisting of Jumbo-Pfandbriefe	complementary product	-

Date	Events affecting the attractiveness of LIFFE	Type	Sign
1/92	Merger with LTOM		+
11/92	Liffe announces that Treuhandstalt Bonds deliverable	quality	+
1/93	Launch of Bobl	complementary product	+
12/93	Launch of new Automated Trading Platform (APT)	market rules	+
2/94	Launch of Bund-Bobl Spread Facility	complementary product	+
9/94	Bobl delisted	complementary product	-
1/95	New incentive scheme for financial option contracts	marketing	+
3/95	French regulatory authorities recognize Liffe	access	+
7/95	Launch of Basis Trading Facility for Bund	complementary product	+
9/96	Merger with the London Commodity Exchange		+
5/97	Liffe-CBOT link started	access	+
6/97	Top step initiative	market rules	+
9/97	Launch of Bobl and Bobl options, Bobl/Bund spread facility	complementary product	+
12/97	End of Liffe-CBOT link, launch of an inter-contract spread facility	access, compl. product	+
3/98	Director David Kyte resigns in protest against Liffe strategy		-
6/98	Bobl and Bobl options delisted	complementary product	-
7/98	Liffe subsidizes APT stations	marketing	+
8/98	Bund trading moved entirely to APT stations	market rules	+
10/98	Launch of Liborfinancebond, launch of euro-Bund	complementary product	+
5/99	Bund only traded on Liffe Connect	market rules	+
8/99	Change in Liffe Connect matching algorithm	market rules	+

10 Appendix B: Microfoundations of traders' profit function

[TO BE WRITTEN]