PRELIMINARY; PLEASE DO NOT QUOTE WITHOUT PERMISSION!

The Microstructure of the Euro Money Market

Bruno Biais, Philipp Hartmann and Michele Manna*

This draft 28 April 2000

Abstract: This paper provides an empirical examination of the microstructure of the euro money market, the interbank market for short-term funds in the transnational currency created in January 1999. The microstructure of the money market has to be delimited in institutional terms as the union of three elements, the central bank's instruments for monetary policy operations, the private market financial instruments and trading mechanisms for funds and the payment and settlement infrastructure for the transfer of those funds. All three elements can significantly influence the intra-day behaviour of money market rates. To study their effects for the euro money market 5 months of intra-day data have been recorded from brokers in four euro area countries and the UK (posting their quotes on Reuters) and from the Italian electronic market MID. The results show "u"-shaped intra-day patterns of quoting frequency and volatility, but more diverse intra-day patterns (sometimes "hump"-shaped) for bid-ask spreads. Quoting activity, spreads and rate volatility are very high on Thursdays, particularly during lunchtime when the ECB's interest rate decisions are released. These features reflect the risks for the market related to the arrival of important new information. Before Tuesday's main refinancing auctions with the open market volatility is high as well, but there seems to be only weak evidence of asymmetric information before the announcement of auction results. However, a short period of high market activity without particularly large spreads after the auction suggests that the post-auction liquidity reallocation process through the interbank market is relatively efficient. Finally, it is shown that spreads and volatility tend to be very high at the end of the minimum reserve maintenance period and that the same happened during the year 2000 changeover days, reflecting the high risks involved in both.

KEYWORDS: auctions, euro, financial market microstructure, high-frequency data, money market, monetary policy instruments, overnight deposit rates, payment systems, reserve requirements

JEL CODES: G14, E43, E52, D44

Paper prepared for the ECB conference "The Operational Framework of the Eurosystem and Financial Markets", 5-6 May 2000, Frankfurt

* Biais is from Toulouse University, Hartmann and Manna are from the European Central Bank's DG Research and DG Economics, respectively. The authors would like to thank SIA, in particular Francesco Cesarini and Mariella Ghinelli, for providing the data on the Italian MID system, Vincent Brousseau for some programming tricks and Andres Manzanares for strong research assistance. They also appreciated discussions with several market participants, in particular Andreas Hauschild and Javier Pazos. Any views expressed are only the authors' own and do not necessarily reflect the views of the ECB or the Eurosystem.

1. Introduction

This paper presents the first broad empirical examination of the euro money market's microstructure. The introduction of the euro provides a unique experiment: the unification of 10 monetary policies into one results in the unification of 10 money markets into a single one. More than a year after the introduction of the euro, it appears interesting to study the state of the market, in particular its microeconomic functioning ("microstructure") and integration.

In contrast to other financial markets, such as bond, equity or foreign exchange markets, there is only a small literature touching upon microstructure issues of the money market. In particular papers addressing intra-day features of the market are extremely rare. To our knowledge only Angelini (forthcoming; for the Italian electronic deposit market before the introduction of the euro) and Furfine (1999, for the US fed funds market) have presented empirical papers on the intra-day behaviour of money markets. Most other papers on money markets follow a traditional macroeconomic approach or look at the time series properties of short rates at a daily (or longer) frequency (see e.g. Hamilton, 1996, for the US fed funds market and Perez-Quiros and Rodriguez, 1999, for the euro overnight market).

The present paper has several objectives. First it aims at showing that the microstructure of the money market is heavily influenced by an institutional environment that can be decomposed in the central banks' monetary policy procedures and operations, such as the central bank auctions serving as the main bank refinancing mechanism; the private market trading structures and procedures, such as "voice" brokers or electronic trading systems; and the payment (and settlement) infrastructure, particularly the structure and timing of large-value payment systems. Second, it seeks to describe and explain the main features characterising euro overnight interbank deposit trading, by studying the intra-week and intra-day behaviour of bid-ask spreads, volatility and quoting frequency observed in the market.

The remainder of the paper is organised as follows. The next section gives a broad description of the institutional environment of the money market, covering the three aspects enumerated above. Section 3 presents the data set collected for the purposes of this study. Section 4 describes and discusses the behaviour of quoting (tick) frequency, bid-ask spreads and mid-rate volatility, both across the trading week and the trading day. Section 5 concludes.

2. The institutional context

The microstructure of the money market can be decomposed in three institutional elements: 1) The operational framework for monetary policy of the central bank (monetary policy instruments, such as open

market operations, standing facilities etc.); 2) the private trading environment, including the different financial instruments traded (deposits, repos, derivatives etc.), the trading facilities (electronic brokering, electronic information systems etc.) and the market organisation (organised exchange vs. over-the-counter market); 3) the payment and settlement infrastructure (large-value payment systems, securities settlement systems, clearing and netting facilities, etc.). The money market is special insofar as the central bank acts as the only ultimate provider of liquidity in a given currency, thereby dominating the supply side. This is done through its operational framework, which can be used to either inject or withdraw liquidity from the banking sector. Apart from directly refinancing from the central bank, money market participants trade with each other to take positions in relation to their short-term interest rate expectations, to hedge their more long-term positions with more short-term contracts and to square individual liquidity imbalances resulting from customer transactions or unsuccessful efforts in central bank refinancing operations. Funds (or securities in the case of secured markets) are ultimately transferred between the central bank and money market participants and among the participants themselves through payment (or settlement) systems. However, the payment flows are not necessarily instantaneous compared to the trading activities. Depending on the respective payment (or settlement) system they have certain patterns during the day. In fact, all the three elements of the money market microstructure, together with macroeconomic news that influence traders' expectations of short-term interest rate developments, can and do influence the evolution of prices and quantities in the money market. Therefore, the present section describes these three institutional elements for the euro money market, starting with a short introduction on the institutional framework for macroeconomic monetary policy decisions.

2.1 The Eurosystem and monetary policy decisions for the euro area

The Eurosystem, composed of the European Central Bank in Frankfurt and the 11 central banks of the countries which joined the third stage of Economic and Monetary Union (EMU), conducts the monetary policy of the euro area. Its goal is to maintain price stability in the euro area, defined as an increase of the harmonised consumer price index (HICP) of the euro area by less than 2%. The monetary policy strategy of the Eurosystem has two pillars: the first pillar assigns a prominent role to money, as reflected by the announcement of a monetary reference value for the growth of the M3 monetary aggregate (currently a 4.5% growth rate). The second pillar is a broadly based assessment of the outlook for future price developments, considering a large list of economic indicators.[1] The Governing Council of the ECB is the main policy making entity of the system, composed of the 6 ECB Board members and the 11 governors of national central banks, which meets every two weeks (usually) on Thursdays. Whereas the main *decisions* of the system, in particular interest rate decisions for the conduct of monetary policy, are taken centrally by the Council, monetary policy operations are *executed* in a decentralised fashion via the national central banks.

[1] See Angeloni, Gaspar and Tristani (1999) and ECB (1999a) for in-depth discussions of the ECB monetary policy strategy.

Interest rate decisions by the Council are first communicated to the market by a communiqué released at 1.45pm on a Council day on the ECB web site and to all the major newswire services. Every other Council meeting is followed by a public press conference at 2.30pm, in which the ECB President answers questions by the press. A transcript of the questions and answers is made available shortly after the press conference. Table 1 summarises the three ECB interest rate changes during the sample period we are going to use below. The ECB publishes some more data relevant for its monetary policy. Towards the end of each month new figures on M3 (referring to the preceding month) are released at a given day around 10am, which the market can then put in relation to the monetary reference value. Finally, the ECB publishes a Monthly Bulletin with a host of macroeconomic data and monetary analysis. The Bulletin is usually released on the ECB web site on the Thursday of the second week of each month at 7pm.

Table 1: ECB interest rate changes between November 1999 and March 2000

Decision on	MRR eff. with tender exec. on	Previous policy rates			New policy rates		
		Deposit rate (%)	MRR (%)	Marg.lend. rate (%)	Deposit rate (%)	MRR (%)	Marg.lend. rate (%)
4 Nov 99	12 Nov 99	1.50	2.50	3.50	2.00	3.00	4.00
3 Feb 00	8 Feb 00	2.00	3.00	4.00	2.25	3.25	4.25
16 Mar 00	21 Mar 00	2.25	3.25	4.25	2.50	3.50	4.50

Note: MRR=main refinancing rate.
Source: ECB

2.2 The Eurosystem's operational framework for monetary policy operations

The operational framework for monetary policy can be defined as the set of instruments that a central bank uses to implement its monetary policy by managing the liquidity provision to the money market and steering money market interest rates. Following a fairly standard taxonomy, we will classify the instruments used by the Eurosystem in open market operations (addressed in 2.1.1 below), standing facilities (2.1.2) and reserve requirements (2.1.3).[2] The open market operations are the general instruments used to manage the liquidity provision and to steer interest rates. Among them, and as suggested by their name, the main refinancing operations are entrusted with the task of providing the bulk of liquidity to the banking system, raising their role to the key operational monetary policy instrument. Additional liquidity is placed through the longer-term refinancing operations. These are operations conducted regularly by means of monthly tenders for reverse transactions with a maturity of three months. However, in general the Eurosystem will not use this instrument to signal monetary policy intentions to the market and therefore conducts them as variable rate

[2] A comprehensive description of the Eurosystem's operational framework is given in ECB (1998). The following contains an extensively abridged overview over ECB operations.

tenders (with pre-announced intended allotment volumes). The Eurosystem may also carry out fine-tuning operations on an ad hoc basis to smooth interest rate movements. During our sample period only one fine-tuning operation in the form of a collection of fixed-term deposits was conducted on 5 January 2000, with the aim to absorb some excess liquidity in the aftermath of the millennium date change. Finally, the Eurosystem may conduct also structural operations to modify its net liquidity position vis-à-vis the banking system over a longer period. So far, the Eurosystem has not conducted any structural operations.

2.2.1 Main refinancing operations

In the light of their prominent role, it may be useful to examine in some greater detail the main refinancing operations. These operations are conducted in the form of a weekly auction for repurchase agreements (repos) with a maturity of two weeks. For reasons of effective policy signalling to the market, the auction has been conducted as a fixed (single) rate tender so far. The ECB determines the overall quantity to be allotted to the market on the basis of its own assessment of the liquidity needed by the market, including an internal liquidity forecast. This quantity is divided pro rata among all bidders against eligible collateral through credits on their reserve accounts.[3] If it perceives that there are inflationary pressures the ECB can choose to allocate less liquidity in the open market, either by reducing the total amount allocated or by raising the main refinancing rate. However, the main policy tool used by the Governing Council is the main refinancing rate and not the quantity of liquidity to be allocated. Allotment decisions are done by the ECB on an operational level. Whereas the ECB does not publish its liquidity forecast, every day - at 9.15am at the latest - it publishes the aggregate reserve account holdings of the banking sector with the Eurosystem on the previous day, its average reserve account holdings since the start of the minimum reserve maintenance period and its aggregate recourse to the standing facilities. (Hence, sophisticated players may use this information for the determination of their bids before the 9.30am main-refinancing auction cut-off time.) In addition, once a week – (usually) on Tuesday at 3pm – it releases its weekly balance sheet, referring to the stock figures of the preceding Friday.

The weekly main refinancing tender auction is usually (but not always) held on Tuesdays. The fixed rate is determined by the latest preceding Governing Council decision on the main refinancing rate, i.e. at the latest at the last Thursday before the next auction. In the larger number of cases so far rate changes have been decided during Council meetings followed by a press conference. However, on 16 March 2000 rates were changed for the first time at a Council meeting without press conference. The timing of the auction itself is the following:

[3] There are two tiers of eligible collateral. Tier 1 consists of marketable debt instruments, which are relevant for the entire euro zone. Tier 2 includes both marketable and non-marketable assets (including equities), which are of particular importance for the respective national financial markets and banking systems.

(i) On Monday around 3.30pm, the day before, the ECB announces the auction and its conditions on Reuters and other wire services. The announcement contains a reconfirmation of the rate and some standard main refinancing operation properties, such as the type of operation, the maturity, the timing for bids and the minimum bid size (see the top of Figure 1 for an example);

(ii) Banks can submit bids at their respective national central banks until 9:30am on Tuesday, the day of the auction, which are then transferred to the ECB that applies the auction procedure;

(iii) At around 11:15am on Tuesday the result of the auction is announced again on Reuters. As shown at the bottom of Figure 1, the allotment announcement includes, inter alia, the total number of bidders (equivalent to the number of bids), the total amount bid, the total amount allotted and the so-called "allotment ratio" (which is the ratio of the latter divided by the former).

Figure 1: ECB auction information on Reuters pages "ECB16" and "ECB17" – the example of the main refinancing operation on 8 February 2000

14:43 07FEB00 EUROPEAN CENTRAL BANK, FRANKFURT a.M. GE66608 ECB16
Main Refinancing Operation – **Announcement**

Reference number: 20000009	Min Allotment:
Transaction Type: Reverse Transactions	Fixed Rate: 3.25 %
Operation Type: Liquidity Providing	Min Bid Amount: 1.00 mn
Procedure: Standard Tender	Max Bid Limit:
Start Date: 09/02/2000	
Maturity Date: 23/02/2000	
Duration (days): 14	
Auction Type: Fixed Rate Tender	
Allotment Method: Single Rate	

10:18 08FEB00 EUROPEAN CENTRAL BANK, FRANKFURT a.M. GE66608 ECB17
Main Refinancing Operation – **Allotment**

Reference Number: 20000009	Min Allotment:
Transaction Type: Reverse Transactions	Fixed Rate: 3.25 %
Operation Type: Liquidity Providing	Max Bid Limit:
Procedure: Standard Tender	
Tender Date: 08/02/2000	% of Allot.: 6.37
Start Date: 09/02/2000	Tot Amount Allotted: 66000.00 mn
Maturity Date: 32/02/2000	
Duration (days): 14	Tot Bid Amount: 1036647.80 mn
	Tot Number of Bidders: 686
Auction Type: Fixed Rate Tender	
Allotment Method: Single Rate	

Note: The time stamp at the upper left-hand corner of each page reprinted here refers to Greenwich Mean Time, so that one hour needs to be added for Central European Time.
Source: ECB, Reuters

Figure 2 plots the total amounts allotted against the total amounts bid for the 21 main refinancing auctions between 1 November 1999 and 23 March 2000. The figure indicates that the total amount bid tends to be weakly increasing in the total amount allotted. This is a reflection of the so-called "overbidding" behaviour. As the auctions are carried out in the form of fixed rate tenders, demand usually exceeds supply and liquidity is allocated according to the pro-rata rule. Anticipating such rationing, banks tend to "overbid", i.e. to demand more than what they actually need. The overbidding behaviour is thus very much the realisation of self-fulfilling expectations, whereas for each bank - to the extent that the amount bid by the others and the total amount allotted are uncertain - the rationing rate is random ex ante.[4] Figure 2 also indicates (with dates) the last main refinancing auctions before an ECB rate increase. It appears that before these policy moves bids tended to be high, but not necessarily the quantities allotted. This observation is consistent with the market having correctly anticipated the rate increases and attempted to get as much "cheap" refinancing as possible before the rate rises. The "smallest" auction was conducted on the 11th of January, the first refinancing operation after the year 2000 changeover date.

[FIGURE 2 ABOUT HERE]

2.2.2 Standing facilities

Standing facilities have the function of providing or absorbing liquidity with an overnight maturity vis-à-vis individual counterparties facing unforeseen liquidity shocks. They therefore provide a type of insurance mechanism, but at penalty interest rates. The initiative is usually on the side of the counterparty. Notably, a Eurosystem counterparty may use the marginal lending facility to obtain (against eligible collateral) overnight liquidity in case of an individual shortage, whereas it may use the deposit facility to make deposits in case of individual excess liquidity. If a counterparty does not have the funds available to settle all payment requirements in TARGET (see 2.4 below), it is at the end of the day automatically referred to the marginal lending facility. The fact that the access to the standing facilities is not subject to rationing (provided adequate collateral is posted in the case of recourse to the marginal lending facility) makes the corresponding interest rates effectively bound the overnight market interest rate, creating a "corridor".

2.2.3 Minimum reserve requirements

The third component of the operational framework of the Eurosystem that influences the market microstructure are minimum reserve requirements. They aim at (i) stabilising money market interest rates without recourse to frequent central bank interventions in the open market and (ii) creating or enlarging the structural liquidity shortage of the banking sector to increase the effectiveness of monetary policy actions (ECB, 1998). According to the current regime, all credit institutions established in the euro area have to keep 2% of the total amount of overnight deposits, other deposits with maturity below 2 years, debt securities

[4] See Bindseil and Mercier (1999) for a general discussion of the bidding behaviour in Eurosystem fixed rate auctions and Nautz and

with maturity below 2 years and money market paper held by institutions and individuals not subject to the Eurosystem minimum reserve requirement system at their reserve accounts with national central banks. These reserves are remunerated at the main refinancing rate. They have to be fulfilled only on average over a one-month maintenance period ("averaging") that runs from the 24th of a month to the 23rd of the following month. The amount of reserves required and held is significant, in the order of EUR 100-110 billion. So they provide a buffer against unexpected liquidity shocks, mitigating the related fluctuations of market rates. However, the stabilising effect of the averaging provision becomes weaker and eventually vanishes towards the end of the reserve maintenance period, when banks no longer in a position to defer the fulfilment of their reserve requirements. This is well illustrated by the plot of broker overnight rates in the euro area between November 1999 and March 2000 displayed in Figure 3. At or shortly before the 23rd of each month euro overnight rates either exhibit a short trough (excess liquidity compared to the required minimum reserve average) or a short peak (shortage of liquidity). On the basis of daily data, Perez-Quiros and Rodriguez (1999) argue that the introduction of a "symmetric" pair of standing facilities by the Eurosystem (see 2.1.2 above) has effectively led to a reduction of this volatility and also to a more symmetric distribution of it.

2.3 The private market trading environment

In a broad sense, the money market is delimited as the market for short-term debt instruments, usually up to one year of maturity. In this paper we focus on the overnight interbank deposit market, which is of particular interest to the liquidity management of the central bank. With an estimated daily turnover of EUR 61 bn (in the second quarter of 1999) it is by far the largest spot segment of the money market in the euro area (figure from an ECB Market Operations Committee Survey covering Belgium, Finland, France, Germany, Ireland, Italy, Portugal and Spain). Other segments of the money market include (i) unsecured deposit contracts "tomorrow next" (overnight contracts for the following day until the next day), and with 1-week, 2-week, 1-month, 3-month, 6-month and 1-year maturity, (ii) repurchase agreements ("repos", reverse transactions secured by securities) also ranging from overnight to 1 year, (iii) forward short-term (up to 1 year) interest rate agreements and (exchange-traded) futures, (iv) foreign currency swaps at the same maturities as for unsecured deposits and repos, and (v) interest rate swaps ranging from 1 week to 1-year maturity, (vi) bank certificates of deposits, (vii) commercial paper and (viii) Treasury bills (short-term government debt securities). In fact, according to the ECB survey, unsecured overnight deposit trading exceeds trading in any of the other segments by a factor of at least 4 and for most of the segments much higher.

The relative importance of the different contracts can vary substantially between countries in the euro area. For example, whereas there are active repo markets in Finland, France, Germany, Italy and Spain, they are hardly developed in other euro area countries. Or the leading euro futures contract, the 3-month Euribor, is

---

Oechsler (1999) for a critical analysis of the over-bidding phenomenon.

mainly traded on the London International Financial Futures and Options Exchange (LIFFE), even outside the euro area. However, the strong growth of the overnight segment, particularly for cross-border transactions, seems to have been relatively uniform across countries in the euro area. This reflects in part the interbank market's role in reallocating liquidity after ECB main refinancing operations in the case that some banks received a larger allotment than needed and other banks received a lower allotment than needed. (As described in 2.1.1, these imbalances may occur because of individual banks' uncertainty about the ECB's total allotments and other banks' bid sizes.) It also reflects the effective functioning of short-term interest rate arbitrage and liquidity equalisation across the euro zone (in the case of asymmetric liquidity shocks).

Most of the contracts enumerated above are traded over-the-counter, in contrast to the futures for example, that are traded on the derivative exchanges in European capitals. As for other financial markets, such as foreign exchange markets or the bond markets trading can be bilateral over the phone or through electronic market communication facilities (such as Reuters) or through "voice" brokers matching counterparties or even through electronic brokering systems. Again the relative importance of the different market trading facilities can be very different from country to country and even from trader to trader. Also government securities and commercial paper tend to be traded separately from interbank deposits.

Focussing again on the unsecured euro deposit market, at one extreme of the trading infrastructure is certainly the *Italian* electronic broker market MID (Market for Interbank Deposits, run now by e-MID S.p.A. of Società Interbancaria per l'Automazione (SIA), Milan). In February 2000 MID had 182 Italian member banks and 7 foreign member banks, participating in trading with very different degrees of involvement. In this system, which covers virtually the entire existing domestic overnight deposit market in Italy, transactions between members are clinched automatically, when the respective rates (offered or bid) and quantities match, provided credit limits are not exhausted. (The repo market happens outside this system though.) However, as in the case of other euro area countries, cross-border trades by Italian banks are still mostly executed via "voice" brokers in the target countries or through bilateral direct transactions. In *Spain*, most of overnight deposit (and short-term repo) trading is executed via 4 main "voice" brokers. By definition, brokers generally do not trade on their own account, but collect desired trading prices and quantities from some customers to match them with other customers against a fee. Many money market brokers (in Spain or elsewhere) also post indicative bid and ask prices on electronic market information systems, such as Reuters, Bloomberg or Telerate. Most of the remaining transactions in Spain (in particular for maturities beyond 1 month) are undertaken bilaterally through electronic market dealing systems. After some consolidation in the last years there remain less than a dozen of main dealers driving money market trading in Spain. In *France* brokers are also used, but the bulk of the negotiations take place over the phone. France is known to have a very active overnight market and the most developed repo market with relatively narrow traded bid-ask spreads. In fact, the Banque de France (1999, p. 54f.) underlines the role of the French euro money market as a hub in distributing liquidity *within* the euro area. It reports figures showing that 40%

of the turnover by the large players asked for their rates to determine EONIA (the standardised daily euro overnight rate calculated by the ECB) had at least one French bank on one side of the transaction. In *Germany* interbank deposit trading is dominated by the 4 large German commercial banks and the semi-public Landesbanken. However, most of these main players tend to have a euro-area wide approach rather than focussing on domestic trading. The larger part of transactions tends to be undertaken directly between traders (over the phone) and only a smaller part through "voice" brokers. The Bundesbank (2000, p. 23f.) also observed that Germany plays a key role in the distribution of liquidity between the euro area and the EU countries that have not joined EMU in the first wave, notably the UK with its large international financial markets in London. (These countries have (limited) access to euro intra-day liquidity through a special remote link to the Eurosystem's TARGET payment system.)

In sum, in spite of the important cross-border activity in the unsecured euro interbank deposit market there remain heterogeneities in the private trading environment. However, these remaining heterogeneities, which mainly result from different traditions and market structures that prevailed before the introduction of the common currency, do not necessarily imply inefficiency or non-integration. In fact, some of them, such as electronic trading versus "voice" broker or telephone trading, do compete with each other, and only the future will show whether this competition will lead to more uniform trading structures in the euro money market or whether important differences continue to exist. For example, one important issue is whether truly euro-area wide electronic trading systems will emerge that attract the bulk of the transactions.

2.4 Payment (and settlement) infrastructure

Payment and settlement refers to the effective transfer of funds and securities in relation to all types of monetary and financial transactions to achieve "finality". In particular, without efficient and safe large-value payment and securities settlement systems monetary and financial integration are virtually impossible to achieve, since interest rate or price differentials would occur, because of the impossibility or cost of transferring funds for arbitrage purposes. In particular, important short-term interest rate differentials in the money market of a currency area would endanger the singleness of monetary policy, which is implemented through a single short-term interest rate for the entirety of the zone. For this reason, among others, the Eurosystem has introduced TARGET at the start of stage 3 of EMU, the Trans-European Automated Real-time Gross settlement Express Transfer system, which is composed of the 15 domestic RTGS (real-time gross settlement) systems, a network of bilateral links (interlinking mechanism) between them and the ECB payment mechanism.

The private sector, more precisely the European Banking Association (EBA), has introduced a parallel area-wide net settlement system, Euro1 (a successor of the previous ECU clearing and settlement system). In addition, there exist two relatively important national hybrid systems (combining features of net and gross

settlement), namely EAF (Euro Access Frankfurt) in Germany and PNS (Paris Net Settlement) in France.[5] Table 2 exhibits the relative use of these systems during the first year of EMU. It turns out that TARGET and Euro1 are the two dominant large-value payment systems for euro-area cross-border transactions. TARGET leads in terms of the value of transactions and Euro1 in terms of the number of transactions executed. This reflects the behaviour by market participants to use the "safer" RTGS system TARGET for larger transactions and the "cheaper" net settlement system Euro1 for smaller transactions. (The average transaction size in each system and period can be easily derived by dividing the average value of transactions (left figures) by the average number of transactions (right figures).)

Table 2: Main large-value payment systems in the euro area in 1999

(daily averages, value of payments in EUR bn. / number of payments in '000)

System	1st quarter	2nd quarter	3rd quarter	4th quarter
TARGET *Total*	964 / 155	906 / 158	884 / 163	947 / 176
Domestic	615 / 130	554 / 130	530 / 133	562 / 144
Cross-border	349 / 25	351 / 28	354 / 30	386 / 32
Euro1	175 / 52	166 / 65	168 / 72	175 / 83
EAF	172 / 48	147 / 45	141 / 46	143 / 48
PNS	92 / 22	94 / 20	89 / 19	97 / 19

Source: ECB (2000)

The functioning of this payments infrastructure can influence euro overnight deposit trading in various ways. First, trading in the money market can be adversely affected in case of technical problems in any of the major systems or by any of the participants in these systems. For example, if information about a computer problem in a (say unnamed) large bank, preventing it from making payments, becomes known to the market, trading might halt and bid-ask spreads increase. Second, current payment systems have procedures in place to close the system at the end of the day without any participant remaining with unsettled payment obligations. As well described by Angelini (forthcoming) for the Italian net settlement system, the timing of these end-of-day procedures can generate certain intra-day money market trading patterns. For example, only shortly before the closing of the net settlement system banks will know with certainty their final net balance to be settled. This can lead to increased and more violent trading behaviour, as reflected for example by intra-day overnight rate volatility, immediately before the net system's closing. Similarly, in an RTGS banks can have incentives to delay payments during the day in order to economise on liquidity and gain flexibility for securities trading. This again can lead to enhanced trading before the closing of the RTGS system (see e.g. Deutsche Bundesbank, 2000, p. 23).

[5] Other purely national systems are of rather minor importance compared to the overall payment traffic in the euro area.

In the euro area Euro1 is scheduled to close at 4.30pm (and analogous the two domestic systems EAF and PNS). Any remaining open settlement obligations at the time of closing have to be settled afterwards through TARGET until it closes itself at 6pm. In the empirical section below we will therefore examine whether enhanced money market activity or volatility can be identified during the European afternoon.

3. Data

In order to study in greater depth some of the microstructure features described above, we have collected for the months of November 1999 through March 2000 an intra-day data set of overnight deposit rate quotes, Eurosystem monetary policy operations and macroeconomic news. The present section briefly describes those data.

3.1 Overnight interest rate quotes

The "heart" of the data set is a continuous (tick-by-tick) record of the quotes for overnight deposits posted on Reuters by 6 money market "voice" brokers from 4 euro area countries and the UK, plus a continuous record of all the quotes posted in the Italian electronic brokerage market MID. The recording started with the beginning of trading on 3 November 1999 in the morning and it finished with the stop of trading in the early evening of 23 March 2000, altogether 101 trading days. The "voice" brokers covered are C. Kliemm Gmbh (Frankfurt/Germany, denoted KLIEMM), Geldhandels Gmbh (Frankfurt/Germany, denoted GEHA), Liberty Grel (Paris/France, denoted GREL), Prebon Yamane (Amsterdam/Netherlands, denoted PYMWEURO), Prebon Yamane (London/England, denoted PYEC), Corretaje e Informaciòn Monetaria y de Devisas (Madrid/Spain, denoted CIMV). All the 6 brokers are major players, at least within their own domestic market.[6]

For reasons of homogeneity with these "regular" broker data, we use only the quoted rates ("proposte") in the Italian electronic broker system MID described in 2.1.2 above. However, the MID quotes are still different from the quotes of the six "regular" brokers. In particular, since it registers all quotes by members on its screen, including many that are dominated by other quotes at a given point in time, whereas the "regular" brokers only post indicative pairs of bid and ask quotes from time to time on Reuters, the available MID quote data are much more frequent than the other available data. As a first step, we therefore eliminated all dominated quotes at any given point in time, thereby deriving the best bid and best ask rate prevailing at any point in time. This procedure also eliminates all domestic arbitrage possibilities for Italy and defines a "market spread" for the MID. We call the new series emerging from this procedure MID-best.

[6] The selection of brokers was determined by the accessibility of their pages through a general Reuters subscription.

Since it is still quite different from the other series, we will treat it separately from the others below, where necessary.

Table 3 shows some summary statistics for all the 7 brokers. It appears that most of the "voice" brokers are comparable in terms of the frequency with which they post quotes on Reuters, except for the French GREL, which seems to be less active in updating its Reuters page, and the London-based PYEC, which seems to be more active. The MID-best ticks series shows how much larger quoting frequency is, when all rates in the market can be considered. In other words, the money market is not as "sleepy" as it looks from the Reuters screens. Average quoted bid-ask spreads seem to be of a similar order of magnitude across brokers (roughly 4 to 5 basis points), except – again – for GREL (7 basis points) and the Spanish CIMV (10 basis points). The two "outliers" illustrate that there can be different conventions for quoted spreads between brokers or countries. Of course, when there is competition and arbitrage activity the implied overnight rate differences cannot be present in the traded rates. It is also instructive to observe that the MID spreads, derived from "best" quotes, are only slightly narrower than the spreads by GEHA, KLIEMM, PYEC and PWYMEURO. In other words, although only indicative the rates by these four brokers must be quite close to competitively traded rates.

Table 3: Summary statistics of broker overnight rate data, whole sample

Broker	Total ticks	Average bid-ask spread	Mid-rate volatility
GREL	144	7.0	2.8
KLIEMM	712	4.5	1.8
GEHA	704	4.4	1.8
CIMV	648	10.2	2.0
PWYMEURO	530	4.9	2.4
PYEC	1144	5.3	1.9
MID-best	8510	3.7	2.3

Note: The average bid-ask spread is the ask rate minus the bid rate for each quote, averaged over the whole sample. The mid-rate volatility is the standard deviation over all intra-day period mid rates.
Source: Reuters, SIA, authors' calculations

Finally, intra-day overnight rate volatility is of similar order of magnitude across countries/brokers but not entirely uniform. For example, the French data from GREL show the largest difference to the average of the others. Interestingly, the two German brokers (KLIEMM and GEHA) quote identically volatile overnight rates, whereas the two Prebon Yamane brokers – located in two different countries, the Netherlands (PWYMEURO) and the UK (PYEC) – quote rates that show some relatively clear difference in volatility. This observation indicates that some of the volatility differences between brokers might have a cross-country component. However, a word of caution regarding broker-to-broker comparisons is also in order. As

the case of bid-ask spreads illustrates, some of the differences might be related to broker-specific conventions and traditions or technical reasons that are unlikely to be present in traded rates. Hence, regarding CIMV, GREL and MID, one has to be somewhat cautious in making cross-country comparisons.

From the raw series, which are irregularly spaced in time, we then derive regularly spaced intra-day time series for ticks (number of quotes/rate changes), spreads and volatility. Due to the relatively low tick frequency of the "voice" broker quotes, the intra-day time period was chosen to be 3 hours. Hence, the day is decomposed in a "morning" interval (8am to 11am Central European Time (C.E.T.), a "lunchtime" interval (11am to 2pm C.E.T.) and an "afternoon" interval (2pm to 5pm C.E.T.).[7] The spreads are calculated for each 3-hour interval as the arithmetic mean of the differences between bid and ask rates for all quotes recorded. Similarly, middle rates are the average of the arithmetic means of bids and asks through the interval. Two volatility measures are calculated, the absolute mid rate change from the start to the end of each interval and the squared rate change for each interval.[8] Figure 3 shows a plot of the resulting 7 overnight middle rate series (at 3-hour frequency) during the sample period.

[FIGURE 3 ABOUT HERE]

A problem with the broker data (except the much "cleaner" MID data) is that, as mentioned above, these quotes are only indicative. Actual rate negotiations and transactions are more frequent than the ticks on Reuters.[9] This is particularly visible for the French broker, where the bulk of the negotiations are conducted on the phone. Yet we will operate under the assumption that this (imperfect) data, to the best of our knowledge the only intra-day data publicly available, is informative. (If it did not convey some information on the orders to buy and sell transmitted to the brokers, it would be hard to understand why it is posted at all). More precisely we will assume that (i) the larger the (unobservable) effective spread, the larger the quoted spread, (ii) the more active the market is, the larger the number of quotes posted by the brokers, (iii) the more volatile the market is, the more volatile is the mid-rate derived by the bids and asks posted by the brokers.

In order to test whether these assumptions make sense, we have examined some of them with the help of the more complete data from MID. For example, Figure 4 plots the intra-day distribution of trading volume and quoting frequency in that system during our sample period (excluding the special end-of-maintenance period

[7] For a higher intra-day frequency there would have been too many empty intervals for several brokers.
[8] For the purpose of calculating these volatility measures, synthetic mid rates have been derived by linear interpolation between the latest quote before the respective interval threshold and the next quote after the interval threshold. Since this procedure ensures uniform time intervals, distortions of volatility measures resulting from differences in quoting frequencies between brokers should be minimised.
[9] This statement does not apply directly to the electronic MID system. Interestingly, the number of ticks according to the MID-best series is roughly similar to the number of transactions actually clinched. This can be explained by the fact that a transaction usually

days and the Christmas/New-Year week). The proportionality between the two variables is evident, except maybe for the first trading hour when, apparently, quotes change frequently without transactions. The correlation between the two series across a representative day is actually 73%. So this little test supports the assumption that intra-day periods with high quoting frequency will normally also have higher market activity in terms of turnover.[10] This confirms the general usefulness of quoting (tick) frequency as a proxy of trading activity in financial markets, as shown earlier for other markets (see, for example, Hartmann (1998, 1999) for the case of foreign exchange markets).

[FIGURES 4 AND 5 ABOUT HERE]

3.2 Eurosystem monetary policy decisions, operations and data releases

From internal ECB sources we established a "calendar" of monetary policy decisions, operations and data releases. For the main refinancing operations it contains – following the information provided on ECB Reuters pages (see Figure 1) – the announcement and execution times, the (fixed) rate, the total number of bids, the total amount allotted, the total amount bid and the allotment rate. It also contains similar information about the less important longer-term refinancing operations and the single fine-tuning operation in January (collection of fixed-term deposits). Moreover, the "calendar" includes the three ECB interest rate changes during the sample period displayed in Table 1 and other Council meetings, communiqué and press release times, details the last and penultimate day of each minimum reserve maintenance period, the times of M3, Monthly Bulletin and weekly balance-sheet publications.

3.3 Payment system information

As described in 2.3 above, the two most important large-value payment systems in the euro area, TARGET and Euro1, are scheduled to close at 6pm and 4.30pm respectively, i.e. during or after our 3-hour "afternoon" period of each trading day. Moreover, we have collected the systems' effective closings as a measure of payment system disruptions. Significantly late closing after the scheduled time is used as an indicator for disruptions. The median time of effective Euro1 closing during the sample period was 4.36pm (average effective closing time 4.39pm). TARGET opening (7am) and closing times (6pm) seem to be more regular. During November and March only one noticeable incident occurred in TARGET, caused by the breakdown of a major euro area bank's system connecting it with its national RTGS system. At this occasion

changes the best bid or ask rate, thereby creating a tick (by construction of the MID-best series). However, total MID quotes are again much higher than MID-best quotes.

[10] However, we discovered some cases for which the link between turnovers and ticks, although not broken, was weakened. During the afternoon of end-of-maintenance period days there is a significant increase in the number of ticks with only a small increase in trading volume, so that for these days the correlation between the two decreases to 55% (Figure 5). Similarly, on Mondays – generally less active days in the euro money market – the link generally weakens and the correlation reduces to 49%.

TARGET stayed open until 6.30pm and the related national RTGS even remained open until 7.30pm, to give the bank's counterparties the occasion to resolve their liquidity problems induced by the incident. (Euro 1 also stayed open until 5.02pm on that day).

4. Intra-week and intra-day patterns

In this section we will discuss the intra-week and intra-day patterns of our data set and try to relate any regularities discovered to the institutional environment of the money market microstructure, as described in section 2. In all tables the two latest business days of each reserve maintenance period and the year 2000 (Y2K) changeover week (25 December 1999 until 3 January 2000) are treated separately, because of their special character.

4.1 Quote frequency ("ticks")

How does trading activity across the week and across the day look in the market for unsecured overnight deposits in the euro area, according to this measure? Table 4 shows the average ticks for each weekday and for each of our three intra-day intervals from November 1999 to March 2000, excluding the special end-of-maintenance period and Y2K-week days. In all countries except Italy market activity is the highest on Tuesdays and Thursdays.[11] This leads directly to the following interpretations.

1) The open market weekly ECB auction (usually) takes place on Tuesdays. Tuesday lunchtime (the period from 11am to 2pm), right after the announcement of the auction results at 11.15am, the market is very active compared to other lunchtime intervals during the week, except the special Thursday (see 2) below). Most likely this reflects banks' activities to reallocate liquidity according to their effective needs. However, as can be seen from Table 4 the later afternoon period (from 2pm to 5pm) is not particularly active compared to other afternoons during the week (except perhaps for the generally inactive GREL in France). This would indicate that the post-auction reallocation process is accomplished relatively quickly after the results have become known, which is consistent with the efficient functioning of the interbank market without major imbalances. It should also be mentioned that market activity tends also to be high during the on-going auction process on Tuesday morning (8am to 11am period). This is consistent with the hypotheses that at least some banks "speculate" or hedge on the basis of their expectations what the auction outcome is going

[11] The German broker KLIEMM is also an exception regarding Thursdays, but not Tuesdays.

to be and that the 9.15am release of reserve account balances and use of standing facilities is informative for the market.[12]

2) Thursdays is the day of Governing Council meetings and therefore of interest rate announcements. The lunchtime period, during which the communiqué about interest rate decisions is issued, is extremely active compared to other lunchtime periods during the week. However, from the data in Table 4 the Council mornings and afternoons seem to be rather regular in terms of quoting frequency in the overnight market. The inactive Council afternoons are consistent with the hypotheses that the market focuses on the lunchtime communiqué (and not so much on the more detailed press conference during the afternoon) and deals with any news emerging from the meeting relatively quickly and efficiently. Since most of the activity during our 3-hour lunchtime period is before the 1.45pm communiqué, it could also be related to hedging activity in the face of the risks related to an interest rate decision.

[TABLE 4 ABOUT HERE]

Large trading volume after announcements is also observed in equity markets, as illustrated in the case of the Paris Bourse by Gajewski (1999). However, the evidence of Table 4 does not signal any significant impact of the publication of the Eurosystem's balance sheet on Tuesday at 3pm. Other news may also have a relevant impact, for example the monthly release of the rate of growth of M3 or of the ECB Bulletin. They will not be considered at this stage of the analysis, as their release does not take place on a fixed day of the week (M3) or happens outside regular trading hours (Monthly Bulletin).

The financial market literature has identified patterns of quasi-market breakdowns before important uncertainty-loaded events, such as auctions, and a picking up of activity afterwards. These patterns could be related to several market imperfections: (i) they could reflect large information asymmetries before the auctions or news announcements; (ii) they could also arise if the liquidity allocation in an auction was inefficient and resulted in giving market power to the banks which were successful in the auction. The evidence about tick frequencies seems to argue against (i). To investigate these hypotheses further in the context of ECB auctions, spreads are analysed in the next subsection. Under the first scenario (i) one would expect to observe large spreads before the auctions and the announcement, while under the second scenario (ii) one would expect to observe large spreads after the auction.

By comparing the distribution of quotes across the week on normal days in Table 4 with those on end-of-maintenance-period (EOM) days, one observes immediately that on EOM days new quotes are posted much

[12] In the MID system, for example, turnover peaks on Tuesdays in the hour from 9am to 10am, going down in the following hour, and peaks again between 11am and noon (most of it after the auction outcome becomes known), before going down again for the lunch break..

more frequently (Table 5). On EOM days banks do not have any longer the option of transferring reserve imbalances to the future and are thus forced to trade in the market, irrespective of the specific market conditions. An interesting feature is also that on EOM days the number of quotes tend to be the higher the later the EOM day is in the week. The short-term destabilising effect of the end of the reserve maintenance period may thus be strengthened through the approach of a weekend. From the point of view of the central bank liquidity manager, this finding suggests ceteris paribus the adoption of special policies on the last days of the reserve maintenance periods, depending on the pattern of the weekdays. As we will show below, spreads also tend to widen with EOM days closer to a weekend.

[TABLE 5 ABOUT HERE]

Looking further at intra-day patterns in Table 4 (but also Table 5), we find clear evidence of the "u"-shaped activity pattern, which is well established in the literature on intra-day market behaviour (see e.g. Wood, McInish and Ord, 1985; Dacorogna et al., 1993; Fleming, 1997). Market activity tends to be more intense early in the morning and towards the end of the business day, while it is relatively slow at midday. The standard argument is that early in the morning the market reacts to news accumulated overnight.[13] As argued by Angelini (forthcoming), in the case of the money market the second trading peak towards the close of the business day may reflect news about payment system obligations, arriving late in the afternoon, such as unforeseen out-payments. Angelini points out that for a risk-averse bank its specific intra-day timing of trading should reflect the relative magnitude of the risks to be expected. Hence, a bank will trade relatively early to hedge against high interest rate risk expected in the afternoon. Conversely, it will preferably trade late in the day, if payment system shocks during the afternoon are expected to be more important.

We also find some signs of change in the functioning of Italian interbank deposit trading. As described by Angelini (forthcoming, Figure 2), in the mid-1990s on normal days trading volume in the MID was highest in the afternoon, before the closing of the domestic net settlement system. However, due to the substantially higher interest rate risk on EOM days, the largest part of the trading shifted to the morning on those days. Our data show that between November 1999 and March 2000 MID market activity on normal days (as measured by quoting intensity) was fairly balanced between mornings and afternoons. On EOM days we still find some evidence of a shift of the market activity from the afternoon to the morning, but this is modest when measured by actual trading volumes (Figure 5).

This development has two possible explanations. First, as observed by Perez-Quiros and Rodriguez (1999) for example, EOM volatility is lower in the euro area than before. This reduces the incentive for risk-averse

[13] The observation for the MID in Figure 4 that during the first hour of the day quotes change frequently without too much transaction volume, which picks up strongly only in the second hour suggests that traders test the market first with unacceptable quotes or with very small quantities associated to quotes.

banks to trade early in the day in order to hedge against interest rate risk. Second, since EOM days fall now together with the Italian tax day on the 23rd of each month (before EMU the end of the reserve maintenance period in Italy was on the 14th of a month), the much enhanced liquidity risk when payment system balances become known in the afternoon, provide an incentive for risk-averse banks to wait with their transactions until later in the day.[14] On the whole, both arguments point in the direction of a more even distribution of trading between morning and afternoon on EOM days after the start of Monetary Union.

[TABLE 6 ABOUT HERE]

In our sample, the "u"-shaped pattern holds for all brokers, except the Spanish one (CIMV), and for all week days except Thursday, the Council day. The exception of CIMV might simply reflect late lunch breaks in Spain, compared to countries like Germany, the Netherlands or the UK. High lunchtime activity on Thursdays has been explained above by the timing of the release of interest rate decisions on that day. Finally, Table 6 shows that in comparison to normal (Table 4) or EOM days (Table 5), the days of the millennium date change were particularly inactive in all countries, as one would have expected.

4.2 Bid-ask spreads

Financial market dealers' bid-ask spreads are determined by three components, order processing costs, inventory holding costs and information costs. Since broker or market spreads, whether they are indicative or the precise current best prices, can only be determined by the customers' or dealers' respective bid and ask prices they will be indirectly determined by the same factors. The first component is related to trading system costs and market liquidity. For example, larger and more actively traded markets tend to exhibit lower bid-ask spreads. The euro money market (in particular in its short-term segments), for example, exhibits narrower spreads than those prevailing in the former national overnight markets, since the union of those markets is more liquid than any single predecessor market. The second component results in a positive relationship between volatility and spreads for example, since more volatile markets result in higher inventory risks for traders. For example, as a consequence of the high volatility of overnight rates at the end of the maintenance period for minimum reserves, one would expect bid-ask spreads to be particularly high on these days. Finally, the arrival of new information and any asymmetric information between traders related to it leads to the information cost component in spreads. In particular, in periods of high uncertainty – such as before important news announcements – spreads increase, since dealers and other traders protect themselves against disadvantageous transactions (an adverse selection problem that might lead to the

[14] Transactions by euro area Treasuries holding their cash balances with their respective national central bank are the single most important source of exogenous liquidity shocks in the euro money market (see ECB, 1999b, p. 16f.).

temporary drying up of market liquidity).[15] As mentioned in sub-section 4.1 above these effects might lead to higher spreads before ECB monetary policy decisions or main refinancing operations, if asymmetric information is important. The present sub-section therefore discusses the intra-week and intra-day behaviour of bid-ask spreads in the euro overnight market, in order to shed some further light on its microstructure and the implications of its institutional environment.

Tables 7, 8 and 9 summarise the intra-week and intra-day behaviour of euro overnight spreads for our sample of five months and 7 brokers, distinguishing again "normal" days (Table 7) from EOM days (Table 8) and Y2K week days (Table 9). Unlike the experience of bond or equity markets, spreads seem to exhibit often a reverse intra-day pattern compared to our market activity measure discussed above, namely a "hump"-shaped form. This is consistent with the order processing cost component in spreads, since when the market is more active and liquid spreads should be lower and vice versa. However, there are also many exceptions in our sample. It is, for example, noteworthy that in the Italian MID spreads are systematically higher during the morning compared to the other two periods of the day, which are more or less flat. Given that market activity was not found to be particularly low during this period (see 4.1), this might have to do with the arrival of new information, but it is not so clear why this new information does not affect spreads in other countries.[16]

[TABLE 7 ABOUT HERE]

Almost across the board spreads are low on Mondays and they do not appear to be exceptionally high on Tuesdays. Whereas for most brokers Table 7 shows spreads on Tuesday morning to be higher than during lunchtime or the afternoon, the morning spreads do not appear to be very much out of line with spreads on the mornings of other days. In other words, there is – if anything – only weak evidence of asymmetric information before the Eurosystem's weekly main refinancing auctions. There is even less evidence of large spreads during lunchtime or the afternoon, which provides little support for the hypothesis that some banks benefit from market power after the auction. This contrasts with the results obtained for equity markets. For example, Lee, Mucklow and Ready (1993) find a significant increase in spread and decrease in depth before announcements. In fact, the combined market activity and spread results in the current and preceding sub-sections are consistent with liquidity being efficiently reallocated after Eurosystem auctions.

Table 7 further shows that spreads are clearly highest on Thursdays and also relatively high on Fridays (except for the MID). This could reflect several economic phenomena:

---

[15] See Stoll (1978), Copeland and Galai (1983), Glosten and Milgrom (1985), Amihud and Mendelson (1986) for some seminal theories on the determinants of bid-ask spreads.

[16] The high morning spreads are unlikely to be a consequence of uncertainties related to the settlement of foreign exchange contracts. As pointed out by Angelini (forthcoming), the settlement of these FX contracts in the morning is known to banks two days in advance.

1) The highest spreads on Thursday are observed in the morning and during lunchtime. Neglecting the last 15 minutes of the lunchtime period, this means that spreads are high *before* ECB Council interest rate decisions, providing evidence in favour of asymmetric information before ECB monetary policy announcements. However, this observation is not consistent with the evidence in Table 4, showing high market activity during the Thursday lunch period. Indeed, as illustrated forcefully by Milgrom and Stokey (1982), adverse selection reduces the trading volume. One explanation of this phenomenon would be that the higher spread is caused by the volatility observed during the same period (see 4.3 below).
2) As discussed for example by Hong and Wang (2000), market participants are reluctant to hold open positions during long no-trading intervals, such as weekends. Consequently traders will be less eager to provide liquidity on Fridays. This results in larger spreads. However, in our data overnight spreads are not always the highest during the last trading interval on Friday.

Spreads tend to widen systematically on EOM days (Table 8). Considering all "voice" brokers the market's average spread reaches 7.7 basis points, compared to 5.6 basis points on normal days. For the MID the difference between the two is even larger (EOM days 7.1 basis points, normal days 2.7 basis points), which might also be a reflection of the liquidity shock through tax payments on the same day. Looking at intra-day spreads for EOM days, for all brokers (except GREL, who appears to stop quoting) they are highest in the afternoon, pointing to the special uncertainties towards the end of trading during these days. For most brokers these higher spreads seem to be related to the higher volatility of interest rates at that time (see 4.3 below). For the MID, this is not the case and higher spreads are more likely to be related to banks' special afternoon payment and liquidity risks on these days, in particular in relation to the coincidence of them with the important Treasury transactions. Spreads therefore confirm the change in the trading patterns in Italy (compared to the situation in the mid-1990s) discussed above in relation to quoting frequency. Also, particularly for EOM days, spreads tend to widen as the week progresses (Table 8). This finding supports the point also already raised above in 4.1 about the link between EOM days and the end of the week.

[TABLE 8 ABOUT HERE]

As illustrated by Table 9, compared to Table 7, quoted bid-ask spreads were also higher during the Y2K changeover week (except for the inactive French broker), in particular in the Italian MID, where they doubled. This is consistent with the hypothesis that market participants regarded trading during these days as more risky than on normal days. Interestingly, comparing spreads in Tables 8 and 9 suggests that market participants regard EOM days as more risky than the Y2K changeover days.

[TABLE 9 ABOUT HERE]

4.3 Volatility

Tables 10 to 15 show the volatility patterns of mid rates in the euro overnight market for all the brokers during our sample period. Two measures are applied, the absolute rate change during an intra-day period (aggregated as an average over the day) and the squared rate change during an intra-day period (summed over the day). Volatility seems to be high on Tuesday mornings and sometimes also on Monday evenings. The most volatile day is the Thursday, usually during the lunch break (but for the French broker GREL and the Italian MID in the morning and for the Spanish broker CIMV in the afternoon). Finally, the Friday afternoon tends to be volatile across the board. These volatility patterns are consistent with the main ECB announcements early on Tuesdays (auctions) and on Thursday around lunchtime (interest rate decisions), which regularly transmit important information to the market, resulting in larger movements in the quotes. (Part of the Thursday lunchtime volatility might be a direct consequence of the three changes of interest rates described in Table 1.) Volatility also exhibits the typical ”u”-shaped pattern during the day (except for the Dutch broker and the special Thursday lunchtime period).

[TABLES 10 AND 11 ABOUT HERE]

For the volatility measure using absolute changes, rate movements appear clearly much larger on end-of-maintenance period days, compared to “normal” days (Tables 12 and 10). This reflects the “last-minute” attempts of banks to hit their target given by the reserve requirement. As can be seen from the troughs and peaks around the 23rd of a month in Figure 3 above, the volatility is either caused by a shortage of liquidity in the market at that time (overnight rate sky-rockets) or by an excess of liquidity (overnight rate slumps). It underlines further the enhanced trading needs at this time and the high risks for liquidity managers already discussed in relation to market activity and spreads above. (Notice that the other volatility measure using sums of squared changes will be distorted during episodes when intra-day periods without any quote are relatively frequent, such as the EOM episodes and the Y2K week.) Notice that the intra-day volatility pattern in the MID is somewhat reversed compared to the other brokers, showing high volatility in the morning on EOM days. This is somewhat surprising, since spreads and ticks are high on EOM afternoons in the MID. One possible explanation for this phenomenon could be that thin trading in the morning leads to relatively large rate movements without very many transactions.

[TABLES 12 AND 13 ABOUT HERE]

In spite of the relatively generous liquidity provision by the Eurosystem to the market before Christmas our data show in Tables 14 and 15 also extremely high volatility during the Y2K changeover days (except for the UK-based broker Prebon Yamane, who virtually ceded quoting during this period). In contrast to what

might have been expected from the result about spreads reported above, it is not clear though whether volatility at the changeover to the new millennium was higher or lower than usually the case at EOM days.

[TABLES 14 AND 15 ABOUT HERE]

5. Conclusion

In this paper we started the empirical analysis of the euro money market's microstructure. This market is particularly interesting, since in its entirety it only exists since the introduction of the new transnational currency in January 1999. The paper begins with a description of the institutional environment of the euro money market, encompassing the central bank's instruments for monetary policy operations, the private market financial instruments and trading mechanisms and the payment and settlement infrastructure for the transfer of funds. It then describes the data collected for this study, namely five months of intra-day overnight rate quotes from 5 euro area and one UK broker as well as from the Italian electronic trading system MID.

A detailed analysis of these data show "u"-shaped intra-day patterns of quoting frequency and volatility (analogous, for example to equity and bond markets), but a more diverse, sometimes rather a "hump"-shaped, intra-day pattern for bid-ask spreads. High spreads between 11am and 2pm may reflect illiquidity of the market around the lunch break and on certain days the arrival of important information during this period. Quoting activity, spreads and rate volatility are very high on Thursdays, particularly during lunchtime when the ECB's interest rate decisions are released. These features reflect the risks for the market related to the arrival of important new information. Before the allotments are made in Tuesday's ECB main refinancing auctions with the open market volatility is high as well, and there seems to be some evidence of asymmetric information before the announcement of auction results. However, a short period of high market activity without particularly large spreads after the auction suggests that the post-auction liquidity reallocation process through the interbank market is relatively efficient. Finally, it is shown that spreads and volatility tend to be very high at the end of the maintenance period for Eurosystem minimum reserve requirements and that the same happened during the year 2000 changeover days, reflecting the high risks involved in both.

References

Amihud, Y., H. Mendelson, 1986, Asset pricing and the bid-ask spread, *Journal of Financial Economics*, 17(2), 223-249.

Andersen, T., T. Bollerslev, F.X. Diebold, P. Labys, 1999, The distribution of exchange rate volatility, *Financial Institutions Center Working Paper*, 99-08, Wharton School, University of Pennsylvania, January.

Angelini, P., 1998, Are banks risk-averse? A note on the intraday timing of operations in the interbank market, mimeo, Banca d'Italia, November. (Forthcoming in the *Journal of Money, Credit, and Banking*.)

Angeloni, I., V. Gaspar and O. Tristani, 1999, The monetary policy strategy of the ECB, in D. Cobham and G. Zis, eds., *From EMS to EMU* (London: Macmillan), 3-42.

Ayuso, J., I. Fuentes, J. Peñalosa, F. Restoy, 1999, El mercado monetario español en la uniòn monetaria, *Estudios Economicos*, Banco de Espana, no. 67.

Banque de France, 1999, L'adaptation des banques françaises au nouveau cadre opérationnel de la politique monétaire, *Bulletin de la Banque de France*, no. 68, aout, 47-63.

Biais, B., T. Foucault, P. Hillion, 1997, *Microstructures des marchés* (Paris: Presses Universitaires de France, Collection Finance).

Bindseil, U. P. Mercier, 1999, The single monetary policy and some aspects of its implementation, in Ø. Thøgersen (ed.), *Økonomisk politikk i en turbulent verdensøkonomi* (Bergen: Fagbokforlaget), 61-92.

Copeland, T. and D. Galai, 1983, Information effects on the bid-ask spread, *Journal of Finance*, 38(5), 1457-1469.

Dacorogna, M., Müller, U., Nagler, R., Olsen, R., Pictet, O. (1993): A geographical model for the daily and weekly seasonal volatility in the foreign exchange market, *Journal of International Money and Finance*, 12, 413-438.

Deutsche Bundesbank, 2000, Die Integration des deutschen Geldmarkts in den einheitlichen Euro-Geldmarkt, *Monatsberichte der Deutschen Bundesbank*, Januar, 15-32.

Escrivá, J.L., G.P. Fagan, 1996, Empirical assessment of monetary policy instruments and procedures (MPIP) in EU countries, *EMI Staff Paper*, no. 2, European Monetary Institute, Frankfurt, May.

European Central Bank, 1998, The single monetary policy in Stage Three: general documentation on ESCB monetary policy instruments and procedures, Frankfurt, September.

European Central Bank, 1999a, The stability-oriented monetary policy strategy of the Eurosystem, *ECB Monthly Bulletin*, January, 39-50.

European Central Bank, 1999b, Treasury activities affecting the liquidity situation in the euro area, *ECB Monthly Bulletin*, July, 16f.

European Central Bank, 2000, The TARGET system, *ECB Monthly Bulletin*, March, 63*f.

Fleming, M., 1997, The round-the-clock market for US treasury securities, *FRBNY Economic Policy Review*, July, 9-32.

Furfine, C.H., 1999, The microstructure of the federal funds market, *Financial Markets, Institutions, and Instruments*, 8(5), 24-44.

Gajewski, J.F., 1999, Earnings announcements, trades and quotes, *European Financial Management*, 411-424.

Glosten, L. and P. Milgrom, 1985, Bid, ask and transaction prices in a specialist market with heterogeneously informed traders, *Journal of Financial Economics*, 14, 71-100.

J.D. Hamilton, 1996, The daily market for federal funds, *Journal of Political Economy*, 104(1), 26-56.

Hartmann, P. (1998): Do Reuters spreads reflect currencies' differences in global trading activity, *Journal of International Money and Finance*, 17(4), 757-784.

Hartmann, P. (1999): Trading volumes and transaction costs in the foreign exchange market - evidence from daily dollar-yen spot data, *Journal of Banking and Finance*, 23(4), 801-824.

Hong, H. and J. Wang, 2000, Trading and returns under periodic market closures, *Journal of Finance*, 55(1), 297-354.

Kim, O., and R.E. Verrecchia, 1991, Market reaction to anticipated announcements, *Journal of Financial Economics*, 273-309.

Kim, O., and R.E. Verrecchia, 1994, Market liquidity and volume around earnings announcements, *Journal of Accounting and Economics*, 41-67.

Lee, C., B. Mucklow and M. Ready, 1993, Spreads, depth and the impact of earnings information: an intraday analysis, *Review of Financial Studies*, 6(2), 345-374.

Milgrom, P., and N. Stokey, 1982, Information, trade and common knowledge, *Journal of Economic Theory*, 26(1), 17-27.

Nautz, D., 1997, How auctions reveal information: a case study of German repo rates, *Journal of Money, Credit, and Banking*, 29(1), 17-25.

Nautz, D., J. Oechsler, 1999, The repo auctions of the European Central Bank and the vanishing quota puzzle, *QSE Discussion Paper*, no. 79, Humboldt-Universität zu Berlin.

Paternello, A., 1999, Il mercato interbancario e-MID. Struttura e operativita' nella transizione all'euro, *mimeo.*, Università Cattolica del Sacro Cuore – Milano.

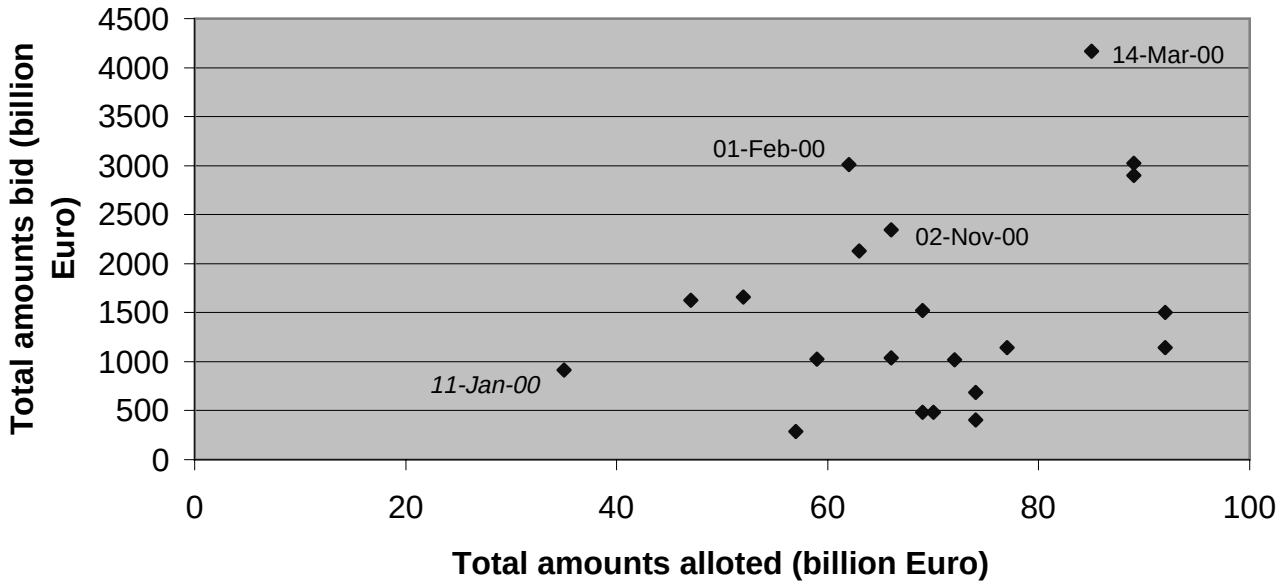
Perez-Quiros, G., H. Rodriguez, 1999, The daily market for funds in Europe: has something changed after the EMU?, *mimeo.*, ECB, December.

Società Interbancaria per l'Automazione (SIA), 2000, Market for interbank deposits – MIDclient user's guide, Milan, 13 January.

Stoll, H., 1978, The supply of dealer services in securities markets, *Journal of Finance*, 33(4), 1133-1151.

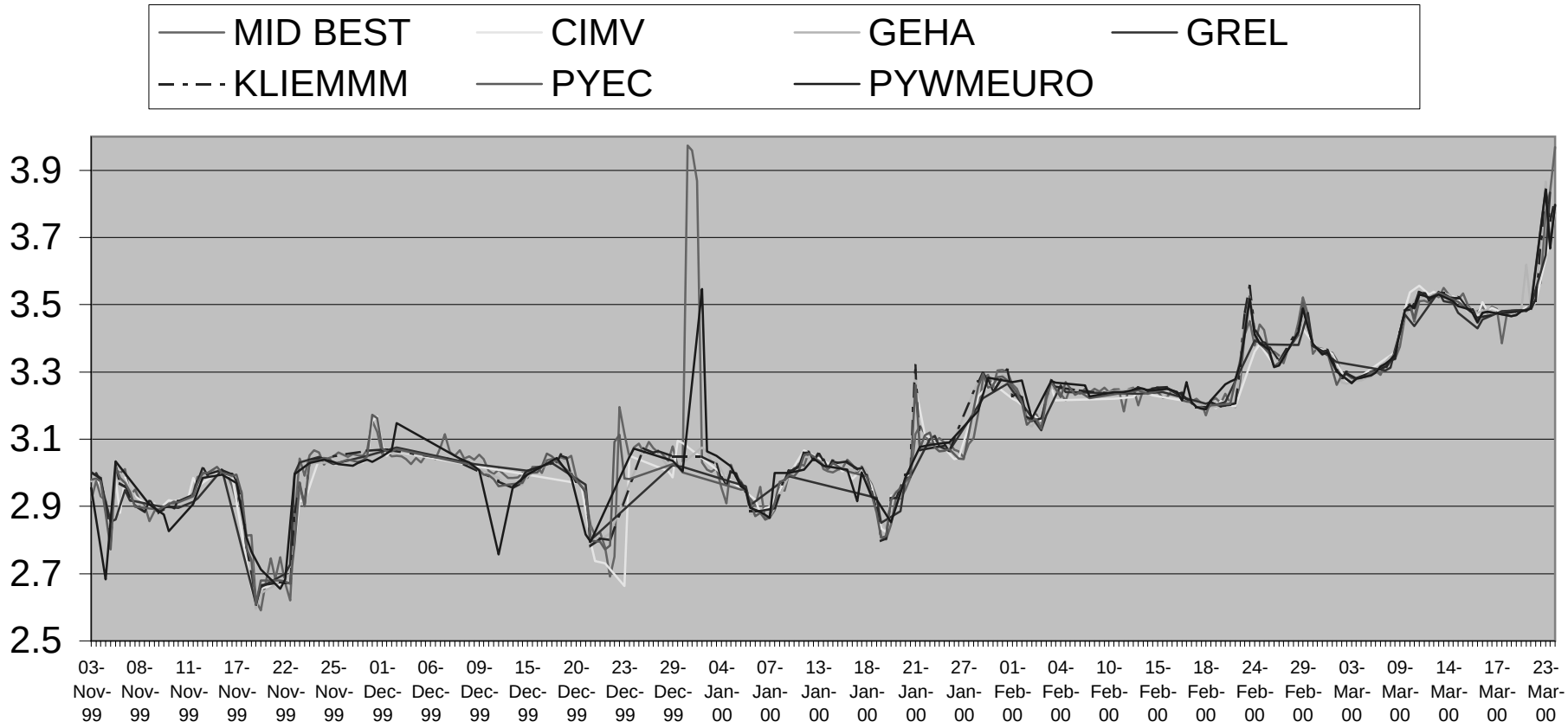
Wood, R.A., T.H. McInish, J.K. Ord, 1985, An investigation of transactions data for NYSE stocks, *Journal of Finance*, 40(3), 723-741.

Figure 2: Amounts bid and alloted in the 21 main refinancing auctions between 3 November 1999 and 23 March 2000



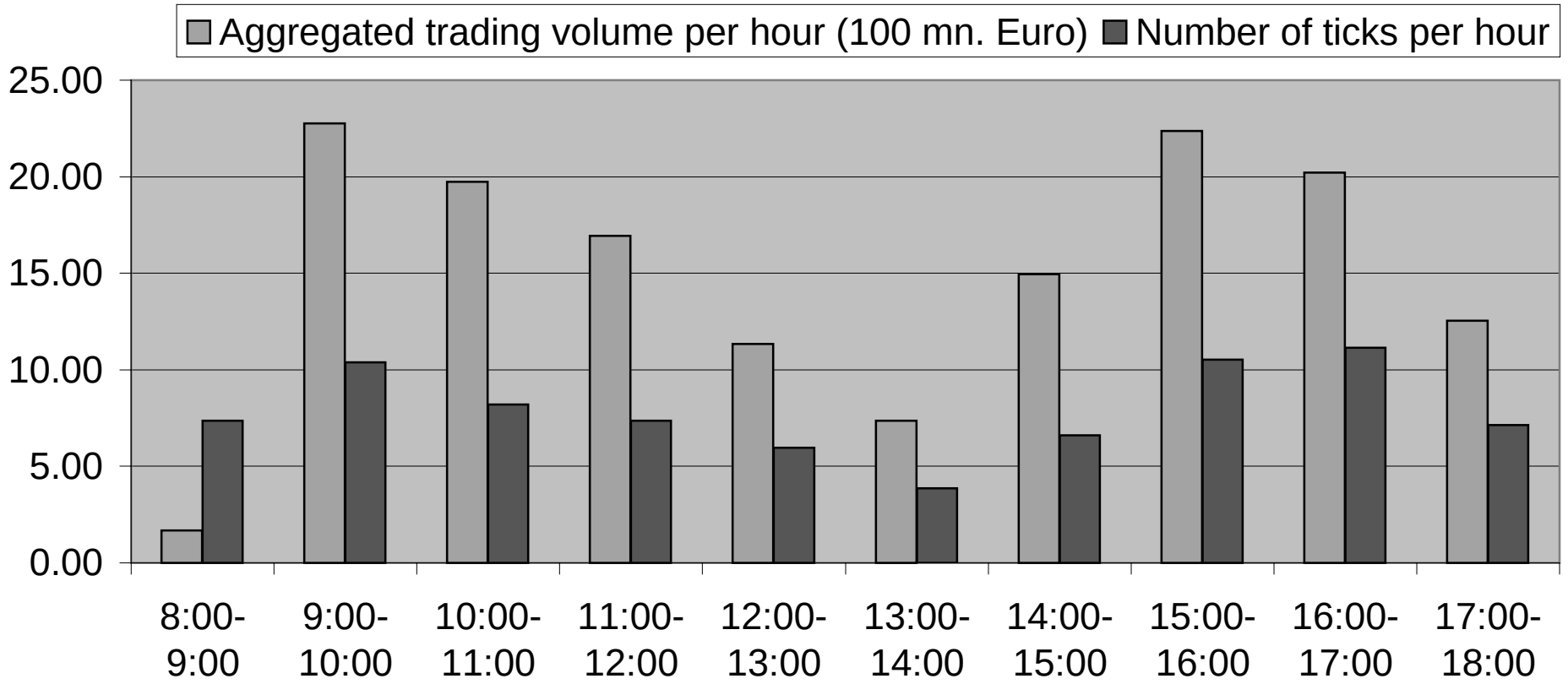
Source: ECB

Figure 3: Euro overnight rates quoted by brokers, Nov 1999 to March 2000, interpolated midrates for 3-hour intervals



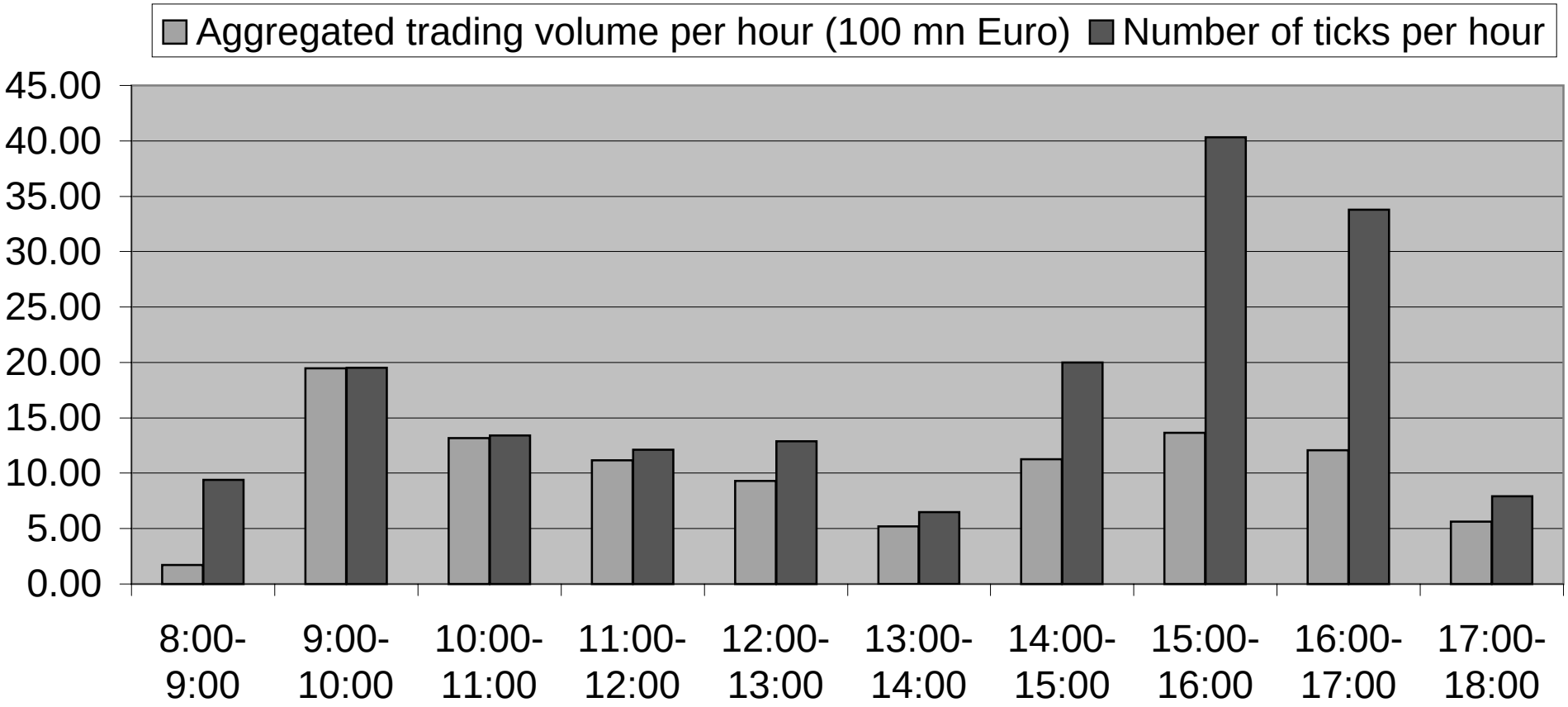
Source: Reuters, SIA, authors' calculation

Figure 4: Trading volume and quoting frequency ("best series") in the MID system, normal days



Source: SIA, authors' calculation

Figure 5: Trading volume and quoting frequency ("best series") in the MID system, EOM days



Source: SIA, authors' calculation

Table 4: Average number of broker price quotes (ticks) per weekday and per intra-day interval, "normal" days, November 1999 - March 20(

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
WEEKDAY	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
MONDAY	**DAY AVERAGE**	0.88	3.12	3.18	5.00	2.47	5.65	20.29	68.12
(17 in sample)	**8:00-11:00**	0.65	2.47	1.59	2.29	1.53	3.29	11.82	27.94
	11:00-14:00	0.06	0.06	0.41	1.18	0.12	0.41	2.24	16.00
	14:00-17:00	0.18	0.59	1.18	1.53	0.82	1.94	6.24	24.18
TUESDAY	**DAY AVERAGE**	2.29	8.35	8.00	7.29	5.94	12.18	44.06	74.35
(17 in sample)	**8:00-11:00**	1.29	4.06	3.71	2.82	2.00	4.94	18.82	25.06
	11:00-14:00	0.24	1.94	2.00	2.65	1.82	2.59	11.24	18.53
	14:00-17:00	0.76	2.35	2.29	1.82	2.12	4.65	14.00	30.76
WEDNESDAY	**DAY AVERAGE**	1.06	7.59	6.76	4.76	4.18	10.53	34.88	65.65
(17 in sample)	**8:00-11:00**	0.53	3.65	3.29	1.76	2.29	4.29	15.82	23.18
	11:00-14:00	0.24	1.18	1.12	0.94	0.35	1.41	5.24	13.71
	14:00-17:00	0.29	2.76	2.35	2.06	1.53	4.82	13.82	28.76
THURSDAY	**DAY AVERAGE**	1.76	5.59	6.88	7.12	6.47	13.06	40.88	82.24
(17 in sample)	**8:00-11:00**	0.29	2.88	3.12	1.47	2.12	5.35	15.24	26.65
	11:00-14:00	0.47	1.82	2.65	3.82	1.65	2.82	13.24	22.35
	14:00-17:00	1.00	0.88	1.12	1.82	2.71	4.88	12.41	33.24
FRIDAY	**DAY AVERAGE**	0.61	6.72	6.56	6.06	5.22	9.50	34.67	84.50
(18 in sample)	**8:00-11:00**	0.11	2.94	3.28	2.28	2.94	3.83	15.39	33.28
	11:00-14:00	0.22	1.11	1.00	2.39	0.44	1.06	6.22	18.83
	14:00-17:00	0.28	2.67	2.28	1.39	1.83	4.61	13.06	32.39
ALL DAYS	**DAY AVERAGE**	1.31	6.28	6.28	6.05	4.86	10.17	34.95	75.08
(86 in sample)	**8:00-11:00**	0.57	3.20	3.00	2.13	2.19	4.34	15.42	27.29
	11:00-14:00	0.24	1.22	1.43	2.20	0.87	1.65	7.62	17.90
	14:00-17:00	0.50	1.86	1.85	1.72	1.80	4.19	11.92	29.90

Notes: "normal" days are all the trading days between 3 November 1999 and 23 March 2000, excluding the two last days of the minimum reserve maintenar
periods and the Y2K changeover week.
Source: Reuters, SIA and authors' calculatio

Table 5: Average number of broker price quotes (ticks) per weekday and per intra-day interval, end-of-maintenance-period days
November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
WEEKDAY	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
MONDAY	**DAY AVERAGE**	2.00	6.00	6.00	12.00	3.00	16.00	45.00	137.00
(1 in sample)	**8:00-11:00**	0.00	2.00	5.00	0.00	2.00	6.00	15.00	35.00
	11:00-14:00	1.00	1.00	0.00	1.00	1.00	2.00	6.00	35.00
	14:00-17:00	1.00	3.00	1.00	11.00	0.00	8.00	24.00	67.00
TUESDAY	**DAY AVERAGE**	2.00	10.00	9.50	11.00	4.00	21.00	57.50	170.00
(2 in sample)	**8:00-11:00**	1.00	5.50	4.00	0.00	1.00	15.50	27.00	35.00
	11:00-14:00	1.00	1.50	2.00	4.50	0.50	3.50	13.00	27.00
	14:00-17:00	0.00	3.00	3.50	6.50	2.50	2.00	17.50	108.00
WEDNESDAY	**DAY AVERAGE**	1.00	23.33	12.67	3.67	11.33	23.67	75.67	145.33
(3 in sample)	**8:00-11:00**	1.00	10.33	7.67	1.67	5.33	9.67	35.67	31.33
	11:00-14:00	0.00	5.33	2.00	2.00	2.33	4.33	16.00	36.67
	14:00-17:00	0.00	7.67	3.00	0.00	3.67	9.67	24.00	77.33
THURSDAY	**DAY AVERAGE**	5.33	10.67	16.33	8.33	20.33	32.67	93.67	179.00
(3 in sample)	**8:00-11:00**	2.00	5.00	8.67	0.33	12.00	15.67	43.67	64.00
	11:00-14:00	2.00	3.00	3.00	4.33	4.33	7.00	23.67	29.00
	14:00-17:00	1.33	2.67	4.67	3.67	4.00	10.00	26.33	86.00
FRIDAY	**DAY AVERAGE**	4.00	30.00	34.00	16.00	1.00	37.00	122.00	229.00
(1 in sample)	**8:00-11:00**	1.00	1.00	1.00	1.00	1.00	0.00	5.00	32.00
	11:00-14:00	3.00	12.00	14.00	13.00	0.00	14.00	56.00	29.00
	14:00-17:00	0.00	17.00	19.00	2.00	0.00	23.00	61.00	168.00
ALL DAYS	**DAY AVERAGE**	2.90	15.80	14.60	8.60	10.70	26.40	79.00	167.90
(10 in sample)	**8:00-11:00**	1.20	6.00	6.30	0.70	5.70	11.30	31.20	42.30
	11:00-14:00	1.20	4.10	3.30	4.20	2.20	5.70	20.70	31.50
	14:00-17:00	0.50	5.70	5.00	3.70	2.80	9.40	27.10	94.10

Note: End-of-maintenance-period days in the sample are 22/11/99, 23/11/99, 22/12/99, 23/12/99, 20/01/00, 21/01/00, 22/02/00, 23/02/00, 22/03/00, 23/03/00.
Source: Reuters, SIA, authors' calculations

Table 6: Average number of broker price quotes (ticks) per day and intra-day interval, Y2K week days
November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
ALL DAYS	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
(5 in sample)	**DAY AVERAGE**	0.40	2.80	3.60	8.40	1.00	1.00	17.20	74.80
	8:00-11:00	0.20	2.60	1.60	3.20	0.60	0.20	8.40	17.20
	11:00-14:00	0.00	0.00	1.20	3.20	0.20	0.20	4.80	26.60
	14:00-17:00	0.20	0.20	0.80	2.00	0.20	0.60	4.00	31.00

Note: The Y2K week was defined to cover 27/12/99, 28/12/99, 29/12/99, 30/12/99, 03/01/00
Source: Reuters, SIA, authors' calculations

Table 7: Average bid-ask spreads per weekday and per intra-day interval, "normal" days, November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
WEEKDAY	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
MONDAY	**DAY AVERAGE**	4.40	3.62	3.63	9.92	3.71	3.79	4.85	2.48
(17 in sample)	**8:00-11:00**	4.27	3.50	3.78	9.92	3.62	3.61	4.78	3.27
	11:00-14:00	4.00	3.00	3.29	10.00	3.50	3.29	4.51	1.89
	14:00-17:00	5.00	4.20	3.55	9.85	3.93	4.12	5.11	2.00
TUESDAY	**DAY AVERAGE**	7.28	4.24	3.19	9.95	4.26	4.06	5.50	2.65
(17 in sample)	**8:00-11:00**	8.00	4.01	3.87	9.98	4.38	3.70	5.66	3.05
	11:00-14:00	6.75	4.45	3.24	9.98	4.19	4.27	5.48	2.06
	14:00-17:00	6.23	4.45	2.05	9.87	4.19	4.19	5.16	2.52
WEDNESDAY	**DAY AVERAGE**	7.11	4.02	3.75	9.86	3.68	4.37	5.47	2.70
(17 in sample)	**8:00-11:00**	6.78	3.79	3.55	10.17	3.49	4.23	5.33	3.37
	11:00-14:00	4.75	4.30	3.95	9.69	4.50	4.58	5.29	2.39
	14:00-17:00	9.60	4.21	3.93	9.69	3.77	4.37	5.93	2.32
THURSDAY	**DAY AVERAGE**	7.90	4.44	4.61	9.99	4.22	4.52	5.95	2.86
(17 in sample)	**8:00-11:00**	7.60	4.35	3.96	10.12	4.36	4.44	5.80	3.23
	11:00-14:00	10.88	4.32	5.40	10.00	4.61	4.13	6.55	2.66
	14:00-17:00	6.59	5.00	4.53	9.87	3.87	4.84	5.78	2.75
FRIDAY	**DAY AVERAGE**	9.27	4.10	3.68	9.98	3.93	4.31	5.88	2.60
(18 in sample)	**8:00-11:00**	7.00	3.87	3.44	9.88	4.09	4.17	5.41	3.50
	11:00-14:00	8.75	4.50	3.94	10.12	4.62	4.42	6.06	2.29
	14:00-17:00	10.60	4.19	3.90	9.92	3.48	4.35	6.07	1.87
ALL DAYS	**DAY AVERAGE**	7.23	4.13	3.77	9.95	4.02	4.23	5.55	2.66
(86 in sample)	**8:00-11:00**	6.86	3.92	3.71	9.99	4.01	4.06	5.42	3.30
	11:00-14:00	8.19	4.38	4.24	9.99	4.40	4.25	5.91	2.28
	14:00-17:00	7.19	4.34	3.48	9.83	3.85	4.41	5.52	2.30

Notes: Bid-ask spreads are defined as the ask overnight rate minus the bid overnight rate for a given quote. The cells contain arithmetic means of quoted spreads over the interval considered. Spreads are multiplied by 100 and therefore in basis points. "normal" days are all the trading days between 3 November 1999 and 23 March 2000, excluding the two last days of the minimum reserve maintenance.
Source: Reuters, SIA, authors' calculations

Table 8: Average bid-ask spreads per weekday and per intra-day interval, end-of-maintenance-period days, November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
WEEKDAY	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
MONDAY	**DAY AVERAGE**	5.00	5.17	6.00	9.67	5.33	2.44	5.60	3.62
(1 in sample)	**8:00-11:00**		3.50	4.80		5.00	2.50	3.95	3.60
	11:00-14:00	10.00	7.00		10.00	6.00	0.00	6.60	3.29
	14:00-17:00	0.00	5.67	12.00	9.64		3.00	6.06	3.91
TUESDAY	**DAY AVERAGE**	11.50	3.65	6.32	9.68	4.12	4.38	6.61	5.94
(2 in sample)	**8:00-11:00**	9.00	3.91	6.12		3.50	3.94	5.29	5.33
	11:00-14:00	14.00	4.33	5.00	10.56	3.00	4.71	6.93	3.04
	14:00-17:00		2.83	7.29	9.08	4.60	7.25	6.21	6.80
WEDNESDAY	**DAY AVERAGE**	4.00	3.67	4.92	9.55	5.93	10.14	6.37	6.24
(3 in sample)	**8:00-11:00**	4.00	3.23	5.22	9.60	6.13	3.76	5.32	3.83
	11:00-14:00		3.62	5.00	9.50	6.29	3.38	5.56	4.15
	14:00-17:00		4.30	4.11		7.27	22.41	9.53	7.75
THURSDAY	**DAY AVERAGE**	6.06	5.41	7.37	13.36	9.81	8.85	8.48	8.20
(3 in sample)	**8:00-11:00**	7.33	6.27	7.23	10.00	8.83	9.00	8.11	7.17
	11:00-14:00	7.50	3.89	7.00	10.31	10.46	8.52	7.95	5.47
	14:00-17:00	2.00	5.50	7.86	17.27	11.17	9.57	8.89	8.43
FRIDAY	**DAY AVERAGE**	1.75	10.03	9.00	12.75	4.00	12.14	8.28	12.41
(1 in sample)	**8:00-11:00**	7.00	3.00	4.00	10.00	4.00		5.60	6.72
	11:00-14:00	0.00	3.17	6.79	9.15		4.57	4.74	2.14
	14:00-17:00		15.29	10.89	37.50		16.74	20.11	15.06
ALL DAYS	**DAY AVERAGE**	5.93	5.28	6.92	11.30	8.07	8.95	7.74	7.12
(10 in sample)	**8:00-11:00**	6.75	4.12	6.11	9.71	7.67	5.92	6.71	5.79
	11:00-14:00	6.92	3.68	6.30	9.88	8.59	5.61	6.83	4.04
	14:00-17:00	1.60	7.67	8.34	13.22	8.46	14.63	8.99	8.75

Notes: Bid-ask spreads are defined as the ask overnight rate minus the bid overnight rate for a given quote. The cells contain arithmetic means of quoted spreads over the interval considered. Spreads are multiplied by 100 and therefore in basis points.
End-of-maintenance-period days in the sample are 22/11/99, 23/11/99, 22/12/99, 23/12/99, 20/01/00, 21/01/00, 22/02/00, 23/02/00, 22/03/00, 23/03/00.
Source: Reuters, SIA, authors' calculations

Table 9: Average bid-ask spreads per weekday and per intra-day interval, Y2K week days, November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
ALL DAYS	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
(5 in sample)	**DAY AVERAGE**	6.00	7.86	4.22	10.67	5.60	6.80	6.86	5.27
	8:00-11:00	5.00	8.08	4.00	9.62	6.33	7.00	6.67	5.63
	11:00-14:00			4.33	10.81	4.00	5.00	6.04	3.23
	14:00-17:00	7.00	5.00	4.50	12.10	5.00	7.33	6.82	6.82

Notes: Bid-ask spreads are defined as the ask overnight rate minus the bid overnight rate for a given quote. The cells contain arithmetic means of quoted spreads over the interval considered. Spreads are multiplied by 100 and therefore in basis points.
The Y2K week was defined to cover 27/12/99, 28/12/99, 29/12/99, 30/12/99, 03/01/00.
Source: Reuters, SIA, authors' calculations

Table 10: Absolute middle rate changes per weekday and per intra-day interval, "normal" days, November 1999 - March 20(

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
WEEKDAY	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
MONDAY	**DAY VOLATILITY (average of abs. changes)**	3.11	3.55	2.23	2.18	4.59	2.45	3.02	2.30
(17 in sample)	**8:00-11:00**	0.86	2.21	0.58	3.71	0.48	3.24	1.85	3.16
	11:00-14:00	7.56	2.94	1.48	1.24	2.99	1.10	2.89	1.19
	14:00-17:00	1.99	3.93	3.26	1.86	6.05	3.28	3.39	2.60
TUESDAY	**DAY VOLATILITY (average of abs. changes)**	4.17	2.67	2.53	2.65	4.33	3.02	3.23	2.53
(17 in sample)	**8:00-11:00**	6.70	4.39	2.71	3.93	1.97	5.08	4.13	3.03
	11:00-14:00	2.47	1.84	2.87	1.63	3.38	2.09	2.38	2.37
	14:00-17:00	4.28	2.28	2.09	2.13	6.18	2.58	3.26	2.18
WEDNESDAY	**DAY VOLATILITY (average of abs. changes)**	3.89	2.93	2.95	4.28	3.42	3.12	3.43	2.94
(17 in sample)	**8:00-11:00**	4.07	3.20	2.89	3.76	5.55	3.25	3.79	3.10
	11:00-14:00	3.13	2.70	2.97	2.63	4.98	2.57	3.16	1.98
	14:00-17:00	4.21	2.97	2.97	7.85	1.96	3.68	3.94	3.73
THURSDAY	**DAY VOLATILITY (average of abs. changes)**	7.10	4.69	4.18	6.45	5.60	4.16	5.36	2.85
(17 in sample)	**8:00-11:00**	13.07	4.56	4.53	4.16	3.73	4.81	5.81	3.97
	11:00-14:00	2.55	6.20	4.70	6.34	6.75	5.47	5.34	2.70
	14:00-17:00	6.01	3.98	3.53	12.97	5.85	2.64	5.83	1.88
FRIDAY	**DAY VOLATILITY (average of abs. changes)**	5.79	3.01	2.65	5.74	3.78	2.62	3.93	2.92
(18 in sample)	**8:00-11:00**	8.50	2.13	1.75	3.17	2.78	2.80	3.52	3.58
	11:00-14:00	5.16	1.60	1.32	1.16	2.45	1.82	2.25	1.67
	14:00-17:00	2.67	4.81	4.06	13.86	5.06	3.27	5.62	3.56
ALL DAYS	**DAY VOLATILITY (average of abs. changes)**	5.09	3.28	2.89	4.27	4.33	3.11	3.83	2.71
(86 in sample)	**8:00-11:00**	9.13	3.57	2.82	3.74	2.97	3.93	4.36	3.37
	11:00-14:00	3.47	2.77	2.62	2.55	4.37	2.66	3.07	1.98
	14:00-17:00	3.96	3.47	3.15	7.42	4.87	3.10	4.33	2.80

Notes: Middle rate volatility measured as the absolute value of the change in the overnight rate from start to end of a period (start and e
mid rates calculated by linear interpolation of the latest preceding and the next following quote). All volatilities multiplied by 100.
Source: Reuters, SIA, authors' calculatio

Table 11: Squared middle rate changes per weekday and per intra-day interval, "normal" days, November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
WEEKDAY	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
MONDAY	**DAY VOLATILITY (sum of squared of changes)**	0.59	7.37	6.40	1.42	4.27	5.02	4.18	5.04
(17 in sample)	**8:00-11:00**	0.01	0.05	0.03	1.15	0.01	0.61	0.31	2.65
	11:00-14:00	0.39	0.47	0.13	0.13	0.45	0.12	0.28	0.33
	14:00-17:00	0.19	6.86	6.24	0.14	3.81	4.28	3.59	2.07
TUESDAY	**DAY VOLATILITY (sum of squared of changes)**	3.74	5.01	5.56	3.72	4.83	6.10	4.83	5.57
(17 in sample)	**8:00-11:00**	2.84	3.87	2.42	2.47	0.55	4.59	2.79	2.80
	11:00-14:00	0.47	0.58	2.56	0.48	0.72	0.95	0.96	1.33
	14:00-17:00	0.43	0.56	0.58	0.76	3.55	0.55	1.07	1.45
WEDNESDAY	**DAY VOLATILITY (sum of squared of changes)**	2.01	6.50	5.97	3.02	3.08	7.80	4.73	9.60
(17 in sample)	**8:00-11:00**	0.55	1.74	1.13	0.75	0.34	1.30	0.97	2.74
	11:00-14:00	0.35	2.15	2.36	0.72	2.28	2.97	1.80	2.26
	14:00-17:00	1.11	2.61	2.49	1.56	0.46	3.54	1.96	4.60
THURSDAY	**DAY VOLATILITY (sum of squared of changes)**	5.40	12.24	11.41	8.60	13.14	14.88	10.95	11.33
(17 in sample)	**8:00-11:00**	4.21	2.96	4.07	1.99	1.18	3.71	3.02	6.26
	11:00-14:00	0.56	5.53	4.26	3.08	6.99	8.29	4.79	3.98
	14:00-17:00	0.63	3.74	3.07	3.53	4.98	2.88	3.14	1.09
FRIDAY	**DAY VOLATILITY (sum of squared of changes)**	1.19	2.58	2.29	35.47	2.85	3.77	8.02	8.84
(18 in sample)	**8:00-11:00**	0.74	0.48	0.37	1.65	0.65	1.02	0.82	3.99
	11:00-14:00	0.37	0.31	0.20	0.21	0.70	0.52	0.38	1.26
	14:00-17:00	0.07	1.79	1.72	33.62	1.50	2.23	6.82	3.59
ALL DAYS	**DAY VOLATILITY (sum of squared of changes)**	12.93	33.70	31.64	52.24	28.17	37.57	32.71	40.39
(86 in sample)	**8:00-11:00**	8.35	9.11	8.01	8.01	2.74	11.24	7.91	18.43
	11:00-14:00	2.15	9.04	9.52	4.62	11.14	12.85	8.22	9.15
	14:00-17:00	2.43	15.55	14.10	39.61	14.29	13.48	16.58	12.80

Notes: Middle rate volatility measured as the squared change in the overnight rate from start to end of a period (start and end mid rates calculated by linear interpolation of the latest preceding and the next following quote). All volatilities multiplied by 100.
Source: Reuters, SIA, authors' calculation

Table 12: Absolute middle rate changes per weekday and per intra-day interval, end-of-maintenance period days, November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
ALL DAYS	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
(10 in sample)	**DAY VOLATILITY (average of abs. changes)**	7.89	7.33	8.39	5.98	10.42	9.17	8.20	8.40
	8:00-11:00	6.61	4.58	8.19	6.22	7.48	6.14	6.54	11.42
	11:00-14:00	3.10	7.38	7.14	6.30	8.10	8.90	6.82	6.09
	14:00-17:00	10.83	9.74	9.67	4.61	12.77	12.83	10.07	7.69

Notes: Middle rate volatility measured as the absolute value of the change in the overnight rate from start to end of a period (start and end mid rates calculated by linear interpolation of the latest preceding and the next following quote). All volatilities multiplied by 100.
Source: Reuters, SIA, authors' calculation

Table 13: Absolute middle rate changes per weekday and per intra-day interval, end-of-maintenance period days, November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
WEEKDAY	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
ALL DAYS	**DAY VOLATILITY (sum of squared of changes)**	12.72	28.05	30.56	13.15	16.90	35.63	22.83	44.82
(10 in sample)	**8:00-11:00**	3.60	4.05	9.01	4.19	3.93	7.04	5.30	27.27
	11:00-14:00	0.11	11.27	10.83	7.69	2.84	11.76	7.41	5.55
	14:00-17:00	9.02	12.73	10.72	1.27	10.13	16.83	10.12	12.00

Notes: Middle rate volatility measured as the squared change in the overnight rate from start to end of a period (start and end mid rates calculated by linear interpolation of the latest preceding and the next following quote). All volatilities multiplied by 100.
Source: Reuters, SIA, authors' calculation

Table 14: Absolute middle rate changes per weekday and per intra-day interval, Y2K week days, November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
ALL DAYS	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
(5 in sample)	**DAY VOLATILITY (average of abs. changes)**	11.46	6.23	4.00	20.84	27.26	2.30	12.01	14.30
	8:00-11:00			1.61	50.55	48.24	0.73	25.28	2.65
	11:00-14:00	0.58	1.51	1.95	0.68	3.03	1.74	1.58	2.73
	14:00-17:00	22.34	7.41	7.83	1.75	28.88	4.44	12.11	37.52

Notes: Middle rate volatility measured as the absolute value of the change in the overnight rate from start to end of a period (start and end mid rates calculated by linear interpolation of the latest preceding and the next following quote). All volatilities multiplied by 100.
Source: Reuters, SIA, authors' calculation

Table 15: Squared middle rate changes per weekday and per intra-day interval, Y2K week days, November 1999 - March 2000

		FRANCE	*GERMANY*		*SPAIN*	*NETHERLANDS*	*UK*		*ITALY*
ALL DAYS	INTERPOLATION_PERIOD	GREL	KLIEMMM	GEHA	CIMV	PWYMEURO	PYEC	ALL VOICE BROKERS	MID BEST
(5 in sample)	**DAY VOLATILITY (sum of squared of changes)**	0.30	1.09	1.23	12.86	30.66	0.06	7.70	163.17
	8:00-11:00			0.10	12.82	23.27	0.01	9.05	0.50
	11:00-14:00	0.00	0.01	0.15	0.01	0.05	0.03	0.04	0.90
	14:00-17:00	0.29	1.08	0.98	0.03	7.35	0.02	1.63	161.78

Notes: Middle rate volatility measured as the squared change in the overnight rate from start to end of a period (start and end mid rates calculated by linear interpolation of the latest preceding and the next following quote). All volatilities multiplied by 100.
Source: Reuters, SIA, authors' calculation