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Journal of International Money and Finance
20 (2001) 895–948

Journal of International Money and Finance

www.elsevier.com/locate/econbase

The microstructure of the euro money market

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Abstract

This paper provides an empirical examination of the microstructure of the euro money market, especially the overnight market, the interbank market for short-term funds in the transnational currency created in January 1999. The institutional framework shaping the microstructure of the money market can be delimited as the union of: (1) central banks' interest-setting bodies and their long-term policy strategy; (2) instruments for monetary policy operations and liquidity management; (3) the private market financial instruments and trading mechanisms for funds; and, (4) the payment and settlement infrastructure for the transfer of those funds. All four elements can significantly influence the intraday behaviour of money market rates. To study their effects on the euro money market, 5 months of intraday data for overnight deposits 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 "two-hump" shaped (or "u"-shaped) intraday patterns of quoting frequency and volatility, but flatter intraday patterns (sometimes weakly single "hump"-shaped) for bid-ask spreads. Even intraday overnight rate levels hardly differ across brokers located in different euro area countries, reflecting the high integration of this market already shortly after the introduction of the euro, despite some remaining heterogeneities in market structures and trading channels. Quoting activity, rate volatility and spreads increase on ECB Governing Council days, particularly after the 1.45 pm release time of interest rate decisions. However, since the amplitude of this volatility is economically small and since turnovers are not indicative of adverse selection, the average degree of policy uncertainty seems to have been rather limited during our sample period. ECB announcements of new M3 data, related to the first pillar of its monetary policy strategy, around 10am seem to be associated with very moderate increases in short-term volatility. Tuesdays' Eurosystem main refinancing auctions with the open market exhibit active pre- and post-auction liquidity re-allocation, but only a very short and moderate increase in volatility after the announcement of the allotments and no signs of market power or adverse selection. Open market operation settlement days exhibit the highest turnovers during the busi-

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PII: S0261-5606(01)00029-8

ness week, at least for the MID, without, however, being affected by any special risks. 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.

JEL classification: G14; E43; E52; D44

Keywords: Euro; Financial market microstructure; High-frequency data; Liquidity; Money market; Monetary policy instruments; Open market operations; Overnight deposit rates; Payment systems; Reserve requirements; Trading volume; Transaction costs; Volatility

1. Introduction

This paper presents the first broad empirical examination of the euro money market's microstructure. In contrast to other financial markets, such as bond, equity or foreign exchange markets, there is only a small amount of literature touching upon microstructure issues of the money market. In particular, papers addressing intraday features of this market are extremely rare. To our knowledge only Angelini (2000; 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 intraday behaviour of money markets. Angelini focuses on the implications risk aversion has on Italian banks' intraday timing of overnight transactions when periods of uncertainty about liquidity needs are determined by institutional features of the payment system. Furfine describes the size, concentration and intraday timing of the fed funds market and analyses bank relationship patterns in it with special consideration of institutions' sizes.[1]

Some theoretical work by Bhattacharya and Gale (1987) and Bhattacharya and Fulghieri (1994) has explained the existence of private interbank markets for short-term funds with the need by banks to "re-insure" against idiosyncratic liquidity shocks coming from their retail depositors. More recent theoretical work has addressed the issue whether this type of interbank liquidity insurance causes systemic risk in the banking system (see De Bandt and Hartmann, 2000, for a survey). Finally, Freixas and Holthausen (2001) started to study the working of international money markets, when information about foreign banks is asymmetric. This theoretical interbank market literature in general does not tackle the role of regular monetary policy, central bank operations and regulations in money markets.

However, there is an earlier literature that relates the behaviour of overnight interbank market rates by a representative bank to monetary policy operational pro-

[1] Most other empirical 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. Spindt and Hoffmeister, 1988; Griffiths and Winters, 1995; Hamilton, 1996 for the US fed funds market and Perez-Quiros and Rodriguez, 2000, as well as Bindseil and Seitz, 2001, who recently started such work for the euro overnight market).

cedures and money market accounting conventions, notably Ho and Saunders (1985), Campbell (1987) and Spindt and Hoffmeister (1988). More recently, Bartolini et al. (1998) introduce a role for central bank liquidity provision. Perez-Quiros and Rodriguez (2000) analyse the behaviour of a representative bank during the minimum reserve period when there is a symmetric pair of standing facilities.

The present paper has several objectives that distinguish it from the few previous studies. 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 decision-making bodies and their policy strategy; its operational procedures and instruments, the private market trading structures and procedures and the payment (and settlement) infrastructure. Second, it seeks to describe and explain the main features characterising euro overnight interbank deposit trading, by studying the intra-week and intraday behaviour of bid-ask spreads, volatility, quoting frequency and — to the extent that it is available — trading volume observed in the market. Special emphasis is given to the intraday behaviour around a number of key events. The type of events considered include ECB interest rate decisions, releases of data on monetary aggregates, Eurosystem open market operations, ECB releases of market liquidity information, the end of the maintenance period for the calculation of banks' minimum reserve requirements, especially large liquidity shocks from Treasury operations, payment system closing times, regular settlement dates of open market operations, disturbances in payment systems and the year 2000 (Y2K) changeover. Third, we deliberately take a euro-area wide, cross-country perspective instead of focussing only on a single country's money market. In order to enhance our understanding about market integration and market heterogeneities, we report the results for brokers located in different countries separately.

To achieve these objectives we have collected two sets of data for the period of November 1999 to March 2000. The first set comprises information about the character and timing of ECB monetary policy decisions and operations, data releases and payment system events. The second set comprises real-time, tick-by-tick Reuters price data for over-night inter-bank deposits from 6 "voice" brokers in four euro area countries and one non-euro area country as well as from the Italian electronic brokering system MID.

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 four aspects enumerated above. Section 3 presents the data set collected for the purposes of this study. Section 4 discusses the behaviour of quoting (tick) frequency, trading volumes (where available), mid-rate volatility and bid-ask spreads in the euro overnight deposit market, both across the trading week and the trading day. It then proceeds to the analysis of key money market events. Section 5 concludes.

2. The institutional context

The institutional environment of the money market can be divided into four elements: (1) The central bank bodies deciding on macro monetary policy and their

analytical strategy; (2) the operational framework for the implementation of the monetary policy and liquidity management by the central bank (monetary policy instruments, such as open market operations, standing facilities, reserve requirements, etc.); (3) 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); and, (4) 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 sets the short-term interest rate and acts as the only ultimate provider of liquidity in a given currency, thereby dominating the supply side. The former is done through its policy strategy and the latter 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 finance their securities trading portfolios (bonds, shares etc.), 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. Depending on the financial instrument traded and the respective payment (or settlement) system used, the payment flows are not generally instantaneous, potentially happening on a day after the related trades, and have certain patterns during the day. In fact, all the four elements of the institutional environment of the money market can and do influence the evolution of prices and quantities in the money market. Therefore, the present section describes these four 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 12 central banks of the countries which joined the third stage of Economic and Monetary Union (EMU), conducts the monetary policy of the euro area.[2] Its goal is to maintain price stability in the euro area, defined as an annual 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 (at the time of writing a 4.5%

[2] Greece joined the euro zone on 1 January 2001. However, most of the empirical analysis to follow below relates to data when the Union was still composed by 11 countries.

growth rate). The second pillar is a broadly based assessment of the outlook for future price developments, considering a large list of economic indicators.[3] The Governing Council of the ECB is the main policy making entity of the system. It is composed of 6 ECB Executive Board members and the 12 governors of the national central banks. Meetings are every two weeks (usually) on Thursdays. Whereas the main *decisions* of the system are taken centrally in particular interest rate decisions for the conduct of monetary policy by the Council, monetary policy operations are *executed* in a decentralised fashion via the national central banks (NCBs).

Interest rate decisions by the Council are first communicated to the market by a communiqué released at 1.45 pm 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 2.30 pm, in which the ECB President makes an introductory statement summarising the meeting and answers questions by the press. The introductory statement by the President and a transcript of the questions and answers is made available to the public shortly after the press conference. Table 1 summarises the three ECB interest rate changes during the sample period we are using below. In two out of three cases 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 ECB publishes more data related to its monetary policy strategy. Towards the end of each month new figures on M3 (referring to the preceding month) are released at a given day around 10 am, which the market can then put in relation to the monetary reference value.[4] Finally, the ECB publishes a Monthly Bulletin with a host of macroeconomic data and monetary analysis, including information on the second pillar of its monetary policy strategy. During our sample period the Bulletin was usually released on the ECB web site on the Thursday of the second week of

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 (%)	MRO rate (%)	Marg.lend. rate (%)	Deposit rate (%)	MRO rate (%)	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: MRO=main refinancing operation. *Source:* ECB

[3] See Angeloni et al. (1999) and ECB (1999a) for in-depth discussions of the ECB monetary policy strategy.

[4] The unofficial rule for M3 release times is the 20th business day of each month, with occasional adjustments for euro area country holidays.

each month (between two Council meetings) at 7 pm (The release time has now been brought forward to 10 am.).

2.2. The Eurosystem's 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 situation in 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 Section 2.2.1 below), standing facilities (Section 2.2.2) and reserve requirements (Section 2.2.3).[5] The open market operations are the general instruments used to manage the liquidity situation and to steer interest rates. Among them, and as suggested by their name, the main refinancing operations (MROs) 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. (During our sample period the amounts allotted in MROs varied between EUR 50 and 100 billion; see also Fig. 3 below.) 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 conducts them as variable rate 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 of absorbing some excess liquidity in the aftermath of the millennium date change. Finally, the Eurosystem may also conduct 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. In this paper we will mainly focus on the main refinancing open market 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 MROs. These operations are conducted in the form of weekly tenders for repurchase agreements (repos) with a maturity of two weeks.[6] For reasons of effec-

[5] A comprehensive description of the Eurosystem's operational framework is given in ECB (1998b, 2000). The following contains an extensively abridged overview over ECB operations. An analysis of the operational framework of the Eurosystem in the context of the ECB's monetary policy strategy is presented in Manna et al. (forthcoming). Escrivá and Fagan (1996), Borio (1997) and Blenck (2000) offer broad descriptions and comparisons of major central banks' operational frameworks for monetary policy and liquidity management.

[6] Repos are financial instruments for the temporary exchange of cash against securities with a transfer of ownership. The operations can also be conducted in the form of collateralised loans in which securities ownership does not change. The specific form used should not have any significant impact on the economic results of the operation.

tive policy signalling to the market, the auction has been conducted as a fixed (single) rate tender during our sample period.[7] In this tender procedure the ECB determined the overall quantity to be allotted on the basis of its own assessment of the liquidity needed by the market, including an internal liquidity forecast.[8] This quantity was divided pro rata among all bidders against eligible collateral through credits on their reserve accounts.[9] 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 MRO rate. However, the main policy tool used by the Governing Council is the MRO rate and not the quantity of liquidity to be allocated. Allotment decisions are taken by the ECB Executive Board on an operational level.

Whereas under this regime the ECB did not publish its liquidity forecast, *every day* — at 9.15 am at the latest — it published on Reuters page ECB40 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. As pointed out by Vergara (2000), ECB40 is an important daily input for money market traders in general, and many players use the information on the liquidity situation of the overnight market for the determination of their bids before the 9.30 am main-refinancing auction cut-off time. Fig. 1 gives an example of this page. In addition, once a week — (usually) on Tuesday at 3 pm — the ECB releases the Eurosystem balance sheet, referring to the stock figures of the preceding Friday.

The weekly MRO tender is usually (but not always) held on Tuesdays. The fixed rate is determined by the latest preceding Governing Council decision on the MRO rate, i.e. at the latest on the last Thursday before the next auction. The timing of the auction itself is the following:

1. On Monday around 3.30 pm, the day before, the ECB announces the auction and its conditions on Reuters and other wire services. The announcement contains a

[7] On 8 June 2000 the Governing Council of the ECB decided to switch from the fixed-rate tender regime to a variable-rate tender regime for MROs (ECB, 2000b). Since then MROs are conducted as a multiple-rate ("American") auction, i.e. bidders are served going down from the highest rates bid to the lowest ones at the rates they effectively bid in the auction until the quantity to be allotted is exhausted. The timetable, the allotment decision and the announcement of the results remained the same as in the previous regime. The main policy rate is now a pre-announced minimum bid rate. In this paper we will restrict ourselves to the functioning of the money market under the fixed-rate regime that characterised the first one and a half years of stage 3 of EMU. The main reason for the change in tender procedures by the Eurosystem was the more and more extreme over-bidding occurring in the fixed-rate tenders.

[8] Whereas the internal forecast was not published under the fixed-rate regime for MROs, the Eurosystem is now indicating the expected liquidity needs of the banking system in the announcements of the variable-rate auctions.

[9] 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. No distinction is made between the two tiers with regard to their eligibility for the various types of Eurosystem monetary policy operations.

08:09 08FEB00 EUROPEAN CENTRAL BANK, FRANKFURT a.M. GE66608 ECB40
Current account holdings of counterparties with the Eurosystem
Including holdings to fulfil reserve requirements. In million of euro.

As at 07/02/2000
(Maintenance period: 24/01/2000 to 23/02/2000)

Current account holdings (*)	109,057	
Estimated reserve requirements (**)	107,500	
Average current account holdings in current maintenance period (*)	108,689	
Use of the standing facilities of the Eurosystem:		
Use of marginal lending facility		11
Use of deposit facility		61

(*) Including minimum reserve holdings. For historical data see ECB41.
(**) Preliminary estimate of reserve requirements for the current MP

Fig. 1. ECB information about the money market liquidity situation on Reuters page "ECB40" — the example of 8 February 2000 detailing the situation on 7 February. *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

reconfirmation of the rate and some standard MRO properties, such as the type of operation, the maturity, the timing for bids and the minimum bid size (see the top of Fig. 2 for an example of the relevant Reuters page ECB16). Normally these MRO announcements do not contain news for the market.

2. Banks can submit bids to their respective national central banks until 9:30 am on Tuesday, the day of the auction, which are then transferred to the ECB that applies the auction procedure. So, the information provided on page ECB40 can be used to fine-tune the bids.
3. At around 11:15 am on Tuesday the result of the auction is announced again on Reuters (page ECB17). As shown at the bottom of Fig. 2, 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" (the ratio between the amount allotted and the amount bid). In contrast to the auction announcement described under (i) above, the allotment announcement *does* contain information for the market, particularly the overall quantities bid and allotted.

Fig. 3 plots the total amounts allotted against the total amounts bid for the 20 MRO auctions between 1 November 1999 and 23 March 2000. The figure indicates that the amounts bid were weakly increasing in the total amount allotted and, in any case, much larger than the allotments. This is a reflection of the so-called "overbidding" behaviour. As the auctions were carried out in the form of fixed rate tenders during the sample period and since the four months coincided with expectations of rising interest rates, demand usually exceeded supply and liquidity was allocated

14:43 07FEB00 EUROPEAN CENTRAL BANK, FRANKFURT a.M. GE66608 ECB16
Main Refinancing Operation – **Announcement**
Reference number: 20000009
Transaction Type: Reverse Transactions
Operation Type: Liquidity Providing
Procedure: Standard Tender
Start Date: 09/02/2000
Maturity Date: 23/02/2000
Duration (days): 14
Auction Type: Fixed Rate Tender
Allotment Method: Single Rate
Min Allotment:
Fixed Rate: 3.25 %
Min Bid Amount: 1.00 mn
Max Bid Limit:

10:18 08FEB00 EUROPEAN CENTRAL BANK, FRANKFURT a.M. GE66608 ECB17
Main Refinancing Operation – **Allotment**
Reference Number: 20000009
Transaction Type: Reverse Transactions
Operation Type: Liquidity Providing
Procedure: Standard Tender
Tender Date: 08/02/2000
Start Date: 09/02/2000
Maturity Date: 32/02/2000
Duration (days): 14
Auction Type: Fixed Rate Tender
Allotment Method: Single Rate
Min Allotment:
Fixed Rate: 3.25 %
Max Bid Limit:
% of Allot.: 6.37
Tot Amount Allotted: 66000.00 mn
Tot Bid Amount: 1036647.80 mn
Tot Number of Bidders: 686

Fig. 2. ECB auction information on Reuters pages "ECB16" and "ECB17" — the example of the main refinancing operation on 8 February 2000. *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

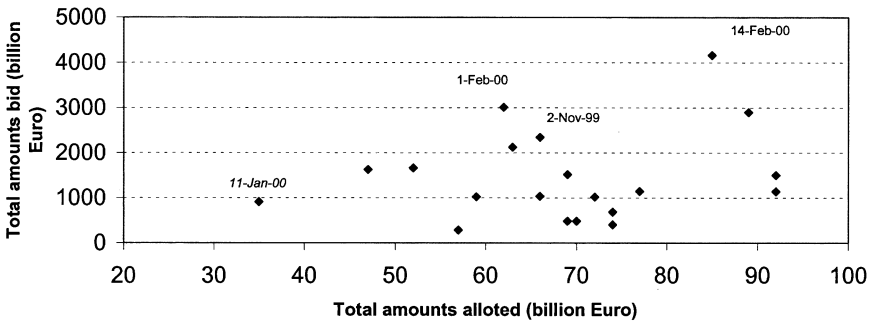

Fig. 3. Amounts bid and allotted in the 20 main refinancing auctions between 1 November 1999 and 23 March 2000

according to the pro-rata rule. Anticipating such rationing, banks tended to "overbid", i.e. to demand more than what they actually needed. The overbidding behaviour is thus at least partly 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.[10]

Fig. 3 also indicates (with dates) the last MROs 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 (see also Section 4.2.1 below). The "smallest" auction was conducted on the 11th of January, the first refinancing operation after the century date change (also indicated with a date in Fig. 3).

2.2.2. Standing facilities

One function of the standing facilities is to provide or absorb liquidity with an overnight maturity vis-à-vis individual counterparties facing unforeseen liquidity shocks. Therefore they provide a type of insurance mechanism for banks, but at penalty interest rates. The initiative is 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 ends the day with an overdraft position on its TARGET account with an NCB (see Section 2.4 below), then the intra-day credit is automatically transformed into an overnight loan via a recourse to the marginal lending facility. The fact that the access to the standing facilities on a given day is not subject to rationing (provided adequate collateral is posted in the case of recourse to the marginal lending facility) effectively bounds the overnight market interest rate, creating a "corridor". Therefore another function of the two standing facilities is to contribute steering interbank market rates in case of larger aggregate liquidity imbalances. For example, towards the end of the minimum reserve maintenance period (see Section 2.2.3 below) or in extreme market situations like the Y2K changeover week (see Section 4.5 below) such imbalances may temporarily occur.

2.2.3. Minimum reserve requirements

The third component of the operational framework of the Eurosystem that influences the market microstructure are the 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, 1998b). According to the current regime, all credit institutions

[10] See Bindseil and Mercier (1999) for a general discussion of the bidding behaviour in Eurosystem fixed rate auctions and Nautz and Oechsler (1999), Ayuso and Repullo (2000), Breitung and Nautz (2000) and Ehrhart (2000) for critical analyses of the over-bidding phenomenon.

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 with maturity below 2 years and money market paper held by institutions and individuals not subject to the Eurosystem minimum reserve requirement system (i.e. excluding interbank liabilities) at reserve accounts with national central banks. These reserves are remunerated at the daily average of MRO rates (over the respective reserve maintenance period). They have to be fulfilled 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 during the period considered. So they provide a buffer against unexpected liquidity shocks, mitigating the related fluctuations of market rates. However, the stabilising effect of the averaging provision, which requires banks to anticipate potential liquidity shocks and plan the holding of liquid funds carefully, becomes weaker and eventually vanishes towards the end of the reserve maintenance period, when banks are 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 Fig. 4 further below. 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 (2000) argue that the introduction of a "symmetric" pair of standing facilities by the Eurosystem (see Section 2.2.2 above) has effectively led to a reduction of this volatility and also to a more symmetric distribution of it. (Fig. 4 illustrates the relatively balanced occurrence of troughs and peaks around the five end-of-maintenance period episodes during our sample period.)

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 (minimum) daily turnover of EUR 61 billion (in the second quarter of 1999) it is by far the largest spot segment of the money market in the euro area. (This figure is taken from an ECB Market Operations Committee Survey covering Belgium, Finland, France, Germany, Ireland, Italy, Portugal and Spain, which is summarised in Santillàn et al., 2000, annex 2, table 1.) 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) short-term forward (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)

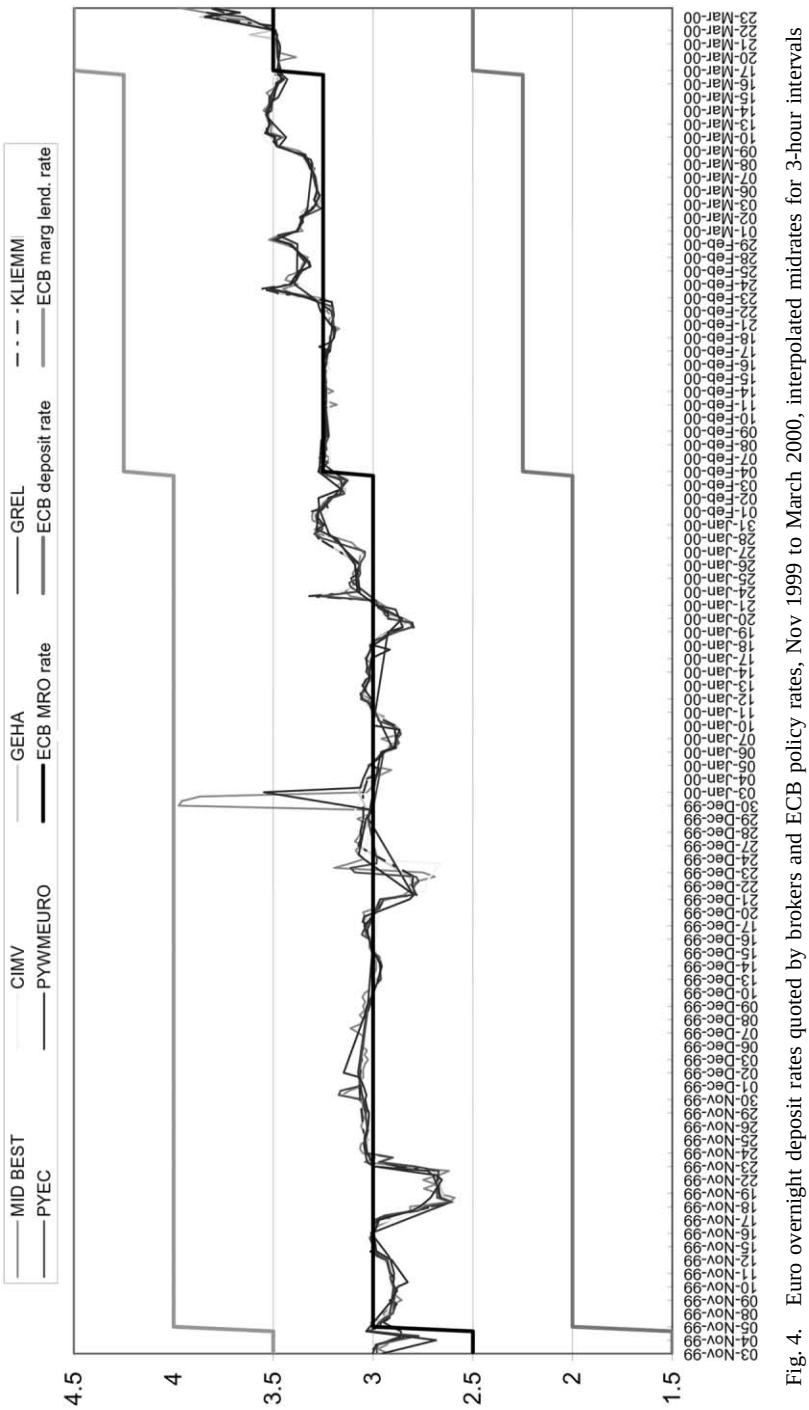

Fig. 4. Euro overnight deposit rates quoted by brokers and ECB policy rates, Nov 1999 to March 2000, interpolated midrates for 3-hour intervals

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 by much more (Santillàn et al., 2000, annex 2, table 1).

The relative importance of the different contracts can vary substantially between countries in the euro area. For example, whereas during our sample period there were active repo markets in Belgium, Finland, France, Germany, Italy and Spain, they were hardly developed in other euro area countries. The leading euro futures contract, the 3-month Euribor, is 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 since the start of stage 3 of EMU, 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 Eurosystem MROs in the case that some banks received a larger allotment than needed and other banks received a lower allotment than needed. (As described in Section 2.2.1, these imbalances could occur under the fixed-rate tender regime 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). Regarding trading hours, which seem to be rather homogenous since the introduction of the euro across the area, the overnight deposit market opens at around 8 in the morning (C.E.T.) and closes at around 17.45 in the afternoon (C.E.T.). (This schedule is closely related to that of TARGET explained below.)

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 various European financial centres. 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, from trader to trader and even for a given trader over time. 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 by e-MID S.p.A., 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 direct bilateral 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 main dealers driving money market trading in Spain.

In *France* brokers are also used, but the bulk of the negotiations takes 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 reference rate) had at least one French bank on one side of the transaction.[11] 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 Deutsche Bundesbank (2000, p. 23f.) also observes 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 intraday liquidity through the Eurosystem's TARGET payment system.[12]) Finally, in the *Netherlands* the upper tier of players driving the deposit

[11] EONIA stands for "euro overnight index average", an index sponsored by a number of European banking and financial associations to measure the effective cost of unsecured overnight money for the euro area. It is calculated daily as a volume-weighted average of unsecured euro overnight deposit contract rates, as reported by a representative panel of 49 large banks from euro area countries (41), other EU countries (4) and overseas (4 with important operations in the euro area), including the main market makers. The index is calculated each business day from all overnight transactions carried out by panel banks between the opening of trading in the euro interbank market and the closing of the respective RTGS system. It is published no later than the opening of the following business day. EURIBORs (Euro Interbank Offered Rates), various reference rates for term deposits (1 week to 1 year) also sponsored by those associations, are published at 11am each business day on the basis of panel banks' contributions shortly before that time. They are based on simple averages of quoted rates only (corrected for the extremes). More information on EONIA and the EURIBORs is available from http://www.euribor.org.

[12] The current non-euro area EU countries ("pre-ins") have a full connection to TARGET. According to the conditions for such a connection, the "pre-in" NCBs can up to a certain aggregate limit on the basis of arrangements with private banks located in the euro area acquire funds to offer intraday liquidity in euro to their domestic credit institutions (up to another maximum amount per bank). The collateral required to secure such external intraday overdrafts in euro has the same quality standards as the assets eligible in the euro area, but it can also be denominated in the respective home currency. The provision of intraday credit in domestic currency to a foreign country is by international standards a very special arrangement, as it is the first time a major central bank has allowed central banks belonging to other currency areas to provide settlement facilities in its own currency. See ECB (1998a) for further details.

market is again composed of the 4 large Dutch commercial banks. The bulk of the trading is undertaken via bilateral communication, particularly through Reuters Dealing, and the rest through "voice" brokers, not only located in the Netherlands. The 4 large Dutch banks tend to do more than half of their business with counterparties located in another euro area country, whereas 2nd tier institutions are much less active in this regard. Overnight deposit trading strategies between the main Dutch players tend to be fairly diverse.

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. On the contrary, Fig. 4 below illustrates how close overnight rates of brokers located in different countries tend to be, except in extreme circumstances like the year 2000 (Y2K) changeover week. Some of the heterogeneities, 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.[13]

2.4. Payment (and settlement) infrastructure

Payment and settlement refer to the effective transfer of funds and securities in relation to all types of monetary and financial transactions to achieve "finality". 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 15 domestic RTGS (real-time gross settlement) systems in the EU, a network of bilateral links (interlinking mechanism) between them and the ECB payment mechanism. The private sector, more precisely the Euro 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 exists 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.[14]

However, large internationally active banks from non-euro area EU countries that have branches or subsidiaries in the euro area would not need to go through their respective NCBs to receive intraday liquidity for euro payments. They could also benefit directly from their branches' or subsidiaries' access to TARGET intraday overdrafts.

[13] For an elaborate pre-EMU perspective on money market integration in Europe, also based on interest rate differentials, see Eijffinger and Lemmen (1995).

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

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 cross-border transactions and the "cheaper" net settlement system Euro1 for smaller cross-border 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).)

Below we will examine whether the euro overnight market exhibited any special features on days with particular events or problems in either Euro1 or TARGET.[15] Furthermore, as well described by Angelini (2000) for the Italian net settlement system, the timing of these end-of-day procedures can generate certain intraday money market trading patterns. For example, only at the time of closing of the net settlement system (defined as the "cut-off time" for new payments) will banks 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 intraday overnight rate volatility, immediately after 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 can lead to enhanced trading before the closing of the RTGS system (see e.g. Deutsche Bundesbank, 2000, p. 23).[16] In the euro area Euro1 is scheduled to close at 4 pm (and similarly the two domestic systems EAF and PNS). This means that no new payments can be entered in the system. Any remaining open settlement obligations at the "cut-off time" have to be settled afterwards through TARGET, following a standard end-of-day settlement procedure that can sometimes take more than an hour. The real-time gross

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 (2000a).

[15] See De Bandt and Hartmann (2000, sections 3.3 and 4.3) for a discussion of "systemic risk" in payment systems and a survey of the related literature.

[16] At present none of the euro area large-value payment systems provides intraday information on balances of participating banks or information on queued payments.

system TARGET closes at 6 pm. In the empirical section we will examine whether enhanced money market activity or volatility can be identified during the European afternoon. Finally, we will also look for special effects on the settlement days of the Eurosystem's large MROs, usually the Wednesday following the expiry day of a two-week repo.

3. Data

In order to study in greater depth the microstructure features of the euro money market and their links to the institutional environment described above, we have collected for the months of November 1999 to March 2000 an intraday data set of overnight deposit rate quotes, details about ECB Governing Council meetings, ECB data releases, Eurosystem monetary policy operations and information about liquidity shocks and important payment system events. 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 Información Monetaria y de Divisas (Madrid/Spain, denoted CIMV). All the 6 brokers are major players, at least within their own domestic market.[17]

For reasons of homogeneity with these "regular" broker data, we use mainly the quoted rates ("proposte") in the Italian electronic broker system MID described in Section 2.3 above, occasionally extended by transactions volumes (from the "contratti" file). 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

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

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". Although regular "voice" brokers' bid-ask quotes might also be regarded as approximations of market spreads, we will treat them separately from the MID-best data below, where necessary, since their still much lower frequency might imply more structural differences for which one might not be able to control.

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. As indicated to us by market participants, the latter may be related to the very active use of the euro overnight market in London for the financing of trading portfolios. The former may be either related to this broker's especially slow way of updating its page or to a generally higher share of direct interbank money market trading compared to brokered trading in France.

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 broker pages. 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 PYWMEURO. In other words, although only indicative, the rates by these four brokers must still be relatively close to competitively traded rates (at least on one market side) and they must also be relatively close to the (quoted) market spread.

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

Broker	Total ticks	Average bid-ask spread	Mid-rate volatility
GREL (FR)	144	7.0	2.8
KLIEMM (DE)	712	4.5	1.8
GEHA (DE)	704	4.4	1.8
CIMV (ES)	648	10.2	2.0
PYWMEURO (NL)	530	4.9	2.4
PYEC (UK)	1144	5.3	1.9
MID-best (IT)	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 intraday period mid rates.
Source: Reuters, e-MID, authors' calculations.

Finally, intraday overnight rate volatility is of a similar order of magnitude across countries/brokers but not entirely uniform. For example, the French data from GREL show the largest deviation from other brokers. 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 (PYWMEURO) and the UK (PYEC) — quote rates that show some differences in volatility. This observation suggests that some of the volatility differences between brokers might have a cross-country component. For example, the positive difference between PYWMEURO and PYEC could indicate that, despite the generally high cross-country arbitrage in the euro overnight market, intraday liquidity in London can sometimes be higher than in one of the smaller euro area countries.[18] 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 quoting conventions and traditions or technical reasons that are unlikely to be present in traded rates. Hence, particularly 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 intraday time series. Due to the relatively low tick frequency of the "voice" broker quotes, the intraday time period was chosen to be 3 hours. Hence, the day is decomposed in a "morning" interval (8 am to 11 am Central European Time (C.E.T.)), a "midday" or "lunchtime" interval (11 am to 2 pm C.E.T.) and an "afternoon" interval (2 pm to 5 pm C.E.T.).[19] As already mentioned in Section 2.2.3, Fig. 4 shows a plot of the resulting 7 overnight middle rate series during the sample period, where middle rates are defined as the average of the arithmetic means of bids and asks through the interval.

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.[20] This is particularly visible for the French broker, since in France the bulk of the negotiations are conducted directly over the phone. Yet we will operate under the assumption that this (imperfect) data, to the best of our knowledge the only intraday 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 more "active" the market is (in terms of turnover or price updating), the larger the number of quotes posted by the brokers,

[18] However, we should also note that the volatility difference between the two Prebon Yamane brokers, while being large in November, December and January, became small in February and vanished in March, the end of our sample period. Therefore, the phenomenon might have been only temporary.

[19] For a higher intraday frequency, such as hourly or half-hourly, there would have been too many empty intervals for several brokers.

[20] 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 in our sample. This can be explained by the fact that a transaction usually 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 more frequent than MID-best quotes.

(ii) the more volatile the market is, the more volatile is the mid-rate derived from the bids and asks posted by the brokers, (iii) the larger the (potentially unobserved) effective spread, the larger the spread quoted by 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, Fig. 5 plots the intraday distribution of trading volume (from the "contratti" series) and quoting frequency (from the "proposte" series) in that system during our sample period (excluding the special end-of-maintenance period 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 intraday periods with high quoting frequency will normally also have high market activity in terms of turnover.

However, in addition to the special first hour of trading we discovered another case for which the link between turnovers and ticks 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% (Fig. 6). In other words, enhanced quoting frequency in the euro money market may at certain special times measure higher market activity in terms of price updating without much increase in trading volume. One explanation for this phenomenon may be special times of high uncertainty or high rates of information arrival, when quoted rates may be updated frequently but traders may be very cautious in acquiring inventories (see also Section 4.4.1 below). Alternatively, as some market participants pointed out to us, in certain

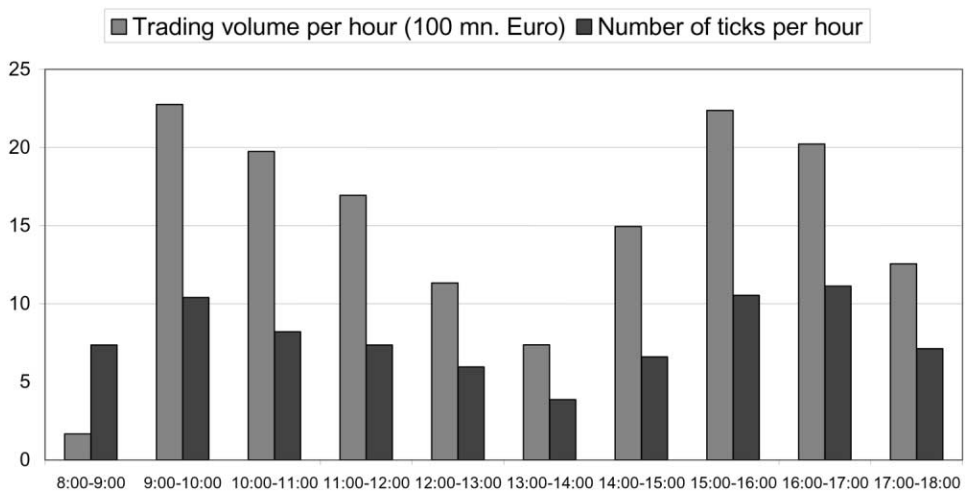

Fig. 5. Intraday trading volume and quoting frequency ("best series") in the MID system, "normal" days

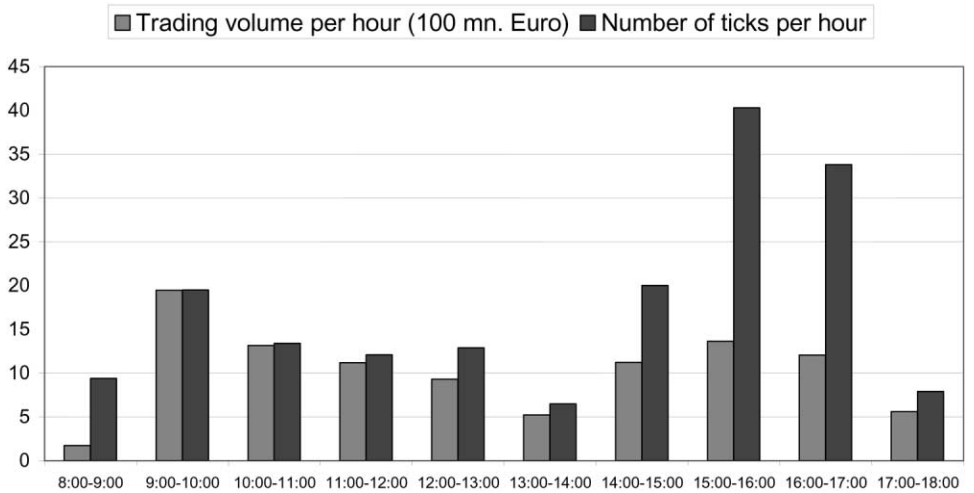

Fig. 6. Intraday trading volume and quoting frequency ("best series") in the MID system, end of maintenance period days

times of stress in the market — when all staff are focussing on the trading — the Reuters "voice" broker pages may not be regularly updated any more.[21]

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. The "calendar" describes the 11 Governing Council meetings during our sample period, including the 3 ECB interest rate changes displayed in Table 1, the 5 meetings with a subsequent press conference and the timing of the regular post-Council press communiqué. It also details the timing of 5 M3 and Monthly Bulletin releases. For the 19 MROs covered it contains the information provided on ECB Reuters pages (see Fig. 2). Furthermore, it includes the daily liquidity releases on ECB40 (see Fig. 1). Finally, it details the last and penultimate day of each of the 5 minimum reserve maintenance periods covered as well as the occurrence of large liquidity shocks from Treasury operations.

[21] Quoting (tick) frequency as a proxy for trading activity has also been used in other financial markets. See for example Hartmann (1998, 1999), who found strong relationships between daily and monthly spot foreign exchange market trading volumes by dealers or "voice" brokers and tick frequency on Reuters. We also tested how closely volatility in quoted overnight rates ("ordini" file) is aligned with volatility in traded rates ("contratti" file) in the MID. We found a similarly close relationship as for ticks and volumes. However, the intraday period with the weakest link between the two was not the opening hour but the closing hour between 5 pm and 6 pm.

3.3. Payment system information

As described in Section 2.4 above, the two most important large-value payment systems in the euro area, TARGET and Euro1, are scheduled to close at 6 pm and 4 pm respectively, i.e. during or after our 3-hour "afternoon" period of each trading day. For Euro1 we have collected the effective completion times of the end-of-day settlement procedure. Since it is the EBA Clearing Company's policy to encourage early completion about half an hour after closing time, much later completion could indicate an unforeseen event or sometimes even a financial disruption. (If a net system participant faces difficulties to settle, this tends to show up ultimately at closing/settlement time. The median time for completing the Euro1 settlement procedure during the sample period was 4.36 pm (average effective completion time 4.39 pm). On 19 days (out of 101) Euro 1 settlement was completed after 4.45 pm. Although on none of these 19 days completion seems to have been as late as causing an emergency in the system, it is still interesting to examine our data with a view on whether any of these late completions coincided with any signs of disruption in the interbank market.

TARGET opening (7 am) and closing times (6 pm) seem to be very 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 TARGET stayed open until 6.30 pm and the related national RTGS even remained open until 7.30 pm, to give the bank's counterparties the occasion to resolve their liquidity problems induced by the incident. (Euro 1 also stayed open until 5.02 pm on that day). We therefore had a separate look at money market trading on this day.

As pointed out to us by various commentators, settlement days of Eurosystem main refinancing operations may also be special, due to the large liquidity needs for settling the repos. We therefore also collected the dates of the 19 settlement days during our sample period.

4. Empirical results

We can now turn to the main empirical analysis of the euro overnight markets' functioning. We do this by studying the quoting activity (and to the extent that it is available, also the trading volume), overnight rate volatility and bid-ask spreads from our broker data. We first draw a general picture of the market across the week and across the days of the week (Section 4.1). We then relate in greater detail specific intraday patterns to the institutional framework of the money market. We chronologically discuss the effects of monetary policy events and monetary news releases (Section 4.2), of operational features of monetary policy implementation (Section 4.3) and of payment system events (Section 4.4). Finally, we also study the behaviour of ticks (MID volumes), volatility and spreads during the critical week of the Y2K changeover (Section 4.5).

4.1. Regular intra-week and intraday patterns

In this sub-section we discuss the intra-week and intraday patterns of our data set and make a first brief attempt to relate any regularities discovered to the institutional environment of the money market microstructure, as described in Section 2. We focus here on "normal" days, which from now on we define as all business days in our sample excluding the two last days of each reserve maintenance period and the days of the Y2K changeover week (25 December 1999 until 3 January 2000). What usually happens at the end of the reserve maintenance period and what happened during the Y2K changeover is addressed in greater depth in Sections 4.3.3 and 4.5. Tables 4–6 show, for each weekday and for each of our three intraday intervals, the average quoting frequency (plus the average trading volume for the Italian MID), the average volatility and the average bid-ask spreads between November 1999 and March 2000.

Quoting frequency is measured as the number of ticks per period averaged over the relevant sub-periods of the entire sample (Table 4). Volatility is measured as the average absolute overnight rate change during an intraday period, calculated from middle rates (Table 5).[22] Occasionally, we will also look at the intra-period tick-to-tick standard deviation, a more high-frequency volatility measure, which we add to the tables in square brackets. Finally, spreads are measured as arithmetic averages of the differences between ask and bid overnight rates per relevant sub-period (Table 6).

Starting with the day-of-the-week patterns quoting activity is the highest on Tuesdays and Thursdays for all brokers except the MID where quoting is also intense on Friday (Table 4).[23] The lowest tick frequency occurs after the weekend on Monday (except in Italy). However, *daily* trading volumes in the MID are not always proportional to *daily* ticks. Surprisingly, the highest trading volumes occur on Wednesdays in this trading system (about EUR 25 billion), in particular during the afternoon before the closing of payment systems, and the lowest volumes on Thursdays. Less surprising are perhaps the high MID volumes on Tuesdays (about EUR 21 billion).

The most volatile day (for "voice" brokers) is Thursday, with an average 3-hourly absolute overnight rate change of 4 to 7 basis points (Table 5). Monday tends to be the least volatile, although not for all "voice" brokers and although the differences to other days can be relatively small. If one looks at the mean 3-hourly rate changes of about 3 to 4 basis points for all our "normal" days, then it appears also that the euro overnight market is in general not a very volatile market. Differences between bid-ask spreads across the trading week are not particularly pronounced (Table 6). Having said that, the largest spreads are observed on the very active and volatile

[22] For the purpose of calculating this volatility measure, 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.

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

Table 4
Average quoting frequency and MID volumes in the euro overnight market on "normal" days, November 1999 to March 2000

		France	Germany		Spain	Netherlands	UK		Italy	
Weekday	Intraday period	GREL	KLIEMM	GEHA	CIMV	PYWMEURO	PYEC	Pooled "voice" brokers	MID best	MID volumes (in mil. Euro)
Monday	*Day average:*	*0.88*	*3.12*	*3.18*	*5.00*	*2.47*	*5.65*	*20.29*	*68.12*	*9495.80*
(17 in sample)	8:00–11:00	0.65	2.47	1.59	2.29	1.53	3.29	11.82	27.94	2951.00
	11:00–14:00	0.06	0.06	0.41	1.18	0.12	0.41	2.24	16.00	2685.08
	14:00–17:00	0.18	0.59	1.18	1.53	0.82	1.94	6.24	24.18	3859.70
Tuesday	*Day average:*	*2.29*	*8.35*	*8.00*	*7.29*	*5.94*	*12.18*	*44.06*	*74.35*	*21214.11*
(17 in sample)	8:00–11:00	1.29	4.06	3.71	2.82	2.00	4.94	18.82	25.06	5949.50
	11:00–14:00	0.24	1.94	2.00	2.65	1.82	2.59	11.24	18.53	6248.45
	14:00–17:00	0.76	2.35	2.29	1.82	2.12	4.65	14.00	30.76	9016.16
Wednesday	*Day average:*	*1.06*	*7.59*	*6.76*	*4.76*	*4.18*	*10.53*	*34.88*	*65.65*	*25026.04*
(17 in sample)	8:00–11:00	0.53	3.65	3.29	1.76	2.29	4.29	15.82	23.18	8478.76
	11:00–14:00	0.24	1.18	1.12	0.94	0.35	1.41	5.24	13.71	5544.02
	14:00–17:00	0.29	2.76	2.35	2.06	1.53	4.82	13.82	28.76	11003.26
Thursday	*Day average:*	*1.76*	*5.59*	*6.88*	*7.12*	*6.47*	*13.06*	*40.88*	*82.24*	*9277.87*
(17 in sample)	8:00–11:00	0.29	2.88	3.12	1.47	2.12	5.35	15.24	26.65	3072.50
	11:00–14:00	0.47	1.82	2.65	3.82	1.65	2.82	13.24	22.35	2302.57
	14:00–17:00	1.00	0.88	1.12	1.82	2.71	4.88	12.41	33.24	3902.81
Friday	*Day average:*	*0.61*	*6.72*	*6.56*	*6.06*	*5.22*	*9.50*	*34.67*	*84.50*	*9720.79*
(18 in sample)	8:00–11:00	0.11	2.94	3.28	2.28	2.94	3.83	15.39	33.28	3391.76
	11:00–14:00	0.22	1.11	1.00	2.39	0.44	1.06	6.22	18.83	2541.83
	14:00–17:00	0.28	2.67	2.28	1.39	1.83	4.61	13.06	32.39	3787.20
All "normal" days	*Day average:*	*1.31*	*6.28*	*6.28*	*6.05*	*4.93*	*10.17*	*34.95*	*75.08*	*14886.15*
(86 in sample)	8:00–11:00	0.57	3.20	3.00	2.13	2.19	4.34	15.42	27.29	4752.69
	11:00–14:00	0.24	1.22	1.43	2.20	0.87	1.65	7.62	17.90	3849.01
	14:00–17:00	0.50	1.86	1.85	1.72	1.80	4.19	11.92	29.90	6284.45

Notes: The cell entries describe the average number of quote revisions (tick frequency) for the respective interval during the sample. "Normal" days are all business days, excluding the last two days of the minimum reserve maintenance period and the days of the year 2000 (Y2K) changeover week. The "pooled" series is derived from the union of "voice" broker quotes in France, Germany, Spain, the Netherlands and the UK. *Source*: Reuters, e-MID, authors' calculations.

Table 5
Average volatility in the euro overnight market on "normal" days, November 1999 to March 2000

		France	Germany		Spain	Netherlands	UK		Italy
Weekday	Intraday period	GREL	KLIEMM	GEHA	CIMV	PYWMEURO	PYEC	Pooled "voice" brokers	MID best
Monday	*Day volatility*	*3.11 [1.11]*	*3.55 [0.94]*	*2.23 [0.97]*	*2.18 [0.73]*	*4.59 [2.47]*	*2.45 [0.78]*	*3.02 [1.17]*	*2.30 [1.41]*
(17 in sample)	8:00–11:00	0.86 [1.12]	2.21 [1.17]	0.58 [1.50]	3.71 [0.99]	0.48 [2.62]	3.24 [0.90]	1.85 [1.38]	3.16 [1.81]
	11:00–14:00	7.56 [0.00]	2.94 [0.00]	1.48 [0.47]	1.24 [0.60]	2.99 [0.00]	1.10 [0.55]	2.89 [0.54]	1.19 [1.16]
	14:00–17:00	1.99 [1.06]	3.93 [0.35]	3.26 [0.64]	1.86 [0.56]	6.05 [2.13]	3.28 [0.68]	3.39 [0.90]	2.60 [1.23]
Tuesday	*Day volatility*	*4.17 [2.80]*	*2.67 [1.33]*	*2.53 [1.63]*	*2.65 [1.08]*	*4.33 [1.64]*	*3.02 [1.31]*	*3.23 [1.63]*	*2.53 [1.75]*
(17 in sample)	8:00–11:00	6.70 [5.34]	4.39 [1.51]	2.71 [1.74]	3.93 [1.70]	1.97 [1.68]	5.08 [1.74]	4.13 [2.29]	3.03 [1.73]
	11:00–14:00	2.47 [1.77]	1.84 [1.40]	2.87 [0.99]	1.63 [0.97]	3.38 [2.29]	2.09 [1.00]	2.38 [1.40]	2.37 [1.60]
	14:00–17:00	4.28 [0.98]	2.28 [0.99]	2.09 [2.12]	2.13 [0.74]	6.18 [0.80]	2.58 [1.17]	3.26 [1.13]	2.18 [1.92]
Wednesday	*Day volatility*	*3.89 [2.30]*	*2.93 [1.43]*	*2.95 [1.21]*	*4.28 [1.09]*	*3.42 [1.73]*	*3.12 [1.14]*	*3.43 [1.48]*	*2.94 [1.51]*
(17 in sample)	8:00–11:00	4.07 [2.40]	3.20 [1.08]	2.89 [1.17]	3.76 [1.31]	5.55 [2.23]	3.25 [1.09]	3.79 [1.55]	3.10 [1.67]
	11:00–14:00	3.13 [1.77]	2.70 [1.59]	2.97 [1.24]	2.63 [0.84]	4.98 [0.64]	2.57 [1.38]	3.16 [1.24]	1.98 [1.28]
	14:00–17:00	4.21 [2.47]	2.97 [1.84]	2.97 [1.24]	7.85 [1.13]	1.96 [0.82]	3.68 [1.07]	3.94 [1.43]	3.73 [1.57]
Thursday	*Day volatility*	*7.1 [2.62]*	*4.69 [1.89]*	*4.18 [1.91]*	*6.45 [1.64]*	*5.60 [2.26]*	*4.16 [1.85]*	*5.36 [2.03]*	*2.85 [1.78]*
(17 in sample)	8:00–11:00	13.07 [0.0]	4.56 [1.84]	4.53 [1.84]	4.16 [0.78]	3.73 [2.62]	4.81 [1.88]	5.81 [1.79]	3.97 [2.01]
	11:00–14:00	2.55 [1.77]	6.20 [1.98]	4.70 [2.26]	6.34 [1.97]	6.75 [1.39]	5.47 [2.26]	5.34 [1.94]	2.70 [1.69]
	14:00–17:00	6.01 [2.76]	3.98 [1.84]	3.53 [1.39]	12.97 [1.72]	5.85 [2.73]	2.64 [1.49]	5.83 [1.99]	1.88 [1.65]
Friday	*Day volatility*	*5.79 [2.12]*	*3.01 [1.32]*	*2.65 [1.32]*	*5.74 [3.51]*	*3.78 [1.40]*	*2.62 [1.12]*	*3.93 [1.80]*	*2.92 [1.56]*
(18 in sample)	8:00–11:00	8.50 [0.00]	2.13 [1.28]	1.75 [1.05]	3.17 [8.35]	2.78 [1.80]	2.80 [1.29]	3.52 [2.75]	3.58 [1.92]
	11:00–14:00	5.16 [3.54]	1.60 [1.12]	1.32 [0.92]	1.16 [1.25]	2.45 [1.59]	1.82 [0.73]	2.25 [1.52]	1.67 [1.47]
	14:00–17:00	2.67 [1.41]	4.81 [1.50]	4.06 [1.87]	7.93 [0.88]	5.06 [0.81]	3.27 [1.12]	4.73 [1.27]	3.56 [1.29]
All "normal" days	*Day volatility*	*5.09 [2.33]*	*3.28 [1.41]*	*2.89 [1.45]*	*3.83 [1.70]*	*4.33 [1.88]*	*3.11 [1.26]*	*3.83 [1.67]*	*2.71 [1.60]*
(86 in sample)	8:00–11:00	9.13 [3.06]	3.57 [1.37]	2.82 [1.45]	3.74 [3.18]	2.97 [2.24]	3.93 [1.35]	4.36 [2.11]	3.37 [1.83]
	11:00–14:00	3.47 [2.21]	2.77 [1.55]	2.62 [1.35]	2.55 [1.23]	4.37 [1.73]	2.66 [1.33]	3.07 [1.56]	1.98 [1.44]
	14:00–17:00	3.96 [1.89]	3.47 [1.37]	3.15 [1.53]	7.42 [0.98]	4.87 [1.38]	3.10 [1.12]	4.23 [1.38]	2.80 [1.53]

Notes: See Table 4. Cell entries describe the average absolute overnight rate change for the respective interval during the sample period. Start and end rates have been derived by linear interpolation. Average quote-to-quote standard deviations for the respective interval are reported in square brackets. Both volatility measures are multiplied by 100, so that they are in basis points (100th of percentage points). *Source*: Reuters, e-MID, authors' calculations.

Table 6
Average bid-ask spreads in the euro overnight market on "normal" days, November 1999 to March 2000

		France	Germany		Spain	Netherlands	UK		Italy
Weekday	Intraday period	GREL	KLIEMM	GEHA	CIMV	PYWMEURO	PYEC	Pooled "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 "normal" 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: See Table 4. Cell entries describe the average quoted bid-ask spread (ask overnight rate minus bid overnight rate) for the respective interval during the sample. Spreads are multiplied by 100 and therefore in basis points (100th of per cent). *Source*: Reuters, e-MID, authors' calculations.

Thursdays (probably related to inventory risk) and the lowest on the inactive and stable Mondays (potentially related to low activity).

Overall, different days of the week stand out for different microstructure features. Mondays stand out with low post-weekend trading and volatility, Tuesdays with high market activity potentially related to MROs (see Section 4.3.1 below), Wednesdays with very large MID trading volumes potentially related to MRO settlement obligations (see Section 4.4.2), Thursdays with high volatility (and higher spreads) potentially related to ECB Governing Council Meetings (see Section 4.2.1). Other features seem more blurred and it appears worthwhile to rather turn the attention to intraday variations.

Looking at Table 4, we find evidence of the "two-hump" (or "u") shaped intraday activity pattern.[24] In our sample, the "u"-shaped pattern holds for ticks for all weekdays except Thursday, the special Council day, and for all brokers.[25] The exception of high midday activity on Thursdays will be explained below by the timing of the release of ECB interest rate decisions on that day. The pattern also holds for MID trading volumes, except in the case of the special Tuesday midday period during which MRO allotment results are released. The general "u"-shape is a pattern that is already well established in the literature on intraday market behaviour in stock, foreign exchange and bond markets (see e.g. Wood et al., 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.[26] As will be discussed in greater depth in Section 4.4, the closing of payment systems late afternoon/early evening and related liquidity needs stimulate trading in the afternoon (see e.g. Angelini, 2000). Finally, in countries where traders have lunch breaks activity slows down over midday.

Volatility also tends to exhibit (weakly) the typical "u"-shaped pattern during the day, although clearly less regular and pronounced than for ticks (Table 5).[27] Moreover, intraday volatility seems also to be high on Tuesday mornings and sometimes on Monday and Friday evenings. These volatility patterns are consistent with the MRO auctions early on Tuesday and with interest rate decisions on Thursday around lunchtime, which regularly transmit important information to the market, resulting

[24] We do not make the distinction between "two-hump" and "u"-shaped intraday patterns in this paper. However, a closer examination of our MID data seems to indicate that ticks and volumes are rather "two-hump" shaped (Fig. 5) and volatility and spreads rather "u"-shaped.

[25] In the Spanish case (CIMV) several exceptions occurred, potentially related to later lunch breaks in this country.

[26] The observation for the MID in Fig. 5 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, often implying large spreads, or with very small quantities associated to quotes.

[27] The most visible exceptions are the Dutch broker, the special Thursday midday period and for several "voice" brokers the Monday. However, as we will see in Section 4.2.1 below, if we distinguish Governing Council Thursdays from non-Governing Council Thursdays, then the "u" volatility shape will re-emerge for the latter.

in larger movements in the quotes.[28] Both phenomena are addressed in greater detail below. Friday evening volatility might be the consequence of liquidity managers' attempts to square undesired positions before the weekend. 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 tend to square their positions when the weekend approaches.

Unlike overnight market activity and volatility and unlike the experience of bond or equity markets, quoted overnight rate spreads in the euro overnight deposit market do not seem to exhibit a clear "u"-shaped intraday pattern (Table 6). First, differences across the trading day appear often rather small. Second, for the "voice" brokers often even a (weakly) reversed, single "hump" shaped intraday pattern emerges. This is consistent with an order processing cost/liquidity component in spreads, since when the market is more (less) active and liquid spreads should be lower (higher).[29] However, there are also other intraday spread patterns 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 the morning period, 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.[30] An alternative explanation is that MID quotes can be directly "attacked" by money market traders, so that — compared to often more indicative "voice" broker quotes — there are stronger incentives for banks to protect themselves against becoming a counterparty in a trade early in the morning when uncertainty is still high and liquidity still low. In any case, a more detailed analysis (not reported in the table) showed that this phenomenon resulted entirely from extremely high spreads during the market opening hour between 8 and 9 am, i.e. before the ECB release of information on the market's liquidity situation on Reuters page ECB40.

However, in contrast to some signs of pre-closing volatility, as discussed above, in our data overnight spreads are not systematically higher during the last trading interval on Friday. In other words, somewhat surprisingly our quoted spreads do not indicate a reluctance of liquidity managers to incur new positions before the weekend.

[28] We found the enhanced Thursday midday volatility to be robust to the elimination of the three pure policy rate changes by the ECB (see Table 1).

[29] Since the euro money market trivially is larger than the money market of any single member country before EMU, one may have expected it to exhibit higher liquidity and narrower spreads. Some early evidence provided by Detken and Hartmann (2000, Table 2) and by spread estimations undertaken by the Banca d'Italia and reported in Santillàn et al. (2000, Annex 3) are consistent with the fulfilment of this expectation.

[30] 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 (2000), the settlement of these spot FX contracts in the morning is known to banks two days in advance.

4.2. Monetary policy news and events

In order to further refine the picture of the euro overnight market's microstructure, we now turn the attention in greater detail to a selection of major monetary policy news and events. We first examine the intraday patterns of Governing Council Thursdays, as compared to non-Governing Council Thursdays. Second, we study the market patterns of morning periods with the release of new M3 data (referring to the first pillar of the ECB's monetary policy strategy) and compare them to non-M3 release mornings. Finally, we briefly comment on ECB Monthly Bulletin releases.

4.2.1. Governing Council meetings and interest rate decisions

Normally, Thursday is the day of Governing Council meetings and therefore of interest rate announcements. However, the preceding analysis still ignored the fact that only every other week there is a Council meeting and a few of them were held on a Wednesday. Therefore, we report in Table 7 ticks (and MID volumes), volatility and spreads for Council days and non-Council Thursdays separately.[31] For all except 1 of our 7 brokers and virtually all of our 3 standardised intraday periods quoting activity is higher on Council days (and usually largely so) than on non-Council Thursdays, which turn out to be relatively inactive days, roughly comparable to Mondays (see Table 4). Whereas for the MID the "classical" "u"-shaped quoting pattern re-emerges for non-Council days, the picture for the "voice" brokers is less clear on these days (potentially related to their inactive nature). For Council days a typical "u" intraday quoting pattern cannot emerge, because of the 13.45 ECB communiqué about interest rate decisions. The midday period, during which the press release on monetary policy decisions is issued, is also very active compared to other midday periods more generally, but Council mornings are not necessarily special in this regard (see Table 4). MID trading volumes, also reported in Table 7, show "u"-shaped transaction patterns for both Council days and non-Council Thursdays. Finally, the indication from Table 4 that Council days are not characterised by particularly high MID trading volumes, in spite of interest rate decisions, is confirmed. MID volumes are only moderately higher on Council days, mainly due to slightly enhanced post-decision afternoon trading.

In order to get an even clearer picture of the market across the Council days, we provide a further refinement of Council and non-Council Thursdays, using 45 minute time intervals for the MID (Table 8). These figures show how trading activity (volume and quoting) exhibits a noticeable increase right after the 13.45 communiqué, as the market "digests" the news from Council decisions and agents rebalance positions. On non-Council Thursdays (and most other normal days) volumes decrease by almost half and quoting stays constant between the same two intraday periods, because of the lunch break. The average volume during the post-announce-

[31] In our sample, 4.11.99, 18.11.99, 2.12.99, 15.12.99, 5.1.00, 20.1.00, 3.2.00, 17.2.00, 2.3.00 and 16.3.00 were Council days. We eliminated the 20 January meeting from our comparison, since it coincided with the end of the minimum reserve holding maintenance period. The 15 December and 5 January Council meetings were held on Wednesdays.

Table 7
Average quoting frequency, MID volumes, volatility and spreads in the euro overnight market on "normal" ECB Governing Council days as compared to "normal" non-Governing Council Thursdays, November 1999 to March 2000 (all brokers)

	France	Germany		Spain	Netherlands	UK	Italy		
	GREL	KLIEMM	GEHA	CIMV	PYWMEURO	PYEC	Pooled "voice" brokers	MID best	MID volumes (in mil. Euro)
Quoting frequency									
Governing Council days (9)									
Whole days	*1.80*	*7.30*	*9.2*	*8.10*	*5.40*	*13.30*	*52.00*	*85.60*	*10049.73*
8:00–11:00	0.30	3.40	4.10	2.00	1.50	4.30	15.60	24.70	2906.69
11:00–14:00	0.50	2.40	3.80	4.30	0.90	2.40	14.30	23.20	2528.26
14:00–17:00	1.00	1.50	1.30	1.80	3.00	6.60	15.20	37.70	4614.77
Non-governing Council Thursdays (8)									
Whole days	*1.00*	*2.89*	*2.67*	*4.33*	*6.11*	*7.89*	*25.33*	*60.78*	*9424.33*
8:00–11:00	0.22	1.56	1.33	0.56	2.33	2.78	8.77	21.11	3444.08
11:00–14:00	0.22	0.78	0.78	2.44	1.89	2.44	8.55	15.78	2196.48
14:00–17:00	0.56	0.56	0.56	1.33	1.89	2.67	7.56	23.89	3783.77
Volatility									
Governing Council days (9)									
Whole days	*7.37*	*4.89*	*4.76*	*6.34*	*7.44*	*5.16*	*5.81*	*3.63*	
8:00–11:00	17.57	3.88	4.91	3.85	4.17	5.39	6.04	4.86	
11:00–14:00	3.03	8.54	6.79	5.64	10.17	6.63	6.72	3.47	
14:00–17:00	2.46	4.05	3.50	11.58	6.35	3.54	4.90	2.56	
Non-governing Council Thursdays (10)									
Whole days	*6.31*	*3.97*	*3.12*	*2.59*	*3.12*	*2.74*	*3.45*	*2.38*	
8:00–11:00	7.80	3.06	2.26	3.87	3.08	3.22	3.42	3.41	
11:00–14:00	1.64	1.95	1.61	2.55	1.41	1.84	1.78	1.28	
14:00–17:00	9.50	6.17	5.11	5.45	4.87	3.25	3.99	2.44	

(*continued on next page*)

Table 7
(*Continued*)

	France	Germany		Spain	Netherlands	UK	Italy		
	GREL	KLIEMM	GEHA	CIMV	PYWMEURO	PYEC	Pooled "voice" brokers	MID best	MID volumes (in mil. Euro)
Spreads									
Governing Council days (9)									
Whole days	*7.97*	*4.72*	*4.10*	*9.90*	*5.58*	*4.45*	*5.61*	*2.89*	
8:00–11:00	6.67	4.12	3.65	10.23	4.96	4.54	4.86	3.47	
11:00–14:00	13.13	5.19	5.52	10.08	6.83	3.98	7.21	2.39	
14:00–17:00	8.33	5.19	4.62	9.54	4.51	4.61	5.25	2.51	
Non-governing Council days (10)									
Whole days	*5.15*	*3.45*	*3.26*	*9.69*	4.26	*4.27*	*4.83*	*2.02*	
8:00–11:00	7.50	3.38	3.89	9.80	4.47	4.57	4.32	2.43	
11:00–14:00	5.00	3.11	3.50	10.04	4.00	4.06	5.05	1.49	
14:00–17:00	4.75	3.67	3.00	10.32	3.82	4.43	5.52	1.77	

Notes: For definitions of quote frequency, volatility and spreads see notes to Tables 4–6. Dates of ECB Governing Council meetings were: 4/11/99, 18/11/99, 2/12/99, 15/12/99, 5/01/00, 20/01/00, 3/02/00, 17/02/00, 2/03/00, 16/03/00. The 20/01/00 meeting is excluded from the data in the table, since it coincided with the end of a reserve maintenance period. "Normal" Thursdays without ECB Governing Council meetings (the control group days) were: 11/11/99, 25/11/99, 9/12/99, 16/12/00, 06/01/00, 13/01/00, 27/01/00, 10/02/00, 24/02/00, 9/03/00. *Source*: Reuters, e-MID, authors' calculations.

Table 8
High-frequency analysis of average quoting frequency, volumes, volatility and spreads in the Italian MID on "normal" ECB Governing Council days as compared to "normal" non-Governing Council Thursdays, November 1999 to March 2000

Intraday period	Quoting frequency	Volumes	Volatility	Spreads
ECB Governing Council days (9)				
Day average	*103.89*	*10998.0*	*1.54 [1.50]*	*3.35*
7:45–8:30	2.00	0.0	0.74 [0.85]	11.39
8:30–9:15	9.33	379.8	3.24 [1.15]	4.02
9:15–10:00	7.00	1120.3	1.70 [1.33]	2.32
10:00–10:45	6.00	1078.7	1.50 [1.42]	3.13
10:45–11:30	8.44	861.6	1.33 [1.49]	4.03
11:30–12:15	6.00	784.4	1.00 [1.39]	2.24
12:15–13:00	5.33	580.4	1.06 [1.05]	2.48
13:00–13:45	4.33	421.0	0.66 [1.17]	2.64
13:45–14:30	9.22	641.2	4.62 [3.26]	5.12
14:30–15:15	13.00	1586.9	1.52 [1.95]	3.58
15:15–16:00	9.33	1279.3	1.20 [1.57]	2.54
16:00–16:45	11.89	1045.1	1.31 [1.60]	2.64
16:45–17:30	8.67	808.5	1.69 [1.71]	2.46
17:30–18:15	3.33	411.5	0.83 [1.10]	2.97
Other Thursdays (10)				
Day average	*70.90*	*8991.2*	*0.97 [0.92]*	*2.11*
7:45–8:30	1.80	1.5	0.93 [0.55]	9.00
8:30–9:15	7.00	402.9	2.73 [1.01]	3.11
9:15–10:00	3.80	1274.1	1.16 [0.73]	1.24
10:00–10:45	7.50	1043.1	1.15 [0.93]	1.56
10:45–11:30	6.20	852.2	0.76 [0.83]	1.61
11:30–12:15	6.90	604.5	0.94 [1.17]	1.80
12:15–13:00	3.70	471.3	0.58 [0.84]	1.35
13:00–13:45	2.00	432.6	0.38 [0.63]	1.05
13:45–14:30	2.10	239.3	0.40 [0.68]	1.52
14:30–15:15	7.00	996.7	0.90 [1.02]	1.59
15:15–16:00	6.40	876.7	0.88 [1.34]	2.66
16:00–16:45	4.80	948.8	0.83 [0.98]	1.67
16:45–17:30	10.70	639.9	1.30 [1.28]	2.33
17:30–18:15	1.00	207.6	0.79 [0.94]	1.40

Notes: See Table 7. Volumes in mil. Euro. *Source*: e-MID, authors' calculations

ment period on Council days is 2.5 times larger than on non-Council Thursdays and tick frequency 4.5 times larger. (Nevertheless, this interval is not the period with the largest MID volume on Governing Council days, which occurs during the subsequent 45 minutes.) Large trading volumes after announcements are also observed in equity markets, as illustrated for example in the case of the Paris Bourse by Gajewski (1999). MID turnover stays somewhat higher across most of the afternoon when compared with non-Council Thursdays, but not when compared with other weekdays.

However, in the intervals directly *before* the 13.45 interest rate announcement, turnover is *not* particularly *low*. It is at about the same level as (or slightly higher than) average volume for non-Council Thursdays. This provides relatively solid first evidence that during our sample period upcoming interest rate decisions by the ECB Governing Council were *not* preceded by substantial asymmetric information, which would have led to adverse selection and hence ceasing volumes. The relationship between asymmetric information, adverse selection and reduced trading volume has been illustrated forcefully by Milgrom and Stokey (1982). This observation seems also consistent with the hypothesis that market participants were relatively confident in having anticipated the interest rate decisions correctly.[32] However, the fact that our sample period falls into a cycle of rising policy rates may also help explain part of the robust trading volumes before the announcements. In such a situation it may pay for traders that give a non-zero probability to an interest rate move by the central bank to "frontload" and borrow liquidity before the announcement.

Turning to volatility, non-Council Thursdays show a "clean" "u"-shaped intraday pattern, which is reversed on Council days, when the 13.45 monetary policy release causes high volatility during the midday period (Table 7). (GREL and MID show a declining volatility pattern due to high pre-announcement volatility and generally high early morning volatility for the MID.) The finer MID data in Table 8 show that most of the 45-minute volatility is concentrated in the interval *right after* the press release. For our standard volatility measure we found an average 4.6 basis point absolute change in overnight rates, which is about 3 times larger than the mean 45-minute rate change over a Council day and 10 times larger than the average change on a non-Council Thursday during the same interval. For the tick-to-tick standard deviation the results (reported in square brackets) are qualitatively similar although somewhat more moderate. For most of the other intraday periods average volatility on Council days is only very moderately above the volatility on non-Council Thursdays but not above the corresponding volatility for an average of all normal non-Council weekdays. This suggests that the new information from interest rate announcements is absorbed by the market relatively fast and efficiently.

A closer examination of the pre- and post-announcement market rates in the MID, led us to the conclusion that the volatility right after the press release was *not* a mechanical effect of the three rate changes during our sample period.[33] It rather seems to come from the interplay between pre-announcement overnight market expectations and the information conveyed by the announcement. Interestingly, an inspection of overnight rate levels quoted in the MID during the hours before and after the announcements led us to the observation that the market was better in anticipating unchanged policy rates than in anticipating changes in policy rates during our sample period. In other words, when the ECB left rates unchanged overnight market rates were not much different or only slightly above the current policy rate

[32] For related discussion of news in equity markets, see Kim and Verrecchia (1991, 1994).

[33] We did this by comparing the volatility of the market rate in Table 7 with the volatility of the difference between the market rate and the MRO rate. We also undertook a visual inspection of all the rates quoted around any single interest rate announcement.

right before the announcement. However, on the days of the three interest rate increases overnight rates — despite having increased by more than half of the subsequent policy change well before the announcement — were only in the case of the 16 March 2000 consistently very close to the future rate. These effects of expectations on the overnight rate can also be seen well from the behaviour of the broker rates before changes in the MRO rate in Fig. 4 above. Therefore, the relatively large volatility (compared to other intraday intervals) measured during the 13.45 to 14.30 period reflected the adjustments resulting from the remaining differences between expectations and actual decisions. However, a 4.6 basis points amplitude of 45-minute post-announcement variations, although large for the standards of the overnight market, is not very large economically, in particular when one compares it to the size of policy rate changes in Table 1 (25 to 50 basis points). One way to read this result is that *on average* the absolute difference between market expectations and actual interest rate decisions has been relatively small during our sample period.

As regards the evidence for bid-ask spreads, Council Thursdays seem to be characterised by slightly higher trading costs than non-Council Thursdays, in particular over the midday interval when the expected arrival of new information in the form of the interest rate decision release gives incentives for dealers to avoid getting into transactions and volatility increases inventory holding costs (Table 7). Neglecting the last 15 minutes of the midday period, the "voice" broker data could suggest that quoted spreads may be high *before* ECB Council interest rate decision releases, potentially providing evidence in favour of some asymmetric information before ECB monetary policy announcements. However, this observation is not consistent with the evidence in Tables 7 and 8, showing relatively high market activity and trading volume during the Thursday midday period. These observations somewhat contrast with those obtained for equity markets. For example, Lee et al. (1993) find a significant increase in spread and decrease in depth before announcements.

The higher frequency MID data in Table 8 show particularly large average spreads (about 5 basis points) during the very active 45-minute interval *following* the interest rate press releases and, compared to non-Council days, also somewhat enhanced spreads during the interval thereafter. In all likelihood they reflect the high inventory costs associated with the high volatility during the same periods reported above, since volume seems abundant and the uncertainty has already been resolved. Whereas the MID spreads before the announcement seem also somewhat higher than those on the inactive non-Council Thursdays, the same does not hold true for a comparison with other non-Council (non-MRO) weekdays (and similarly so for the late Council afternoon). Hence, overall we feel that the evidence on volumes, volatility and spreads considered here is not suggestive of strong asymmetric information and adverse selection directly *before* ECB interest rate decisions. This observation would be consistent with the conclusion that overnight market participants were not subject to very large uncertainty in relation to ECB interest rate decisions, for example since they could by and large anticipate the outcome of Council meetings, as already concluded from the discussion on volumes and volatility above (and also indicated by the MRO bidding behaviour described in Section 2.2.1, Fig. 3). It is also in line with the recent results by Gaspar et al. (2001), who do not find evidence of important

market misperceptions or large and significant volatility increases on Council days for daily data.

4.2.2. M3 releases

Another major news release in relation to the monetary policy stance of the ECB is the latter's publication of euro area M3 data (first pillar of its strategy) once a month around 10 in the morning. Table 9 compares ticks, volatility and spreads for M3 release mornings with the same variables for non-release mornings of all other "normal" days (i.e. excluding end-of-maintenance period days and Y2K changeover days).[34] It indicates increased quoting activity and perhaps slightly increased spreads, but volume is rather low (or comparable to normal days, as displayed in Table 4 for example). Our standard measure of volatility (mean absolute rate change) also looks rather low compared to non-M3 release days. However, when using the more short-term volatility measure (the mean tick-to-tick standard deviation over the morning interval, indicated in square brackets in Table 9), then this reverses and it turns out that on M3 release mornings high-frequency volatility is slightly above the one on other days (excluding special event days).

Table 10 further refines the picture for the Italian MID data, using 30-minute intervals during mornings. The first notable feature is that quoting almost ceased during the half-hour before the 3 releases, dragging also volatility and spreads to low levels during that time, although in line with the "voice" broker data it is rather high before and after this special interval. Perhaps somewhat surprisingly, due to a limited number of large transactions during this interval, MID trading volume is not particularly low during this half-hour compared to before and after. Generally, volume is lower than on other days though, but this phenomenon seems to be spread out over the whole M3 release morning. This analysis also confirms that high-frequency volatility is somewhat higher than on non-release days, particularly early in the morning before the release and somewhat less after the release. Accordingly, spreads also go up during certain intervals before and after the releases.

Because of the low number of M3 releases that all happened on either a Monday or a Friday these patterns have to be interpreted with an extra dose of caution. With this caveat in mind the results at hand suggest that the market is paying attention to M3 releases (special behaviour of ticks and volatility), contradicting some ECB "watchers" who believe that the first pillar of the monetary policy strategy of the ECB is of little practical relevance for actual policy-making and the market, and that there may be a modest degree of uncertainty about the effective M3 figures to be released before the announcement. However, trading volumes before the announcement are not consistent with the notion of a slowing market due to asymmetric information about the M3 numbers and related adverse selection. Finally, in contrast to interest rate decisions no post-announcement increase of volume can be detected

[34] There were four M3 data releases during our sample: 29.11.99, 28.12.00, 28.1.00 and 25.2.00. Because of the special factors playing a role on Y2K changeover days, we eliminated the December release from our comparison.

Table 9
Average quoting frequency, MID volumes, volatility and spreads in the euro overnight market on "normal" ECB M3 data release mornings as compared to "normal" non-release mornings, November 1999 to March 2000 (all brokers)

	France	Germany		Spain	Netherlands	UK			Italy
	GREL	KLIEMM	Geha	CIMV	PYWMEURO	PYEC	Pooled "voice" brokers	MID best	MID volumes (in mil. Euro)
Quoting frequency									
M3 release mornings (3)									
8:00–11:00	0	9.00	5.33	2.67	6.33	8.67	19.20	38.00	3342.90
Other mornings, excl. GC and MRO days (60)									
8:00–11:00	0.59	2.99	2.92	2.11	2.04	4.18	15.42	26.90	4654.30
Volatility									
M3 release mornings (3)									
8:00–11:00	2.16 [1.74]	2.45 [1.74]	32.63 [1.79]	3.04 [3.18]	2.68 [1.56]	13.51 [2.02]	3.07 [2.69]		
Other mornings, excl. GC and MRO days (60)									
8:00–11:00	8.63	3.75 [1.28]	3.48 [1.23]	5.81 [1.34]	5.08 [2.08]	4.28 [1.22]	3.53 [1.51]	4.16 [1.77]	
Spreads									
M3 release mornings (3)									
8:00–11:00	4.22	4.19	9.50	5.67	3.93	4.73	3.89		
Other mornings, excl. GC and MRO days (60)									
8:00–11:00	6.57	3.77	3.66	10.0	4.08	4.07	4.60	3.15	

Notes: For definitions of quote frequency, volatility and spreads see notes to Tables 4–6. M3 data are released monthly, around the 20th business day (net of holidays), around 10:00 AM. Releases included in the table are 29/11/99, 28/01/00, 25/02/00. Because of the special character of Y2K changeover days, we excluded the 28/12/99 release from the analysis. The control group mornings include all "normal" days without an M3 release, without an ECB Governing Council meeting and without an MRO auction. *Source*: Reuters, e-MID, authors' calculations.

Table 10
High-frequency analysis of average quoting frequency, volumes, volatility and spreads in the Italian MID on "normal" ECB M3 data release mornings as compared to "normal" non-release mornings, November 1999 to March 2000

Intraday period	Quoting frequency	Volumes	Volatility	Spreads
M3 release mornings (3)				
Morning average	*42.67*	*3945.0*	*1.63 [1.74]*	*4.04*
8:00–8:30	2.00	0.0	1.76 [1.92]	11.8
8:30–9:00	11.00	338.8	5.27 [2.18]	7.15
9:00–9:30	7.67	820.7	5.40 [1.64]	1.96
9:30–10:00	2.00	949.7	1.39 [0.64]	1.00
10:00–10:30	7.67	787.0	1.75 [1.52]	1.65
10:30–11:00	7.67	446.6	1.87 [1.70]	3.26
11:00–11:30	3.00	214.8	1.15 [3.58]	4.44
11:30–12:00	1.67	387.3	1.71 [0.73]	1.20
Other mornings, excl. Gc and mro days (60)				
Morning average	*34.08*	*6170.2*	*0.99 [1.18]*	*2.96*
8:00–8:30	1.97	2.9	0.93 [1.11]	10.9
8:30–9:00	5.52	132.8	2.06 [1.00]	5.05
9:00–9:30	6.67	1108.7	2.39 [0.99]	2.01
9:30–10:00	4.52	1194.3	1.16 [0.94]	1.67
10:00–10:30	4.77	1094.3	0.91 [1.05]	1.76
10:30–11:00	3.87	1121.3	0.92 [1.35]	2.34
11:00–11:30	3.68	804.4	0.76 [0.99]	1.94
11:30–12:00	3.07	711.4	0.89 [1.01]	1.87

Notes: See Table 9. *Source*: e-MID, authors' calculations.

in our sample, although for certain post-announcement intervals volatility and bid-ask spreads appear slightly higher than for the same time intervals on non-announcement days.[35]

4.3. Monetary operations and liquidity management

We now extend the analysis of euro money market microstructure to the effects of the operational implementation of monetary policy and the related money market liquidity management by the ECB. We first consider the weekly main refinancing operations (MROs) by the Eurosystem, we then briefly study the daily release of money market liquidity information by the ECB, subsequently we look at the special days at the end of the minimum reserve holding maintenance period and finally we examine the effects of special liquidity shocks resulting from operations related to

[35] We also analysed the behaviour of the euro overnight market before and after the publication of the ECB Monthly Bulletin that, inter alia, contains data and analysis about the second pillar of the ECB monetary policy strategy. However, the results were little conclusive, so that we save space here by referring the interested reader to the more comprehensive working paper (Hartmann et al., 2001).

national Treasuries, when the respective national central banks act as a banker for the government.

4.3.1. Main refinancing operations

The weekly MRO (usually) takes place on Tuesdays.[36] Let us first look at our three standard intraday intervals, as displayed in Tables 4–6 again. On Tuesday midday (the period from 11 am to 2 pm), right after the announcement of the auction results at 11.15 am, the market is very active compared to other midday intervals during the week (Table 4). For example, Tuesday lunchtime MID turnover is the highest for all midday periods during the week (on average 6.2 bn euro). Tuesday lunchtime tick frequency is the second highest, only after the special (Council) Thursdays discussed above. This reflects banks' activities to reallocate liquidity according to their effective needs, since first smaller banks that have not bid in the auction themselves may borrow overnight money from larger banks and second even some of the bidding banks may sometimes receive more or less than the quantities optimal for them (because the total amounts bid by other banks is uncertain for each bidding bank under the fixed-rate tender regime).

However, high Tuesday market activity is not only limited to the post-auction midday period. "Voice" broker quoting frequency and MID trading volume tend also to be high during the on-going auction process on Tuesday morning (8 am to 11 am 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 to be and that the 9.15 am release of reserve account balances and use of standing facilities on Reuters page ECB40 (see Fig. 3 above) is informative for the market. The later afternoon period (from 2 pm to 5 pm) is also relatively active in terms of MID turnover compared to other afternoons during the week. This could indicate that the post-auction reallocation process is carrying on for most of the afternoon.

Is this high market activity around Eurosystem open market operations associated with less desirable features, such as high volatility or high bid-ask spreads? As can be seen from Table 5 auction Tuesdays are not particularly volatile days in general, even for the post-auction liquidity re-allocation period. Similarly, bid-ask spreads seem to be relatively close to those of non-MRO auction days during the week (Table 6). All this evidence would suggest that the overnight market functions relatively normally and efficiently before, during and after the MROs, irrespective of the high volumes that have to be moved.

In order to further clarify the picture, we look again at the MID data alone for a higher frequency (45 minute intervals), comparing MRO days with ("normal") non-MRO days (an average of "normal" Mondays, Wednesdays, non-Council Thursdays

[36] Almost every Tuesday during our sample period there was an MRO. The exceptions were 9.11.99 and 7.3.00, when the MRO was held a day earlier (on Mondays), as well as 28.12.99, when it was held two days later (on a Thursday). We eliminated the operations of 30.12.00 (Y2K changeover day) and of 23.11.99, 21.12.99, 22.2.00 and 22.3.00 (end of reserve holding period) from the general analysis of MROs.

and Fridays; Table 11). Perhaps the most visible information from this additional comparison is the almost doubling of MID turnover and tick frequency in the interval right after the announcement of the auction results of 11.15 am compared to the 45 minutes before. Volume and ticks are also 2 to 3 times larger than on non-MRO days at the same time, further substantiating the post-auction liquidity re-allocation hypothesis mentioned above. Actually, MID volume is also somewhat higher than

Table 11
High-frequency analysis of quoting frequency, volumes, volatility and spreads in the Italian MID on "normal" MRO auction days as compared to "normal" non-MRO week days, November 1999 to March 2000

Intraday period	Quoting frequency	Volumes	Volatility	Spreads
MRO auction days (14)				
Day average	*81.21*	*25154.0*	*1.25 [2.02]*	*2.30*
8:15–9:00	6.79	341.5	1.19 [0.91]	4.82
9:00–9:45	9.07	3167.6	1.79 [1.09]	2.13
9:45–10:30	4.79	2395.5	0.88 [1.14]	2.13
10:30–11:15	5.29	1626.0	0.90 [1.35]	1.96
11:15–12:00	9.79	2872.7	1.83 [1.39]	1.99
12:00–12:45	4.57	1228.5	1.62 [1.24]	1.84
12:45–13:30	3.36	1499.4	1.11 [1.31]	2.21
13:30–14:15	1.64	552.4	0.81 [0.73]	1.30
14:15–15:00	5.71	3280.1	1.44 [1.28]	2.11
15:00–15:45	7.79	3220.2	1.00 [1.15]	1.83
15:45–16:30	7.50	2265.8	1.33 [0.99]	1.87
16:30–17:15	8.79	2013.9	1.18 [1.32]	2.13
17:15–18:00	5.86	690.6	1.06 [1.36]	2.26
Other days, excl. GC days (58)				
Day average	*79.53*	*15412.0*	*1.18 [2.11]*	*2.53*
8:15–9:00	7.52	146.3	2.59 [1.30]	6.51
9:00–9:45	9.05	1804.6	1.71 [1.10]	1.92
9:45–10:30	6.95	1649.9	1.12 [1.11]	1.75
10:30–11:15	5.86	1507.6	0.92 [1.28]	2.34
11:15–12:00	4.71	1059.7	0.92 [0.99]	1.71
12:00–12:45	4.59	731.2	0.83 [1.18]	1.96
12:45–13:30	3.88	1029.0	0.83 [1.06]	2.44
13:30–14:15	1.90	257.8	0.75 [1.39]	2.46
14:15–15:00	5.72	1156.0	0.88 [0.99]	2.07
15:00–15:45	7.53	1886.5	1.10 [1.07]	1.86
15:45–16:30	9.00	1586.8	1.03 [1.27]	1.95
16:30–17:15	8.10	1335.7	1.47 [1.37]	2.42
17:15–18:00	4.41	1261.0	1.17 [1.33]	2.64

Notes: For definitions of quote frequency, volatility and spreads see notes to Tables 4–6. Dates of MROs are: 8/11/99, 16/11/99, 23/11/99, 30/11/99, 07/12/00, 14/12/99, 21/12/99, 30/12/99, 11/01/00, 18/01/00, 25/01/00, 01/02/00, 08/02/00, 15/02/00, 22/02/00, 29/02/00, 06/03/00, 14/03/00, 22/03/00. The operations of 23/11/99, 21/12/99, 22/02/00, 22/03/00 (end of reserve maintenance period) and 30.12.99 (Y2K changeover day) are excluded from the analysis. The control group includes all "normal" days without an MRO or an ECB Governing Council meeting. Volumes are in mil. Euro.
Source: e-MID, authors' calculations.

on non-MRO auction days for most of the other intraday periods (but not MID best ticks). For example trading volume is also particularly high (but not ticks) during the interval around the 9.15 am ECB release of liquidity information from the previous day. In other words, as already conjectured above from the "voice" broker results the market seems to trade already early in the morning, based on the information this release provides in relation to the likely auction outcome two hours later. However, despite the generally enhanced trading activity on MRO days volatility is only somewhat higher for the two 45-minute intervals immediately following the auction announcements and bid-ask spreads even not for those, confirming the qualitative results from the "voice" brokers.

As indicated before, the financial market literature has identified patterns of quasi-market breakdowns before important uncertainty-loaded events, such as auctions or news announcements, 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 high tick frequencies and volumes before Eurosystem MRO auctions clearly argue against (i). In relation to bid-ask spreads one would expect under the first scenario (i) that they would be large *before* the auctions, while under the second scenario (ii) one would expect them to be *large* after the auctions. Since MID or "voice" broker bid-ask spreads are neither particularly high before the auctions nor after the auctions, the available evidence seems to suggest that despite substantial overbidding in the fixed rate tenders no important market imperfections occurred around Eurosystem main refinancing operations executed from November 1999 to March 2000.

4.3.2. Release of liquidity information on ECB40

As pointed out most forcefully by Vergara (2000) and as described above in Section 2.2.1, an important event for money market traders under the fixed tender regime was the daily 9.15 am ECB release of information on the money market liquidity situation for the previous day (aggregate reserve account holdings and recourse to standing facilities).[37] For both active and more passive money market traders this release provides a signal about the likely liquidity situation in the overnight market on the present day (particularly for the start of trading) and more generally in the remainder of the maintenance period. From this consideration one would expect the market to be relatively active around that particular time of the day, potentially with some volatility related to the time it takes that the new information is incorporated in market rates.

This expectation seems to be borne out by our more frequent data from the MID. First, when looking at the intraday activity patterns, as displayed in Fig. 5, the inter-

[37] ECB40 may have even become more important under the new variable rate tender regime, under which it also contains the ECB liquidity forecast and under which precision in the amounts bid are more important for banks.

val around 9.15 am is on average the most active of the day in terms of trading volume and also very active in terms of quote revision frequency. When we look at the volatility measures in Tables 8 and 10, 11 and 14, we also observe regularly some evidence of relatively large rate fluctuations either directly before or directly after the standard release time. The enhanced tick frequency or rate fluctuations seem to be somewhat further reinforced on days with special events (compared to "normal" days without special events), such as ECB Governing Council days (Table 8 above), M3 release days (Table 10 above) and perhaps also MRO settlement days (Table 14 below) but not really on MRO auction days where only MID turnover tends to spike up (Table 11). Although the volatility and tick frequency reactions are not necessarily very large, we take these observation as a confirmation of the special importance of the 9.15 liquidity release for overnight market participants.

4.3.3. The end of the minimum-reserve maintenance period

Another feature of monetary operations and liquidity management is the minimum reserve regime for banks operating in the euro area. As described in Section 2.2.3 above, the requirement to hold on average a certain amount of reserves in Eurosystem accounts, can mean that if there are unexpected liquidity shocks or banks' planning was imperfect, then shortages or excesses of liquidity at the end of the maintenance period can lead to special behaviour of overnight rates during those days.

By comparing the distribution of quotes across the week on normal days in Table 4 with those on end-of-maintenance-period (EOM) days in Table 12, one observes immediately that on EOM days new quotes are posted much more frequently (about twice as often). However, MID trading volume remains on a rather "normal" level or somewhat below. Volatility of overnight rates appears clearly much larger on end-of-maintenance period days than on "normal" days (usually even more than double), particularly in the afternoon (Table 12).[38] 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 Fig. 4 above, the volatility is either caused by an aggregate shortage of liquidity in the market at that time (overnight rate sky-rockets) or by an aggregate excess of liquidity (overnight rate slumps). It underlines the extreme trading needs by banks with reserve imbalances at this time and the high risks for liquidity managers already referred to before.

In line with the high uncertainty and inventory risk created by the overnight rate volatility described above, quoted spreads tend to widen systematically on EOM days (Table 12). 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). Looking at intraday spreads for EOM days, for all brokers (except GREL, who appears to stop quoting) they are highest in the afternoon, pointing to

[38] The 11 basis points average rate change in the MID during EOM mornings seems to be an exception. However, when we look at the higher frequency tick-to-tick standard deviation for the MID (and the "voice" brokers; reported in square brackets), then afternoon volatility is also highest in this system. We verified that the same results hold for the volatility of transaction rates.

Table 12
Average quoting frequency, MID volumes, volatility and spreads in the euro overnight market on the two last days of the minimum reserve maintenance period, November 1999 to March 2000

	France	Germany		Spain	Netherlandsnds	UK		Italy	
Intraday period	GREL	KLIEMM	GEHA	CIMV	PYWMEURO	PYEC	Pooled "voice" brokers	MID best	MID volumes (in mil. Euro)
Quoting frequency (10 days)									
Day average	*2.90 (3.57)*	*15.80 (17.97)*	*14.60 (13.34)*	*8.60 (5.21)*	*10.70 (20.05)*	*26.40 (24.56)*	*79.00 (71.10)*	*167.90 (52.98)*	*9700.74*
8:00–11:00	1.20	6.00	6.30	0.70	5.70	11.30	31.20	42.30	3435.60
11:00–14:00	1.20	4.10	3.30	4.20	2.20	5.70	20.70	31.50	2570.65
14:00–17:00	0.50	5.70	5.00	3.70	2.80	9.40	27.10	94.10	3694.49
Volatility (10 days)									
Day average	*7.89 [5.22]*	*7.33 [3.86]*	*8.39 [4.00]*	*5.98 [3.84]*	*10.42 [3.85]*	*9.17 [5.35]*	*8.2 [4.35]*	*8.4 [7.17]*	
8.00–11.00	6.61 [6.99]	4.58 [3.12]	8.19 [4.43]	6.22 [0.79]	7.48 [3.90]	6.14 [3.28]	6.54 [3.75]	11.42 [5.33]	
11:00–14:00	3.1 [4.62]	7.38 [2.87]	7.14 [2.15]	6.30 [2.36]	8.10 [4.09]	8.90 [2.98]	6.82 [3.18]	6.09 [3.78]	
14:00–17:00	10.83 [3.49]	9.74 [5.44]	9.67 [5.73]	4.61 [5.75]	12.77 [3.62]	12.83 [10.07]	10.07 [5.68]	7.69 [12.40]	
Spreads (10 days)									
Day average	*5.93*	*5.28*	*6.92*	*11.30*	*7.84*	*8.65*	*7.74*	*7.45*	
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: For definitions of quote frequency, volatility and spreads see notes to Tables 4–6. End of reserve 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, e-MID, authors' calculations.

the special uncertainties towards the end of trading during these days. For most brokers these higher spreads seem to be at least partly related to the higher volatility of interest rates at that time. Otherwise, the high afternoon spreads may simply reflect the fact that most market participants reached their reserve target and are therefore unwilling to trade, since a newly acquired imbalance would in all likelihood force them to borrow from the marginal lending facility (in the case of a liquidity shortfall) or to put excess balances in the deposit facility, both at penalty rates.

4.3.4. Liquidity shocks from Treasury operations

It is by now well known that operations by some euro area Treasuries with their national central banks can significantly change the liquidity situation in the money market and are therefore of special concern to central bank liquidity management (see e.g. Escrivá and Fagan, 1996; ECB, 1999b). Actually, they have been identified as the largest irregular "autonomous" liquidity shocks since the start of stage 3 of EMU (Bindseil and Seitz, 2001).[39] Often they are triggered by tax payments in countries in which the central bank acts as the bank for the government.

The first remark in relation to these shocks is a caveat for the analysis of EOM days undertaken above. Rather by coincidence a special large liquidity shock through tax payments and related Treasury operations occurs in Italy on the 23rd of each month, exactly on the day at which the Eurosystem reserve maintenance period is ending. Behind this shock are tax payments to the Treasury, which deposits the money with the Banca d'Italia. During our sample period the size of these shocks varied, withdrawing each time between 12 and 25 billion euro of liquidity — a considerable amount even for the large euro money market. This causes an identification problem, in so far as part of the enhanced quoting, volatility and transaction costs observed above may be a result of these shocks, hitting at the same time as banks have to meet their minimum reserve targets. For example, this feature may explain why the increase in bid-ask spreads is way more dramatic in the Italian MID system than suggested by the "voice" broker data for other countries. However, with the small number of Italian tax days in our sample there is no easy solution how to disentangle the relative importance of the end of the reserve maintenance period and the Italian tax day liquidity shocks, and we therefore leave it for future research.

Instead we identified the remaining "normal" days (excluding EOM and Y2K days) in which aggregate government deposits with Eurosystem member central banks varied by more than two standard deviations from their mean absolute change over our sample period in order to compare overnight market behaviour on those days with non-Treasury operation days (excluding special days, such as Council or MRO days). Since only 4 such days could be identified, 3 of them exhibiting a withdrawal of liquidity from Treasury operations and 1 showing an increase in liquid-

[39] "Autonomous" shocks in the language of central bank liquidity management refer to shocks caused by factors that cannot be influenced directly by the central bank. Hamilton (1996) describes similarly important effects caused by Treasury operations in the US money market. Bindseil and Seitz (2001) show that changes in banknote demand can also cause sizeable "autonomous" shocks, but that they are much more regular, following a seasonal pattern that is relatively easy to predict.

ity, we do not report the full results.[40] Keeping in mind the low number of observations, we note that the only special feature characterising those days was an increase in volatility for overnight rate quotes from all brokers, including the MID system. This is the result one would expect, if rates vary as a consequence of the change in liquidity demand or supply, until the imbalance is removed.

4.4. Payment and settlement events

The close link between payment and settlement system obligations and certain trading patterns is often overlooked in the financial market literature. In this subsection we are going to address three issues regarding the link between euro overnight market trading and payment system events. First, we are studying the distribution of money market activity between morning and afternoon periods. Then we are asking the question whether settlement transactions in relation to large expiring open market operations are causing repercussions in the overnight market. Finally, we identify the days of our sample in which some disturbance in TARGET or Euro1, the two main large-value payment systems in the euro area, occurred and study whether those caused significant repercussions in euro overnight market trading.

4.4.1. Intraday timing

As argued by Angelini (2000), 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 intraday 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.

In this regard we find some signs of change in the functioning of Italian interbank deposit trading after the euro was introduced. As described by Angelini (2000, 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 and trading volume) was fairly balanced between the first and the second half of the trading day (Fig. 5 and Table 4). For EOM days we find only a very moderate shift of *trading volume* from the afternoon to the morning, if any at all (Fig. 6 and Table 12). Notice that quoting frequency gives the opposite picture in this particular case, namely more numerous price updating in the afternoon than in

[40] Large negative liquidity shocks occurred on 5.11.99, 7.12.99 and 24.1.00 (the latter an Italian tax operation that did not fall on the 23rd because of a weekend, whereas the maintenance period finished the Friday before the weekend), a large positive shock happened on 1.12.00.

the morning of EOM days. This is the source of the weakened link between quoting intensity and trading volume on those special days described above in Section 3.1. As this high quoting activity goes hand in hand with enhanced volatility (Table 12), a plausible explanation for this phenomenon is that the banks that still have reserve holdings above target very actively try to keep the funds away from the market, testing whether they can "squeeze" the potentially few banks that still need liquidity to reach their target with high overnight rates.[41] Alternatively, in case of an aggregate excess of liquidity, the few banks that still want to buy liquidity may test actively very low rates.

The changes in intraday timing for Italy have two possible explanations. First, as observed by Perez-Quiros and Rodriguez (2000), for example, EOM volatility is lower in the euro area than before. This reduces the incentive for risk-averse 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 provides an incentive for risk-averse banks to wait with their transactions until later in the day. 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, which is what our data suggest.

4.4.2. Main refinancing operation settlement days

The weekly MROs lead to very large exchanges of liquidity against eligible assets between the central bank and the market. As described in Section 3.3, each transaction is normally settled on the Wednesday following the expiry of the two-week repo contract. Table 13 compare ticks, volatility and spreads for these MRO settlement days with other "normal" days (excluding Council and MRO auction days).[42] The data indicate that quoting activity, volatility and spreads are hardly changed on MRO settlement days. However, the MID data suggest a massive increase in turnover. The refined picture of Table 14 indicates this tripling of turnover is distributed relatively evenly over the morning and the afternoon, and the changed volume pattern is in no way associated with any noteworthy changes in ticks, volatility or spreads. However, there is no guarantee that the turnover increase on settlement Wednesdays is generally equally large outside the MID system. Since the biggest euro money market traders are normally not active in the MID and since for them MRO settlement transactions are not larger than many other tickets they handle over the day, it cannot be taken for granted that their trading swells on those days in proportion to MID turnover.

In sum, the available evidence suggests that the market deals with the extremely large trading requirements on MRO settlement days with ease and without any sig-

[41] See Nyborg and Strebulaev (2000) for an analysis of money market squeezes in relation to auctions.

[42] Following those criteria out of 19 settlement days happening during our sample period 15 entered the comparison.

Table 13
Average quoting frequency, MID volumes, volatility and spreads in the euro overnight market on "normal" MRO settlement days as compared to "normal" non-MRO settlement days, November 1999 to March 2000 (all brokers)

	DE, ES, FR, NL, UK	Italy	
Intraday period	Pooled "voice" brokers	MID best	MID volumes (in mil. Euro)
Quoting frequency			
MRO settlement days (15)			
Day average	*33.20*	*62.80*	*27287.40*
8:00–11:00	16.87	23.87	9313.68
11:00–14:00	5.07	11.53	5961.41
14:00–17:00	11.27	27.40	12012.31
Other days, excl. GC and MRO days (49)			
Day average	*30.71*	*75.63*	*9319.05*
8:00–11:00	14.37	28.61	3114.16
11:00–14:00	5.90	17.47	2488.31
14:00–17:00	10.45	29.55	3716.58
Volatility			
MRO settlement days (15)			
Day average	*2.74*	*2.25*	
8:00–11:00	2.95	1.89	
11:00–14:00	3.09	2.60	
14:00–17:00	2.20	2.26	
Other days, excl. GC and MRO days (49)			
Day average	*3.32*	*2.70*	
8:00–11:00	4.24	3.03	
11:00–14:00	3.43	3.53	
14:00–17:00	2.13	1.56	
Spreads			
MRO settlement days (15)			
Day average	*4.77*	*2.59*	
8:00–11:00	4.62	3.25	
11:00–14:00	5.16	2.11	
14:00–17:00	4.81	2.22	
Other days, excl. GC and MRO days (49)			
Day average	*5.11*	*2.59*	
8:00–11:00	4.74	3.28	
11:00–14:00	6.12	2.11	
14:00–17:00	5.05	2.21	

Notes: For definitions of quote frequency, volatility and spreads see notes to Tables 4–6. "Normal" trading days on which MRO settlements took place are: 10/11/99, 17/11/99, 24/11/99, 01/12/99, 08/12/00, 15/12/99, 12/01/00, 19/01/00, 26/01/00, 02/02/00, 09/02/00, 16/02/00, 01/03/00, 08/03/00, 15/03/00. 4 MRO settlement days are excluded, because they happened on a day at the end of the minimum reserve maintenance period or during the Y2K changeover week. The control group includes all "normal" days without MRO settlement, without an MRO and without an ECB Governing Council meeting. *Source*: Reuters, e-MID, authors' calculations.

Table 14
High-frequency analysis of average quoting frequency, volumes, volatility and spreads in the Italian MID on "normal" MRO settlement days as compared to "normal" non-MRO settlement week days, November 1999 to March 2000

Intraday period	Quoting frequency	Volumes	Volatility	Spreads
MRO settlement days (15)				
Day average	*67.60*	*30885.5*	*1.18 [1.14]*	*2.58*
8:15–9:00	6.40	199.3	1.90 [1.17]	6.04
9:00–9:45	10.40	3414.6	1.90 [1.03]	2.28
9:45–10:30	3.87	3151.3	1.07 [1.14]	1.88
10:30–11:15	4.33	3045.2	0.79 [1.12]	2.03
11:15–12:00	3.13	1757.3	0.92 [0.90]	1.79
12:00–12:45	3.53	1000.1	0.74 [1.02]	1.47
12:45–13:30	2.47	2504.6	1.30 [0.89]	2.97
13:30–14:15	1.60	335.3	1.16 [1.52]	2.50
14:15–15:00	5.40	1883.5	1.02 [1.27]	2.59
15:00–15:45	7.87	4043.6	1.38 [1.24]	2.16
15:45–16:30	9.00	3360.6	0.95 [1.00]	1.92
16:30–17:15	6.13	2830.8	1.18 [1.26]	2.28
17:15–18:00	3.13	3359.3	1.19 [1.23]	2.77
Other days, excl. GC and MRO days (49)				
Day average	*83.00*	*10592.7*	*1.25 [2.22]*	*2.58*
8:15–9:00	7.78	129.0	2.75 [1.27]	6.66
9:00–9:45	8.49	1232.9	1.60 [0.98]	1.78
9:45–10:30	7.78	1114.8	1.19 [1.01]	1.70
10:30–11:15	6.37	959.1	0.96 [1.24]	2.45
11:15–12:00	5.14	890.8	0.96 [0.89]	1.82
12:00–12:45	4.86	1152.3	0.94 [0.97]	2.08
12:45–13:30	4.06	510.2	0.69 [0.93]	2.31
13:30–14:15	2.04	220.0	0.60 [0.96]	2.39
14:15–15:00	5.78	960.4	1.05 [0.91]	2.02
15:00–15:45	8.00	1113.2	1.12 [1.04]	2.06
15:45–16:30	9.31	969.9	1.12 [1.27]	1.97
16:30–17:15	8.71	803.7	1.77 [1.40]	2.76
17:15–18:00	4.76	536.3	1.18 [1.15]	3.01

Notes: See Table 13. Volumes are in mil. Euro. *Source*: e-MID, authors' calculations.

nificant repercussions. One factor for this calm market may be the revolving nature of MROs, namely that the usual settlement Wednesday is preceded by a Tuesday MRO in which market participants can procure liquidity from the Eurosystem needed on the next day. Another one may be that for the larger players MRO settlement transactions are not of extraordinary size.

4.4.3. Payment system disturbances

If market participants become aware that a disturbance in a major payment system may prevent them from settling transactions with their counterparties, they may become reluctant to enter into new contracts. Hence, severe payment system problems might be associated with large bid-ask spreads and fading trading activity. In

order to check whether such effects can be observed in the euro overnight market, we compared ticks, MID volumes, volatility and spreads for the special payment system days described in Section 3.3 with those observed on "normal" days without late net settlement completion or problems.[43] Since there were few interesting features on those days and since any changes were relatively small, we do not report the results in detail, but rather give a brief summary of them.

It turns out that the special payment system days identified tend to have slightly higher quoting activity for several brokers but not the MID, particularly in the afternoon, right before the systems close. Volatility does not seem to change, except perhaps in the MID where it is slightly up. Bid-ask spreads are slightly higher as well for a few brokers, in particular in the pre-closing afternoon period. However, MID trading volume was even higher than "normal", particularly during the afternoon. In addition, we also scrutinised the only day when there was a problem affecting TARGET, the 1 December 1999. Our data did not show any special features on that day. In sum, the number of days with real payment system problems seem to have been extremely small during the five months examined. Moreover, effects of any payment system problems seem to have been rather contained, so that one cannot reject the hypothesis that the euro overnight market has been relatively resilient to such problems during our sample period. However, apart from the general caveat that the "voice" broker data may sometimes not give a very precise picture, this does not mean, of course, that if a very large and severe payment system crisis was to happen in the future the money market would necessarily remain unaffected by it.

4.5. The year 2000 changeover week

Finally, since our sample extends over the millennium change date, we want to briefly examine how the money market behaved from Christmas 1999 (25 December) to the start of 2000 (3 January). This year 2000 (Y2K) changeover week was regarded as a particular risky episode for financial market participants, because information technology system failures could prevent banks from trading or settling their transactions in the payment system. Therefore, observers anticipated trading in the money and other financial markets to dry up.

Table15 displays ticks, MID volumes, volatility and spreads of the 5 Y2K changeover weekdays, so that they can be compared to those of "normal" days, as contained in Tables 4–6. The first observation is that the days of the millennium date change were particularly inactive in terms of quoting for all "voice" brokers but not the MID. Then, our data show extremely high volatility during the Y2K changeover days (except for the UK-based broker Prebon Yamane, who virtually ceded quoting during this period). For example, this volatility at the changeover to the new millennium tended to be somewhat higher than usually the case at the special

[43] Using the criterion of late Euro1 end-of-day settlement completion and late TARGET closing described in Section 3.3, 19 days in our sample were denoted as being special or having payment system problems. These 19 days also included the only TARGET problem on 1 December 1999.

Table 15
Average quote frequency, MID volumes, volatility and spreads in the euro overnight market on days of the year 2000 (Y2K) changeover week

Intraday period	France	Germany		Spain	Netherlands	UK		Italy	
	GREL	KLIEMM	GEHA	CIMV	PYWMEURO	PYEC	Pooled "voice" brokers	MID best	MID volumes (in mil. Euro)
Quoting frequency (10 days)									
Day average	*0.40*	*2.80*	*3.60*	*8.40*	*1.00*	*1.00*	*17.20*	*74.80*	*8686.21*
8:00-11:00	0.20	2.60	1.60	3.20	0.60	0.20	8.40	17.20	2899.19
11:00-14:00	0.00	0.00	1.20	3.20	0.20	0.20	4.80	26.60	2553.32
14:00-17:00	0.20	0.20	0.80	2.00	0.20	0.60	4.00	31.00	3233.70
Volatility (10 days)									
Day average	*11.46*	*6.23 [1.78]*	*4.00 [0.84]*	*20.84 [2.39]*	*27.26 [34.65]*	*2.30 [0.76]*	13.14 [8.08]	*14.30 [3.77]*	
8:00-11:00			1.61 [0.91]	50.55 [2.81]	48.24 [34.65]	0.73	25.28 [10.04]	2.65 [2.65]	
11:00-14:00	0.58	1.51	1.95 [0.73]	0.68 [2.08]	3.03	1.74	1.58 [1.41]	2.73 [3.57]	
14:00-17:00	22.34	7.41	7.83	1.75 [2.33]	28.88	4.44 [0.76]	12.11 [1.55]	37.52 [5.08]	
Spreads (10 days)									
Day average	*6.00*	*7.86*	*4.22*	*10.67*	*5.60*	*6.80*	*6.86*	*5.52 (7.55)*	
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: For definitions of quote frequency, volatility and spreads see notes to Tables 4–6. Days included in the Y2k changeover week are: 27/12/99, 28/12/99, 29/12/99, 30/12/99, 03/01/00. *Source*: reuters, e-mid, authors' calculations.

end-of-reserve maintenance period days. The huge spikes in Fig. 4 above, almost hitting the marginal lending facility rate level for the MID series on 30 December 1999, illustrate the point. 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. Interestingly, comparing these spreads to EOM spreads suggests that market participants may regard EOM days as slightly more illiquid or risky than the Y2K changeover days. However, in line with the hardly lower MID ticks MID turnovers were only moderately lower than on "normal" Mondays, Thursdays or Fridays.

In sum, the observations on ticks, volatility and spreads are consistent with the hypotheses that traders were more reluctant to enter transactions during the Y2K changeover days and therefore overnight market liquidity dried up, so that sometimes extreme volatility emerged. However, electronic trading in the Italian MID carried on with almost normal turnovers, in spite of large transaction costs and high volatility.

5. Conclusion

In this paper we started the empirical analysis of the euro money market's microstructure. This market is particularly interesting, since it is one of the largest money markets in the world and 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 interest-rate setting bodies, the 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 intraday 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 "two-hump" or "u"-shaped intraday patterns for quoting frequency and a little bit less pronounced for volatility (analogous, for example, to equity and bond markets), but a flatter, sometimes rather weakly (single) "hump"-shaped intraday pattern for bid-ask spreads. High spreads between 11 am and 2 pm may reflect the lower liquidity of the market around the lunch break (in particular when coupled with low turnover) and on certain days the arrival of important information during the midday period. Quoting activity, rate volatility and spreads are relatively high on days with ECB Governing Council meetings (usually Thursdays) compared to non-Council days in the euro overnight market, particularly during midday 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. However, overnight rate fluctuations after the press release detailing monetary policy decisions are not large compared to the usual step sizes of policy rate changes and there is no evidence that trading volume dries up before the release, which is both consistent with the absence of large asymmetric information and relatively precise rate expectations by the market. We also found that ECB releases of M3 figures,

referring to the first pillar of the ECB's monetary policy strategy, are preceded by a moderate increase in short-term volatility, but a very short slump in quoting activity in the half-hour before is not accompanied by a similar slump in trading volume, suggesting only a moderate degree of uncertainty.

Tuesday's Eurosystem main refinancing operations with the open market are associated with high MID trading volumes across the whole day, particularly right after the announcement of the tender allotment results. The latter reflects the post-auction liquidity re-allocation process, which however seems to cause some moderate volatility only for a very short period. Since in addition bid-ask spreads are not particularly high, neither before nor after the announcement of the auction results, one may conclude that — despite large overbidding in the fixed-rate tenders — the overnight market functioned fairly efficiently (without signs of adverse selection or market power) around Eurosystem open market operations. It is also shown that spreads and volatility tend to be very high at the end of the maintenance period for Eurosystem minimum reserve requirements, reflecting the high risks involved for banks when staying too long above or below their reserve targets. Finally, the largest irregular "autonomous" liquidity shocks for the euro money market, operations between national Treasuries and central banks, seem to cause some moderate high-frequency volatility in the overnight market until the imbalances are absorbed.

Turning to the payment system results, most importantly we found that settlement days of Eurosystem main refinancing operations are characterised by very large market turnovers (at least for the Italian electronic trading system MID), which however the market seems to transact with ease and without any increases in transaction costs or volatility. We also argued that institutional changes of EMU led to a balancing of activity between the morning and afternoon trading in the Italian segment. Finally, payment system disturbances seem to have been extremely rare and benign, so that we could not detect any strong signs of difficulty in the overnight market related to the events identified for the two largest euro area payment systems. Last but not least, we illustrated how the Y2K changeover led to very large volatility and bid-ask spreads in the euro overnight market, although the MID did not experience substantial volume reductions during this relatively risky week. Perhaps with the exception of some episodes during the very special Y2K changeover week, overnight rate differentials between brokers located in different euro area countries seem extremely small, even intraday, reflecting the very high degree of integration of this market.

The purpose of this paper has been to review a wide range of microstructure issues for the euro area money market related to the institutional environment of it and other money markets more generally. The euro overnight market is also interesting, because it is probably the financial market that integrated fastest with the EMU. As illustrated by our analysis, remaining cross-country heterogeneities in terms of trading channels and practices do not lead to the emergence of any noticeable cross-border overnight rate differentials, thereby ensuring a single interest rate for the euro area at the short end of the yield curve. The breadth of the present analysis did not allow for going into greater depth on many of the important issues raised. For example, future research could focus on more elaborate analyses of the relationship between money market expectations and ECB Governing Council policy decisions

as well as on the implications of changes in open market operation tender procedures for money market trading and efficiency.

Acknowledgements

The authors are grateful to Bruno Biais, who co-authored an earlier version of this paper, for discussions and guidance, Jürgen von Hagen for his encouragement and an anonymous referee for constructive criticism that helped to improve the paper. They would also like to thank e-MID S.p.A., in particular Francesco Cesarini and Mariella Ghinelli, for providing the data on the Italian MID system, Vincent Brousseau for some programming tricks, Tom Kokkola and Stefania Secola for some inputs on payment systems and the participants of the ECB conference "The Operational Framework of the Eurosystem and Financial Markets" (May 2000) as well as of the CEI conference "Central Bank Operations: Theory and Evidence" at the Bundesbank in Frankfurt (September 2000) for their comments, particularly their discussants Javier Alonso and Juan Ayuso (both Banco de España), Elisabeth Pauly (Banque de France), Kostas Tsatsaronis (BIS) and Godfried de Vidts (European Repo Council). They also appreciated discussions with Ulrich Bindseil, Michael Melvin, Cornelia Holthausen and several market participants, in particular Massimo Ciampolini, Andreas Hauschild, Jan Piet Kastelein, Javier Pazos, Bernd Rohde and Pablo Vergara, and the editorial help by Sabine Wiedemann. Any views expressed are only the authors' own and do not necessarily reflect the views of the ECB or the Eurosystem.

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