THE ITALIAN OVERNIGHT MARKET: MICROSTRUCTURE EFFECTS, THE MARTINGALE HYPOTHESIS AND THE PAYMENT SYSTEM

by Emilio Barucci[*], Claudio Impenna[†], Roberto Renò[‡]

Abstract

This paper analyzes the Italian segment of the Eurozone money market since the start of the European Monetary Union. Some relevant variables are analyzed at different frequencies (intramonth, intraweek and intraday): both level and volatility of the overnight interest rate, volume exchanged in the Italian overnight market, domestic and cross-border large value payments channeled in the Italian real-time gross settlement system (BI-REL). Patterns against the martingale hypothesis on the short-term interest rate are detected, and the relationship between the payment flows and the rate itself is investigated. Overall, evidence comes out that in the new framework Italian banks seem to manage liquidity efficiently.

Keywords: overnight market, interest rate, payment system

Classification:E42,E43,E50.

[*]University of Pisa
[†]Bank of Italy, Payment System Department
[‡]University of Siena

Contents

1 Introduction

The European money market is now a fully developed market with a well defined architecture. This paper analyzes the Italian segment of this market since the start of the European Monetary Union (EMU). While the literature on this topic for the US Federal Funds market is wide, contributions on the Eurozone money market are still limited (Hartmann et al., 2001; Prati et al., 2001; Angelini and Silipo, 2001).

A first goal of the paper is to examine the Italian overnight market since the start of EMU, including the interaction between the money market and the payment system. Through a unique data set of overnight fund exchanges, intraday, intraweek and intramonth patterns in the level and volatility of the overnight rate as well as in fund negotiations are investigated. The existence of relevant seasonalities and the martingale hypothesis (interest rate changes are unpredictable inside a reserves maintenance period and therefore there are no calendar effects) are verified in detail. The relationship between large-value fund transfers and the overnight interest rate established by Furfine (2000) for the US federal funds market is also checked.

A second goal is to evaluate the effect on the market of some features of the European System of Central Banks (ESCB) monetary policy set-up (refinancing auction mechanism, interest rate announcements), the integration of the Italian money market in that of the EMU and the dynamics of reserves during the maintenance period.

As far as the martingale hypothesis and intramaintenance regularities for the interest rate are concerned, there are some similarities with the US federal funds market as well as some differences. The Italian overnight interest rate follows a clear pattern, with a peak at the end of the calendar month and a decline during the last days of the maintenance period (which, in the EMU set-up, goes from the 24^{th} of month t to the 23^{rd} of month $t+1$). Only the first effect is statistically significant; other calendar effects are detected. Previous evidence (Angelini and Silipo, 2001; Angelini, 2000; Hartmann et al., 2001) is only partially confirmed; overall, the results of this paper against the martingale hypothesis are much stronger. The positive relationship between large-value payments and the interest rate (both in levels and volatilities) that is established for the US federal funds market in Furfine (1999, 2000) is not confirmed in the Italian market: the relation between the levels is significant and negative and the relation between volatilities is positive but not significant. The difference between transactions generated by applying an ask and a bid quote is significant in explaining the interest rate prevailing the next day (order flow); the relation is positive (i.e. large ask-bid volume differences reflect liquidity shortage, inducing an increase in the interest rate). This result confirms those obtained for exchange rates (Evans and Lyons, 2002).

Daily volume and volatility are characterized by a strong auto-regressive component. Volume declines on the end of maintenance (EOM) days while volatility, confirming many studies, rises on the same days and at the end of the calendar month. Daily bid-ask spread is fairly constant during the maintenance period and suddenly increases on EOM days. Bid-ask spread and volatility show a similar intramaintenance pattern.

On the intraweek basis, there are no statistically significant dynamics in volume and interest rate; on the other hand, volatility shows a two-peak pattern (on Tuesday and Thursday). Intradaily, a two-peak pattern in volume and interest rate volatility and a decrease in the interest rate level over the day are observed. The last result confirms those obtained in Cyree and Winters (2001) for the federal funds market, but the decline is significant only on EOM days.

As in stock markets (Gallant et al. , 1992), volume and volatility turn out to be linked. This link breaks down on EOM days, when both the intraday dynamics and daily observations show interesting differences. On these days, volatility and volume are weakly linked: volatility is high during the last hours of the day, while exchanges increase at the beginning of the day and of the afternoon. This observation confirms Angelini (2000): banks expecting a high volatility at the end of the day trade in the morning or early in the afternoon. The rationale of these phenomena lies in the peculiarity of the market: trades in the overnight market are executed for hedging reasons (liquidity management) and not for speculative-informative reasons. As a consequence, on EOM days there are fewer exchanges than on other days but volatility is high because interest rate elasticity to liquidity shocks is high.

As far as the functioning of monetary policy is concerned, it is necessary to evaluate the effect on the Italian market of the refinancing auction mechanism and of interest rate announcements by the European Central Bank (ECB). There is a peak in trading volume when auction results are announced (Tuesday at 11.15 a.m.) but it is small and lasts fifteen minutes [1]. Interest rate ECB announcements on Thursday increase interest rate volatility and market exchanges. The change of the refinancing auction mechanism in June 2000 (from a fixed to a variable tender mechanism) has only partially increased the interest rate volatility, as suggested in Nautz (1998).

The relationship between excess reserves and high interest rate on EOM days established in Bartolini et al. (2001a) and confirmed empirically for the US federal funds market is not verified in the Italian money market (Angelini and Silipo, 2001). There are no excess reserves during the last days of a maintenance period, though banks hold more reserves on those days (when the interest rate is low). This pattern indicates that banks optimize their reserve holdings during the maintenance period. The evidence is confirmed by low exchanges on EOM days and by the positive relationship between cash inflow from other EMU countries and the overnight - EONIA interest rate differential. The last result provides evidence of a high degree of market integration in the Eurozone.

The paper is organized as follows. Section 2 contains a brief description of the institutional setting, i.e. the interbank money market, the main features of the Eurosystem's operational framework and of monetary policy conduct, the architecture of the Italian settlement system. The literature on interbank markets, the main empirical regularities and theoretical results are reviewed in Section 3. Section 4 presents the empirical investigation of intramonth patterns and relations of several variables: the overnight interest rate, its volatility, bid-ask spread, and exchanged volume. The relationship between the overnight interest rate, the payment system and bank reserves is also analyzed. In Section 5, intraweek and intraday patterns are considered. The last Section reports the

[1] This result confirms many other studies of the effect of macroeconomic news on high frequency data; e.g. Almeida, Goodhart and Paine (1998) find a significant impact of macroeconomic news on the DEM/USD exchange rate for a short time horizon.

conclusions of the work.

2 The Institutional Setting

Regular patterns of money market interest rates within the maintenance period can largely be explained by the institutional arrangements of both monetary policy management and payment system. A wide number of contributions show that the level and - to a major extent - the volatility of short-term interest rates are significantly different on the EOM days in an averaging reserve requirement regime (see Section 3 for a review of the literature). Moreover, central banks steer short-term interest rates by open market operations, whose features (in terms of frequency, duration and auction regime) play a role in determining transaction expectations in the funds market. Finally, payment system design has an influence - albeit often ignored - on money market equilibrium conditions. The large, dramatic increase in the amount of transferred funds in the last decade has led to the generalized adoption in Western countries of real-time-gross-settlement (RTGS) systems with provision of intraday liquidity. With the exponential growth of both domestic and cross-border financial transactions, uncertainty in bank demand for reserves has become a major driving force for movements in short term rates (Furfine, 1999, 2000).

2.1 The Eurosystem's open market operations

Among the instruments available to the Eurosystem for intervention in the Euro-area money market, the weekly auction ("main refinancing operations", MRO) is by far the most important, both for the amounts (approximately three-quarters of the total liquidity was injected in the Eurozone by MROs in 2000 and 2001, see European Central Bank, 2001, 2002) and for its goals: signaling the current monetary policy stance, steering interest rates, managing liquidity in the system. MRO are conducted on a weekly basis and have a two-week maturity. Normally they are announced on Monday, carried out on Tuesday morning, settled in banks' accounts by National Central Banks (NCBs) on

Wednesday[2]. Therefore, the time interval between the announcement of an MRO and the disclosure of its results is 24 hours. The normal timing of the auction has been determined by the Eurosystem (which can in any case decide to change it for a single auction; European Central Bank, 2000). On Monday afternoon, usually between 3.30 and 4.00 p.m., the Eurosystem announces (on Reuters) that an MRO auction is to be conducted the day after[3]. From Monday afternoon until 9.30 a.m. on Tuesday eligible counterparts (namely, credit institutions) present their bids to the respective NCB. The ECB collects bids in the interval between 9.30 and 10.30 a.m. on Tuesday. The auction takes place until 11.15 a.m.; immediately afterwards results are disclosed and allotments to single counterparts are checked and certified.

MROs can be executed in the form of fixed or variable rate tenders. From the start of EMU to 26 June 2000 they were conducted on a fixed rate base: the rate was decided in advance by the Governing Council of the ECB and counterparts' bids determined the total amount of money transacted against collateral. Since 27 June 2000 MROs are executed as variable rate tenders: counterparts bid both the amount of money they want to transact and the interest rate they are ready to pay for it. Under both types of auction, the ECB decides in advance the fixed amount of liquidity to be supplied through the auction. Auctions of the fixed rate type end up in pro rata allotment of individual bids, which depends on the ratio between total liquidity to be allotted and total bank bids. In auctions of the variable rate type, bids with the highest rates are satisfied first, followed by those with lower interest rates, until the total amount of liquidity to be injected is allotted. The Eurosystem has so far conducted competitive variable rate auctions ("American type" auctions), in which the allotment interest rate is equal for each bank to the offered rate. The Governing Council fixes a "minimum bid rate", which has replaced the fixed rate in signaling the current policy stance to the market. Since

[2] In order to enhance the effectiveness of the operational procedures of monetary policy, the ESCB has recently (January 2003) decided to modify two basic features of policy functioning: i) maintenance periods will be re-defined in such a way that the first days will correspond to the settlement day of the first MRO to be executed after meetings of the Governing Council taking decisions on monetary policy stance (once a month); ii) MRO duration will be reduced from two to one week.

[3] As pointed out in Hartmann et al. (2001), this announcement does not normally contain news for the market. It reconfirms the rate and the standard information on the maturity and technical timing of the auction.

the adoption of the variable rate auction, the ESCB publishes weekly forecasts of the effect of ”autonomous” factors (banknotes in circulation and Government deposits with the Eurosystem) on the liquidity situation in the Eurozone for the period until the day before the settlement of the next MRO (European Central Bank, 2000, 2001). This forecast helps banks to plan their liquidity needs - and therefore their bids for MRO - in the short-term horizon.

The switch to a variable rate tender aimed essentially at bringing counterparts' bids into line with individual liquidity needs. In the former regime, bids consistently exceeded total offered liquidity, which led to low allotment rates (“overbidding”). This phenomenon was reinforced by expectations of rising interest rates, as in the first half of 2000.

2.2 The architecture of the Italian payment system

Our data set includes overnight and “large” (i.e. equal to or greater than Ă 100 million) overnight deposits transacted in the Italian screen-based interbank market (e-MID); the overnight deposit is the shortest term available contract (76 percent of the market in 2000 and 79 percent in 2001; Banca d'Italia, 2001, 2002). The overnight rate reflects the actual degree of availability of short term liquidity in the market and is therefore highly representative of the ESCB monetary policy stance. In the e-MID funds are exchanged between two classes of intermediaries: Italian banks directly participating in the market (163 by the end of 2001) and foreign banks connected to it by remote access (24 at the same date). Whenever an Italian counterpart is involved in the exchange, settlement takes place in the Italian RTGS system (BI-REL).

BI-REL represents the Italian component of the European settlement system, TARGET. It is useful to examine briefly the interaction between the settlement system and the market for liquidity, since this can improve understanding of the time patterns of fund negotiations and interest rates both on a daily and an intraday basis.

In previous empirical investigations of the Italian money market the old settlement regime was considered, i.e. the multilateral net system (Angelini, 1997, 2000). In that system, net multilateral balances stemming from the single money transactions are settled at designated times during the day; in Italy settlement took place approximately at 4.30 p.m.. As a consequence, precautionary behaviour of risk averse banks in the money market and related expectations about the intraday pattern of rates were formulated according to a finite time horizon, ending at 4.30 p.m.. With the full adoption of the RTGS system in January 1998 as part of a unified payment system in the EU, banks' liquidity needs are determined by continuous payment inflows and outflows during the operational day. Due to the technical and institutional features of BI-REL it is possible to identify potential "critical" moments (peaks of liquidity shortage or excess) during the day:

- approximately at 9 a.m. pending payments of various nature are settled automatically. The bulk of them consists of reimbursements of previous days' e-MID contracts. For bank treasurers the resulting amount of liquidity transferred at this time of the day is extremely large;
- at approximately 12 noon banks settle in BI-REL the balance of the net payment system (BI-COMP). Since the 1997-98 reform BI-COMP settles multilateral balances of the subsystems devoted to low-value, retail payments instructed by customers;
- at approximately 12.30 p.m. banks settle in BI-REL the cash leg of the net securities settlement system (SSS), the "Liquidazione dei titoli". This can prove critical for treasurers, owing to the amounts of exchanges in the domestic Treasury bills and stock markets.

In the afternoon, banks mainly settle financial and interbank payments. Payments in the final hours of the day have become more important since the launching of the European settlement system TARGET, as they derive from cross-border transactions carried out in the Eurozone, which are essentially wholesale in nature: cross-border adjustment of single liquidity positions, distribution of funds within corporate banking groups and inventory accumulation of reserves on accounts are carried out in the latest hours of the operational day. This is confirmed by evidence on the average size of payments channeled through TARGET: the lower value, retail cross-border payments (less than 10,000 euros) are mainly settled in the first hours of the day, while the opposite happens for financial transactions (larger than 10,000,000 euros; Banca d'Italia, 2001).

On a daily basis, significant calendar anomalies can be explained by institutional and operating procedures of both the Eurozone reserve regime requirements and the Italian financial and budgetary context. Treasury bonds are issued twice a month, at approximately the middle and the end, and settlement follows the auctions. The 23^{th} of each month is important in two respects. First, in the Eurozone it is the EOM day of the reserve requirement; if the 23^{rd} is a holiday, then the EOM is brought forward to the first preceding working day (the 22nd or the 21st). Second, in Italy (and not in other countries) fiscal disbursements and outflows of the banks to the Treasury take place on the 23rd, too, but with a difference with the EOM: in the case of a holiday, fiscal payments are postponed to the first subsequent working day. This technical feature makes it possible to test separately for statistical significance of the two maturities, the EOM and the "Treasury day".

2.3 The data set

The empirical analysis is based on daily and high frequency data. Daily data span from 4 January 1999 to 31 August 2001, for a total of 685 working days. They include overnight exchanges and average interest rates; daily data on e-MID (Figures 1, 2) are recorded by S.I.A. (*Società Italiana per l'Automazione*) and are split into exchanges generated by applying either a "bid" or an "ask" price[4]. Furthermore, daily data include aggregate payment system flows recorded by the Bank of Italy. Two broad kinds of operation are considered and handled separately: BI-REL domestic debit flows and cross-border debit

[4] Banks participating in e-MID can disclose continously on the screen bid and ask proposals (in terms of both volume and interest rates) for each maturity. Thus, each final exchange is closed by applying either a "bid" or an "ask" proposal of another participant. The difference is obviously important, since *ceteris paribus* "ask" ("bid") contracts will prevail in conditions of liquidity shortage (surplus).

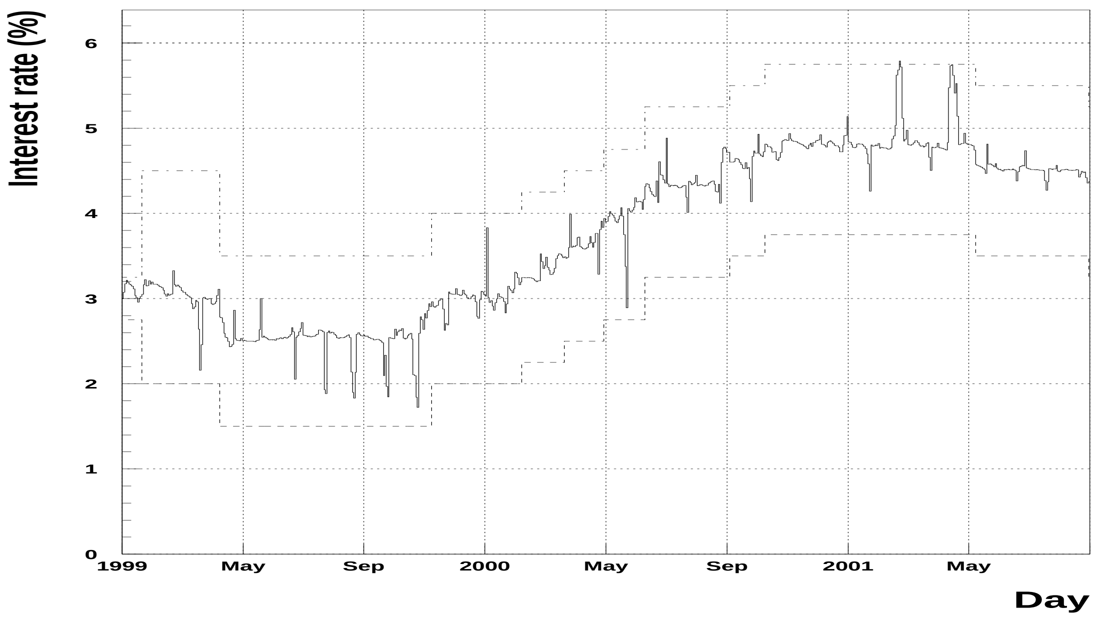

Figure 1: Solid line: daily mean overnight e-MID rate from 4 January 1999 to 31 August 2001. The dashed line is the refinancing rate, the dotted-dashed line is the overnight deposit rate.

and credit payments. The first time series includes large value payments stemming from customer orders and interbank transfers of various kinds. The other series encompasses cross-border inflows and outflows channeled through the European system TARGET; only the interbank component is considered, the most reactive to interest rate differentials and to shocks. On the whole, large-value payments are quite significant for banks' liquidity management: in 2001 the average daily payments (domestic component and cross-border outflows) amounted to Ă 101 billions. Finally, data on the reserve position of the banking system are included. Three daily reserve balances are considered: the required amount (calculated on the previous calendar month), the single day balance and the average progressive position.

Intraday analysis focuses on e-MID, where the available information starts from 1 April 1999, for a total of 587 working days. Data are aggregated on a minute-by-minute

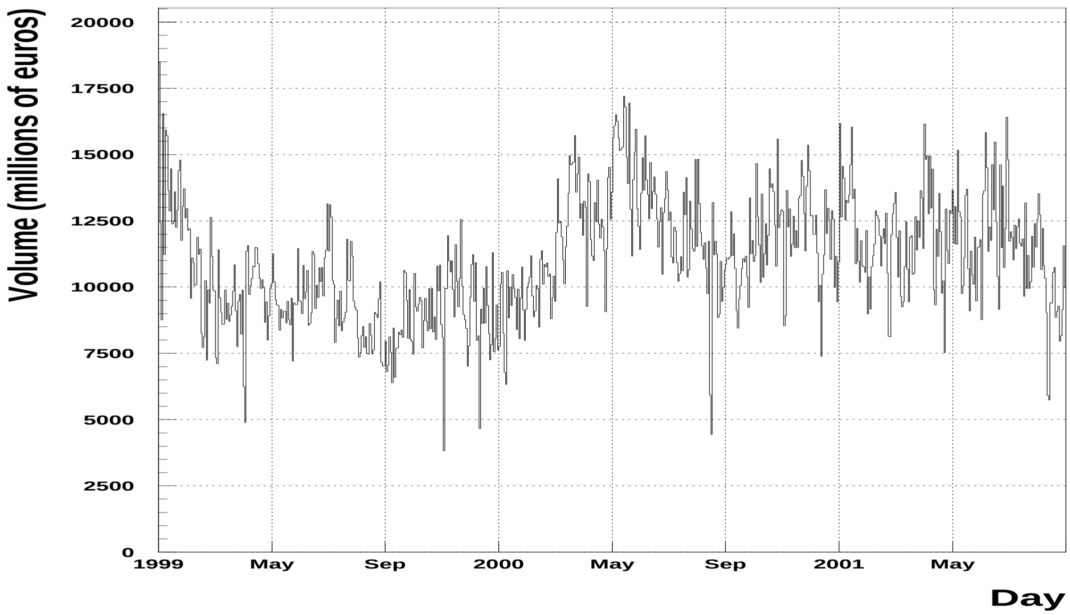

Figure 2: Daily overnight exchanges in e-MID from 4 January 1999 to 31 August 2001.

basis at the system level. Sums of exchanged amounts, number of contracts and weighted averages of interest rates are calculated; in total, 164,699 ticks are considered. Due to data set problems, in some days of 1999 the daily volume does not match with sum of intraday trades. Hence, days where this discrepancy is larger than 5 percent have been discarded (18 days). The average rate in the sample is 3.745, while the average transaction volume per day is 11,013 billions of euros. As explained later in the paper, intraday data are used to compute daily volatility. Figure 3 shows daily volatility in the data sample. Tables 1 and 4 report some summary statistics on volume, volatility and interest rate level.

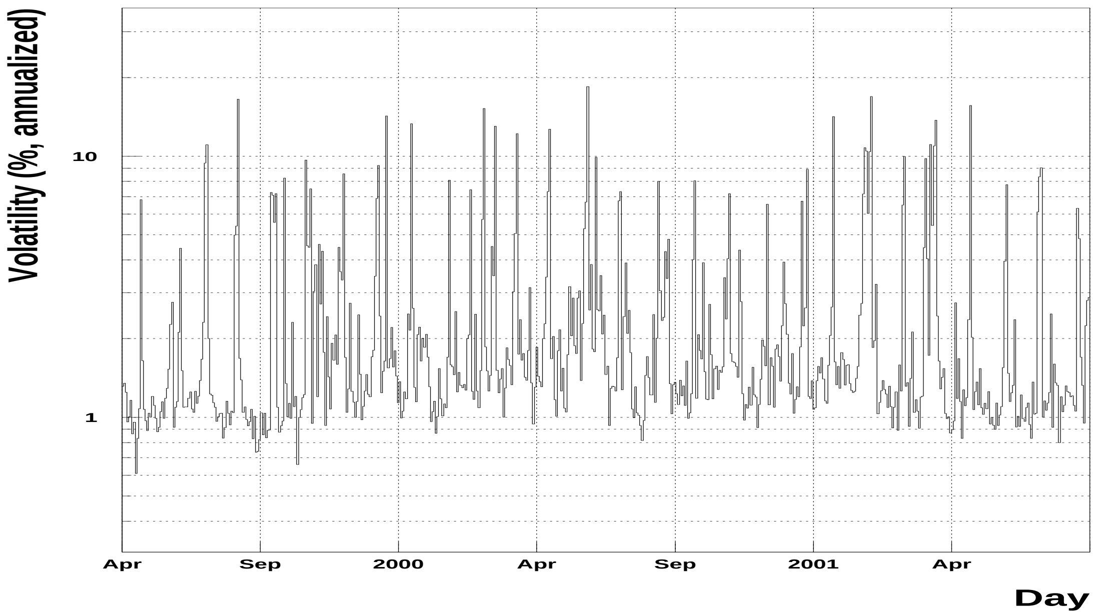

Figure 3: Daily overnight e-MID rate volatility from April, 1^{st} 1999 to August, 30^{th} 2001.

3 Review of the Literature

The literature on the interbank funds market is quite large. Most of it concerns the US federal funds market, while the analysis of the Euro money market is still limited.

The reference model for day-to-day behaviour of the overnight interest rate is the martingale model, which exploits standard no arbitrage equilibrium arguments. The martingale hypothesis implies that interest rate changes should not be predictable, since otherwise banks could exploit interest rate predictability to minimize reserve requirement costs within the maintenance period. The implicit cost of the reserve requirement is represented by the differential between the money market rate and the remuneration

Week day	Number of days	Volume	Rate	Volatility	Bid-ask spread
Mon	113	11208.9	3.71645	3.34	0.0159
Tue	120	11016.5	3.73715	2.93	0.0168
Wed	118	10919.8	3.76537	3.13	0.0142
Thu	119	10891.0	3.75752	3.81	0.0195
Fri	117	11035.1	3.74856	4.21	0.0189

Table 1: Summary statistics for the days of the week (full sample average). Volume is reported in millions of euros, volatility and rate are percentage values, volatility is annualized.

of the requirement,[5] and banks would obviously like to detain reserves to satisfy their requirement when the interest rate is low compared to other days.

Empirical investigations on the US federal funds market show that the overnight interest rate does not satisfy the restrictions imposed by no arbitrage-equilibrium conditions. In particular, the rate follows regular patterns both over the maintenance period and on an intra-week basis. Among others, Campbell (1987), Hamilton (1996) and Bartolini et al. (2001a, 2002) show that the federal funds rate rises on EOM days with a slight decline over the first days of each period.[6] The evidence in the above papers is inconsistent with the martingale hypothesis. The intramonth pattern of the federal funds rate is associated with a pattern in excess reserves, with banks holding a large amount of reserves during the last days of a maintenance period (Bartolini et al., 2001a). On an intraweek basis, the rate tends to fall slightly on Friday and to rise on Monday (Hamilton, 1996). Volatility patterns are also observed: it is significantly higher on EOM than on other days and at the end of the business day (Spindt and Hoffmeister, 1988; Griffiths and Winters, 1995; Cyree and Winters, 2001).

On the whole, the literature on the federal funds market has verified a bunch of seasonalities regarding the level and the volatility of the federal funds rate (Spindt and

[5] It is computed as the average, over the maintenance period, of the marginal MRO rate, see European Central Bank (2001).

[6] Bartolini et al. (2001a) assess an increase of 18 basis points. According to Taylor (2000), this tendency has reversed since 1998, with lower rates at EOM days.

Hoffmeister, 1988; Hamilton, 1996; Bartolini et al., 2002; Furfine, 1999; Prati et al., 2001):

- *end of maintenance*: both the level and the volatility of the interest rate and reserves rise, while on average the interest rate level decreases during a maintenance period;
- *end of the year*: volatility (strongly) increases and the interest rate decreases;
- *end of quarter*: both the rate and volatility increase;
- *end of month*: both the rate and volatility increase;
- *non-trading day*: volatility rises in the first following trading day, rates tend to fall before (three day) holidays and to rise afterwards;
- *week effects*: the rate is low on Friday and high on Monday.

Regularities at end-of-month, end-of-quarter and end-of-year may originate from banks' window dressing practice (Allen and Saunders, 1992).

Higher rates and higher reserves on EOM days cannot be explained according to simple models where banks optimize the time of borrowing and lending bearing an opportunity cost (the differential between the market rate and the remuneration of the requirement). Weekly regularities and intramonth patterns over the maintenance period can be explained better by models based on transaction costs and credit line limits (Campbell, 1987; Hamilton, 1996; Bartolini et al., 2001a). Bartolini et al. (2001a) show that in a model with uncertainty on reserve needs, small transaction costs and central bank intervention to control the supply of reserves, both interest rates and reserves rise on EOM days. Bartolini et al. (2002) build on a similar model to show that volatility is higher on EOM days, when the elasticity demand for reserves declines to zero and the interest rate reacts more strongly to reserve shocks. On EOM days banks are less confident in central bank intervention to cope with liquidity shocks and therefore interest rate volatility rises; for a model explaining the above phenomenon see also Spindt and Hoffmeister (1988). The above patterns are not completely confirmed all over the world (see Prati et al. (2001) for an empirical analysis of the overnight interest rate in G-7 countries and the Eurozone). In particular, rate patterns over the maintenance period display wide differences, but in general the martingale hypothesis is rejected; on the other hand, higher volatility on EOM days is generally confirmed.

A further insight into the federal funds market has been introduced by Furfine (2000), who has verified a significant positive correlation within the maintenance period between daily rate and payment flows, both in levels and volatilities. His model posits a positive correlation between payment values and reserve balance uncertainty. This link helps to explain the above regularities: reserve balance uncertainty generates a precautionary demand for reserves and therefore a higher rate is observed. Furfine (1999) shows that the log of total Fed-wire fund transfers is positively significant in explaining federal fund rate changes.

The literature on the Euro-area money market is quite limited. Angelini (2000) develops a model on the timing of borrowing and lending in the interbank market. A risk averse bank faces two different types of risk during a business day, namely interest rate and liquidity risk (reserve shocks). Operating early during the business day, the bank reduces interest rate uncertainty, but the risk associated with liquidity shocks in the afternoon increases. On the other hand, the bank operating at the end of the business day faces a small liquidity risk. The model predicts that the percentage of trades performed in the early morning should be larger on days when interest rate volatility is higher. Analyzing the overnight rate of the Italian money market (hourly data in the period 1993-96), the author verifies the prediction on settlement days, when the rate volatility is larger than on other days. He does not detect any significant pattern for the interest rate during the maintenance period and during the day; moreover, there is no difference between EOM day patterns and other days. Volume shows a two-peak pattern during a day; the peak is more pronounced in the afternoon of non-EOM days and in the morning of EOM days. Volatility and, to some extent, bid-ask spread show a U-shape pattern; the bid-ask spread is higher late in the afternoon.

Nautz (1998) investigates the presence of a similar effect intramonthly. When future refinancing conditions are uncertain or more costly (higher rate) banks increase their reserves and therefore the money market rate decreases. These predictions are confirmed by the experience of the Bundesbank prior to the start of EMU; the author observes that changes in key interest rates by the Bundesbank up to 1998 reduced uncertainty about future refinancing conditions, leading to money market rate increases.

Quirós and Mendizábal (2000), in turn, compare the behaviour of the German money market rate before the start of EMU and of the EONIA rate afterwards. They find that up to 1998 EOM days were characterized by high rates and high volatility. Since 1999, on EOM days the volatility is not as high as before and the interest rate does not increase. After the start of EMU the model is still rejected, though the interest rate has become closer to a martingale; the authors claim that the effect may be due to the stabilizing role played by deposit facilities.

Angelini and Silipo (2001) have detected the presence of weak seasonalities in the pattern of the EONIA rate. There is some evidence against the martingale hypothesis but it is weaker than in the US market; they observe no effect associated with EOM days. The tom-next rate (the forward contract on the e-MID), used as a proxy for one-day expectations of the overnight rate, turns out to be significant. An analysis of the demand of settlement balances is also proposed.

A descriptive analysis of the Euro money market - including e-MID - with high frequency data is conducted in Hartmann et al. (2001). Analyzing quote arrival rates, it is shown that in all countries - except Italy - activity is heavier on Tuesdays (as a result of the Repo auction) and on Thursdays (when the Governing Council meeting takes place). Post-auction reallocation of funds is quick and efficient. On EOM days volatility is higher in the morning. At the intraday frequency volume shows a two-peak pattern, confirming the effect detected in Angelini (2000). Volatility is high on Tuesday mornings, Thursday and Friday afternoons, and on average shows a U-shaped intraday pattern.

Finally, other studies investigate the effects of the new auction system for MRO adopted by the ECB in June 2000. Bindseil (2001) develops a model showing that announcing liquidity estimates of the banking system should allow lower volatility. Nautz (1998) claims that the conditional variance of the money market rate should be lower with fixed than with variable rate tenders. However, the fixed rate tender mechanism has proved ineffective in allocating liquidity, leading to high overbidding by banks (see subsection 2.1). This phenomenon has made auction results useless as an indicator of monetary policy, motivating the switch to a variable rate mechanism (Nautz and Oechssler, 2000).

4 Intramonth patterns and the martingale hypothesis

Patterns of both level and volatility of the overnight rate, of e-MID exchanges and large-value payment transfers have been evaluated with two different methodologies:

- Equivalence tests on the moments of the distribution at hand, reported in Appendix B;
- Significance of dummy variables associated with calendar effects in an auto-regressive set-up.

By inserting dummy variables it is possible to look for calendar effects on volume, volatility and interest rate and to test the martingale hypothesis. Figure 4 shows patterns in average level and volatility of the interest rate, exchanged values, large-value payments and bid-ask spread during the maintenance period.

The martingale hypothesis - according to which interest rate changes should not be predictable - is the reference model for the overnight rate. The martingale hypothesis on the interest rate has been tested in many papers taking into account interest rate heteroskedasticity. In Hamilton (1996), Quirós and Mendizábal (200), Prati et al. (2001), Furfine (1999) and Angelini and Silipo (2001), a GARCH or an EGARCH model has been estimated handling volatility as a latent variable [7].

[7] Considering a GARCH model, returns are modeled as follows: $r_t = \sigma_t \varepsilon_t$, where ε_t is A sequence of i.i.d distributed random variables distributed as a N(0,1), and the variance is modeled as

$$\sigma_t^2 = \gamma + \alpha \sigma_{t-1}^2 + \beta r_{t-1}^2.$$

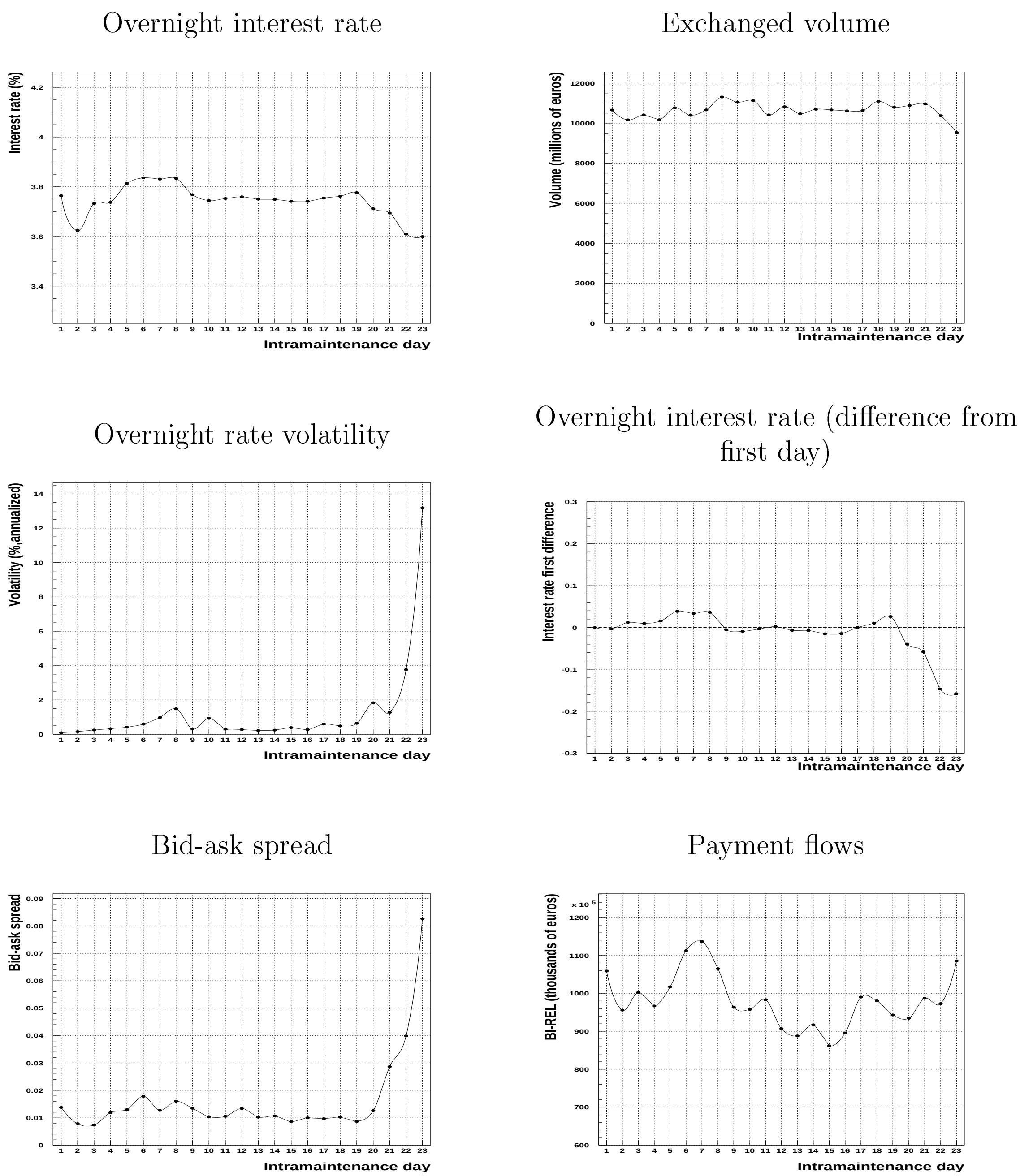

Figure 4: Patterns in the maintenance period; averages over the full sample

4.1 Overnight rate level

As far as the overnight interest rate is concerned, the following model is estimated:

$$i_t - i_{t-1} = \sum_{k=1}^{n_i} \beta_k \left(i_{t-k} - i_{t-k-1}\right) + m_t + \gamma_1(\text{ASK} - \text{BID})_{t-1} + \gamma_2 B_t + \sigma_t \eta_t \qquad (1)$$

where i_t is the overnight rate at day t, n_i is the number of lags, $(ASK - BID)_t$ is the difference between exchanges generated by applying an ask quote and exchanges generated by applying a bid quote, B_t is the wholesale payment values, σ_t is the volatility on day t and m_t is of the form:

$$m_t = \sum_{k=1}^{n_{di}} \beta_k X_k \qquad (2)$$

where X_k are the variables listed in Table 2 (n_{di} denotes the number of dummy variables). Conditional volatility can be computed as the daily integrated volatility with the method described in Appendix A; excluding B_t conditional volatility is σ_t. Handling σ_t as an observable variable (1) is estimated via OLS after dividing both sides by the observed σ_t. This estimation technique can be regarded as a weighted least squares (WLS) estimation, where the weights are daily integrated volatilities. Results are shown in Table 2; the Ljung-Box test rejects the presence of autocorrelation in residuals and in squared residuals. Similar tests have been conducted on the ARCH effect, which decreases from 11.97 for simple OLS estimation to 0.18 for WLS, being distributed as a $\chi^2(1)$. This result shows that the adopted WLS estimation technique allows heteroskedasticity to be removed from the data.

The overnight rate shows patterns over the maintenance period, as described in Figure 4: it increases significantly during the last days of the month, then it behaves approximately like a martingale with a decline on EOM days. However, only the increase at the end of the month is statistically significant, while the decline on EOM days is not (Table 2 and Appendix B). By looking at the auto-regressive coefficients, the martingale hypothesis does not work well: coefficients associated with lagged interest

More complicated variance dynamics give rise to different specifications of GARCH models, e.g. EGARCH models.

Regressor	Coefficient	Standard error
$i_{t-1} - i_{t-2}$	-0.10152***	0.02355
$i_{t-2} - i_{t-3}$	-0.05651***	0.01896
$i_{t-3} - i_{t-4}$	-0.03065*	0.01728
$i_{t-4} - i_{t-5}$	-0.02083	0.01769
$i_{t-5} - i_{t-6}$	-0.03139**	0.01561
constant	0.01658	0.01156
EOM t- 0	-0.01169	0.06444
EOM t- 1	-0.02619	0.02307
EOM t- 2	-0.01221	0.01326
$i_{t-1} - i_{t-2}$*Dummy first maint. day	-0.69606***	0.05847
$i_{t-2} - i_{t-3}$*Dummy first maint. day	-1.32740***	0.08003
$i_{t-3} - i_{t-4}$*Dummy first maint. day	-0.79233***	0.07752
$i_{t-4} - i_{t-5}$*Dummy first maint. day	-0.77526***	0.08815
$i_{t-5} - i_{t-6}$*Dummy first maint. day	-1.11535***	0.12970
End of month	0.05428***	0.01416
End of quarter	0.01739	0.01274
End of year	0.29094	0.27994
First day of month	0.00545	0.00987
First day of the year	-0.44747***	0.03953
Domestic payment volume	-0.00064***	0.00018
Bid-Ask volume t-1	2.61499**	1.02708
Before 3-4 holiday	0.03534**	0.01651
After 3-4 holiday	0.01692	0.01653
Tuesday	0.00748	0.00646
Wednesday	-0.00176	0.00650
Thursday	-0.00253	0.00686
Friday	-0.00253	0.00677
Linear trend ($\times 10^4$)	1.14388**	0.49816
Square time trend ($\times 10^6$)	-0.22426***	0.08267

Table 2: Overnight rate level fit, equation (1) (one star denotes 90 percent significance, two stars, 95 percent, three stars 99 percent); $R^2 = 78.1$ percent; Ljung-Box on residuals: $L(10) = 20.57$; Ljung-Box on squared residuals: $L(10) = 2.87$. The rate is measured in percentage, domestic payment volume and bid-ask volume in millions of euros, time values in days.

rate movements are statistically significant. The above dynamics contrast in part with the evidence detected for the EONIA and the Eurozone by several authors, who did not discover any significant pattern for the interest rate over the maintenance period (Angelini, 2000; Angelini and Silipo, 2001; Quirós and Mendizábal, 2000; Prati et al., 2001). There are other calendar effects: the rate rises after and before 3-4 holiday days, but declines significantly on the first day of the year (Table 2).

As far as the rate on the first day of a maintenance period is concerned, the martingale hypothesis does not provide any insight. As in Angelini and Silipo (2001), there is a clear break in the auto-regressive pattern, see the coefficients of dummy variables associated with the first day of a maintenance period. It has to be remarked that, estimating equation (1) after removing the dependence on the payment values and the bid-ask volume differential, almost the same calendar effects are detected.

As expected, γ_1 is positive and significant: a strong difference between ask and bid originated volume highlights a liquidity shortage inducing an interest rate increase. The increasing relation between the level of the overnight rate and the simultaneous difference between ask and bid volume is illustrated in Figure 5.

It is possible to evaluate the interaction between overnight rate and large-value payment transfers recalling the contributions of Furfine (2000). Examining the US RTGS system Fedwire, he finds a positive and significant correlation between payment flows and the federal funds interest rate, both in level and volatility. In particular, at the end of a maintenance period (which lasts ten days in the US) both payments and overnight rate show an upward peak. Figure 4 shows - among others - the percentage variation of the Italian overnight rate and of payment value during the maintenance period. A clear difference with US data emerges: the rate decreases on EOM days. On the other hand, payment pattern shows a double-spike behaviour, being higher at the end of the month and on EOM days (for the above mentioned reasons); both peaks are statistically significant (see Table 7 and the analysis in Section 4.4). The decline in the interest rate during the EOM period coupled with the increase in payment transfers induces a (statistically significant) negative correlation between the two (see the coefficient of the

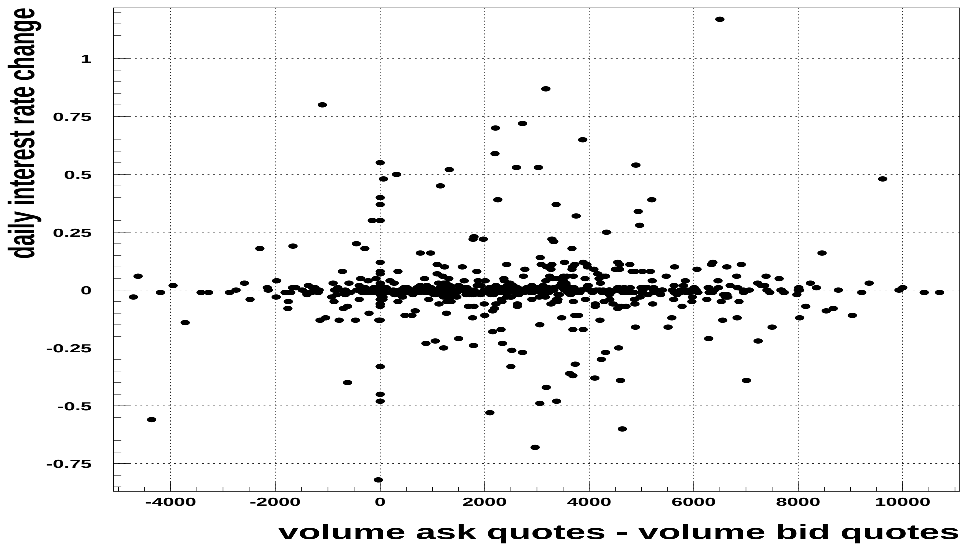

Figure 5: Scatter plot of ask overnight exchanges minus bid overnight exchanges and overnight e-MID rate change.

regression for the rate in Table 2).[8]

4.2 Overnight rate volatility

Measuring volatility is an awkward task. Estimating it via daily observations (by the squared interest rate difference or its absolute value) provides an unbiased but very noisy estimate. Intraday observations can be used to overcome these problems, as suggested in Andersen and Bollerslev (1998), who propose estimating the (integrated) volatility in a day as the cumulative squared intraday returns. By exploiting this procedure, it is possible to estimate more precisely daily volatility and handle it as an observable variable instead of a latent one. Andersen et al. (2001) and Barucci and Renò (2002c) exploit

[8]During the last days of a maintenance period a decrease in e-MID exchanges is also observed. Actually, the upsurge in payments during EOM days is caused by another institutional factor, namely payments to the Treasury (see Section 2).

this key advancement to forecast volatility through a simple autoregressive model[9].

This paper follows this strand of literature to estimate volatility and adopts a method recently proposed by Malliavin and Mancino (2002), which is briefly sketched in Appendix A. The method turns out to be particularly well-suited to estimate volatility through high-frequency data using all the observations with no aggregation. As far as precision is concerned, the method improves that of the cumulative squared intraday returns having a lower variance and no bias in mean as the frequency is increased (Barucci and Renò, 2002a,b).

Let σ_t be the integrated volatility over day t; to include calendar effects on the volatility evolution the following autoregressive model is estimated:

$$\log \sigma_t = \sum_{k=1}^{n_r} \alpha_k \log \sigma_{t-k} + \mu_t + \epsilon_t \tag{3}$$

where n_r is the number of lags in the auto-regressive setting and

$$\mu_t = \sum_{k=1}^{n_d} \beta_k X_k \tag{4}$$

and $X_k,\ k = 1, \ldots, n_d$, is a set of n_d variables reported in Table 3. An advantage of handling volatility as an observable variable is that equation (3) can be simply estimated by OLS, thus avoiding all numerical problems of maximum likelihood estimation associated with standard volatility models. Regression results are shown in Table 3, daily volatility estimates for the full sample are reported in Figure 3. Specification tests in the form of Ljung-Box portmanteau tests on residuals and on squared residuals show that the autocorrelation in residuals was removed as well as heteroskedasticity, as indicated by the test on squared residuals.

In order to check the robustness of these results, a joint estimate of models (1-3) was also performed, using Seemingly Unrelated Regression (SUR) to identify and remove possible sources of correlation among residuals. The results, reported in Appendix C,

[9] In Andersen et al. (2001) a long-memory component is added to a similar model for exchange rates.

Regressor	Coefficient	Standard error
$\log(\sigma_{t-1})$	0.43505***	0.03926
$\log(\sigma_{t-2})$	0.05105*	0.03071
$\log(\sigma_{t-3})$	0.02951	0.02814
constant	-1.43934***	0.14293
EOM t- 0	1.42957***	0.08920
EOM t- 1	0.94825***	0.07713
EOM t- 2	0.44082***	0.07715
EOM t- 3	0.45137***	0.07522
EOM t- 4	0.04022	0.07627
First maintenance day	-0.68279***	0.10355
BCE (Thursday)	0.51420***	0.13038
BCE (Friday)	-0.20796	0.13326
End of quarter	0.06727	0.10931
First day of a new quarter	0.28098**	0.12040
Domestic payment volume	2.16577	1.49595
End of month	0.42057***	0.08581
First day of month	-0.23696***	0.08740
End of year	0.98181***	0.30279
First day of the year	-0.90538***	0.30921
Before 3-4 holiday	0.09601	0.11618
After 3-4 holiday	-0.03255	0.11649
Tuesday	0.07425	0.05037
Wednesday	0.08897*	0.05075
Thursday	0.13106**	0.05137
Friday	0.08739*	0.05130

Table 3: Overnight rate volatility fit, equation (3) (one star denotes 90 percent significance, two stars, 95 percent, three stars 99 percent); $R^2 = 69.08$ percent; Ljung box on residuals: $L(10) = 6.63$; Ljung-Box on squared residuals: $L(10) = 20.98$. The volatility is measured in percentage, domestic payment volume in billions of euros, time values in days.

do not differ qualitatively from those obtained in the main analysis but, given the high level of heteroskedasticity in the residuals of the interest rate equation, standard errors turn out to be much higher. As a consequence, the significance of the autoregressive coefficients cannot be assessed any more, but calendar effects are confirmed and overall

Day of the week	Volume fixed rate	Volume variable rate	Volatility fixed rate	Volatility variable rate	Rate fixed rate	Rate variable rate
2	10659.6	11928.7	3.60	3.08	2.99473	4.66215
3	10551.0	11631.9	2.99	2.87	3.02943	4.67278
4	10502.2	11438.5	2.64	3.52	3.02143	4.68931
5	10307.2	11615.9	4.55	2.98	3.01679	4.67747
6	10408.3	11805.8	3.99	4.40	3.00747	4.65975

Table 4: Summary statistics: fixed and variable rate auctions (full sample average). Volume is reported in millions of euros, volatility and rate are percentage values, volatility is annualized.

the martingale hypothesis is rejected.

Volatility changes remarkably intramonth with a certain degree of persistence. The autoregressive component in volatility is significant, even if it is small (around 0.51) compared to the universal finding on integrated volatility of financial time series.

The main regularities on volatility are shown in Figure 4. Volatility is higher on the last four days of a maintenance period than on other days; it is also high on the last day of a month and of a year. On the other hand, it decreases substantially on the first day of the year and of the maintenance period. Some of these findings are confirmed by tests on the equivalence of moment distributions, see Appendix B.

Interest rate volatility is not influenced by domestic payment values; this holds true if we include cross-border variables. Again these results do not confirm those obtained in Furfine (2000) for the US funds market.

It is possible to evaluate the effect on interest rate volatility of the tender auction regime, which was changed by the ECB in June 2000 (see subsection 2.1). According to Nautz (1998), a variable rate tender mechanism should increase volatility. The evidence on this point is mixed: an increase of the volatility is observed on Wednesday and Friday, a decrease on Monday, Tuesday and Thursday (Table 4). Overall, a decrease is observed but the equivalence between the interest rate volatility with a fixed rate tender and that with a variable rate tender is not rejected (see Appendix B).

4.3 Exchanges in the e-MID and reserves

E-MID transaction values apparently do not show a significant pattern over the month (Figure 4). Denoting by V_t the volume of day t, the following equation is estimated:

$$V_t = \alpha V_{t-1} + \sum_{i=1}^{n_V} \beta_i X_i + \varepsilon_t \qquad (5)$$

where X_i are n_V dummy variables listed in Table 5. The autoregressive component in transactions is strong and significant. The same model has been estimated without the auto-regressive component (Table 6), but R^2 is considerably lower and autocorrelation is not removed from residuals, as highlighted by Ljung-Box tests. Exchanges are high after 3-4 holiday days and low before. An increase over the sample is observed: there is a positive linear trend which is statistically significant. Exchanges decrease significantly during the last two days of the maintenance period (see also Appendix B). On the other hand, exchanges are high on the first day of the maintenance period. It has to be noted that the ECB's interest rate announcements increase transactions in a significant way (see Section 5).

The decline in exchanges on EOM days suggests that banks manage their reserves efficiently, without entering into last minute trades. The same conclusion is drawn regarding banks' liquidity management by looking at the progressive average reserve holdings during the maintenance period, as discussed in Angelini and Silipo (2001). On EOM days, when the overnight rate is low, there are no excess reserves, though banks hold more liquidity than at the beginning of the period, see Figure 6. This evidence is at odds with the behaviour of the US federal funds market and with Bartolini et al. (2001a) (high interest rate and excess reserves during EOM days) but in line with a simple reserve costs minimization model.

Regressor	Coefficient	Standard error
Volume t- 1	0.66806***	0.03096
constant	3267.76025***	356.46893
EOM t- 0	-1112.45984***	304.39618
EOM t- 1	-565.55621*	292.91528
EOM t- 2	191.40161	297.00555
EOM t- 3	290.24606	298.34341
First EOM day	1301.56689***	306.16800
BCE (Thursday)	887.66602*	519.09680
BCE (Friday)	-272.36661	522.52777
End of month	-238.04770	314.40897
End of quarter	31.74009	331.97025
End of year	1728.55103	1202.93884
First day of the year	2346.71460**	1146.68079
Before 3-4 holiday	-502.26459	466.24646
After 3-4 holiday	408.60794	464.26535
Tuesday	-280.93088	196.32553
Wednesday	-54.54891	197.88428
Thursday	-92.13455	203.58620
Friday	197.34831	203.87338
Linear trend	1.55672***	0.39914

Table 5: Fit of the exchanges in the e-MID according to the model: $V_t = \alpha V_{t-1} + \sum_{i=1}^{n_V} \beta_i X_i + \varepsilon_t$, where V_t is the volume at time t and X_i are the regressors indicated in the table (one star denotes 90 percent significance, two stars, 95 percent, three stars 99 percent). $R^2 = 54.59$ percent; Ljung-Box on residuals: $L(10) = 48.06$; Ljung-Box on squared residuals: $L(10) = 32.21$. Volume is measured in millions of euros.

4.4 Domestic and cross-border payments

An autoregressive model is estimated for payment transfers, both domestic and cross-border (Table 7). The specification for large-value payment values, labeled as B_t, is

$$\log B_t = \sum_{k=1}^{n_b} \alpha_k \log B_{t-k} + M_t + \epsilon_t \tag{6}$$

Regressor	Coefficient	Standard error
constant	9895.11523***	243.47833
EOM t- 0	-1360.81445***	409.32452
EOM t- 1	-307.85257	393.84015
EOM t- 2	425.77261	399.40475
EOM t- 3	442.50299	401.36002
First EOM day	374.57797	407.92499
BCE (Thursday)	1472.07788**	697.58258
BCE (Friday)	691.76990	700.57513
End of month	-413.77127	422.94940
End of quarter	406.89954	446.10992
End of year	194.54904	1615.93188
First day of the year	2462.97729	1543.03931
Before 3-4 holiday	-748.25409	627.22729
After 3-4 holiday	-232.63084	623.46759
Tuesday	-286.34174	264.18961
Wednesday	-275.43793	265.93069
Thursday	-348.15152	273.49457
Friday	-13.73053	274.03058
Linear trend	4.81812***	0.49710

Table 6: Fit of the exchanges in the e-MID according to the model: $V_t = V_0 + \sum_{i=1}^{n_V} \beta_i X_i + \varepsilon_t$, where V_t is the volume at time t and X_i are the regressors indicated in the table (one star denotes 90 percent significance, two stars, 95 percent, three stars 99 percent). $R^2 = 18.32$ percent; Ljung-Box on residuals: $L(10) = 1341.27$; Ljung-Box on squared residuals: $L(10) = 454.26$. Volume is measured in millions of euros.

where n_b is the number of lags,

$$M_t = \sum_{k=1}^{n_{db}} \beta_k X_k \tag{7}$$

and $X_k,\ k = 1, \ldots, n_{db}$, is a set of $0-1$ dummies whose list is reported in Table 7. The analysis shows that there is a significant autoregressive component as well as a significant increase at the beginning and at the end of a maintenance period. Increases in payments are also observed on the first and on the last day of a month, due to technical maturities (like the settlement of Treasury payments or periodic settlement of corresponding interbank account balances), which confirms the indication that liquidity

Regressor	Coefficient	Standard error
log BI-REL $t-1$	0.19177***	0.04050
log BI-REL $t-2$	0.12632***	0.03674
log BI-REL $t-3$	0.13743***	0.03709
log BI-REL $t-4$	0.05087	0.03744
log BI-REL $t-5$	0.06392*	0.03551
constant	1.85710***	0.20449
EOM t- 0	0.13752***	0.02344
EOM t- 1	0.05295**	0.02248
EOM t- 2	0.06129***	0.02298
EOM t- 3	0.03053	0.02335
EOM t- 4	0.01305	0.02389
First maintenance day	0.11511***	0.02395
BCE (Thursday)	0.06171	0.03956
BCE (Friday)	0.06402	0.03980
End of quarter	0.01264	0.03286
First day of a new quarter	0.08318**	0.03601
End of month	0.27501***	0.02469
First day of month	0.06894**	0.02838
End of year	-0.02370	0.09302
First day of the year	-0.14613	0.09382
Before 3-4 holiday	0.00921	0.03570
After 3-4 holiday	0.06597*	0.03566
Linear trend ($\times 10^3$)	0.59814***	0.13317
Square time trend ($\times 10^6$)	-0.74624***	0.20652
Tuesday	-0.07278***	0.01616
Wednesdays	0.04060***	0.01557
Thursday	-0.04674***	0.01601
Friday	-0.02525	0.01652

Table 7: Fit for the model of $log(BI-REL)$ outflows, equation (6). $R^2 =$ 59.09 percent (one star denotes 90 percent significance, two stars, 95 percent, three stars 99 percent); Ljung box on residuals: $L(10) = 10.96$; Ljung-Box on squared residuals: $L(10) = 8.92$. Payment volume is measured in billions of euros.

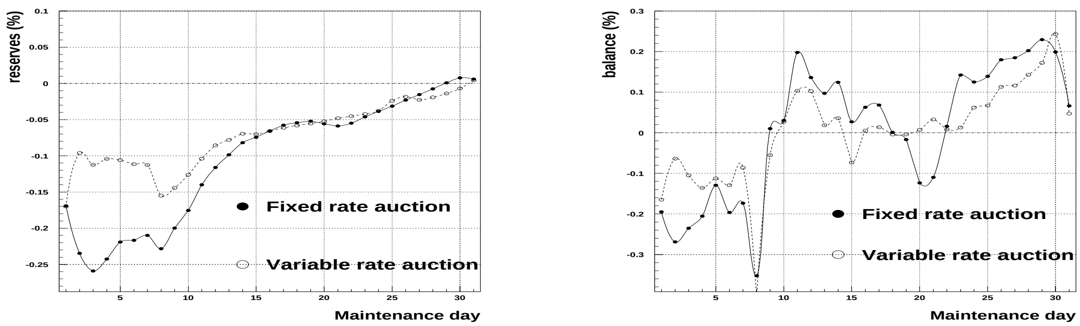

Figure 6: Progressive average reserves (left) and daily balance (right) over the maintenance period (full sample average)

adjustments are carried out by banks.

A closer analysis of the cross-border component makes it possible to evaluate better the degree of bank efficiency in liquidity management and of integration of the Eurozone money market. Since the latter works on a decentralized basis, each regional segment is affected by 'regional' liquidity shocks and institutional peculiarities (e.g. fiscal dates), which in turn can result in short-term interest rate differentials. It is worthwhile investigating whether arbitrageurs operate to exploit such opportunities.

Let T denote the cross-border interbank TARGET payments traffic of banks (inflow and outflow in absolute value). Figure 7 shows the scatter plot of T against the differential between the e-MID and EONIA rate. When the differential is large, cross-border payment activity increases. Let ΔT denote the net balance in cross-border payments from and to Italy. A positive (negative) ΔT indicates net inflows (outflows). Figure 8 shows the scatter plot of ΔT against the differential between the e-MID and EONIA rate. A linear relation between the two is found to be significant. The following regression was performed:

$$\Delta T = \alpha \Delta r + \varepsilon_t, \tag{8}$$

where Δr denotes the e-MID - EONIA rate differential, giving $\alpha = 2.71 \cdot 10^7$ with a $t-$test of 4.72. The mechanism behind this result is simple: when the e-MID rate is lower (higher) than EONIA, foreign countries buy (sell) liquidity in (to) Italy.

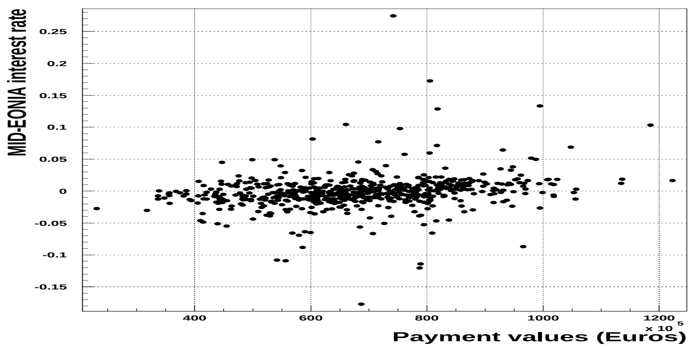

Figure 7: Scatter plot of payment values (X axis) vs. the e-MID - EONIA rate differential (Y axis)

5 Intraweek and intraday patterns

Intraweek volatility patterns are remarkably affected by the refinancing operations mechanism (Table 4 and Appendix B). Before June 2000, in the fixed tender regime, the volatility pattern was U-shaped and the highest volatility level was observed on Thursdays. After the switch to the variable rate tender auction, volatility shows a double peak, on Wednesday and on Friday. After June 2000 there is a strong increase in volatility on Wednesday and Friday and a decrease on Thursday. This evidence can be explained by the change in the refinancing operations mechanism. A variable rate auction introduces more uncertainty in the market than a fixed rate one, and therefore volatility goes up on MRO days (Wednesday). On the other hand, a change of the policy rate by the Governing Council conveys more information in a fixed rather than in a variable rate system, which may explain the decrease in volatility on Thursdays after June 2000.

On the full data set, volatility of the e-MID overnight rate is statistically higher on Wednesday, Thursday and Friday (Table 3); there is a U-shape pattern, volatility being higher on Monday and Friday (Table 1).

Exchanges in e-MID decline over the week with a small increase on Friday. A more

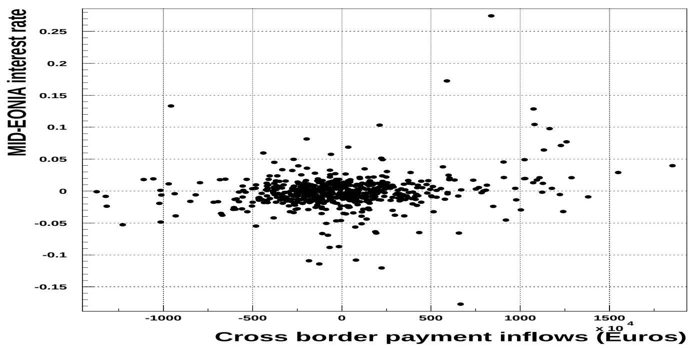

Figure 8: Scatter plot of net cross-border payments inflows vs. the e-MID - EONIA rate differential.

pronounced U-shape pattern is observed since June 2000 (Tables 1 and 4). However, intraweek differences are not statistically relevant[10]. Interest rates are lower on Monday and higher on Wednesday, but this effect is not statistically significant (see Table 2). The result is confirmed in both sub-samples (fixed and variable rate tender).

Analyzing volatility and transaction values on Thursday and Friday separately in days when the ECB has or has not changed policy rates (Table 3 and 5), the announcement of a change makes both values increase, see also Appendix B. In most of the literature on financial markets, public news generates both volatility and volume increases; the two phenomena are linked because agents differ on the interpretation of public news and trade both for hedging and speculative reasons[11]. This is also the case in the interbank market. After an interest rate announcement, banks trade mainly for hedging reasons.

Figures 9 and 10 show that the interest rate level decreases through the day up to 3 basis points (on average). The significance of this decline has been tested by performing an equality test between the distribution of the rate late in the afternoon (4 p.m. - 6

[10]Volume and volatility patterns do not confirm those observed in stock markets (Foster and Viswanathan, 1990, 1993): agents have more private information on Monday and volume is low on that day.

[11]See for example Barucci (2000).

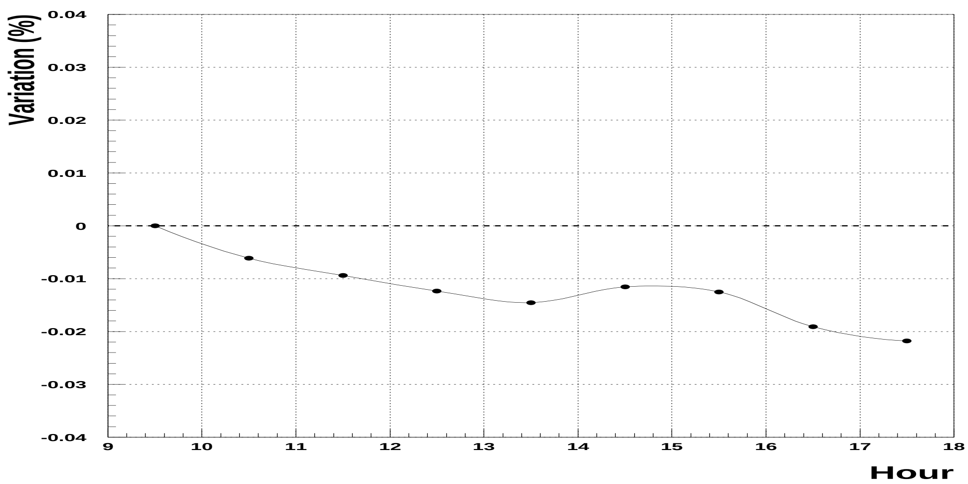

Figure 9: Intraday pattern of the variation of the overnight e-MID rate from its opening value

p.m.) and the rest of the day. Excluding the last two days of a maintenance period, the decline in late afternoon is less than one basis point and is not statistically significant, see Appendix B. On the last two maintenance days the decline is on average more than 10 basis points; the decline is stronger on Thursday before June 2000 and on Friday after June 2000.

Dividing the business day into three time windows (9 a.m. - 12 noon, 12 - 3 p.m., 3 p.m. - 6 p.m.), the average annualized volatility is respectively 2.02, 1.95, 4.08 percent. It declines at midday, slightly but significantly, and rises considerably in the afternoon. Thus, the daily pattern is of a U-shape kind, as shown in Figure 11. The pattern is statistically significant, see Appendix B. Again, the increase in the afternoon is greater during EOM days.

As far as e-MID overnight transaction values are concerned, a two-peak shape is observed in a day (Figure 12), confirming the result of Angelini (2000). After June 2000 an increase of volume in the morning is observed. A similar pattern is detected for the number of contracts (Figure 13). On EOM days - when volatility is higher - the

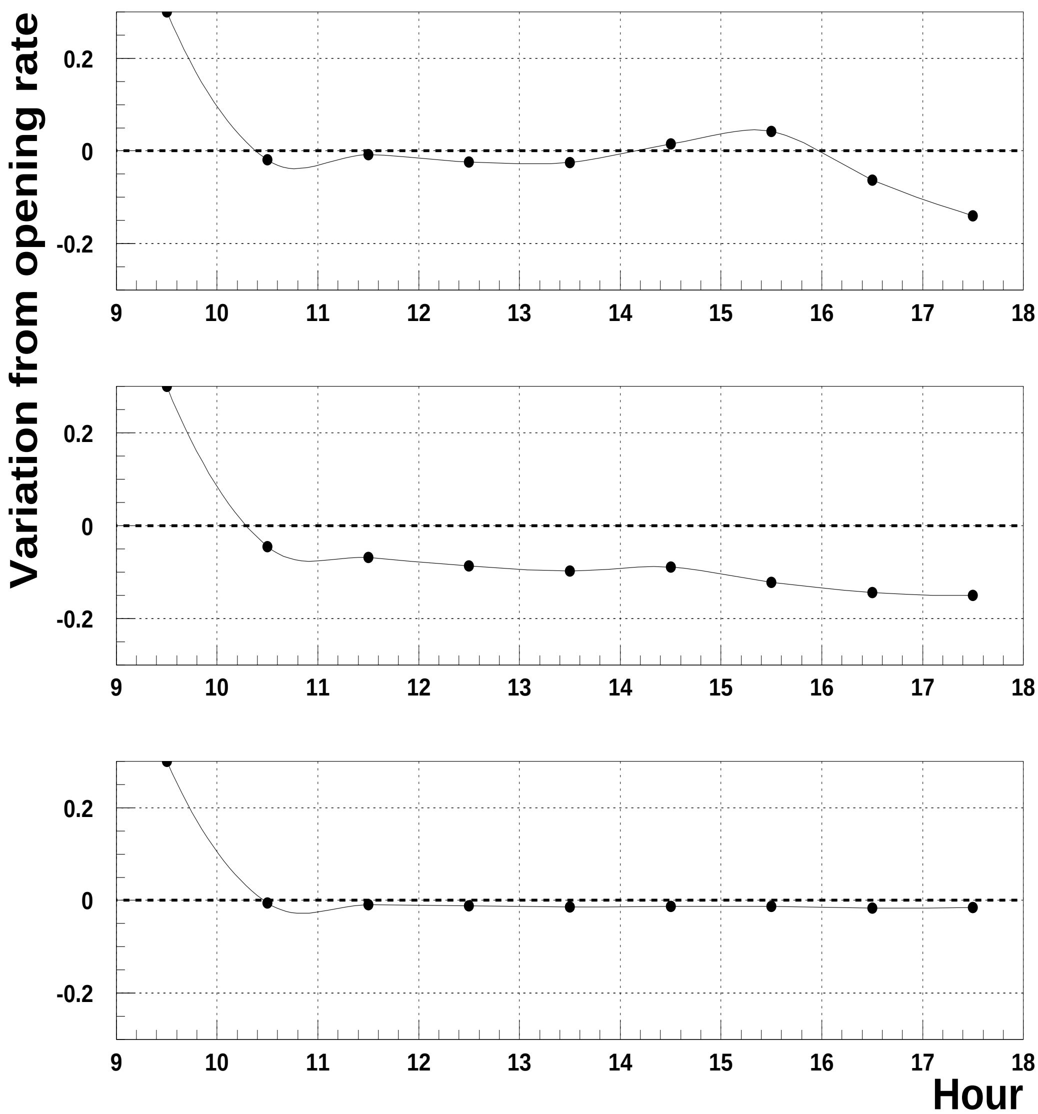

Figure 10: Intraday patterns of the variation of the overnight e-MID rate from its opening value in the EOM day (top), in the first day before EOM (centre) and in the other days (bottom).

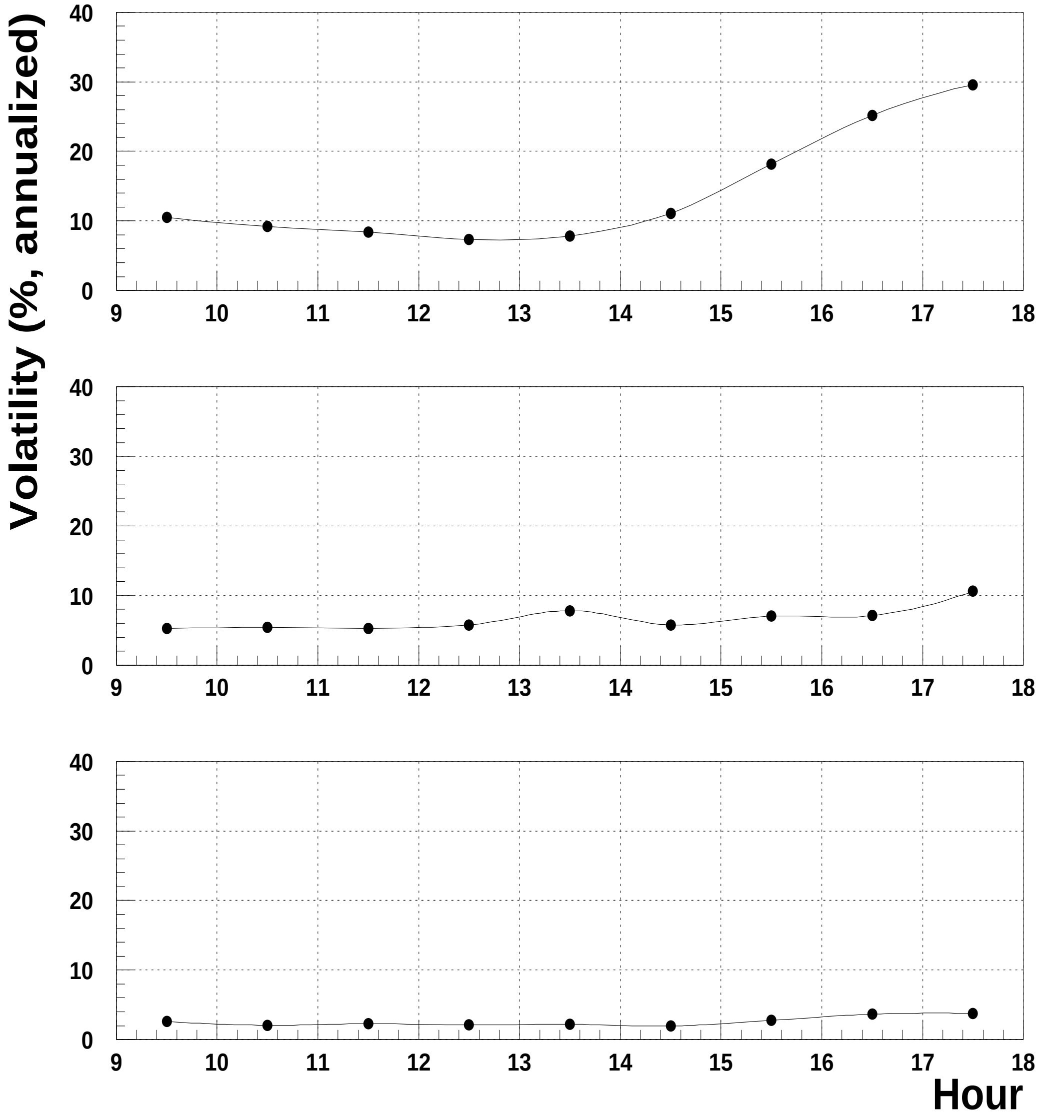

Figure 11: Intraday patterns of the overnight e-MID rate; volatility in the EOM day (top), in the first day before EOM (centre) and in the other days (bottom).

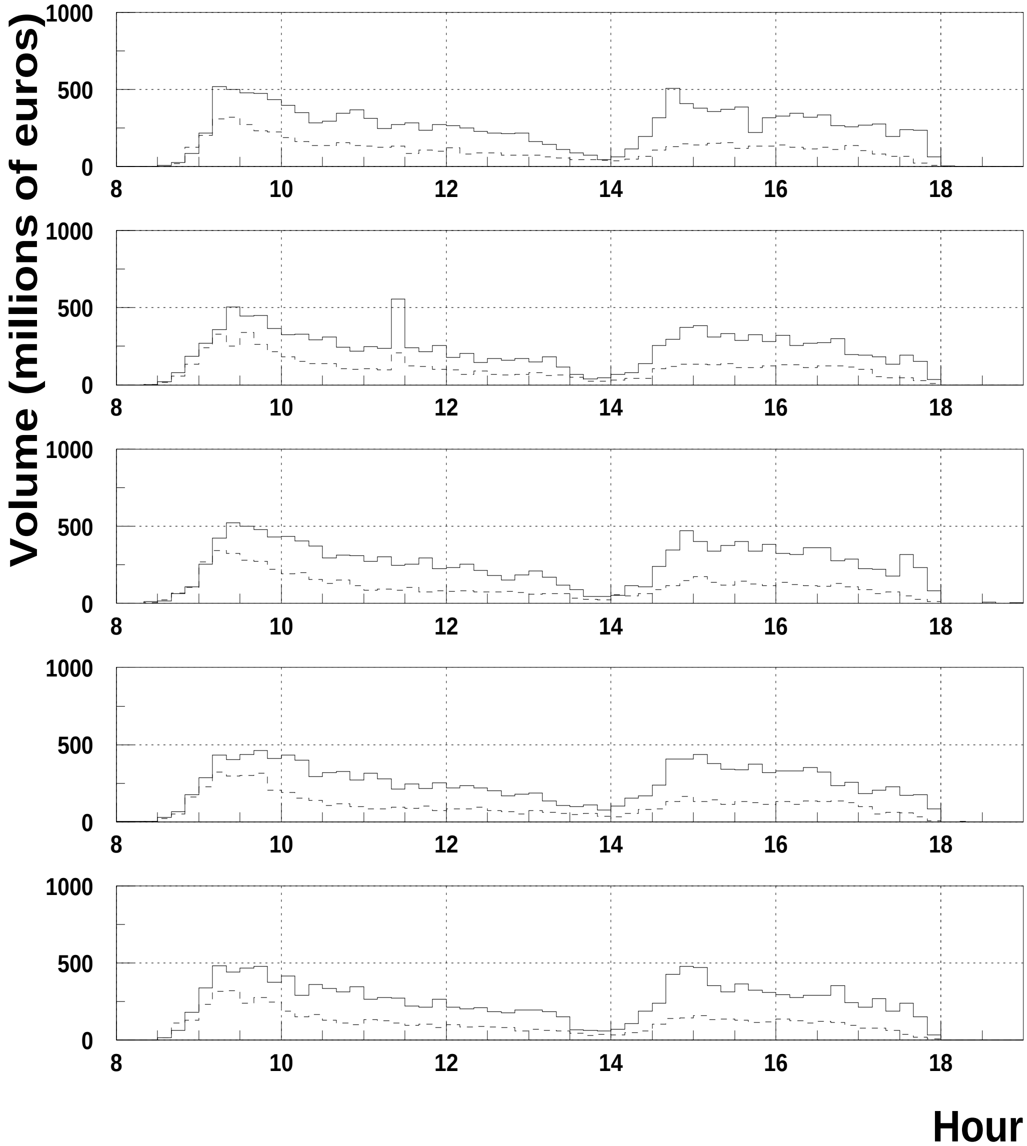

Figure 12: Intraday patterns of the overnight exchanges in e-MID from Monday (top) to Friday (bottom). The solid line refers to the period before 28th June 2001 (fixed rate auctions); the dashed line refers to the period thereafter (variable rate auctions)

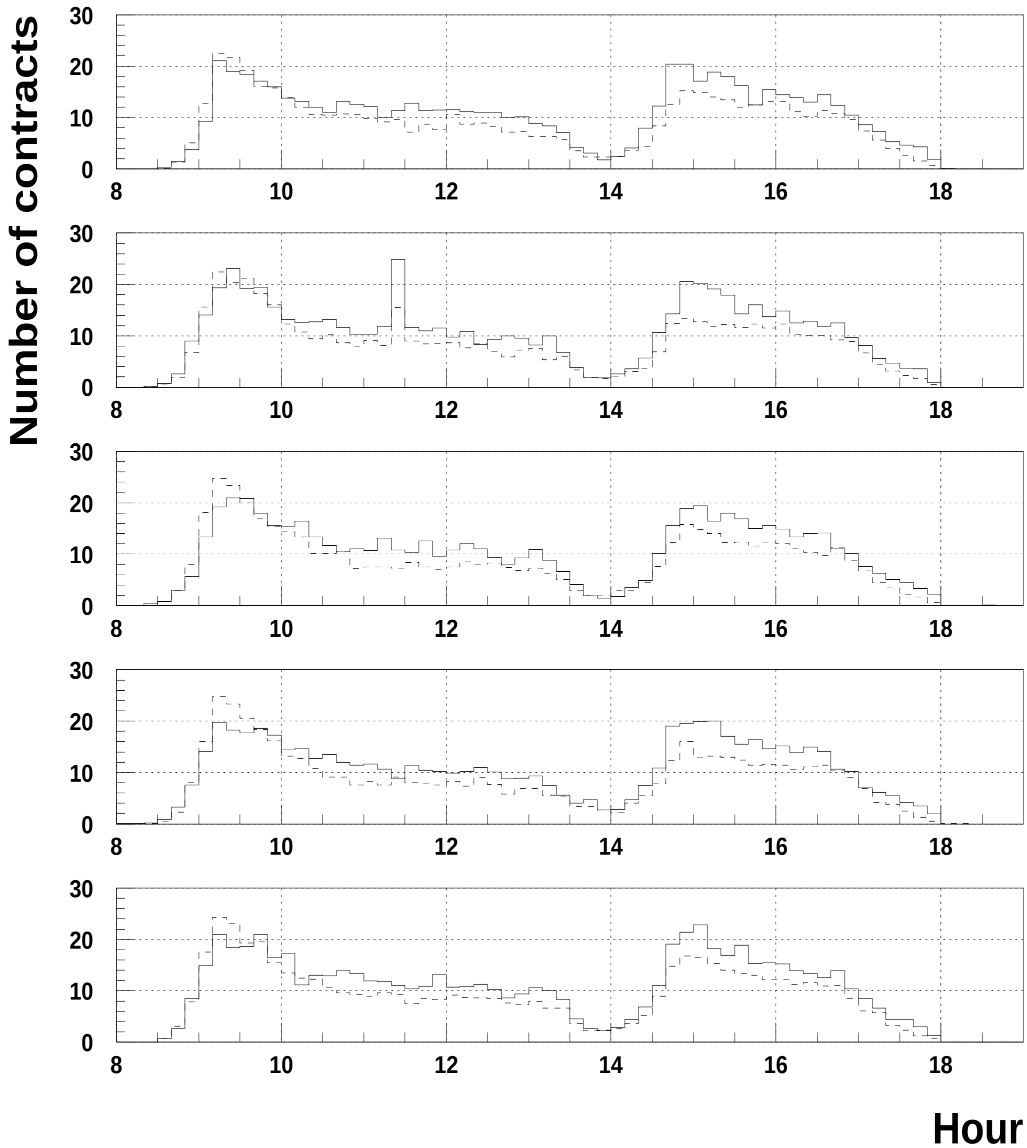

Figure 13: Intraday patterns of the number of overnight e-MID contracts from Monday (top) to Friday (bottom). The solid line refers to the period before 28th June 2001 (fixed rate auctions); the dashed line refers to the period thereafter (variable rate auctions)

percentage of trades in the morning is greater than in non EOM-days (Figure 14). The average percentage of trades between 9 a.m. and 1 p.m. is 59 percent on EOM days and 55 percent on the others, and this difference is statistically significant, see Appendix B. A peak is observed on Tuesday morning around noon, after auction results are released.

Figure 15 shows a direct comparison between intraday volume, number of contracts and volatility. It shows that the volume-volatility correlation is respected if EOM days are excluded from the sample. This is consistent with most of the theories on volume and volatility (see the discussion in Cyree and Winters, 2001). The relation is no more respected on EOM days, when liquidity needs of banks in the afternoon make volatility rise enormously. This observation confirms Angelini (2000): banks expecting a high volatility at the end of the day trade in the morning or early in the afternoon.

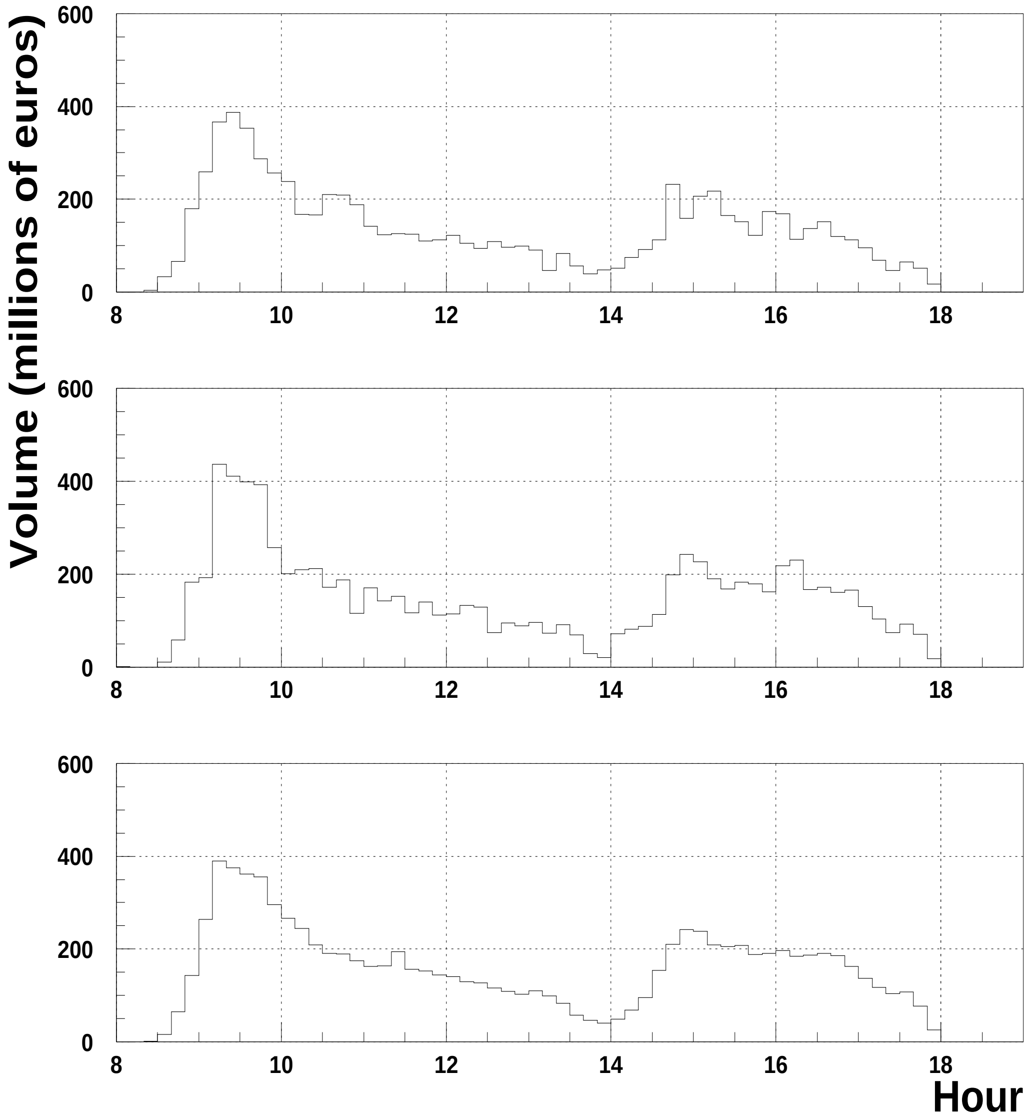

Figure 14: Intraday patterns of overnight exchanges in e-MID in the EOM day (top), in the first day before EOM (centre) in the and other days (bottom).

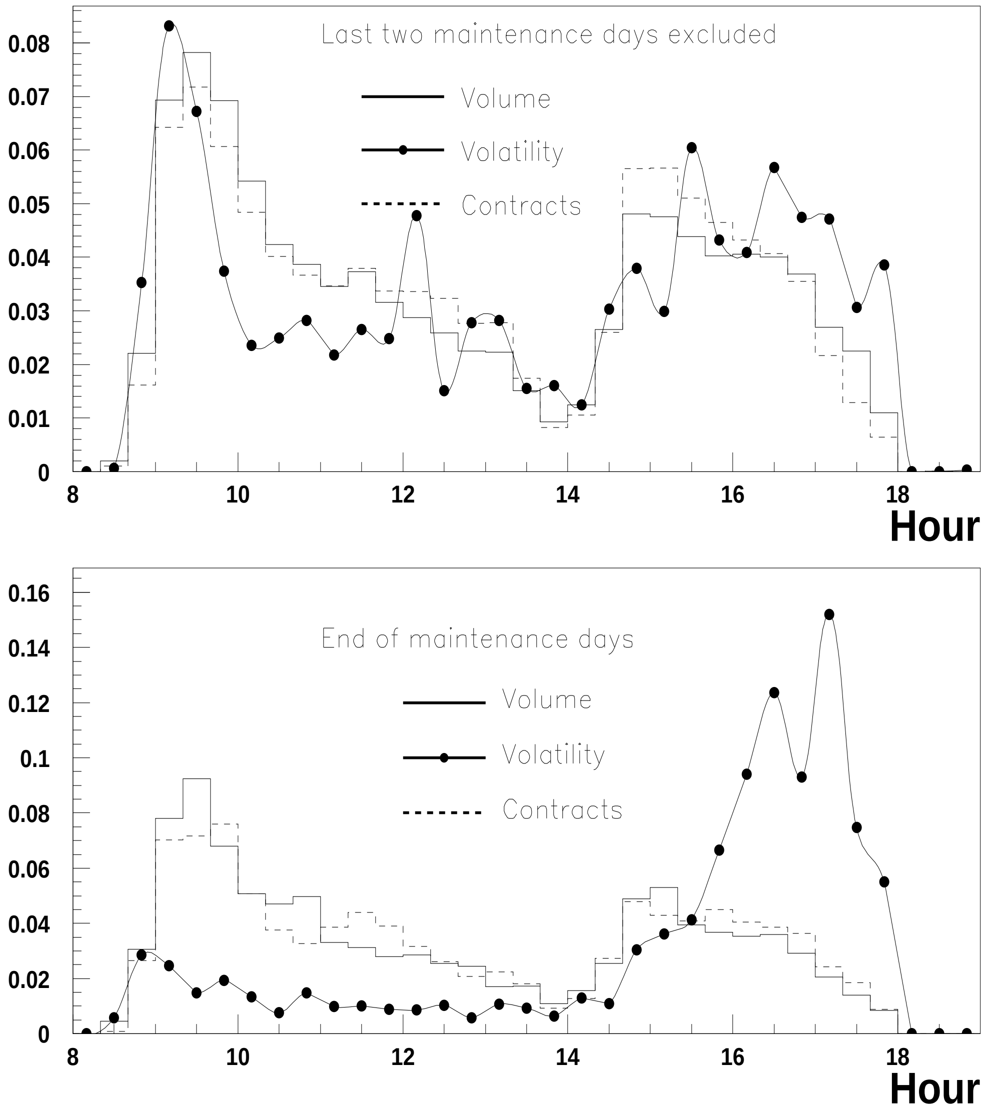

Figure 15: Top: intraday volume, volatility and number of contracts averaged over all days with the exception of the last two maintenance periods. Bottom: intraday volume, volatility and number of contracts averaged over end of maintenance days.

6 Conclusions

The analysis contained in this paper allows us to draw some interesting conclusions on the Italian overnight market.

First of all, it does not conform to the martingale hypothesis. There are patterns in the interest rate that do make it predictable; in particular, it decreases on EOM days and increases at the end of the month. There are other calendar effects in the interest rate, volatility and volume time series. As in many other money markets, volatility is high on EOM days. The connection between payment transfers and the overnight rate established in Furfine (2000) is not confirmed.

The analysis allows us to evaluate some features of the ESCB monetary policy set-up. The refinancing auction mechanism works quite well (there is a moderate peak in volume that lasts for fifteen minutes); interest rate announcements on Thursday increase both volatility and volume. Banks seem to manage their reserves efficiently to minimize opportunity cost: they do not hold excess reserves in the EOM period but hold more reserves on those days (when the interest rate is low). The result is confirmed by the quick reaction of bank cross-border payment flows to short-term differentials within the Euro-area money market.

Appendix A: The Fourier Method

In this Appendix we briefly review the method we adopt to compute volatility, which has been proposed by Malliavin and Mancino (2002).

Let us assume that $p(t)$ follows a diffusion process, its instantaneous volatility is defined as follows

$$\Sigma(t) := \lim_{\epsilon \downarrow 0} \frac{1}{\epsilon} I\!\!E \left[(p(t+\epsilon) - p(t))^2 \,|\mathcal{F}_t \right], \tag{9}$$

where $\mathcal{F}_t$ denotes the filtration at time t. Σ is required to be well-defined (i.e. that the above limit exists) and bounded for every t. The idea behind the Fourier estimator is to compute the Fourier coefficients of Σ from the Fourier coefficients of dp. Let us compress the time interval into which the time series is recorded to $[0, 2\pi]$. The Fourier coefficients of dp are defined as

$$\begin{aligned} a_0(dp) &= \tfrac{1}{2\pi} \int_0^{2\pi} dp(t) \\ a_k(dp) &= \tfrac{1}{\pi} \int_0^{2\pi} \cos(kt) dp(t) \\ b_k(dp) &= \tfrac{1}{\pi} \int_0^{2\pi} \sin(kt) dp(t), \end{aligned} \tag{10}$$

and similar formulas hold for $a_k(\Sigma), b_k(\Sigma)$; from its Fourier coefficients, $\Sigma(t)$ can be obtained point-wise by the Fourier-Féjer inversion formula:

$$\Sigma(t) = \lim_{n\to\infty} \sum_{k=0}^{n} \left(1 - \frac{k}{n}\right) \cdot \left[a_k(\Sigma)\cos(kt) + b_k(\Sigma)\sin(kt)\right]. \tag{11}$$

In Malliavin and Mancino (2002) it is proved that:

$$a_0(\sigma^2) = \lim_{n\to\infty} \frac{\pi}{n+1-n_0} \sum_{s=n_0}^{n} \frac{1}{2} \left[a_s^2(dp) + b_s^2(dp)\right] \tag{12}$$

$$a_k(\sigma^2) = \lim_{n\to\infty} \frac{2\pi}{n+1-n_0} \sum_{s=n_0}^{n} a_s(dp) a_{s+k}(dp) \tag{13}$$

$$b_k(\sigma^2) = \lim_{n\to\infty} \frac{2\pi}{n+1-n_0} \sum_{s=n_0}^{n} a_s(dp) b_{s+k}(dp). \tag{14}$$

where n_0 is a given integer. Thus, formula (12) allows us to compute Fourier coefficients of Σ from the Fourier coefficients of dp, then to reconstruct $\Sigma(t)$ via (11). Anyway, we are not interested in the instantaneous volatility Σ, but in its integrated value over a time window (e.g. a day), defined as

$$\hat{\sigma}^2 = \int_0^{2\pi} \Sigma(s)ds, \tag{15}$$

which in our framework is easily given by:

$$\hat{\sigma}^2 = 2\pi a_0(\Sigma), \tag{16}$$

where $a_0(\Sigma)$ is given by (12).

This estimator is then implemented as follows; since it is not possible to compute the Fourier coefficients of dp directly, they are computed via integration by parts:

$$a_k(dp) = \frac{1}{\pi}\int_0^{2\pi} \cos(kt)dp(t) = \frac{p(2\pi) - p(0)}{\pi} - \frac{k}{\pi}\int_0^{2\pi} \sin(kt)p(t)dt. \tag{17}$$

In financial markets, and in particular in the interbank market, $p(t)$ is not observed continuously. Thus, we need to make an assumption on the interpolation of observations computing the integrals in (10); we assume $p(t) = p(t_j)$ where t_j is the largest observation time before t. Usually, this interpolation scheme is referred to as the previous-tick interpolation, see Barucci and Renò (2002a) for a discussion of this point. Throughout all the computations, we set $n_0 = 1$.

A crucial point is the choice of the maximal M in the expansion (12). As shown in Barucci and Renò (2002a), larger frequencies distort the volatility estimate, mainly because of microstructure effects. This empirical feature does not necessarily affect the volatility estimate; indeed, expansion (12) can be stopped at a proper frequency, so as to rule out microstructure effects. The choice of the stopping frequency M is largely an empirical matter.

Appendix B: Equivalence tests

We performed equivalence tests on the mean and on the median of a distribution (the latter implemented via Kruskal-Wallis and Wilcoxon-Mann-Withney tests). The tests are reported in the following tables.

1) Volume, fixed rate tenders		2) Volume, variable rate tenders	
Mean 1	Mean 2	Median 1	Median 2
10485.7822	11681.0566	9978.2002	11644.7002
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
51.84***		8.22***	67.55***
1) EOM volume		2) Other days volume	
Mean 1	Mean 2	Median 1	Median 2
9828.08008	11070.8027	9766.	11027.
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
9.54***		3.53*	12.49***
1) Perc. afternoon volume, BCE announcement days		2) Perc. afternoon volume, other Thursdays	
Mean 1	Mean 2	Median 1	Median 2
0.496893406	0.452424735	0.535368681	0.454179049
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
2.73*		1.48	2.19
1) Perc. afternoon volume, Thursday		2) Perc. afternoon volume, other days	
Mean 1	Mean 2	Median 1	Median 2
0.45587495	0.440782726	0.463342398	0.438193202
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
3.65*		1.69	2.85*
1) Volume 13-18, Thursday		2) Volume 13-18, other days	
Mean 1	Mean 2	Median 1	Median 2
5852.45703	5446.85449	5812.	5259.
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
7.97***		2.81*	7.90***
1) Volume 13-18, BCE announcement Thursdays		2) Volume 13-18, other Thursdays	
Mean 1	Mean 2	Median 1	Median 2
7052.	5438.21484	6148.	5331.
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
11.68***		2.50	6.26**
1) Perc. Volume 9-13, EOM days		2) Perc. Volume 9-13, other days	
Mean 1	Mean 2	Median 1	Median 2
0.589259505	0.554416597	0.612648666	0.557663083
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
5.24**		2.79*	7.76***
1) EOM rate		2) Other days rate, EOM-1,EOM-2 excluded	
Mean 1	Mean 2	Median 1	Median 2
3.59933114	3.76329803	3.98850012	3.90429997
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.96		0.88	0.77

Table 8: Equivalence Tests. The considered variables are indicated by 1 and 2. The mean and the median of the first variable (Mean 1 and Median 1), of the second variable (Mean 2, Median 2) and the equivalence tests are reported. One star denotes 90 percent significance, two stars 95 percent, three stars 99 percent.

1) EOM day volatility		2) Other days volatility, excluded EOM-1,2,3	
Mean 1	Mean 2	Median 1	Median 2
0.506922662	0.0186950769	0.338691562	0.00660666125
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
580.74***		8.44***	71.16***
1) EOM volatility (fixed rate tenders)		2) Other days volatility, excluded EOM-1,2,3	
Mean 1	Mean 2	Median 1	Median 2
0.595745146	0.0190053117	0.593213499	0.00633845991
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
334.23***		5.75**	33.08***
1) EOM volatility (variable rate tenders)		2) Other days volatility, excluded EOM-1,2,3	
Mean 1	Mean 2	Median 1	Median 2
0.430789083	0.0184012372	0.259371042	0.00690400647
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
269.59***		6.15**	37.81***
1) End of month volatility		2) Other days volatility, last four maint. excluded	
Mean 1	Mean 2	Median 1	Median 2
0.0878663659	0.0142373787	0.0247809663	0.00635223836
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
40.80***		5.77**	33.31***
1) End of quarter volatility		2) Other days volatility, last four maint. days excluded	
Mean 1	Mean 2	Median 1	Median 2
0.0900596455	0.0147653166	0.0133016855	0.00642319443
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
36.82***		3.81*	14.50***
1) BCE announcement days volatility, Thursday		2) Other Thursday volat., last four maint. days excluded	
Mean 1	Mean 2	Median 1	Median 2
0.0389765054	0.0232132003	0.0300946403	0.0065005864
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.26		3.95**	15.62***
1) Volatility 9-12, last four maint. days excluded		2) Volatility 12-15, last four maint. days excluded	
Mean 1	Mean 2	Median 1	Median 2
0.00631481968	0.0060704546	0.00302446797	0.00217699865
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.04		5.97**	35.69***
1) Volatility 15-18, last four maint. days excluded		2) Volatility 12-15, last four maint. days excluded	
Mean 1	Mean 2	Median 1	Median 2
0.0170354377	0.0060704546	0.00311937369	0.00217699865
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
3.46*		6.69***	44.77***

Table 9: Equivalence Tests (continued)

1) Volatility, fixed rate tenders		2) Volatility, variable rate tenders	
Mean 1	Mean 2	Median 1	Median 2
0.0522289984	0.0467964523	0.00749348151	0.00739565399
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.21		0.62	0.38
1) Volatility, fixed rate, Tuesdays, last 4 main days excl		2) Volatility, variable rate, Tuesdays, last 4 main days excl	
Mean 1	Mean 2	Median 1	Median 2
0.0103036603	0.0128616393	0.0066921832	0.00729812495
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.74		0.74	0.55
1) Volatility, fixed rate, Wednesdays, last 4 main days excl		2) Volatility, variable rate, Wednesdays, last 4 main days excl	
Mean 1	Mean 2	Median 1	Median 2
0.010909928	0.0191030446	0.0063234074	0.00615507457
Mean equivalence (t-test)		Wilcoxon-Mann-W hitney	Kruskal-Wallis
0.99		0.27	0.07
1) Volatility, fixed rate, Thursdays, last 4 main period excl		2) Volatility, variable rate, Thursdays, last 4 main period excl	
Mean 1	Mean 2	Median 1	Median 2
0.0362625942	0.0143061373	0.0063661309	0.00703089125
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
1.50		0.85	0.72
1) Volatility 13-15, fixed rate, Wednesdays, last 4 excl		2) Volatility 13-15, variable rate, Wednesdays, last 4 main excl	
Mean 1	Mean 2	Median 1	Median 2
0.0031002257	0.00481689814	0.00125642144	0.00158965401
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
2.31		3.06*	9.34***
1) End of quarter rate		2) Other days rate	
Mean 1	Mean 2	Median 1	Median 2
388.51825	388.085083	379.137451	432.198517
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.00		0.42	0.18
1) End of month rate		2) Other days rate	
Mean 1	Mean 2	Median 1	Median 2
3.76979351	3.74309969	3.89820004	3.83669996
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.02		0.29	0.08
1) Rate between 16 and 18		2) Rate between 9 and 16 (EOM,EOM-1 excluded)	
Mean 1	Mean 2	Median 1	Median 2
3.88990092	3.89659166	4.31938791	4.3256588
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.01		0.52	0.28

Table 10: Equivalence Tests (continued)

Appendix C: SUR estimates

In this Section, we report estimates of model (1)-(3) via the Seemingly Unrelated Regression technique.

Regressor	Coefficient	Standard error
Constant	-1.269428832***	0.096783814
$\log(\sigma_{t-1})$	0.443208849***	0.038932092
$\log(\sigma_{t-2})$	0.050342401*	0.030563097
$\log(\sigma_{t-3})$	0.034914713	0.027952502
EOM day	1.445803217***	0.087471998
EOM t-1	0.947494287***	0.077003780
EOM t-2	0.443569075***	0.076913699
EOM t-3	0.447140107***	0.075169724
First maintenance day	-0.690537226***	0.103181509
BCE (Thursday)	0.518342481***	0.129613045
BCE (Friday)	-0.190698603	0.132121570
End of quarter	0.056368946	0.109248334
First day of a new quarter	0.312417262***	0.119180676
End of month	0.460818702***	0.080141224
First day of the month	-0.230967513***	0.086621369
End of year	0.971924023***	0.303359947
First day of the year	-0.945882433***	0.309249381
Before 3-4 holiday	0.094111116	0.116418353
After 3-4 holiday	-0.022528686	0.116527964
Tuesday	0.064246467	0.049945437
Wednesday	0.096676936*	0.050228149
Thursday	0.124767180**	0.051292280
Friday	0.081569781	0.051376022

Table 11: Overnight rate volatility fit via SUR (one star denotes 90 percent significance, two stars, 95 percent, three stars 99 percent).

Regressor	Coefficient	Standard error
Constant	-0.020308755	0.018301609
$i_{t-1} - i_{t-2}$	-0.004958243	0.037875342
$i_{t-2} - i_{t-3}$	-0.054708319	0.034494449
$i_{t-3} - i_{t-4}$	-0.046845403	0.034458633
$i_{t-4} - i_{t-5}$	-0.052709688	0.033415387
$i_{t-5} - i_{t-6}$	-0.002002891	0.032697384
Linear trend	0.000137279	0.000116974
Square time trend	-0.000000219	0.000000190
EOM day	-0.022528514	0.023959366
EOM t-1	-0.081251541***	0.022573197
EOM t-2	-0.032446728	0.022852342
EOM t-3	-0.058225328**	0.022857133
First maintenance day	0.041268493	0.030651891
$i_{t-1} - i_{t-2}$*Dummy first maint. day	-0.739816340***	0.096919815
$i_{t-2} - i_{t-3}$*Dummy first maint. day	-1.240416911***	0.139699591
$i_{t-3} - i_{t-4}$*Dummy first maint. day	-0.583347914***	0.146418833
$i_{t-4} - i_{t-5}$*Dummy first maint. day	-0.549447857***	0.211904152
$i_{t-5} - i_{t-6}$*Dummy first maint. day	-1.259606889***	0.227164901
End of month	0.078144827***	0.024176955
End of quarter	0.034152337	0.025492992
End of year	0.333016619***	0.092145710
First day of the month	-0.102663103***	0.024004531
First day of the year	-0.483925105***	0.090815460
Before 3-4 holiday	0.075436850**	0.036197054
After 3-4 holiday	0.029927332	0.037096827
Tuesday	0.010874925	0.015301035
Wednesday	0.020008059	0.015277116
Thursday	-0.005684310	0.015398340
Friday	0.006638835	0.015527149

Table 12: Overnight rate level fit via SUR (one star denotes 90 percent significance, two stars, 95 percent, three stars 99 percent).

References

Almeida, A., Goodhart, C. and Payne, R. (1998) The Effects of Macroeconomic News on High Frequency Exchange Rate Behavior. *Journal of Financial and Quantitative Analysis*, 33, (3), 383-408.

Allen, L. and Saunders, A. (1992) Bank Window Dressing: Theory and Evidence. *Journal of Banking and Finance*, 16, (3), 585-623.

Andersen, T. and Bollerslev, T. (1998) Answering the Skeptics: Yes, Standard Volatility Models Do Provide Accurate Forecasts. *International Economic Review*, 39, (4), 885-905.

Andersen, T. Bollerslev, T., Diebold, F. and Labys, P. (2001) Modeling and Forecasting Realized Volatility. *Econometrica*, forthcoming.

Angelini, P. (1997) An Analysis of Competitive Externalities in Real Time Gross Settlement Systems. *Journal of Banking and Finance* 22, (1), 1-18.

Angelini, P. (2000) Are Banks Risk Averse? Intraday Timing of Operations in the Interbank Market. *Journal of Money Credit and Banking*, 32, (1), 54-73.

Angelini, P. and Silipo, P. (2001) The Demand for Settlement Balances in the Euro Area. Mimeo, Bank of Italy.

Balduzzi, P., Bertola, G., Foresi, S. and Klapper, L. (1998) Interest Rate Targeting and the Dynamics of Short Term Rates. *Journal of Money, Credit, and Banking*, 30, (1), 26-50.

Banca d'Italia (2001) Relazione annuale.

Banca d'Italia (2002) Relazione annuale.

Bartolini, L., Bertola, G., Prati, A. (2001) Banks' Reserve Management, Transaction Costs, and the Timing of the Federal Reserve Intervention. *Journal of Banking and Finance*, 25, (1), 1287-1317.

Bartolini, L., Bertola, G., Prati, A. (2002) Day-to-Day Monetary Policy and the Volatility of the Federal Funds Interest Rate. *Journal of Money Credit and Banking*, 34 (1).

Barucci, E. (2000) Teoria dei mercati finanziari. Il Mulino.

Barucci, E. and Renò, R. (2002a) On Measuring Volatility and the GARCH Forecasting Performance. *Journal of International Financial Markets, Institutions and Money*, 12, (3), 183-200.

Barucci, E. and Renò, R. (2002b) On Measuring Volatility of Diffusion Processes with High Frequency data. *Economics Letters*, 74, 371-378.

Barucci, E. and Renò, R. (2002c) Value at Risk with High Frequency Data. In *New Trends in Banking Management*, 223-232. Physica-Verlag.

Bindseil, U. (2001) Central Bank Forecasts of Liquidity Factors: Quality, Publication and the Control of the Overnight Rate. *European Central Bank Working Paper Series*, No. 71.

Campbell, J. (1987) Money Announcements, The Demand for Bank Reserves, and the Behavior of the Federal Funds Rate within the Statement Week. *Journal of Money Credit and Banking*, 19, 56-67.

Cyree, K. and Winters, D. (2001) An Intraday Examination of the Federal Funds Market: Implications for the Theories of the Reverse-J Pattern. *Journal of Business*, 74, 4, 535-556.

European Central Bank, (2000) The Single Monetary Policy in Stage Three: General Documentation on Eurosystem Monetary Policy Instruments and Procedures. November 2000.

European Central Bank, (2001) The Monetary Policy of the ECB.

European Central Bank, (2001) Annual Report.

European Central Bank, (2002) Annual Report.

Evans, M. and Lyons, R. (2002) Order Flow and Exchange Rate Dynamics. *Journal of Political Economy*, 110, 1, 170-180.

Foster, D. and Viswanathan S. (1990) A Theory of Interday Variations in Volume, Variances and Trading Costs in Securities Markets. *Review of Financial Studies*, 3, 593-624.

Foster, D. and Viswanathan S. (1993) Variations in Trading Volume, Return Volatility, and Trading Costs: Evidence on Recent Price Formation Models. *Journal of Finance*, 48, 187-211.

Furfine, C. (1999) The Price of Risk at Year-End: Evidence from Interbank Lending. *BIS Working Paper*, No.76.

Furfine, C. (2000) Interbank Payments and the Daily Federal Funds Rate. *Journal of Monetary Economics*, 46, 535-553.

Gallant, R., Rossi, P. and Tauchen, G. (1992) Stock Prices and Volume. *Review of Financial Studies*, 5, 199-242.

Griffiths, M. and Winters, D. (1995) Day of the Week Effects in Federal Funds Rates: Further Empirical Findings. *Journal of Banking and Finance*, 19, (7), 1265-1284.

Hamilton, J. (1996) The Daily Market for Federal Funds. *Journal of Political Economy*, 104, (1), 26-56.

Hartmann, P., Manna, M. and Manzanares, A. (2001) The Microstructure of the Euro Money Market. *Journal of International Money and Finance*, 20, (6), 895-948.

P. Malliavin, M. Mancino, (2002) Fourier Series Method for Measurement of Multivariate Volatilities. *Finance & Stochastics*, 6, (1), 49-61.

Nautz, D. (1998) Banks' Demand for Reserves when Future Monetary Policy is Uncertain. *Journal of Monetary Economics*, 42, (1), 161-183.

Nautz, D. and Oechssler, J. (2000) The Repo Auctions of the European Central Bank and the Vanishing Quota Puzzle. Humboldt University, Berlin.

Prati, A., Bartolini, L. and Bertola, G. (2001) The Overnight Interbank Market: Evidence from the G-7 and the Eurozone. *Journal of Banking and Finance*, forthcoming.

Quirós, G. and Mendizábal, H. (2000) The Daily Market for Funds in Europe: Has Something Changed with the EMU? *European Central Bank Working Paper Series*, No. 67.

Spindt, P. and Hoffmeister, R. (1988) The Micromechaniscs of the Federal Funds Market: Implications for Day of the Week Effects in Funds Rate Variability. *Journal of Financial and Quantitative Analysis*, 23, (4), 401-416.

Taylor, J. (2000) Expectations, Open Market Operations, and Changes in the Federal Funds Rate. Stanford University.