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E. Barucci, C. Impenna, R. Renò

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Via Cosimo Ridolfi, 10 - 56124 PISA - Tel. Segr. Amm. 050 945231 Segr. Stud. 050 945317 Fax 050 945375
Cod. Fisc. 80003670504 - P. IVA 00286820501 - Web http://statmat.ec.unipi.it/ - E-mail: dipstat@ec.unipi.it

The Italian Overnight Market: microstructure effects, the martingale hypothesis and the payment system

Emilio Barucci
Dipartimento di Statistica e Matematica Applicata all'Economia
Università di Pisa.
Via Cosimo Ridolfi, 10 - 56124 Pisa, ITALY
e-mail: ebarucci@ec.unipi.it
Claudio Impenna
Servizio Sistema dei pagamenti
Banca d'Italia
Via Milano, 60-G - 00183 Rome, ITALY
e-mail: impenna.claudio@insedia.interbusiness.it
Roberto Renò
Dipartimento di Economia Politica
Università di Siena
Piazza S.Francesco 7 - 53100 Siena, ITALY
e-mail: reno@unisi.it

Abstract

We analyze the Italian overnight market since the start of the European Monetary Union. We provide an analysis at different frequencies (intra-maintenance, intraweek and intraday) of both level and volatility of the overnight interest rate, of volume exchanged in the Italian overnight market, of large value payments. We show patterns against the martingale hypothesis and investigate the relationship between the payment system and the overnight rate.

Keywords: Overnight market, Interest rate, Payment system
Classification:E42,E43,E50.

1 Introduction

The European money market is now a fully developed market with a well defined architecture. In this paper we analyze the Italian segment of this market since the start of the European Monetary Union (EMU). Using a data set on overnight fund exchanges at different frequencies we investigate intraday, intraweek and intramonth patterns in the level and volatility of the overnight rate as well as in fund negotiations. We look for seasonalities and we test for the martingale hypothesis. We also analyze the interaction between the money market and the payment system. In particular, we check for the relation between large value fund transfers and the overnight interest rate established by Furfine (2000) for the US federal funds market; in this context, we also look for relationships between the Italian overnight rate - EONIA differential and cross-border money transfers.

The main novelties of our paper can be synthesized as follows. This is the first paper providing an analysis of the Italian overnight market since the start of EMU. Being the Italian overnight rate aligned with EONIA, our analysis provides useful insights also for the European money market, see (Hartmann et al., 2001; Prati et al., 2001; Angelini and Silipo, 2001) for a study of the European money market and of the EONIA. Time series are analyzed handling volatility as a measurable quantity, exploiting high frequency data and the methodology developed in Malliavin and Mancino (2001); Barucci and Renò (2000a). The main results of the paper can be described as follows:

- confirming many studies, volatility of the overnight rate rises at the end of the maintenance period and at the end of the calendar month;
- the overnight interest rate follows a clear pattern during the maintenance period, with a peak at the end of the month and a decline during the last days of the maintenance period. Only the first effect is statistically significant. Furthermore, other calendar effects are detected; these are the main results against the martingale hypothesis; previous evidence (Angelini and Silipo, 2001; Angelini, 2000; Hartmann et al., 2001) is only partially confirmed, our results against the martingale hypothesis are stronger;
- volume is characterized by a strong auto-regressive component with a decline at the end of the maintenance period;
- daily bid-ask spread blows up at the end of the maintenance period;
- the relationship between excess reserves and high interest rate at the end of the maintenance period established in Bartolini et al. (2000) and confirmed for the US Federal Funds market is not verified in the Italian money market; there are no excess reserves during the

last days of a maintenance period, however banks hold more reserves when the rate is low;

- the positive relationship established for the US Federal Funds market in Furfine (1999, 2000) between large value payments and interest rate (both in levels and volatilities) is not confirmed in the Italian market: the relation in the levels is significant and negative, the relation between volatilities is positive but not significant;
- the change of the refinancing auction mechanism in June 2000 (from fixed to a variable tender mechanism) has only partially increased the interest volatility, as suggested in Nautz (1998);
- there is a positive relationship between cash inflow from other EMU countries and the overnight interest rate-EONIA differential, pointing out a high degree of market integration in the Eurozone;
- interest rate announcements by the European Central Bank (ECB) on Thursday increase interest rate volatility and market exchanges;
- on the intraweek basis, there are no statistically significant patterns in volume and interest rate; on the other hand, volatility shows a two peak pattern (on Tuesday and Thursday);
- on the intraday basis, a two peak pattern in volume is observed; volatility of the overnight rate is (significantly) U shaped, and a decrease of the interest rate level over the day is observed, but it is significant only in the last days of the maintenance period;
- the difference between transactions generated by applying an ask and a bid quote is significant in explaining tomorrow interest rate; the relation is positive (i.e. large ask-bid volume differences reflect liquidity shortage, inducing an increase in the interest rate).
- findings in Angelini (2000) on a shift to the morning of volume when volatility is high are confirmed;
- overall, the Italian overnight market differs in many features from the US federal funds market.

The paper is organized as follows. In Section 2 we briefly describe the institutional setting, i.e. the inter-bank money market, the main features of the Eurosystem's operational framework and of the monetary policy conduct, the architecture of the Italian settlement system. In Section 3 we review the literature on inter-bank markets, highlighting the main empirical regularities and theoretical results. In Section 4 we look for seasonalities on a monthly basis for the overnight interest rate, its volatility, bid-ask spread, and exchanged volume. We also analyze the relationship between the overnight interest rate, the payment system and bank reserves.

In Section 5, intraweek and intraday patterns are analyzed. The last Section reports the conclusions of the work.

2 The Institutional Setting

Regular patterns of the money market interest rates within the maintenance period can largely be explained by the institutional arrangements of both monetary policy management and payment system functioning. A wide number of contributions show that the level and - to a major extent - the volatility of short term interest rates are significantly different at the end of a maintenance period ("settlement 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 the money market equilibrium conditions. The large, dramatic increase in the amount of transferred funds in the last decade has led in Western countries to the generalized adoption 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 banks' 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 (European Central Banks System, ECBS) for intervention in the Euro-area money market, the weekly auction ("main refinancing operations", MRO) is by far the most relevant, both for the amounts (three quarters of the total liquidity was injected in the Eurozone by MRO in 2000, see European Central Bank (2001)) and 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-weeks maturity. Normally, they are announced on Monday, carried on on Tuesday morning, settled on banks' accounts by National Central Banks (NCBs) on Wednesday. Therefore, the time interval between the announcement of a 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 PM, the Eurosystem announces (on Reuters) that a MRO auction is to be conducted the day after[1]. Since Monday afternoon till 9.30 AM of 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 AM of Tuesday. The auction is executed till 11.15 AM; immediately afterward results are disclosed and allotments to single counterparts are checked and certified.

MRO can be executed in the form of fixed rate or variable rate tenders. From the start of EMU to the 26^{th} of June 2000 they were conducted on a fixed rate base: the rate was decided in advance by the Governing Council of ECBS and counterparts' bids determined the total amount of money transacted against collateral. Since the 27th of June 2000, MRO 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 banks' bids. In auctions of the variable rate type, bids with the higher 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 conducted so far competitive variable rate auctions ("American type" auctions), according to 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 to the market the current policy stance. Since the adoption of the variable rate-based auction, the ECBS weekly publishes forecasts of the effect of the "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 in line with individual liquidity needs. In the former regime, bids consistently exceeded total offered liquidity, which led to low allotment rates ("overbidding"). This phenomenon has been reinforced by expectations of rising interest rates, like in the first half of 2000. During 1999 the average bidded amount had been 954 billions of Euro, with an allotment rate of 11% (European Central Bank, 2001). In the first half of 2000 average bid jumped to 3614 billions of Euro, with an allotment rate of 2.7%. Finally, in the last two auctions before the adoption of the

[1]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 execution technical timing of the auction.

variable rate tender mechanism the allotment rate dropped to 1%. In the first months of 2000, generalized expectations of higher interest rates pushed market short term rates significantly above the fixed MRO rate. The switch to the new tender system has been successful. The average bid in the second half of 2000 has been equal to 161 billions Euro, with an allotment rate of nearly 60%. Moreover, the average number of counterparts bidding at MRO has dropped from 814 to 640, from the 1^{st} to the 2^{nd} half of 2000.

2.2 The Italian payment system architecture

Our data set includes overnight and "large" (i.e. equal to or greater than 100 millions Euro) overnight deposits transacted in the Italian screen based inter-bank market (e-MID); the overnight deposit is the shortest term available contract (76% of the market in 2000; Banca d'Italia (2001)). The overnight rate reflects the actual degree of availability of short term liquidity in the market and is therefore highly representative of the ECBS monetary policy stance. In the e-MID funds are exchanged among two classes of intermediaries: Italian banks directly participating to the market (185 by the end of 2000) and foreign banks connected to it by remote access (14 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 briefly examine the interaction between the settlement system and the market for liquidity, since this can improve the understanding of time patterns of funds negotiations and interest rates both on a daily and an intraday basis.

In previous empirical investigations on the Italian money market the old settlement regime was considered, i.e. the multilateral net system (Angelini, 1997, 2000). In such a system, net multilateral balances stemming from the single money transactions are settled in designated times during the day; in Italy settlement took place approximately at 4.30 PM. As a consequence, precautionary behavior 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 PM. 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. Payments stem from transactions executed: i) on customers' orders; ii) following autonomous investment decisions by banks (in the FX markets and in the money market); iii) reflecting liquidity transfers to other banks (e.g. among banks belonging to the same group). 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 AM pending payments of various nature are settled automatically. The bulk of them is represented by reimbursements of previous days' e-MID contracts. For banks' treasurers the resulting amount of liquidity transfer at this time of the day is extremely relevant;
- approximately at 12 AM banks settle in BI-REL the balance of the netting payment system (BI-COMP). After the reform of 1997-98 BI-COMP settles multilateral balances of the subsystems devoted to low-value, retail payments disposed by customers: the "Dettaglio" and the "Recapiti locale" (essentially, balance of transactions executed by checks, debt and credit cards, credit transfers, operations at ATM and POS, post-office payment orders);
- approximately at 1.30 PM each bank settles in BI-REL the cash leg of the net securities settlement system (SSS), the "Liquidazione dei titoli". It can reveal critical for banks, due to the amounts of exchanges in the domestic Treasury bills and stock markets.

In the afternoon banks settle mainly 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 on in the latest hours of the operational day. This is confirmed by the evidence on average size of payments channeled through TARGET: the lower value, retail cross border payments (less than 10.000 Euro) are settled mainly in the first hours of the day, while the opposite happens for the financial transactions (larger than 10.000.000 Euro; Banca d'Italia (2001)).

On a daily basis, relevant 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, approximately at the middle and final days of it. Settlement follows the auctions, but takes place in different days for short term (BOT and CTZ) and medium and long term bonds (BTP and CCT), respectively (usually it is positioned on the 1st and 15th of each month for BOT and CTZ, in the days after for other bonds). The 23^{th} of each month is relevant under two respects. First, in the Eurozone it represents the 'end-of-maintenance' (EOM) day of the reserve requirement; if the 23^{th} is a holiday day the EOM is anticipated 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 case of holiday,

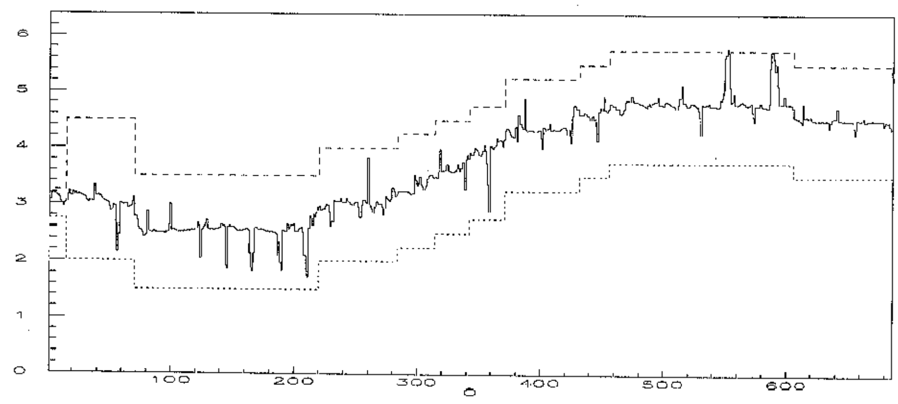

Figure 1: Daily mean overnight e-MID rate from January, 4^{th} 1999 to August, 30^{th} 2001. The dashed line is the refinancing rate, the dotted line is the overnight deposit rate.

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 January, 1^{st} 1999 to August, 31^{th} 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 splitted into exchanges generated by applying either a 'bid' or an 'ask' price, which is important in order to detect microstructure effects of the market in different liquidity macro-conditions [2]. Furthermore, daily data include aggregate payment system flows, recorded by the Bank of Italy. Two broad kinds of operations are considered and separately handled: BI-REL domestic debit flows and cross border debit and credit payments. The first time series includes large value payments stemming from customers' 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

[2] Banks participating to e-MID can disclose in the screen on a continuous basis 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 relevant, since ceteris paribus 'ask' ('bid') contracts will prevail in a liquidity shortage (surplus) condition.

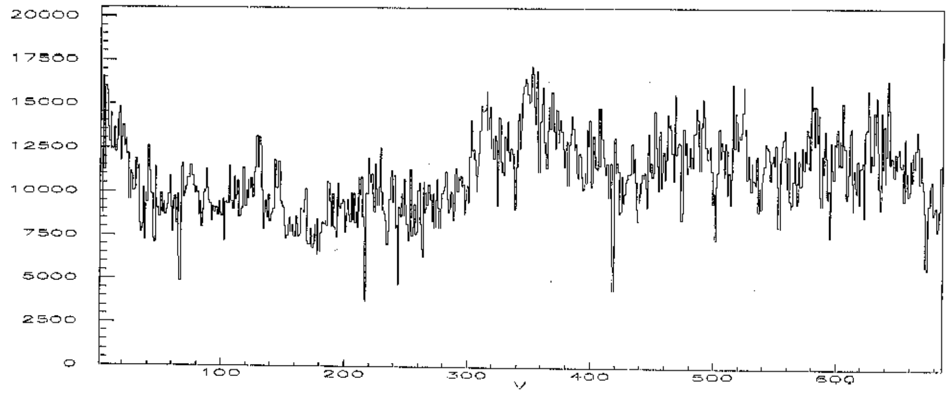

Figure 2: Daily overnight exchanges in e-MID from January, 4^{th} 1999 to August, 30^{th} 2001.

the whole, large value payments are quite relevant for banks' liquidity management: in 2001 the average daily payments (domestic component and cross border outflows) amounted to 101 billions of Euro. Finally, data on 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 start from April, 1^{st} 1999, for a total of 587 working days. Data are aggregated on a minute-by-minute basis at the system level. Sums of exchanged amounts, number of contracts and weighted averages of interest rates are calculated; totally, 164,699 ticks are considered. Due to data set problems, in some days of 1999 daily volume does not match with the sum of intraday trades. Hence, days where this discrepancy is larger than 5% have been discarded (18 days). The average rate in the sample is 3.745, while the average transaction volume per day amounts to 11.013 billions of Euro. As explained later in the paper, we use intraday data to compute daily volatility. Figure 3 shows daily volatility in the data sample. Tables 1, 2, 3 report some summary statistics on volume, volatility and interest rate level.

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 behavior of the overnight interest rate is the martingale

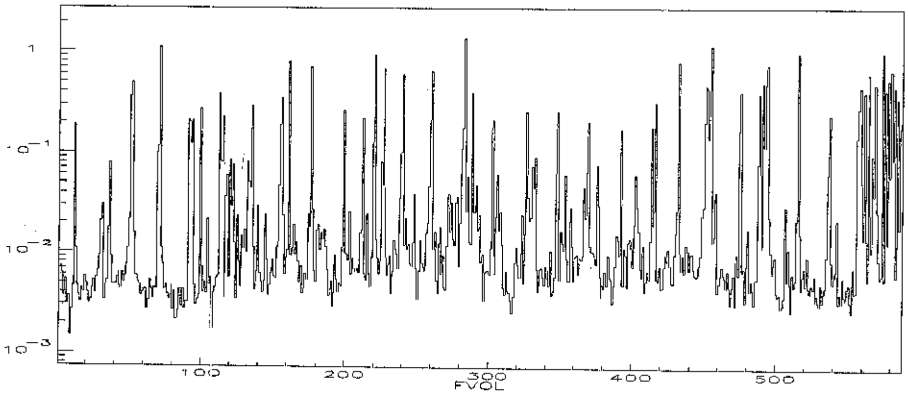

Figure 3: Daily overnight e-MID rate volatility from April, 1^{st} 1999 to August, 30^{th} 2001.

Day	Number of days		Average volume		Average volatility	
	normal days	ECB int.	normal days	ECB int.	normal days	ECB int.
5	128	11	10778.3	12202.1	0.067028	0.055599
6	125	11	10965.6	11825.6	0.080716	0.032719

Table 1: Summary statistics for the days when ECB changes reference rates (full sample average)

model, which exploits standard no arbitrage arguments. Banks consider funds with different maturities as perfect substitutes and therefore no patterns should be observed in the interest rate time series within a maintenance period. The martingale hypothesis implies that interest rate changes should not be predictable, otherwise banks could exploit interest rate predictability in order to minimize reserve requirement costs within the maintenance period. The implicit cost of reserve requirement is represented by the differential between the money market rate and the remuneration of the requirement,[3] and therefore banks would obviously like to detain reserves to satisfy their requirement when the interest rate is low compared to other days.

Empirical investigations on US Federal Funds market show that the 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); Bartolini et al. (2000, 2001) show that the federal

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

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	0.05182	0.04939	2.99473	4.66215
3	10551.0	11631.9	0.03585	0.07511	3.02943	4.67278
4	10502.2	11438.5	0.02790	0.05827	3.02143	4.68931
5	10307.2	11615.9	0.08272	0.05094	3.01679	4.67747
6	10408.3	11805.8	0.06376	0.08920	3.00747	4.65975

Table 2: Summary statistics: fixed vs. variable rate auctions (full sample average)

Week day	Number of days	Volume	Rate	Volatility	Bid-Ask spread
Mon	113	11208.9	3.71645	0.05058	0.0159
Tue	120	11016.5	3.73715	0.05515	0.0168
Wed	118	10919.8	3.76537	0.04386	0.0142
Thu	119	10891.0	3.75752	0.06616	0.0195
Fri	117	11035.1	3.74856	0.07702	0.0189

Table 3: Summary statistics for the days of the week (full sample average)

funds rate rises at the end of the maintenance period (EOM) with a slight decline over the first days of each period.[4] The evidence in the above papers is inconsistent with the martingale hypothesis. The intramonth pattern of the federal funds rate is associated to a pattern in excess reserves, i.e. banks hold a large amount of reserves during the last days of a maintenance period (Bartolini et al., 2000). On an intraweek basis, the rate tends to fall slightly on Fridays and to rise on Mondays (Hamilton, 1996). Patterns in volatility of the rate are also observed: it is significantly higher in settlement days than in other days and at the end of the business day, (Spindt and Hoffmeister, 1988; Griffiths and Winters, 1995).

The above papers on the Federal Funds market discovered also a bunch of seasonalities regarding the level and the volatility of the federal funds rate (Spindt and Hoffmeister, 1988; Hamilton, 1996; Bartolini et al., 2001; Furfine, 1999; Prati et al., 2001):

- *end of maintenance*: both the level and the volatility of the interest rate and reserves rise; the interest rate level decreases during a typical maintenance period;
- *end of the year*: volatility (strongly) increases and the interest rate decreases;
- *end of quarter*: both the rate and volatility increase;

[4] Bartolini et al. (2000) assess an increase of 18 basis point. According to Taylor (2000), this tendency has been reverted since 1998, with lower rates at EOM days.

- *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 afterward;
- *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 bank's window dressing (Allen and Saunders, 1992).

Higher rates and higher reserves during EOM days cannot be explained according to simple models where banks optimize the time of borrowing and lending with an opportunity cost given by the differential between the market rate and the remuneration of the requirement. Models based on transaction costs and credit line limits help to explain weekly regularities and intramonth patterns over the maintenance period (Campbell, 1987; Hamilton, 1996; Bartolini et al., 2000). Bartolini et al. (2000) show that in a model with uncertainty on reserve needs, small transaction costs and Central Bank's intervention aiming at controlling the supply of reserves, both interest rates and reserves rise around the EOM period. Bartolini et al. (2001) build on a similar model to show that volatility is higher on EOM days, when the elasticity demand for reserves declines toward zero and interest rate reacts more strongly to reserve shocks. In the EOM period banks are less confident on a Central Bank's 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 the martingale hypothesis is in general rejected; on the other hand, higher volatility in settlement days is generally confirmed.

A further insight on 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 provides a motivation to 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 funds transfers is positively significant in explaining federal funds rate changes.

The literature on the Euro-area money market is quite limited.

Angelini (2000) proposed a model on the time 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 (reserves shocks). Operating early during the business day, the bank faces little interest rate uncertainty but a large risk associated to liquidity shocks in the afternoon. 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 in days when interest rate volatility is higher than in other days. Analyzing the overnight rate of the Italian money market (hourly data in the period 1993-1996), the author verifies the prediction on settlement days, when the rate volatility is larger than 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 days patterns and other days. Volume shows a two peak pattern in 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 inside a day; the bid-ask spread is higher late in the afternoon.

Nautz (1998) investigates the presence of a similar effect intramonthly. The main result of his model is that 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 Bundesbank experience prior to the start of EMU; the author observes that changes of key interest rates by the Bundesbank till 1998 reduce uncertainty about future refinancing conditions, leading to money market rate increases.

Quirós and Mendizábal (2000), in turn, compare the behavior of the German money market rate before the start of EMU and that of EONIA rate afterward. They find that till 1998 EOM days were characterized by high rates and high volatility. Since 1999, in EOM days the volatility is not so 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; authors claim that the effect may be due to the stabilizing role played by deposit facilities.

Angelini and Silipo (2001) have analyzed the EONIA rate. They discover the presence of weak seasonalities. There is some evidence against the martingale hypothesis but it is weaker than in the US market; they observe no effect associated to the EOM period. The tom-next rate (the forward contract on the e-MID), used as a proxy for the 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 the e-MID - with high frequency data is conducted in Hartmann et al. (2001). Analyzing quote frequencies, it is shown that in all countries - except Italy - activity is higher on Tuesdays (as a result of the Repo auction) and on Thursdays (when the Governing council meeting take place). Post auction reallocation of funds is quick and efficient. In 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) provides a model showing that announcing liquidity estimates of the banking system should allow for 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 resulted to be ineffective in allocating liquidity, leading to high overbidding by banks (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 are evaluated through two different methodologies:

- Equivalence tests on the moments of the distribution at hand, which are reported in Tables 4, 5, 6;
- Significance of dummy variables associated to calendar effects in an auto-regressive setup.

By inserting dummy variables, not only we look for calendar effects on volume, volatility and interest rates, but we also 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 (Hamilton, 1996; Quirós and Mendizábal, 2000; Prati et al., 2001; Furfine, 1999; Angelini and Silipo, 2001). All the above papers employ daily data. To take into account the volatility dynamics, in particular heteroscedasticity, a GARCH or an EGARCH model is estimated handling volatility as a latent variable.

4.1 Overnight rate level

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

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

where i_t is the overnight rate at day t, n_i is the number of lags, $ASK - BID_t$ is the difference between ask and bid exchanges, B_t is the payment values, σ_t is the volatility at day t computed

1)	Mean 1	Mean 2	Mean equivalence (t-test)	2)	Median 1	Median 2	Wilcoxon-Mann-Whitney	Kruskal-Wallis
1) EOM day volatility	0.511322379	0.0274392497	404.90***	2) Other days volatility, excluded EOM-1,2,3	0.397883594	0.00683629373	8.27***	68.46***
1) EOM volatility (fixed rate tenders)	0.595745146	0.0190053117	334.23***	2) Other days volatility, excluded EOM-1,2,3	0.593213499	0.00633845991	5.75**	33.08***
1) EOM volatility (variable rate tenders)	0.438959897	0.0354274996	131.80***	2) Other days volatility, excluded EOM-1,2,3	0.259371042	0.00738964556	5.88**	34.56***
1) EOM, EOM-1 volatility (fixed rate tenders)	0.343476802	0.308055699	0.16	2) EOM, EOM-1 volatility (variable rate tenders)	0.214466184	0.213666782	0.42	0.17
1) Volatility, fixed rate tenders, EOM,EOM-1 excluded	0.0283382032	0.0397209227	1.90	2) Volatility, variable rate tenders, EOM,EOM-1 excluded	0.00701335398	0.00746696908	1.31	1.71
1) EOM rate	3.59933114	3.76329803	0.96	2) Other days rate, EOM-1,EOM-2 excluded	3.98850012	3.90429997	0.88	0.77
1) Volume, fixed rate tenders	10485.7822	11681.0566	51.84***	2) Volume, variable rate tenders	9978.2002	11644.7002	8.22***	67.55***
1) EOM volume	9828.08008	11070.8027	9.54***	2) Other days volume	9766.	11027.	3.53*	12.49***
1) End of month rate	3.76979351	3.74309969	0.02	2) Other days rate	3.89820004	3.83669996	0.29	0.08
1) End of month volatility	3.60115457	3.62844849	0.02	2) Other days volatility, last four mant. excluded	3.28430009	3.24629998	0.09	0.01

Table 4: Equivalence Tests. One star denotes 90% significance, two stars 95%, three stars 99%.

1) Monday volume, fixed rate tenders		2) Other days volume, fixed rate tenders	
Mean 1	Mean 2	Median 1	Median 2
10659.5996	10442.752	10241.	9950.7998
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.51		0.83	0.68
1) BCE announcement days volatility, Thursday		2) Other Thursday volat., last four maint. days excluded	
Mean 1	Mean 2	Median 1	Median 2
0.0555989072	0.032599438	0.0300946403	0.006660996
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.39		3.77*	14.25***
1) BCE announcement days volatility, Friday		2) Other Friday volat., last four maint. days excluded	
Mean 1	Mean 2	Median 1	Median 2
0.0327185206	0.0274783876	0.0120633682	0.00724645751
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.04		1.60	2.57
1) Perc. afternoon volume, BCE announcement days		2) Perc. afternoon volume, other Thursdays	
Mean 1	Mean 2	Median 1	Median 2
0.496057868	0.452608705	0.535368681	0.454179049
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
2.61		1.47	2.16
1) Perc. afternoon volume, Thursday		2) Perc. afternoon volume, other days	
Mean 1	Mean 2	Median 1	Median 2
0.455979764	0.440948397	0.463342398	0.438193202
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
3.63*		1.70	2.90*
1) Volume 13-18, Thursday		2) Volume 13-18, other days	
Mean 1	Mean 2	Median 1	Median 2
5858.83643	5453.14795	5812.	5263.
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
8.04***		2.83*	7.99***
1) Volume 13-18, BCE announcement Thursdays		2) Volume 13-18, other Thursdays	
Mean 1	Mean 2	Median 1	Median 2
7061.55566	5445.08398	6148.	5331.
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
11.79***		2.51	6.31**
1) End of quarter volatility		2) Other days volatility, last four maint. days excluded	
Mean 1	Mean 2	Median 1	Median 2
0.0900596455	0.023990998	0.0133016855	0.00667161634
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
12.72***		3.45*	11.93***
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) Volatility, fixed rate tenders		2) Volatility, variable rate tenders	
Mean 1	Mean 2	Median 1	Median 2
0.0522289984	0.0645996407	0.00749348151	0.00851343572
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.89		1.98	3.91**

Table 5: Equivalence Tests (continued)

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
0.00849838089	0.00940419734	0.00305783493	0.00219962467
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.17		5.68**	32.23***
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
0.0195499659	0.00940419734	0.00313418498	0.00219962467
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
2.65		6.27**	39.28***
1) Perc. Volume 9-13, EOM days		2) Perc. Volume 9-13, other days	
Mean 1	Mean 2	Median 1	Median 2
0.58924973	0.55425626	0.612648666	0.557663083
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
5.30**		2.80*	7.83***
1) Volatility, fixed rate, Tuesdays, last 4		2) Volatility, variable rate, Tuesdays, last 4 main	
Mean 1	Mean 2	Median 1	Median 2
0.0103036603	0.0634241179	0.0066921832	0.00762158912
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
4.20**		1.86	3.46*
1) Volatility, fixed rate, Thursdays, last 4		2) Volatility, variable rate, Thursdays, last 4 main	
Mean 1	Mean 2	Median 1	Median 2
0.0362625942	0.033442501	0.0063661309	0.00762332045
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
0.02		1.39	1.94
1) Volatility 13-15, fixed rate, Wedsnedays, last 4		2) Volatility 13-15, variable rate, Wedsnedays, last 4 main	
Mean 1	Mean 2	Median 1	Median 2
0.0031002257	0.0104358466	0.00125642144	0.0015941076
Mean equivalence (t-test)		Wilcoxon-Mann-Whitney	Kruskal-Wallis
5.27**		3.40*	11.55***

Table 6: Equivalence Tests (continued)

as the integrated volatility through the method described in the Appendix, and m_t is of the form:

$$m_t = \sum_{k=1}^{n_{di}} \beta_k X_k \tag{2}$$

where X_k are the variables listed in Table 7 (n_{di} denotes the number of dummy variables). Note that σ_t is the standard deviation of $i_t - i_{t-1}$, so that we estimate (1) again via OLS after dividing by the observed σ_t both sides in (1). Results are shown in Table 7; again the Ljung-Box test rejects the presence of autocorrelation in residuals and in squared residuals.

The overnight rate shows patterns over the maintenance period. Figure 4 shows the following pattern: the overnight rate is low the first day of the maintenance period, increases significantly in the last days of the month, then behave more or less like a martingale with a decline at the end of the maintenance period. However, the decline is not statistically significant, as confirmed by equivalence tests. By looking at the auto-regressive coefficients, the martingale hypothesis

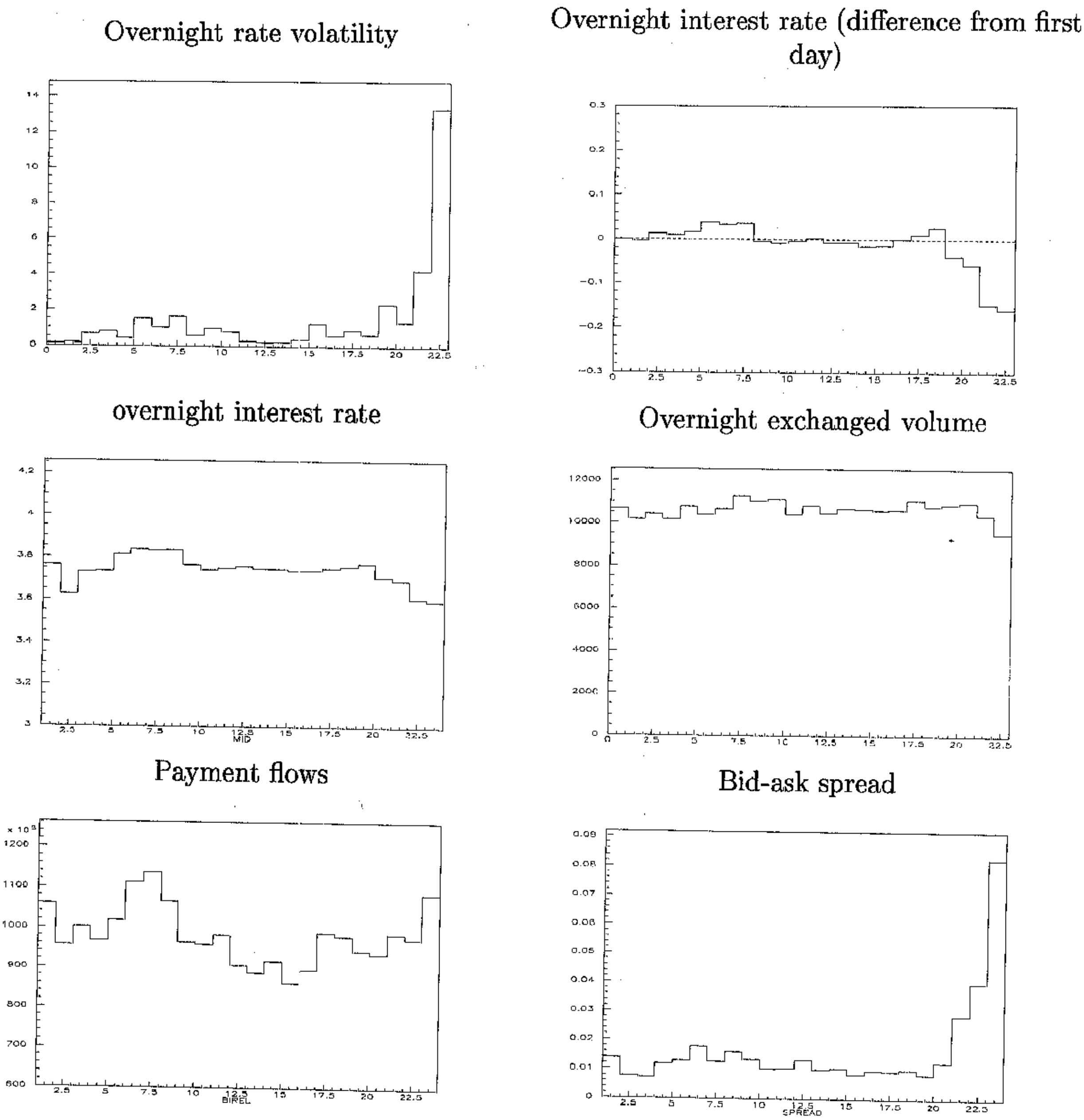

Figure 4: Patterns in the maintenance period; averages over the full sample

works well: the coefficient of i_{t-1} is statistically significant and next to 1, other auto-regressive coefficients are not significant. The above pattern contrasts in part the evidence detected for the EONIA and the Eurozone by several authors, who did not discover any significant pattern in 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,

Regressor	Coefficient	Standard Error
MID (t-1)	0.88647***	0.02695
MID (t-2)	0.03403	0.02675
MID (t-3)	0.01639	0.02171
MID (t-4)	0.01066	0.02111
MID (t-5)	0.01873	0.01869
constant	0.00092***	0.00025
EOM t- 0	-0.00019	0.00070
EOM t- 1	-0.00023	0.00025
EOM t- 2	-0.00012	0.00015
MID (t-1)*dummy first maintenance day	-0.46226***	0.05795
MID (t-2)*dummy first maintenance day	-0.67571***	0.12163
MID (t-3)*dummy first maintenance day	0.39872***	0.12529
MID (t-4)*dummy first maintenance day	-0.21356*	0.11389
MID (t-5)*dummy first maintenance day	0.95414***	0.09168
End of month	0.00060***	0.00016
End of quarter	0.00016	0.00014
End of year	0.00270	0.00302
First day month	0.00011	0.00011
First day of the year	-0.00456***	0.00043
Domestic Payment volatility	-0.50475*	0.26997
Payment volume volatility	-0.01064	0.01156
Ask-Bid volume t-1	2.94143**	1.14633
Before 3-4 holiday	0.00052***	0.00018
After 3-4 holiday	0.00034*	0.00018
Day of the week 2	0.00005	0.00007
Day of the week 3	0.00003	0.00007
Day of the week 4	0.00001	0.00008
Day of the week 5	-0.00001	0.00007
Linear Trend	0.00000***	0.00000
Square time Trend	0.00000***	0.00000

Table 7: Overnight rate level fit, equation (1); $R^2 = 99.906\%$; Ljung box on residuals: $L(50) = 56.73$; Ljung-Box on squared residuals: $L(50) = 123.70$.

see Table 7.

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. During the last day of maintenance period and the first day of the subsequent period, the overnight rate recovers all the decline occurred one day and two

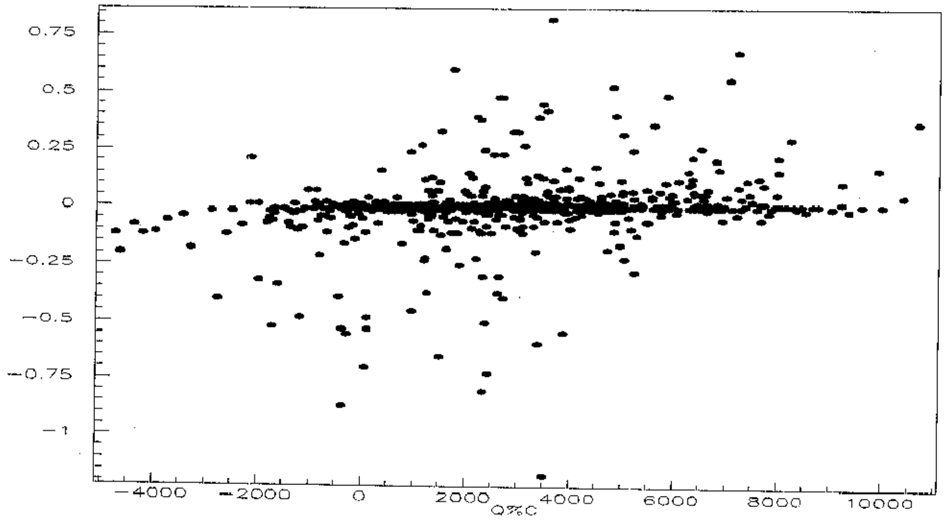

Figure 5: Scatter plot of ask overnight exchanges minus bid overnight exchanges and overnight e-MID rate change.

days before EOM days.

Let us remark that, estimating equation (1) after removing the dependence from the payment values and the bid-ask volume differential, we get almost the same calendar effects.

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 linear relation between the level of the rate and the contemporaneous 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 the level and volatility. In particular, at the end of the maintenance period (which lasts ten days in US) both payments and the overnight rate show an upward peak. It is then natural to ask whether the same phenomenon occurs in the Italian market. Looking at Figure 4, which shows - among others - the percentage variation of the overnight rate and of payments value during the maintenance period, we immediately recognize a difference with U.S. data: the rate decreases in EOM days. On the other hand, payments pattern shows a double-spike behavior, being higher at the end of the month and at the end of the maintenance period (for the reasons recalled before); both peaks are statistically significant. The strong decline in the interest rate during the EOM period joined by the increase in payment transfers induces a (statistically significant) negative correlation between the two (see the coefficient of the regression for the rate in Table 7).

During last days of a maintenance period, a decrease in e-MID exchanges is also observed. Actually, the upsurge of payments in EOM days is caused by another institutional factor, namely payments to the Treasury (see Section 2). On the whole interest rate, reserves and transactions patterns in the money market during the maintenance period support the view of efficient risk management by banks. On this point see also Section 4.3. Interest rate level is also negatively correlated with payment values volatility,[5] although not significantly.

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. To overcome these problems intraday observations can be used, as suggested in Andersen and Bollerslev (1998), who propose to estimate 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); Barucci and Renò (2001) exploit this key advancement to forecast volatility through a simple autoregressive model[6]; their results show that, in spite of its simplicity, the forecasting performance of such a model is better than that of classical models, like GARCH(1,1) or Riskmetrics.

We will follow this strand of literature to estimate volatility, adopting a recently proposed method by Malliavin and Mancino (2001) which is briefly described in the Appendix. 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, 2000a, 2002).

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

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

[5] We estimate payment volume volatility via the standard deviation of intraday payments.

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

Regressor	Coefficient	Standard Error
sigma t- 1	0.31869***	0.04039
sigma t- 2	0.13642***	0.03262
sigma t- 3	0.02768	0.03110
constant	-1.57579***	0.16210
EOM t- 0	1.51494***	0.10250
EOM t- 1	0.98021***	0.08995
EOM t- 2	0.50496***	0.09017
EOM t- 3	0.49567***	0.08819
EOM t- 4	0.01730	0.08947
First maintenance day	-0.44083***	0.11500
Bce (THURSDAY)	0.56540***	0.15283
Bce (FRIDAY)	-0.12000	0.15675
End of quarter	0.03822	0.12786
First day of a new quarter	0.32806**	0.14118
Domestic payment volatility	-0.00058	0.00220
Payment volume volatility	0.08795	0.08742
End of month	0.52856***	0.10104
First day month	-0.15947	0.10231
End of year	0.93803***	0.35552
First day of the year	-0.83095**	0.36231
Before 3-4 holiday	0.08558	0.13752
After 3-4 holiday	0.00010	0.13860
Linear Trend	0.00049	0.00046
Square time Trend	0.00000	0.00000
Tuesday	0.12522**	0.05921
Wedsnedays	0.06636	0.06136
Thursday	0.14680**	0.06033
Friday	0.10131*	0.06026

Table 8: Overnight rate volatility fit, equation (3) (one star, 90%, two stars, 95 %, three stars 99% significance); $R^2 = 62.21\%$; Ljung box on residuals: $L(50) = 71.46$; Ljung-Box on squared residuals: $L(50) = 235.82$.

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 8. 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 to standard

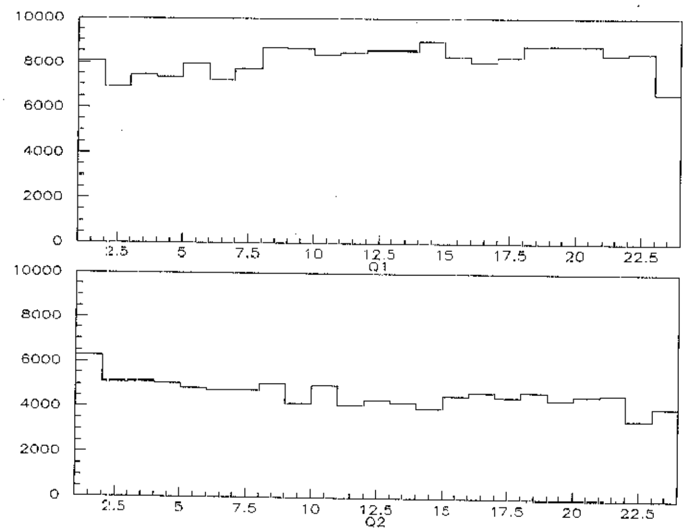

Figure 6: Overnight ask (top) and bid (bottom) transactions in the e-MID in the maintenance period

volatility models. Regression results are shown in Table 8, daily volatility estimates for the full sample are reported in Figure 3. We run specification tests in the form of Ljung-Box portmanteau tests on residuals and on squared residuals; the tests show that we managed to remove the autocorrelation in residuals and in squared residuals.

Volatility changes remarkably intramonth with a high degree of persistence. The autoregressive component in volatility is significant. The main regularities on volatility are shown in Figure 4: the last four days of a maintenance period are characterized by a volatility higher than other days; volatility is also high the last day of a month and of a year. On the other hand, volatility is substantially low 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.

Interest rate volatility is not influenced by domestic payment values. This is true also if we include cross-border variables, in order to capture the effect of Euro-area payment transfers; we have controlled for both Italian and whole EMU cross-border interbank payments. On the other hand, the relation between interest rate and payment values daily volatilities is positive but not significant. 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, as noted above (subsection 2.1), was changed by ECB in June 2000. According to

Nautz (1998), a variable rate tender mechanism should increase the volatility. The evidence on this point is mixed: an increase of the volatility is observed on Tuesday, Wednesday and Friday, a decrease on Monday and Thursday, see Table 2. Overall, an increase is observed but the equivalence between the interest rate volatility with a fixed rate tender and that with a variable rate tender is only in part rejected, see Table 4. Since June 2000, we observe a reduction of volatility in the last three days of a maintenance period and an increase in the others, see Table 4.

4.3 Exchanges in e-MID, bid ask spread and reserves

Transaction values do not show apparently a significant pattern over the month (Figure 4). Letting V_t be volume at time t, the following equation is estimated:

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

where X_i are n_V dummy variables listed in Table 9. The autoregressive component in transactions is strong and significant. They are high after 3-4 holiday days and low before. Note that an increase in exchanges over the sample is observed: there is a positive linear trend which is statistically significant. Estimating the above equation without the autoregressive component (Table 10), a significant decrease in volume is observed on the last two days of the maintenance period (see also the equivalence test). On the other hand, exchanges are high on the first day of the maintenance period. It has to be noted that Central Bank's interest rate announcements increase transactions in a significant way, see Table 1. The decline at the EOM period suggests that banks manage their reserves during the maintenance period in an efficient way, without incurring in last minute trades.

The same conclusion on banks' liquidity management efficiency is drawn by looking at the progressive average reserve holdings during the maintenance period. According to Angelini and Silipo (2001) and to Figure 7 there are no excess reserves during EOM days, but banks hold more reserves on the last days of a maintenance period (when the overnight rate is low) than at the beginning. This evidence is at odds with the behavior of the US federal funds market and of the model in Bartolini et al. (2000) (high interest rate and excess reserves during EOM days) but in line with a simple reserve costs minimization model. This conclusion is confirmed by observing that banks hold negative reserves during the last days of a month when the interest rate is high.

The data-set includes daily data on transactions (volume and interest rates) originated by applying a bid quote, transactions originated by applying an ask quote, an average interest

Regressor	Coefficient	Standard Error
Volume t- 1	0.69100***	0.02804
constant	2975.42456***	297.58978
EOM t- 0	-928.81708***	264.70813
EOM t- 1	-513.07416**	259.82828
EOM t- 2	190.88690	264.49670
EOM t- 3	278.64670	269.69659
First EOM day	1368.25269***	286.21332
Bce (THU)	813.89209*	476.51492
Bce (FRIDAY)	-38.62835	400.87555
End of month	-178.85516	277.87207
End of quarter	32.05989	309.83911
End of year	1676.00012	1104.50708
First day of the yea	895.07513*	536.18372
Before 3-4 holiday	-356.99109	359.23199
After 3-4 holiday	253.43810	277.11893
Day of the week 1	56.81850	148.42979
Day of the week 2	-199.83308	148.88496
Day of the week 3	0.15893	148.00623
Day of the week 4	-1.56072	3.55122
Linear Trend	1.54269***	0.37330

Table 9: Fit of the exchanges in the e-MID according to the model: $V_t = \alpha V_{t-1} + \sum_{i=1}^{nv} \beta_i X_i + \varepsilon_t$, where V_t is the volume at time t and X_i are the regressors indicated in the table.R^2 = 89.96%; Ljung box on residuals: $L(50) = 142.37$; Ljung-Box on squared residuals: $L(50) = 112.161$.

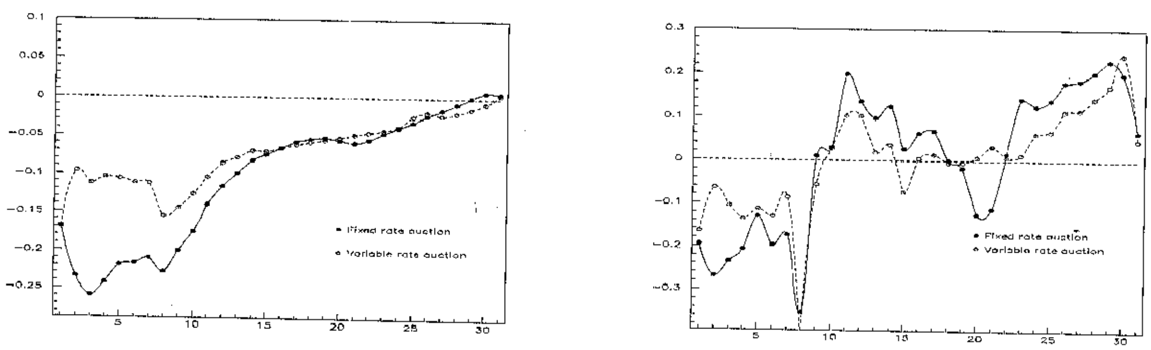

Figure 7: Progressive average reserves (left) and balance (right) over the maintenance period (full sample average)

Regressor	Coefficient	Standard Error
constant	9456.05957***	192.08626
EOM t- 0	-1107.83752***	364.92999
EOM t- 1	-216.58591	357.95334
EOM t- 2	434.41064	364.52127
EOM t- 3	468.25137	371.79593
First EOM day	420.55054	391.14682
Bce (THU)	1453.00854**	656.20306
Bce (FRIDAY)	769.27063	551.00964
End of month	-320.94821	383.14001
End of quarter	451.53122	426.66412
End of year	-64.34085	1520.14380
First day of the year	926.50012	739.46631
Before 3-4 holiday	-463.49329	495.39230
After 3-4 holiday	-143.24278	381.53964
Monday	328.14285	204.14075
Tuesday	64.73277	204.79793
Wednesday	82.58426	204.06802
Thursday	-7.32397	4.88697
Linear Trend	5.16193***	0.47332

Table 10: Fit of the exchanges in the e-MID according to the model: $V_t = V_0 + \sum_{i=1}^{nv} \beta_i X_i + \varepsilon_t$ (Foster and Viswanathan, 1993), where V_t is the volume at time t and X_i are the regressors indicated in the table. $R^2 = 81.02\%$; Ljung box on residuals: $L(50) = 2534.31$; Ljung-Box on squared residuals: $L(50) = 276.26$.

rate and the sum of the two kinds of exchanges. We observe two interesting regularities. The average bid-ask spread computed as the difference between average bid transaction rate and average ask transaction rate is small and stable over the maintenance period but blows up during the last three days, see (4). The percentage of exchanges originated by applying ask quotes is higher than the percentage of those originated by applying bid quotes; moreover, ask originated transactions decline over a maintenance period, see Figure 6. As far as the intramonth bid-ask spread is concerned, we observe that it is highly correlated with interest rate volatility. Finally, as shown above, the difference between volume generated by applying ask and bid quotes is relevant in explaining the one day-ahead rate. This relation is positive and significant.

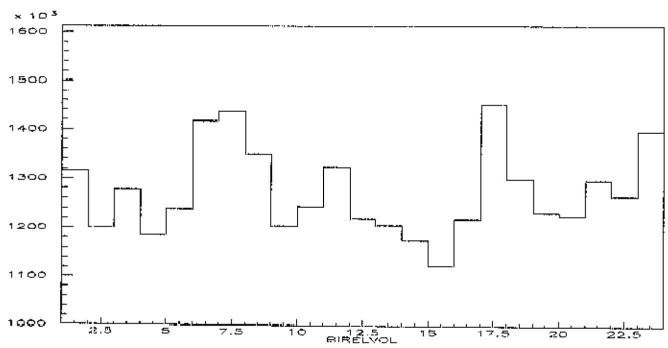

Figure 8: Intramainteinance pattern of volatility of payment outflows.

4.4 Domestic and cross border payments

We have estimated an autoregressive model also for payment transfers, both domestic and cross border (Table 11). The specification for the payment values, labeled as B_t, is

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

where n_b is the number of lags and

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

and $X_k,\ k = 1, \ldots, n_{db}$ is a set of $0-1$ dummies whose list is reported in table 11. 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. Confirming the liquidity adjustments carried on by banks, increases in payments are also observed on the first and on the last day of a month, due to technical maturities (i.e. settlement of the Treasury payments, periodic settlement of correspondent interbank accounts balances).

A closer analysis of the cross border component makes it possible to better evaluate the degree of banks' 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. the fiscal system), which in turn can result in very-short term interest rate differentials. It is worthwhile to investigate whether arbitrageurs operate to exploit such opportunities.

Let us denote by ΔT the net balance in cross border interbank TARGET payments from and to Italy. A positive (negative) ΔT indicates net inflows (outflows) to (from) Italy. Figure 9 shows the scatter plot of cross-border payments against the differential between e-MID and

Regressor	Coefficient	Standard Error
log Birel $t-1$	0.19177***	0.04050
log Birel $t-2$	0.12632***	0.03674
log Birel $t-3$	0.13743***	0.03709
log Birel $t-4$	0.05087	0.03744
log Birel $t-5$	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 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	0.00060***	0.00013
Square time Trend	0.00000***	0.00000
Tuesday	-0.07278***	0.01616
Wedsnedays	0.04060***	0.01557
Thursday	-0.04674***	0.01601
Friday	-0.02525	0.01652

Table 11: Fit for the model of $log(BI - REL)$ outflows, equation (6). $R^2 = 59.09\%$; Ljung box on residuals: $L(50) = 84.86$; Ljung-Box on squared residuals: $L(50) = 65.02$.

EONIA rate. First of all, the figure shows that when the differential is large, the cross-border payments activity increases. Secondly, figure 10 shows the scatter plot of ΔT against the same differential; a linear relation between the two is evident, and it is found to be highly significant: we performed the regression:

$$\Delta T = \alpha(MID - EONIA) + \varepsilon_t, \tag{8}$$

we estimate $\alpha = 2.71 \cdot 10^7$ with a $t-$ test of 4.72. The mechanism behind this behavior is clear:

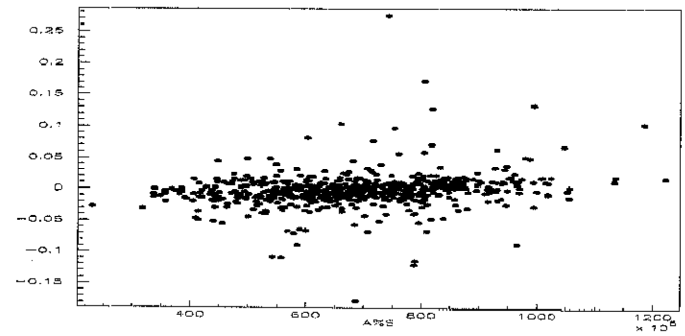

Figure 9: Scatter plot of payment values (X axis) vs. the e-MID - EONIA rate differential (Y axis)

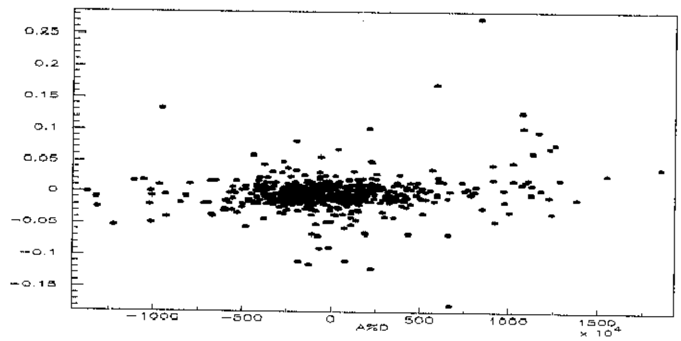

Figure 10: Scatter plot of net cross-border payments inflows vs. the e-MID - EONIA rate differential.

when the e-MID rate is lower (higher) then EONIA foreign countries buy (sell) liquidity in (to) Italy.

5 Intraweek and Intraday patterns

Intraweek volatility patterns depend on the refinancing operations mechanism, see 2. 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 adoption of the variable rate tender auction, volatility shows a double peak, on Tuesday and on Friday. Comparing volatility levels, we observe that after June 2000 there is a strong increase of the volatility on Tuesday, Wednesday and Friday and a strong decrease on Thursday. The increase on Tuesday and on Wednesday is in part statistically significant while the decrease on Thursday is not. This evidence can be explained by the change of 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 (Tuesday and Wednesday when the auction is settled). On the other hand, a change of the policy rate by the Governing Council conveys more information in a fixed rather than in variable rate system, this observation may explain the decrease in volatility on Thursday after June 2000.

On the full data set, volatility of e-MID rate is statistically higher on Tuesday, Thursday and Friday, (Table 8); there is a two peaks pattern (on Tuesday and Friday), see Table 3. The rationale is that both the refinancing auction and interest rate decisions of the ECB increase volatility.

Exchanges in e-MID decline over a week with a small increase on Friday. A more pronounced U-shape pattern is observed since June 2000, see Tables 2,3. However, intraweek differences are not statistically relevant[7]. Interest rates are lower on Monday and higher on Wednesday, but this effect is not statistically significant. The result is confirmed in both sub-samples (fixed and variable rate tender). Remarkably, this evidence contrasts results obtained for the US Federal Funds market (Hamilton, 1996).

Analyzing volatility and transaction values on Thursday and Friday separately in days when the ECB has or has not changed policy rates (Figure 11 and table 1), the announcement of a change makes both values increase (see equivalence tests and autoregressive equations). In large part of the literature on financial markets public news generate both volatility and volume increase; the two phenomena are linked because agents differ in the interpretation of public news and trade both for hedging and speculative reasons[8]. This is also the case in the interbank market. After an interest rate announcement, banks trade mainly for hedging reasons. Interest rate announcements by the ECB on Thursday lead to a volume increase with respect to other days and Thursdays when there is no policy change. This increase is statistically significant, see Table 5.

Figures 12,13,14 allow us to establish that the interest rate is decreasing through the day up to 3 basis points in mean. We have tested for the relevance of this decline by performing an equality test between the distribution of the rate late in the afternoon (16.00 - 18.00) 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 the equivalence

[7]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.

[8]See for example Barucci (2000).

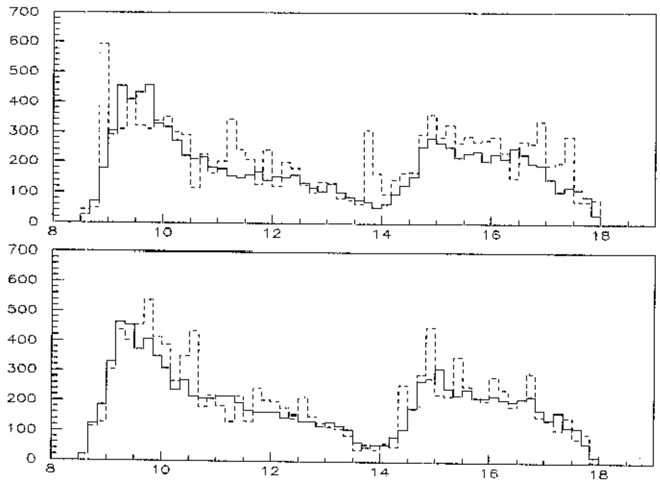

Figure 11: Intraday patterns of overnight exchanges in e-MID, Thursday (top) and Friday (bottom). The solid line are normal days; the dashed line are those days in which the BCE changes the main refinancing rate on Thursday (top) and Wedsneday (bottom).

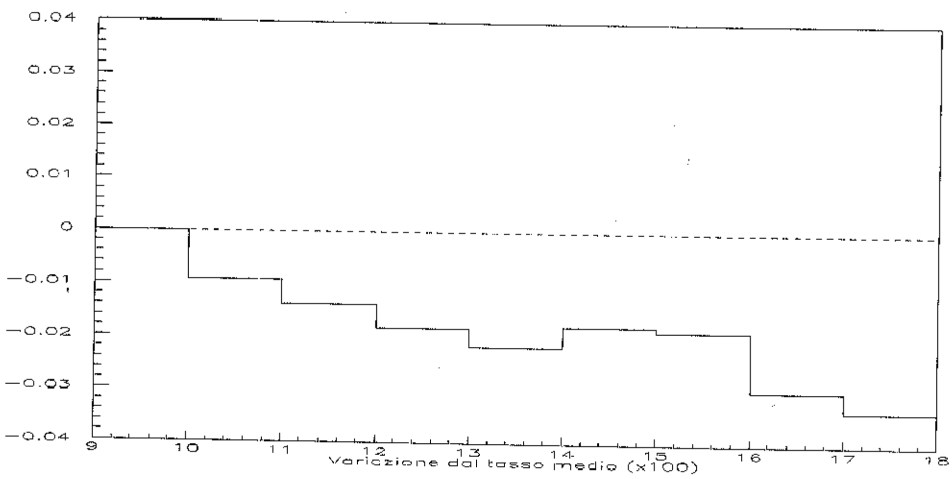

Figure 12: Intraday pattern of the variation of overnight e-MID rate from its opening value

test). During the last two maintenance days the decline is more than 10 basis points; it is stronger on Thursday before June 2000 and on Friday after June 2000.

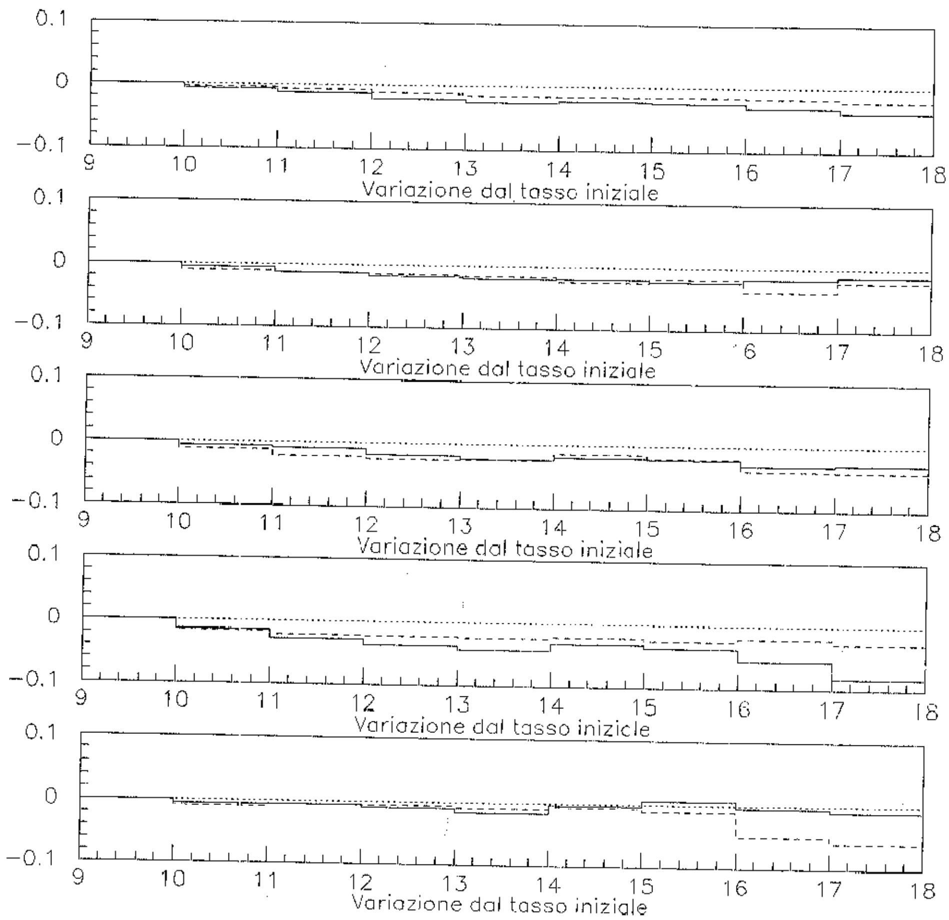

Figure 13: Intraday patterns of the variation of the overnight e-MID rate from its opening value, from Monday (top) to Friday (bottom). The solid line refers to the period before 28th June 2001 (fixed rate auctions); the dashed line refers to the period thereafter (variable rate auctions)

Dividing the business day in three time windows (9.00 − 12.00, 12.00 − 15.00, 15.00 − 18.00), the average volatility is respectively 0.019, 0.018, 0.069. It declines at midday, slightly but significantly, and rises consistently in the afternoon. Thus, the daily pattern is of an U-shape kind, as shown in Figure 15. Again, the increase in the afternoon is stronger during EOM days (figure 16).

As far as e-MID transaction values are concerned, a two peaks shape is observed in a day (Figure 17), confirming the result of Angelini (2000). After June 2000 an increase of volume in

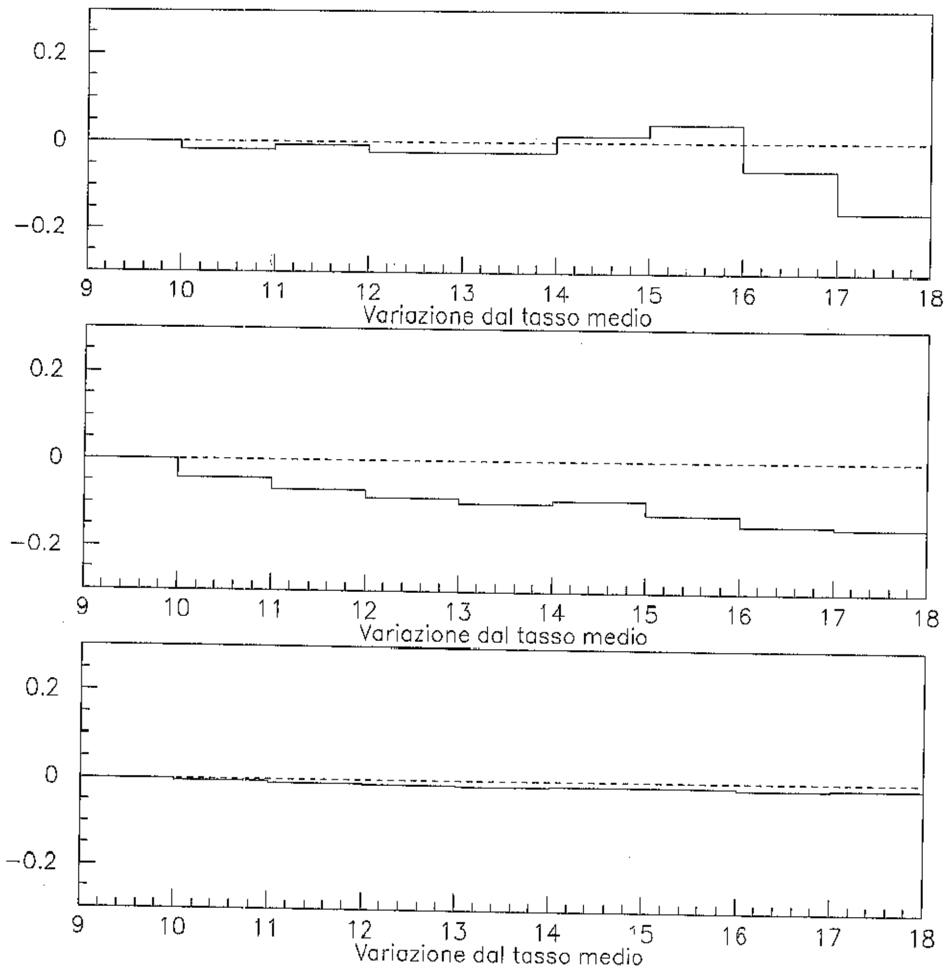

Figure 14: Intraday patterns of the variation of the overnight e-MID rate from its opening value in the EOM day (top), in the first day before EOM (center) and in the other days (bottom).

the morning is observed. A similar pattern is detected for the number of contracts (Figure 18). In EOM days - when volatility is higher - the percentage of trades in the morning is greater than in non EOM days (Figure 19). The average percentage of trades between 9.00 - 13.00 is 59% in EOM days and 55% in the others, and this difference is statistically significant. Note that a peak is observed on Tuesday morning around 12.00, after auction results are released.

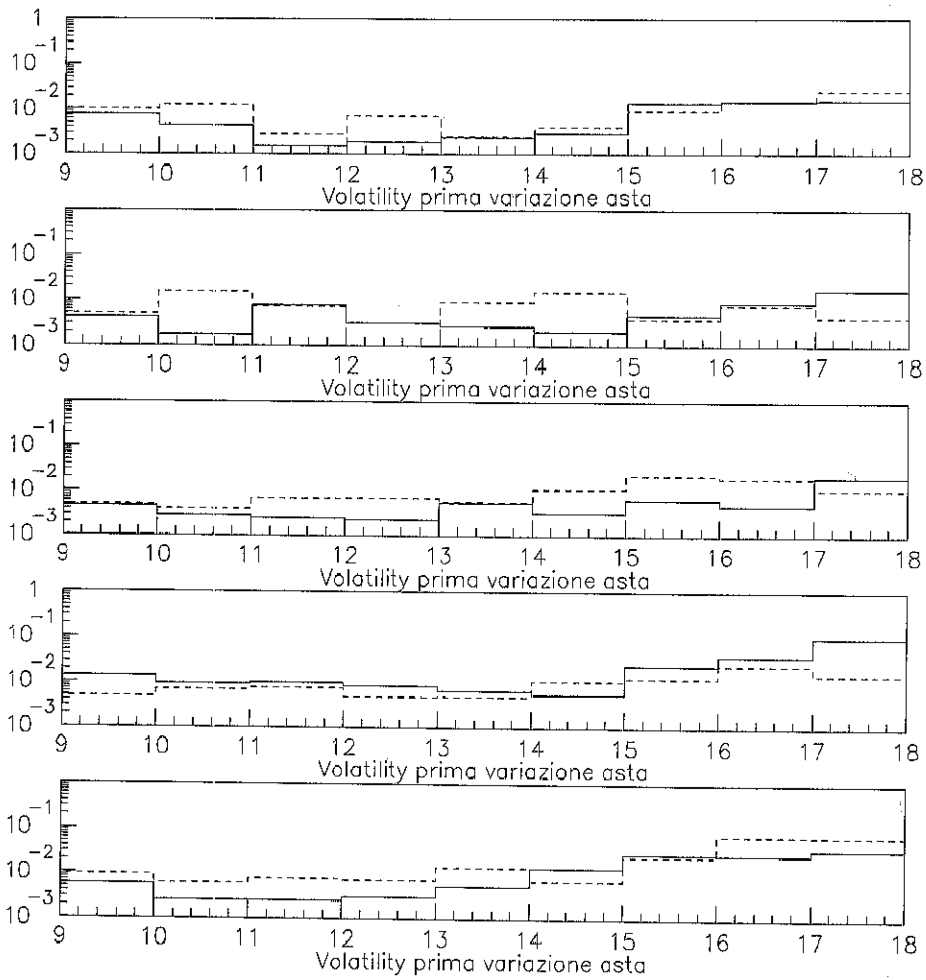

Figure 15: Intraday patterns of overnight e-MID rate volatility from Monday (top) to Friday (bottom). The solid line refers to the period before 28th June 2001 (fixed rate auctions); the dashed line refers to the period thereafter (variable rate auctions)

6 Conclusions

The analysis contained in this paper allows to draw some interesting conclusions on the Italian Overnight market. First of all, the Italian overnight market does not conform to the martingale hypothesis. There are patterns in the interest rate that do make it predictable. Some regularities detected in the US Federal Funds market are not confirmed in the Italian overnight

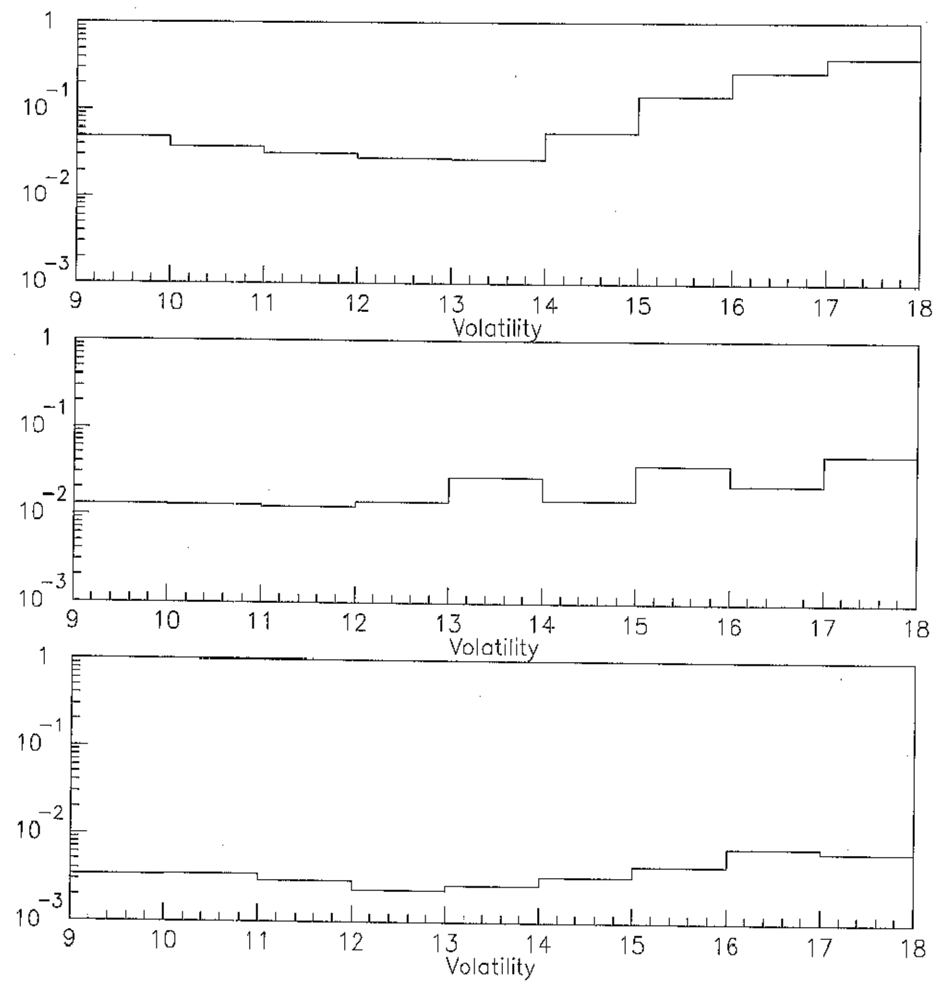

Figure 16: Intraday patterns of overnight e-MID rate; volatility in the EOM day (top), in the first day before EOM (center) and in the other days (bottom).

market; the main differences are that the overnight interest rate decreases and that banks do not hold excess reserves during EOM days. Overall this seems to indicate that banks manage efficiently their reserves in order to minimize their cost. The result is confirmed by the quick reaction of banks' cross border flow to short term differentials within the EURO area money market. In general, level and volatility patterns of the interest rate and transactions in the e-mid are associated to institutional features of the money market and of the Italian payment system. Note that the connection between payment transfers and the overnight rate established

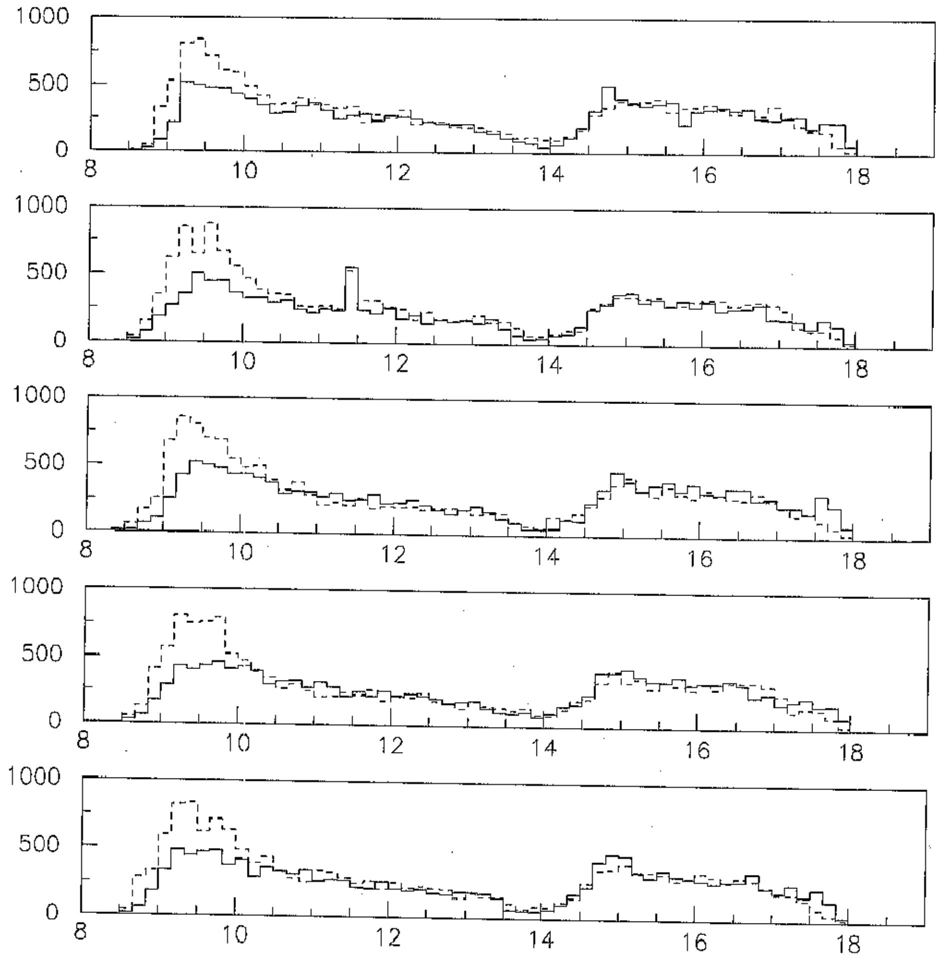

Figure 17: Intraday patterns of overnight exchanges in e-MID from Monday (top) to Friday (bottom). The solid line refers to the period before 28th June 2001 (fixed rate auctions); the dashed line refers to the period thereafter (variable rate auctions)

in Furfine (2000) is not confirmed in the Italian overnight market.

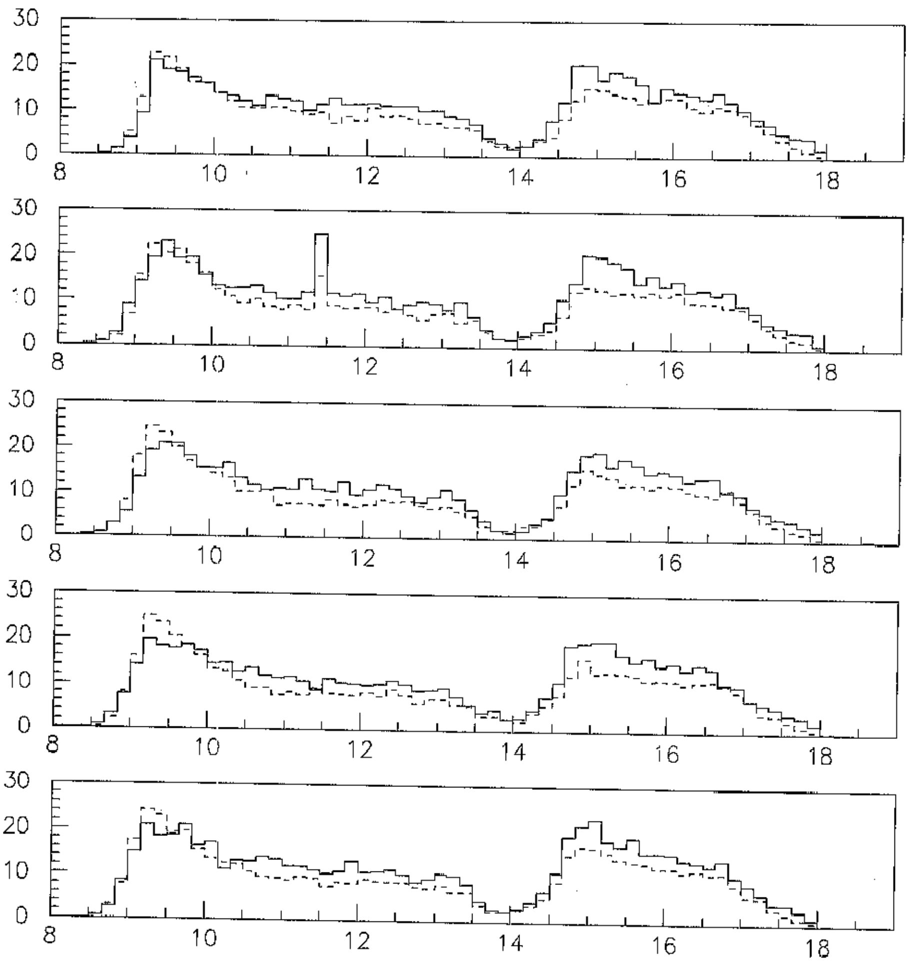

Figure 18: Intraday patterns of the number of overnight e-MID contracts from Monday (top) to Friday (bottom). The solid line refers to the period before 28th June 2001 (fixed rate auctions); the dashed line refers to the period thereafter (variable rate auctions)

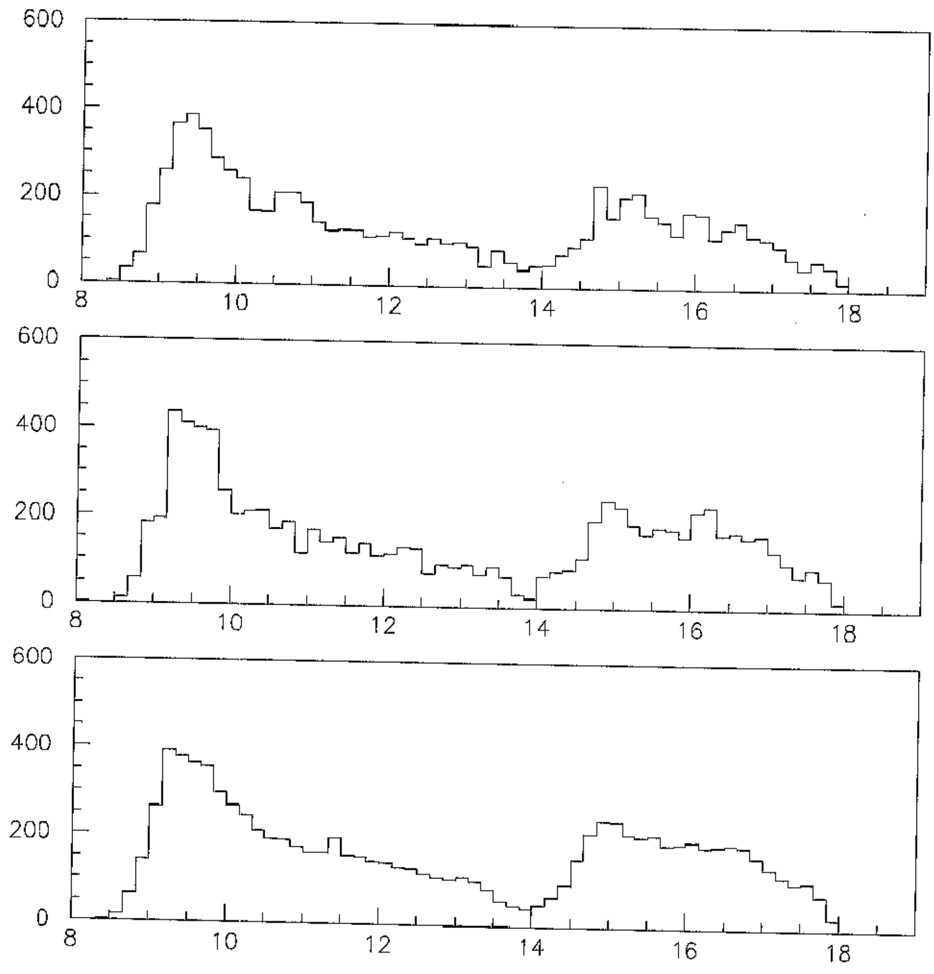

Figure 19: Intraday patterns of overnight exchanges in e-MID in the EOM day (top), in the first day before EOM (center) in the and other days (bottom).

A Appendix: The Fourier Method

In this Appendix we briefly review the method we adopt to compute the volatility, which has been proposed by Malliavin and Mancino (2001).

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

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

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

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

and similar formulas hold for $a_k(\Sigma), b_k(\Sigma)$; from its Fourier coefficients, $\Sigma(t)$ can be obtained pointwise 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 (2001) 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 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 directly the Fourier coefficients of dp, they are computed via integration by parts:

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

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 (2000a) 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 (2000a), 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, such as to rule out microstructure effects. The choice of the stopping frequency M is largely an empirical matter.

References

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.

Allen, L. and Saunders, A. (1992) Bank window dressing: theory and evidence. *Journal of Banking and Finance*, 16 pp.585-623.

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

Andersen, T. Bollerslev, T., Diebold, F. and Labys, P. (2001). Modeling and Forecasting Realized Volatility. NBER Working paper.

Angelini, P. (1997) An analysis of competitive externalities in real time gross settlement systems. *Journal of Banking and Finance* 22, 1-18.

Angelini, P. (2000) Are banks risk averse? Intraday timing of operations in the interbank market. *Journal of Money Credit and Banking*, 32, pp.54-73.

Angelini, P. and Silipo, P. (2001) The demand for settlement balances in the Euro area. Mimeo Bank of Italy.

Banca d'Italia (2001) Relazione annuale sul 2000. Maggio 2001.

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, pp.26-50.

Bartolini, L., Bertola, G., Prati, A. (2000) Banks' reserve management, transaction costs, and the timing of the Federal Reserve intervention. Forthcoming *Journal of Banking and Finance*.

Bartolini, L., Bertola, G., Prati, A. (2000) Day-to-day monetary policy and the volatility of the Federal Funds Interest rate. Forthcoming in *Journal of Money Credit and Banking*.

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

Barucci, E. and Renò, R. (2000a) On measuring volatility and the GARCH forecasting performance. Forthcoming *Journal of International Financial Markets, Institutions and Money*.

Barucci, E. and Renò, R. (2001). Value at Risk with High Frequency Data. Forthcoming in *New Trends in Banking Management*, Ed. Physica-Verlag.

Barucci, E. and Renò, R. (2002). On measuring volatility of diffusion processes with high frequency data. *Economics Letters*, 74 , 371-378.

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, pp.56-67.

Foster, D. and Viswanathan S. (1990) A theory interday variations in volume, variances and trading costs in securities markets. *Review of Financial Studies*, 3, pp.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, pp.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, pp.535-553.

Griffiths, M. and Winters, D. (1995) Day of the week effects in federal funds rates: further empirical findings. *Journal of Banking and Finance*, 19, pp.1265-1284.

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

Hartmann, P., Manna, M. and Manzanares, A. (2001) The microstructure of the Euro Money Market. European Central Bank no.80.

P. Malliavin, M. Mancino, (2001) Fourier series method for Measurement of Multivariate Volatilities. Forthcoming *Finance & Stochastics*.

Nautz, D. (1998) Banks' demand for reserves when future monetary policy is uncertain. *Journal of Monetary Economics*, 42, pp.161-183.

Nautz, D. and Oechssler, J. (2000) The Repo auctions of the European Central Bank and the vanishing quota puzzle. Mimeo.

Prati, A., Bartolini, L. and Bertola, G. (2001) The overnight interbank market: evidence from the G-7 and the Euro zone. Mimeo.

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.

Taylor, J. (2000) Expectations, open market operations, and changes in the Federal Funds rate. Mimeo.