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Palombini, Edgardo

March 2003

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Edgardo Palombini
Fondo Interbancario di Tutela dei Depositi

Working Paper n. 6, marzo 2003
Classificazione JEL: C14, C22, E43, G14
Parole chiave: dati ad alta frequenza, liquidità, mercato monetario, *overnight*, riserva obbligatoria, sistema dei pagamenti, volatilità.

Sintesi

Il presente lavoro analizza l'andamento e le principali determinanti della volatilità giornaliera e oraria del tasso *overnight* negoziato sul mercato italiano dei depositi interbancari (e-MID). Le misure di volatilità impiegate sono costruite utilizzando un campione di dati costituito dai tassi negoziati sull'e-MID dal gennaio 2000 al settembre 2002, rilevati ogni cinque minuti. Tali misure presentano il notevole vantaggio di non richiedere l'assunzione di un modello che descriva l'andamento delle grandezze studiate e di essere contaminate da un errore di misurazione virtualmente nullo.

I maggiori incrementi della volatilità del tasso *overnight* sono osservati in corrispondenza con la fine del periodo di mantenimento della riserva obbligatoria e riflettono la necessità per le banche dell'Eurosistema di aggiustare in tempi molto ristretti la propria posizione di liquidità. Tali aumenti della volatilità non risultano mediamente maggiori allorquando la scadenza della riserva obbligatoria coincide con un altro impegno di liquidità piuttosto rilevante per le banche italiane, ossia i pagamenti fiscali mensili. Notevoli incrementi di volatilità, sebbene di entità inferiore, si verificano anche al termine di ogni trimestre, in quanto questo costituisce il periodo di riferimento

utilizzato per verificare il rispetto dei requisiti patrimoniali stabiliti dalle norme di vigilanza. L’effetto legato alle operazioni di politica monetaria dell’Eurosistema e alle decisioni sui tassi di interesse ufficiali dell’area dell’euro non risulta in media significativo, indicando che i partecipanti al mercato riescono ad anticipare efficacemente l’esito di questi eventi.

La volatilità infragiornaliera del tasso *overnight* mostra un andamento a “U”, seppure poco marcato, nel corso delle giornate di mercato “ordinarie”; tale andamento si modifica alla fine del periodo di mantenimento della riserva obbligatoria e del trimestre, allorquando la variabilità dei tassi aumenta considerevolmente durante le ultime ore di contrattazioni.

Un ulteriore obiettivo del lavoro è quello di valutare la “liquidità” dell’e-MID, ovvero l’esistenza di una relazione tra volumi scambiati e volatilità dei tassi di interesse. Le evidenze empiriche suggeriscono che il mercato interbancario italiano ha la capacità di assorbire notevoli incrementi di attività, senza che ciò determini, in assenza di nuove informazioni, apprezzabili movimenti delle quotazioni. L'andamento infragiornaliero dei volumi negoziati risente dei meccanismi di funzionamento del sistema dei pagamenti italiano; in particolare, gli scambi si concentrano tra le 9 e le 10 del mattino, dopo il regolamento dei contratti conclusi sull’e-MID nei giorni precedenti, e nel primo pomeriggio, dopo la chiusura del sistema italiano di regolamento delle operazioni in titoli.

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Edgardo Palombini*
Fondo Interbancario di Tutela dei Depositi

Abstract

This paper constructs unbiased and model-free measures of daily and hourly volatility of the overnight interest rate negotiated on the Italian interbank deposits market (e-MID) using high-frequency transaction data. We find that the largest increases in volatility and the most notable variations of its intraday pattern occur at the end of the reserve maintenance period and at the end of each quarter. The average effect on market volatility of Eurosystem money market operations and interest rate decisions is not significant. We then try to assess the liquidity of the market investigating the relation between trading volume and volatility, finding that even large increases in trading activity do not cause sharp movements in interest rates.

KEYWORDS: high-frequency data, liquidity, money market, overnight, payment system, reserve requirements, volatility.

JEL CODES: C14, C22, E43, G14

This paper draws on the author Ph.D. dissertation discussed at the University of Naples "Parthenope" in January 2002. The author thanks Salvatore Vinci, the supervisor, Claudio Impenna and Valerio Vacca for their comments, an anonymous referee for her suggestions and observations and Massimo Panunzi for his help in constructing the data-set.
E-mail: epalombini@fitd.it

1. Introduction

Financial markets volatility is not constant but changes over time. The relevance of this phenomenon - originally noted by Mandelbrot (1963) and Fama (1965) - for asset pricing, asset allocation and risk management favours the development of an extensive literature.

Clark (1973) is the first researcher to assume that the number of factors affecting volatility is a random variable; Officer (1973) argues that movements in volatility are determined by macroeconomic variables; Black (1976) and Christie (1982) relate these changes to financial leverage; Merton (1980), French, Schwert and Stambaugh (1987) and Abel (1988) investigate the relation between volatility and expected risk premia; Poterba and Summers (1986) measure the degree of persistence of unexpected shocks on volatility.

Volatility remains inherently unobservable but ARCH and GARCH models, originally proposed by Engle (1982) and Bollerslev (1986), and all their successive extensions allow to explicitly model time-varying second-order moments.[1]

An alternative approach to estimating and forecasting financial market volatility is represented by "implied volatility" models; many studies compare forecasts from GARCH models with implied volatilities (e.g. Day and Lewis, 1993; Lamoreux and Lastrapes, 1993) but results are often controversial.

Recently, Andersen and Bollerslev (1997) show that ARCH models provide very accurate volatility forecasts at daily or lower frequencies; the same models prove to be inaccurate when applied to high frequency data, because the U-shaped pattern of intraday returns volatility requires to be explicitly modelled.

In contrast to other financial markets, few empirical papers on money markets deal with interest rates volatility (e.g. Cyree and Winters, 2001); an extensive literature

[1] Extensive surveys on ARCH models and their empirical applications are Bollerslev, Chou and Kroner (1992) and Bera and Higgins (1993).

investigates the time series properties of interest rate level at a daily frequency (e.g. Campbell, 1987; Hamilton, 1996) or focuses on the "liquidity effect", i.e. changes in interest rates triggered by a variation in monetary base, and the related "martingale hypothesis" (e.g. Hamilton, 1997; Bartolini, Bertola and Prati, 2000). At the same time, the literature dealing with microstructure issues of the money market is still limited: Angelini (2000) focuses on the implications of banks' risk-aversion for the intraday pattern of their trading volume; Furfine (1999) provides a general description of the Fed funds market; Hartmann, Manna and Manzanares (2001) examine the euro money market.

The present paper constructs unbiased and "model-free" estimates of daily and hourly volatility of the overnight interest rate through high-frequency intraday transaction data collected on the Italian money market, according to a methodology proposed by Andersen and Bollerslev (1998) and Andersen, Bollerslev, Diebold and Labys (1999). The availability of such measures allows to identify those days in which the overnight interest rate is subject to the most wide fluctuations and to investigate the intraday pattern of its volatility. Furthermore, we estimate the relation between trading volume and volatility, trying to assess the "liquidity" of the Italian money market.

The remainder of the paper is organised as follows. Next section introduces the concept of realised volatility and illustrates the methodology used to calculate it. Section 3 describes the data set constructed for our purposes. Section 4 investigates the main determinants of the overnight interest rate realised volatility, its relation with trading volume and the intraday behaviour of such variables. Section 5 presents the main conclusions.

2. Realised Volatility: Theory

The measures of volatility used in this paper are calculated on the basis of an application of quadratic variation theory to money market data. According to this theory, high-frequency intraday transaction prices of a financial asset allow to construct an estimate of its lower-frequency volatility and to consider this volatility as "observable".

Arbitrage-free price processes belong to the class of special martingales discussed by Back (1991) and can be represented as the sum of a deterministic component and an unpredictable innovation[2]. A quadratic variation process can be associated to any of these variables; such process solely depends upon the realisation of price innovations, thus it can be obtained without assuming any specific model.[3]

Consider, for example, the case of a logarithmic price process, p_t, which follows a stochastic volatility diffusion,

$$dp_t = \mu_t dt + \sigma_t dW_t$$

where W_t denotes a Brownian motion and σ_t is a strictly stationary process.

If we divide the unit time interval we wish to consider (one hour, one day, etc.) into m fractions, the continuously compounded variation of p_t in each of these fractions is

$$r_{(m),t} \equiv p_t - p_{t-1/m} = \int_0^{1/m} \mu_{t-1/m+\tau} d\tau + \int_0^{1/m} \sigma_{t-1/m+\tau} dW_{t-1/m+\tau}$$

where $t = 1/m, 2/m, \ldots, T$.

Assuming σ_t and W_t to be independent, the variance of a variation of p_t in h time-units ($h>0$), i.e. the variance of $r_{t,t+h}$, conditional on the series $\{\sigma_{t+\tau}\}_{\tau=0}^{h}$, is

$$\sigma_{t,h}^2 = \int_0^h \sigma_{t+\tau}^2 d\tau$$

This integrated volatility represents a natural measure of the true latent h-period volatility but is not observable. However, it can be estimated summing the squares of high-frequency returns and obtaining an ex-post "realised" volatility.

[2] The decomposition is a result of stochastic integration theory and, as shown in Protter (1990), is compatible with the presence of "jumps" and does not require a Markov assumption.
[3] See Protter (1990).

Andersen, Bollerslev, Diebold and Labys (2001) prove that the integrated volatility of p_t can be measured through its quadratic variation, $Qvar_{t,h}$. In particular,

$$Q\,\mathrm{var}_{t,h} \equiv [p,p]_{t+h} - [p,p]_t = \int_0^h \sigma_{t+\tau}^2 \, d\tau$$

At the same time, the quadratic variation of p_t can be approximated through its high-frequency returns because

$$p\lim_{m\to\infty} \sum_{j=1,\ldots,mh} r_{(m),t+j/m}^2 = Q\,\mathrm{var}_{t,h}$$

This means that realised volatility, being the sum of squared high-frequency returns, represents an arbitrarily good approximation of integrated volatility, because it converges to quadratic variation as the sampling frequency increases.[4]

The described measures of volatility are "model-free" because, under the sole no-arbitrage hypothesis, the quadratic variation of p_t depends on its unpredictable component and not on its conditional mean.

Standard volatility models typically use ex-post squared returns over the entire relevant *h*-period horizon to estimate integrated volatility; such estimator is unbiased but contaminated by a significant measurement error. Realised volatility becomes free of measurement error as *m* tends to infinity.

In this paper, high-frequency transaction data on the overnight interest rate are used to calculate both daily and hourly realised volatility. In fact, Andersen and Bollerslev (1998) demonstrate that, even for small (but greater than 1) values of *m*, realised volatility allows to largely reduce the measurement error with respect to standard volatility models.[5]

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[4] See Karatzas and Shreve (1991) and Barndorff-Nielsen and Shepard (2001).

[5] Taylor and Xu (1997) estimate hourly volatility through high-frequency returns.

3. Data

Our empirical analysis focuses on the overnight interest rate negotiated on the Italian interbank deposits market (e-MID), a very actively traded financial instrument, which permits the estimation of accurate volatility measures.

In the construction of a dataset of financial markets prices, some relevant microstructure issues have to be addressed. First, tick-by-tick prices are only available at unevenly spaced time points; this non-synchronous trading may i) undermine the hypothesis of identically distributed observed variables; ii) induce non-genuine variance increase and negative auto-correlation in the series. Second, traded prices originate from either bid or ask quotes (bid-ask bounce), again inducing non-genuine variance and negative auto-correlation in the series. Moreover, actual prices are discrete variables, thus any continuous-time model represents a poor approximation for their behaviour. [6]

The sampling frequency at which microstructure biases become a practical concern is largely an empirical question. In our case, a sampling frequency of five minutes seems to represent a reasonable compromise between the accuracy of the theoretical approximations on which our volatility measures are based and market microstructure concerns.

Our full sample consists of continuously-recorded 5-minute variations of the overnight interest rate; its construction utilises all the negotiations concluded on the market from January 3, 2000 through September 30, 2002. The Italian money market is open from 8 am to 6 pm, each working day is divided into 120 intervals, to any of which the interest rate of the last trade concluded in the interval is associated [7]. The dataset is constituted by a total of 83.280 observations (694 days times 120 time-intervals).

In order to define formally our daily and hourly volatility measures, let the time series of the logarithmic overnight interest rate variations be denoted by

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[6] Campbell, Lo and MacKinlay (1997).

[7] If no trades are concluded in a time-interval, the overnight interest rate is assumed to be constant and its variation equal to zero.

$$\Delta \log(on)_{m,t}$$

where $m = 1, 2, \ldots, 120$ and $t = 1, 2, \ldots, 694$. [8]

After filtering the data for outliers and other anomalies, daily and hourly realised variances are calculated according to the theory exposed in section 2:

$$Var(on)_t \equiv \sum_{m=1}^{120} (\Delta \log(on)_{m,t})^2 \quad \text{and} \quad Var(on)_{h,t} \equiv \sum_{j=1}^{12} (\Delta \log(on)_{j,h,t})^2$$

where $j = 1, 2, \ldots, 12$, $h = 1, 2, \ldots, 10$ and $t = 1, 2, \ldots, 694$.

For the reasons explained in the next section, alternative measures of volatility are mainly considered, in particular daily and hourly logarithmic standard deviations:

$$Lstd(on)_t \equiv \frac{1}{2} \log \left(Var(on)_t\right) \quad \text{and} \quad Lstd(on)_{h,t} \equiv \frac{1}{2} \log \left(Var(on)_{h,t}\right)$$

where $h = 1, 2, \ldots, 10$ and $t = 1, 2, \ldots, 694$.

4. Empirical Results

4.1 Daily volatility

The unconditional distribution of the daily realised variance of the overnight interest rate is extremely right-skewed and cannot be approximated by the normal distribution. Realised logarithmic standard deviation (hereinafter realised volatility), as defined in section 3, provides a more readily interpretable measure of volatility because, even if its distribution clearly remains non-normal, the right-skewness is significantly lower (figure 1a, in the appendix). This evidence is coherent with what French, Schwert and Stambaugh (1987) and Andersen, Bollerslev, Diebold and Labys (1999) find, respectively, for equity index and exchange rate volatility.

[8] The first overnight interest rate variation of each day is conventionally assumed to be equal to zero.

As for conditional distribution, daily volatility (estimated through realised logarithmic standard deviation) is subject to fluctuations, sometimes very high, which seem to occur at regular intervals of time. The exam of the correlogram allows to reject the *white-noise* hypothesis, showing that the series is positively serially auto-correlated because of the extensively documented volatility clustering effect (figure 2a). In contrast with previous financial market literature, which usually finds a clear long-run dependence for price volatility, autocorrelation functions decay rapidly, indicating that shocks are not very persistent. Moreover, autocorrelation functions show a clear cyclical behaviour because, after the initial decay, they grow again at a displacement of 20-22 days (one calendar month), suggesting that volatility shocks are regularly observed on specific dates. As expected, the Dickey-Fuller test with 10 augmentation lags soundly rejects the unit-root hypothesis (table 1a).

Daily realised logarithmic standard deviations are plotted in figure 1. The volatility of the overnight interest rate is usually not very high and the simple observation of the series allows to identify those days characterised by the most significant fluctuations of such variable.

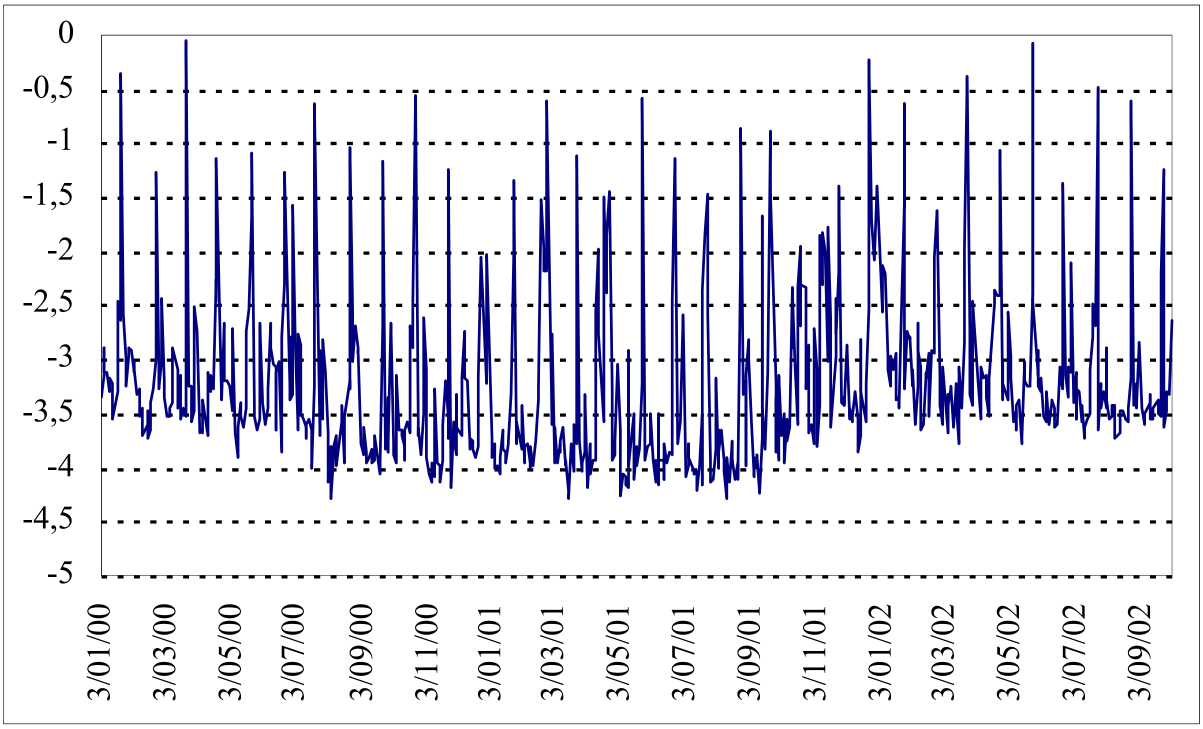
The most relevant increases in volatility occur on the last working day of the reserve maintenance period (which ends on the 23rd of each month) and, quite often, during the previous market session as well [9]. Such volatility peaks are caused either by an aggregate shortage or by an aggregate excess of liquidity in the market and reflect the necessity for banks with reserve imbalances to meet their requirements. A potential, additional source of volatility is represented by the monthly fiscal payments from Italian banks to the Treasury, which usually took place on the same day.[10]

Highly volatile interest rates are observed also at the end of each quarter, i.e. when balance sheets must respect the banking supervision capital requirements and treasurers

[9] The Eurosystem's reserve maintenance regime is illustrated in European Central Bank (2001).
[10] Fiscal outflows from banks to the Treasury were normally due on the 23rd of each month, but if this was not a trading day, they were postponed to the following working day. The system was recently reformed and, since August 2002, fiscal payments no longer coincide with the end of the reserve period.

are asked to adjust their lending and borrowing positions, and sometimes at the end of each month, probably due to some banks' internal limits to investments.

Figure 1 – Overnight interest rate daily volatility



Other potential sources of volatility like interest rate decisions by the Governing Council of the European Central Bank (ECB) and Eurosystem main refinancing operations (MROs) do not usually determine huge fluctuations of the overnight interest rate.[11]

Models of dealership markets based on an asymmetric distribution of information, e.g. Admati and Pfleiderer (1988) and Foster and Viswanathan (1990), predict the existence of a relation (positive or negative) between market volatility and trading volume. This prediction is confirmed by a number of empirical studies, which usually

[11] Interest rate decisions are taken by the Governing Council of the ECB, which meets every two weeks (usually) on Thursday. Main refinancing operations are the key monetary policy instrument through which the Eurosystem provides liquidity to the banking system; they are (usually) conducted on Tuesday and settled on Wednesday. For a description of the Eurosystem's monetary policy goals and instruments see European Central Bank (2001).

find that high trading volumes are often associated to large price changes, especially at the beginning of market sessions (e.g. Foster and Viswanathan, 1993). Investigating the relation between trading volume and volatility allows to evaluate the "liquidity" of the interbank market, i.e. its capacity to absorb large trading orders without major impacts on interest rates, given the absence of new relevant information.[12]

Based on all these considerations, daily volatility was regressed on a constant, its first-lag and trading volume; a series of dummy variables was also included to measure the impact of particularly relevant events like end of reserve maintenance period, start of a new period, fiscal payments, end of quarter, end of month, ECB Governing Councils and Eurosystem monetary policy operations (operation and settlement day). The results of the regression are reported in table 1.

Table 1 - Dependent Variable: Daily Volatility
(sample period: 3/1/2000 – 30/9/2002)

	Coefficient	**Standard Error**
Constant	-3.238	0.122
End of reserve period (last trading day)	2.101	0.133
Fiscal payments on last day of reserve period	-0.268^	0.153**
Day before end of reserve period	0.524	0.119
First day of reserve period	-0.166	0.086**
Fiscal payments on first day of reserve period	0.210^	0.210**
End of month	0.453	0.082
End of quarter	0.508^	0.140
ECB Governing Council interest rate decisions	0.112	0.059**
Eurosystem MROs (operation day)	0.015	0.039**
Eurosystem MROs (settlement day)	-0.021	0.041**
Trading volume	-0.000	0.000**
AR(1) component	0.602	0.032

OLS estimates; N. of observations: 381; R^2: 0.665; F-stat: 112.694.
One or two asterisks denote coefficients that are not significant at the 99 and 95 percent levels, respectively.
^ Additional effect to the preceding dummy variable.

[12] For a review of such models see Gallant, Rossi and Tauchen (1992) and O'Hara (1995).

The results confirm that the end of the reserve maintenance period is, by far, the dominant cause of overnight interest rate volatility; daily volatility usually rises already during the day before the end of the reserve period and immediately declines to its "normal" level on the first day of the new period. Interestingly, the effect on volatility of fiscal payments to the Italian Treasury is never significant, neither when such payments coincide with the end of the reserve period, nor when they are due at the beginning of the new period. Relevant increases in volatility are observed at the end of each quarter and, to a lower extent, at the end of each month.

The coefficients of the dummies for interest rate decisions and main refinancing operations are not significant, indicating that, on average, market participants predict the outcome of these events quite efficiently. [13]

Finally, overnight interest rate volatility is not influenced by trading volume, a result which, once again, underlines the difference between a financial market and a market for overnight liquidity, where interest rates level is determined by information arrival but trading volumes are more influenced by institutional factors like the functioning of the payment system, as discussed in section 4.2.

4.2 Intraday volatility

In line with the evidence found for daily volatility, the unconditional distribution of hourly realised logarithmic standard deviation (hereinafter hourly volatility) presents a right-skewness not compatible with the normal distribution, because of some relevant outliers (figure 3a).

The autocorrelation function declines slowly, indicating that the series is positively serially auto-correlated and that shocks on volatility tend to persist for more than one day. Moreover, the auto-correlation function seems to have a cyclical behaviour, slightly growing at a displacement of 10 hours (one day), thus showing that hourly

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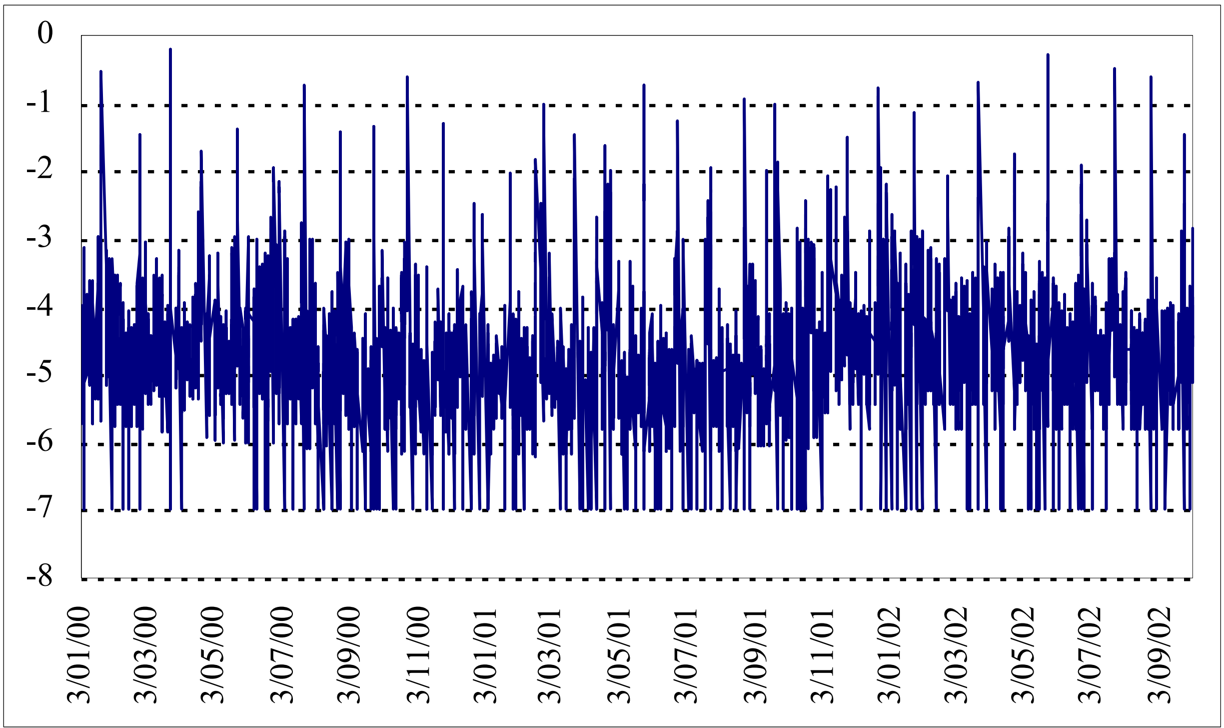
[13] Dummy variables for ECB Governing Council interest rate decisions and Eurosystem main refinancing operations are equal to zero if these events occur on the last trading day of the reserve maintenance period.

volatility follows a regular intraday pattern (figure 4a). The Dickey-Fuller test with 10 augmentation lags soundly rejects the unit-root hypothesis (table 2a).

Hourly volatility is plotted in figure 2; the exam of the series shows the existence of regular fluctuations similar to those observed for daily volatility.

Figure 2 - Overnight interest rate daily volatility



Hourly volatility is assumed to be equal to –7 when the overnight interest rate remains constant

The availability of an exact measure for hourly volatility allows to describe its intraday behaviour and to see how such behaviour changes during those days characterised by major interest rate fluctuations, as identified in section 4.1. Furthermore, it can be useful to investigate the relation between volatility and trading volume also at an intraday frequency. In order to do so, an ARMA(1,1) model for hourly volatility was estimated, including a constant, trading volume and a series of dummy variables to capture intraday seasonality during “ordinary”, end-of-reserve-period and end-of-quarter trading sessions. The results of the regression are reported in table 2.

Table 2 – Dependent Variable: Hourly Volatility

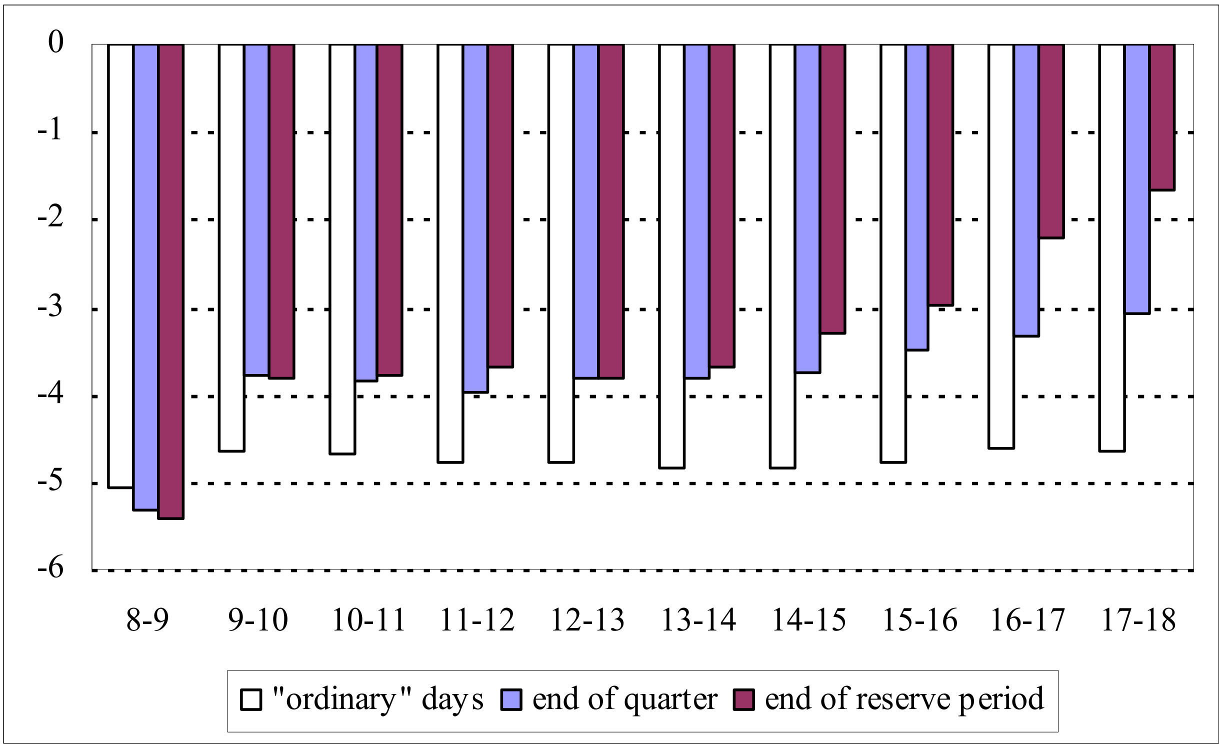
(sample period 3/1/2000 – 30/9/2002)

	Coefficient	Standard Error
AR(1)	0.936	0.006
MA(1)	-0.703	0.013
Trading Volume	0.000	0.000*
Hourly Dummies		
8 – 9	-5.061	0.040
9 – 10	-4.647	0.055
10 – 11	-4.691	0.044
11 – 12	-4.792	0.042
12 – 13	-4.783	0.041
13 – 14	-4.857	0.040
14 – 15	-4.838	0.041
15 – 16	-4.787	0.043
16 – 17	-4.636	0.043
17 – 18	-4.637	0.040
End of reserve period (last trading day) dummies		
8 – 9	-0.364	0.106
9 – 10	0.837	0.109
10 – 11	0.896	0.110
11 – 12	1.106	0.111
12 – 13	0.979	0.112
13 – 14	1.158	0.112
14 – 15	1.524	0.111
15 – 16	1.796	0.110
16 – 17	2.417	0.108
17 – 18	2.979	0.106
End of quarter (last trading day) dummies		
8 – 9	-0.264	0.181**
9 – 10	0.848	0.184
10 – 11	0.831	0.187
11 – 12	0.819	0.189
12 – 13	0.964	0.190
13 – 14	1.054	0.190
14 – 15	1.086	0.189
15 – 16	1.304	0.188
16 – 17	1.291	0.185
17 – 18	1.572	0.182

OLS estimates; N. of observations: 6.940; R^2: 0,491.
One or two asterisks denote coefficients that are not significant at the 99 and 95 percent levels, respectively
Larger values (in algebraic terms) of hourly dummies' coefficients indicate higher volatility.

The auto-regressive and moving average coefficients at lag 1 are of opposite sign and highly significant, with the first one greater in absolute magnitude. On balance, the model finds positive serial correlation, again due to the volatility clustering effect. Hourly volatility significantly increases during end-of-quarter and, most of all, end-of-reserve-period sessions, confirming the results of section 4.1. The intraday behaviour of hourly volatility can be represented through the graph of the hourly dummies' estimated coefficients (figure 3).

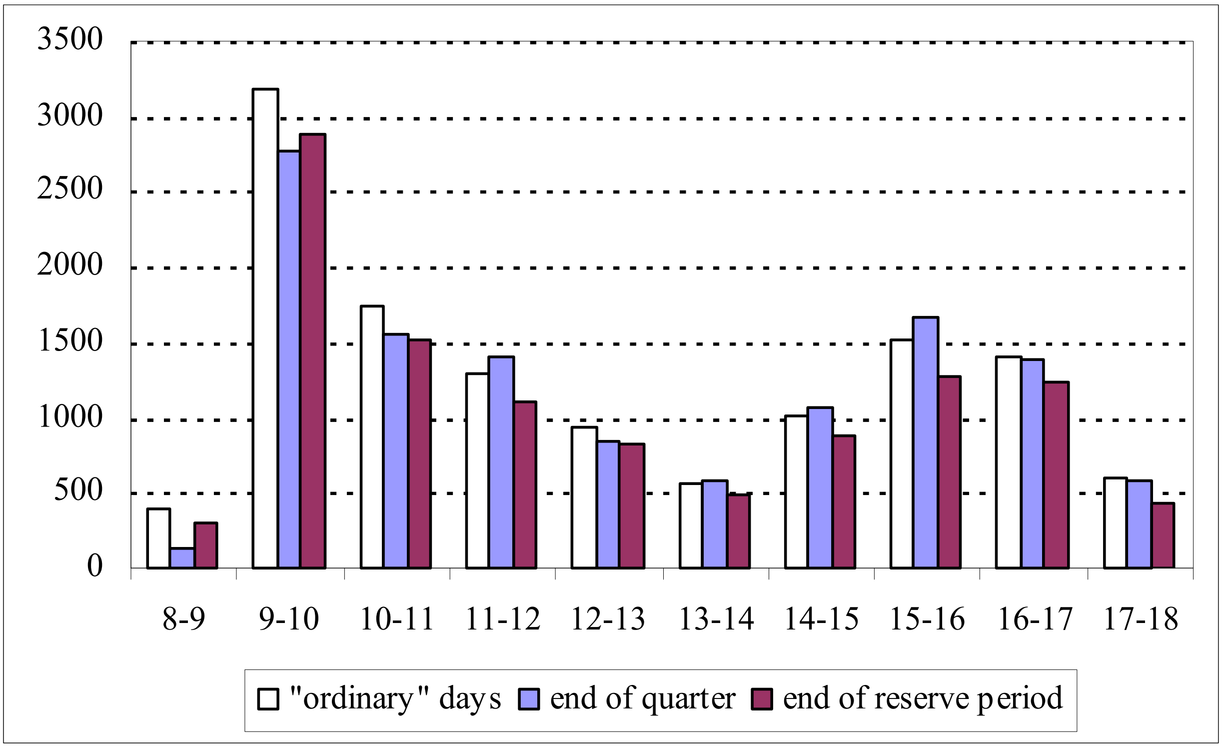
Figure 3 - Intraday volatility of the overnight interest rate



During "ordinary" trading days, overnight interest rate volatility follows a slightly pronounced U-shaped pattern: it is higher early in the morning (with the exception of the first hour of negotiation, when many traders are not active), when the market reacts to news accumulated during non-trading hours, and late in the afternoon, when banks adjust their liquidity position to reach their end-of-day target. The increase during the last part of the market session is much larger at the end of the reserve period, when banks cannot defer the fulfilment of their reserve requirements.

Average trading volume, graphed in figure 4, exhibits a different "two hump" behaviour: it is very low at the beginning of the market session, reaches its maximum between 9 and 10 am, declines gradually during the morning and the lunch break, then rises again in the early afternoon and eventually becomes low after 5 pm. The intraday pattern of trading volume appears to be mainly determined by the institutional setting of the Italian payment system; every day, two events typically originate huge liquidity transfers and a consequent reallocation of liquidity among banks: i) immediately after 9 am, e-MID previous days contracts are settled automatically; ii) around 1 pm the cash balances coming from the Italian securities settlement system are settled.

Figure 4 - Intraday trading volumes on the overnight maturity



The pattern of trading volume is coherent with the risk-aversion hypothesis proposed by Angelini (2000): banks manage to buy (sell) liquidity as soon as they realise to be short (long) of funds; i.e. they adjust their positions early in the morning, after the settlement of previous days contracts, and early in the afternoon, after the settlement of securities transactions and the lunch break.

It is interesting to notice that, in contrast to what the risk aversion hypothesis implies, during the most volatile days (at the end of the reserve maintenance period) there is no significant shift of trading volume from the afternoon to the morning, suggesting that banks are efficient in reallocating liquidity, but do not anticipate payment system obligations, even when they know in advance the final net balance to be settled.

Finally, at an hourly frequency, our results show the existence of a positive, marginally significant relation between volatility and trading volumes; such evidence is due to the fact that before 9 am many traders are not active, very few trades are concluded, thus volumes and volatility are both very low. To test this hypothesis, we have excluded the first hour of negotiation from our sample: the relation between volatility and trading volumes turns out to be not significant, confirming the high degree of liquidity of the market.

5. Conclusions

High-frequency intraday transaction data on the Italian money market (e-MID) are used to construct an unbiased and “model-free” estimate of its daily and hourly volatility and to consider this volatility as “observable”. The availability of such measures allows to identify those days in which the overnight interest rate is subject to the most wide fluctuations and to investigate the intraday pattern of its volatility.

The end of the reserve maintenance period is, by far, the dominant cause of volatility, which may be originated either by an aggregate shortage or by an aggregate excess of liquidity in the market and reflects the necessity for banks with reserve imbalances to meet their requirements. The effect of the reserve requirement is not significantly exacerbated by the monthly fiscal payments of banks to the Italian Treasury, often due on the same day.

Significant average increases in volatility are observed at the end of each quarter, due to liquidity adjustments aimed at satisfying banking supervision capital requirements. On the contrary, Eurosystem interest rate decisions and main refinancing operations do not have, on average, a significant impact on volatility.

Overnight interest rate volatility is not influenced by trading volume; this is essentially explained by the fact that, while interest rates level is determined by information arrival, trading volumes are more influenced by institutional factors like the functioning of the payment system. Such evidence allows to positively evaluate the "liquidity" of the interbank market, i.e. its capacity to absorb large trading orders without major impacts on interest rates, given the absence of new relevant information.

Overnight interest rate volatility follows a slightly pronounced U-shaped intraday pattern. The increase in the last part of the market session is much larger at the end of the reserve period, when banks cannot defer the fulfilment of their reserve requirements.

Average trading volume exhibits a different "two hump" behaviour and appears to be mainly determined by the institutional setting of the Italian payment system, characterised by two "critical" events like the settlement of e-MID previous days transactions and of cash balances coming from the Italian securities settlement system. No shift of trading volume from the afternoon to the morning is observed during the most volatile days (i.e. at the end of the reserve period), suggesting that banks are efficient in reallocating liquidity after meeting payment system obligations, but do not anticipate them.

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APPENDIX

Figure 1a – Distribution of daily realised logarithmic standard deviation

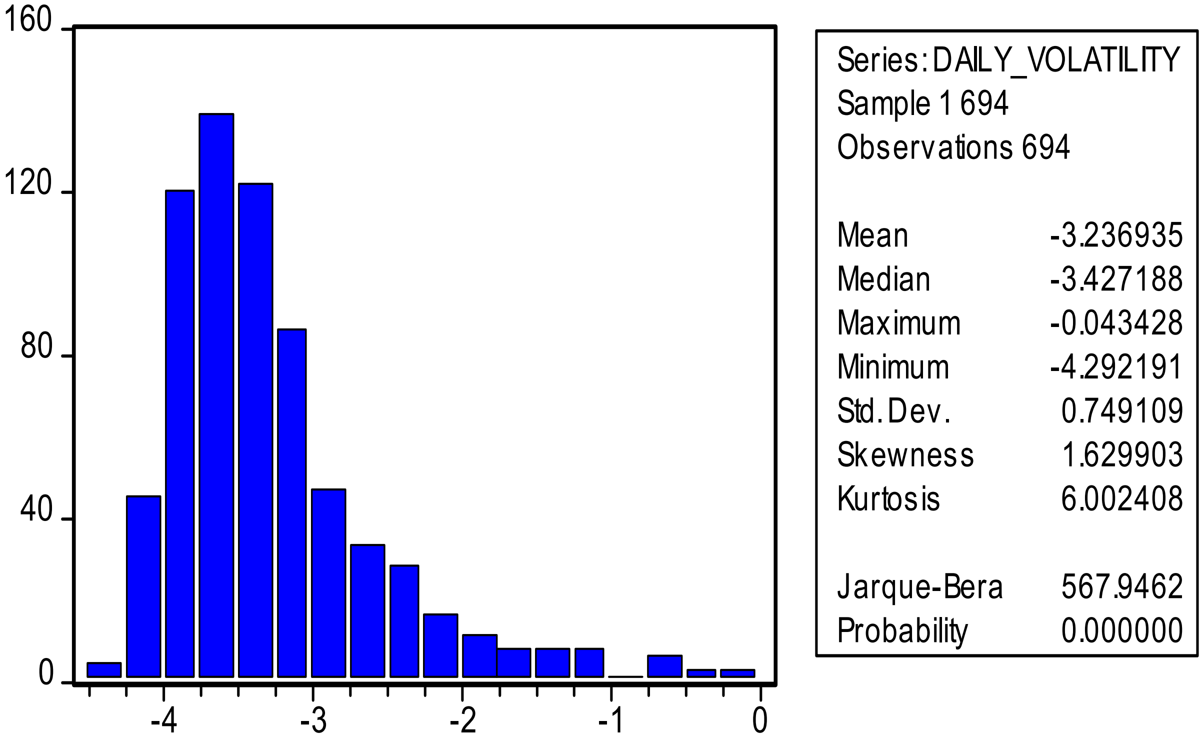

Figure 2a - Correlogram of daily realised logarithmic standard deviation

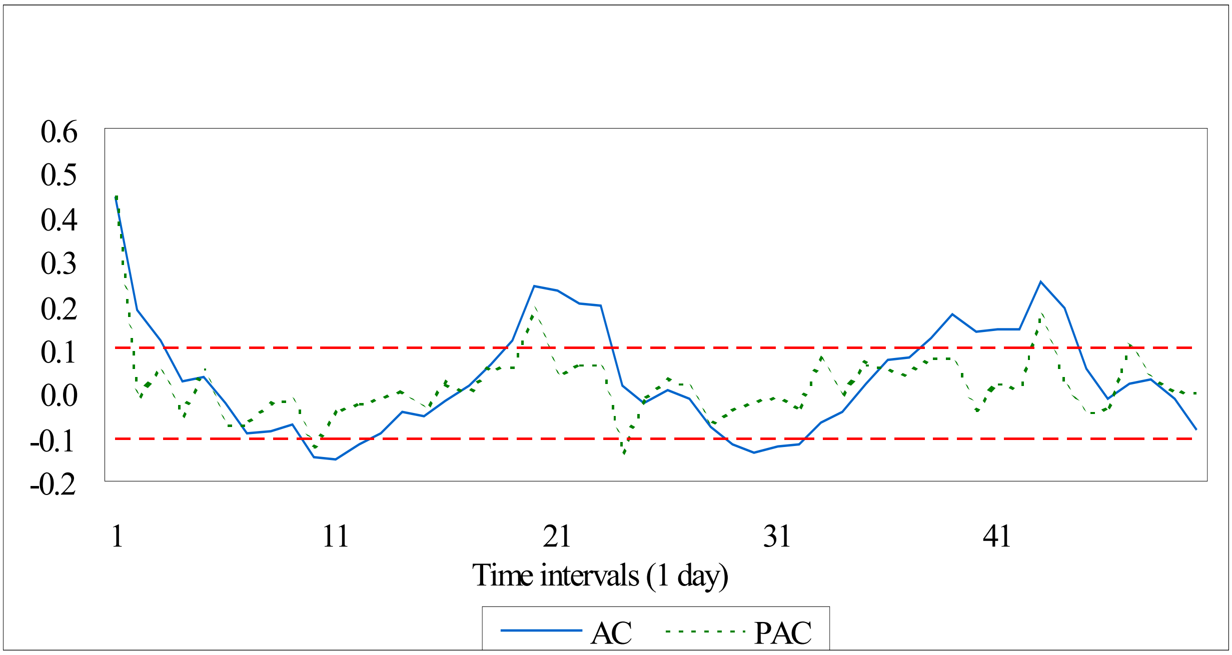

Figure 3a - Distribution of hourly realised logarithmic standard deviation

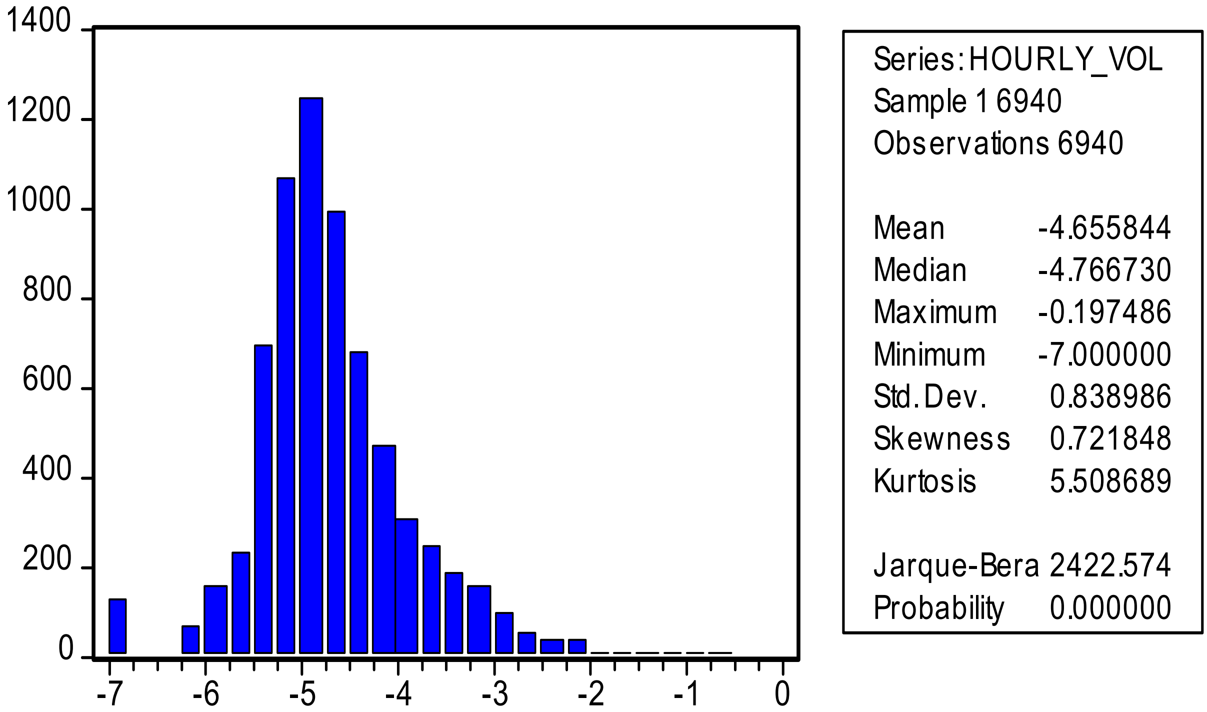

Figure 4a - Correlogram of hourly realised logarithmic standard deviation

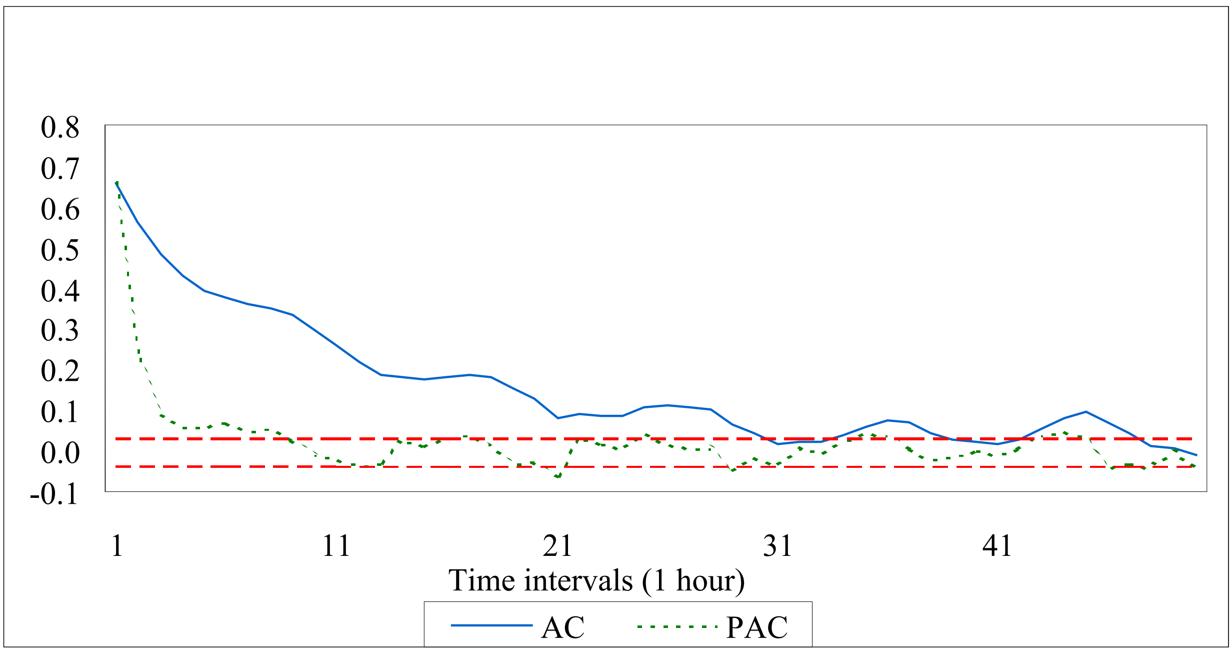

Table 1a - Unit root test for daily realised logarithmic standard deviation

	Critical values*		
ADF Test	1%	5%	10%
-8.430	-3.442	-2.866	-2.569

Table 2a - Unit root test for hourly realised logarithmic standard deviation

	Critical values*		
ADF Test	1%	5%	10%
-13.606	-3.435	-2.863	-2.567

* Mac Kinnon critical values.