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Liquidity and announcement effects in the euro area

by Paolo Angelini

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LIQUIDITY AND ANNOUNCEMENT EFFECTS IN THE EURO AREA

by Paolo Angelini *

Abstract

The paper analyzes the euro-area interbank market. The martingale hypothesis for the Eonia, the reference overnight interest rate, is tested and rejected. Such rejection is a sufficient condition for a liquidity effect, which is then estimated. The magnitude of the effect is found to depend on the perceived degree of persistence of the liquidity shock. At the beginning of the reserve maintenance period a liquidity drain amounting to 3 per cent of required reserves raises the Eonia by 4 basis points, by 13-15 points, by 25 points or more (up to the limits of the official rate corridor, i.e. roughly ± 100 basis points), depending on whether it is expected to be purely temporary, to last at least through the following day or through the rest of the holding period. Non-purely-temporary effects may take place when the liquidity shock has some signaling value for the monetary policy stance; however, little if any evidence of shocks of this kind is found.

The liquidity effect is read off the slope of a euro-area-wide demand equation for daily reserves which incorporates the current as well as the expected overnight rate among the regressors. The two elasticities are very similar in absolute value and have opposite signs; this is consistent with the announcement effect, the ability by the central bank to influence the current rate without resorting to open market operations.

The area-wide demand curve is retrieved by estimating separate relationships for each of the 11 euro-area national banking systems. Some heterogeneity across the different countries is detected. In particular, in some cases the demand for reserves turns out to be interest rate-inelastic over the holding period, suggesting that there is room for further efficiency improvements.

JEL classifications: E52

Keywords: Liquidity effect; announcement effect; overnight; martingale; interbank market.

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* Bank of Italy, Economic Research Department

1. Introduction[1]

Several recent contributions to the literature on interbank markets have focused on the liquidity effect, the high-frequency (daily or weekly) changes in short-term interest rates triggered by a variation in the monetary base, explicitly taking into account the role of the reserve maintenance period (e.g. Hamilton, 1997, 1998; Bartolini, Bertola and Prati, 2000, 2002; Thornton 2001; Hayashi, 2001).[2] Within this context, the liquidity effect is strictly related to the so-called martingale hypothesis: under the assumption that reserves are only held in order to meet the requirement, banks should regard balances held on different days of the averaging period as perfect substitutes; hence, predictable deviations of the future interest rate from its current level should be arbitraged out, and the overnight rate should behave like a martingale — its current and expected values should coincide. In principle, rejection of the martingale hypothesis (relatively common in the literature; see e.g. Hamilton, 1996, Hayashi 2001 for evidence on the US and Japanese markets) is a sufficient condition for a liquidity effect within the averaging period: if reserves held on different days are not perfectly substitutable, then full arbitrage will be prevented, and changes in the system's liquidity will affect the overnight rate.

However, rejection of the martingale hypothesis is not a necessary condition for a liquidity effect, which may also materialize if the liquidity shock is perceived by the market as having some signaling value for the monetary policy stance. It is easy to see that in this case a liquidity effect and martingale behavior may well coexist: following a larger-than-expected liquidity injection (drain), according to the arbitrage argument given above, both the current overnight rate and its expected value will decline (rise) by the same amount, preserving the martingale property.

But what is the signaling value of liquidity shocks? In most modern operational frameworks short-term interest rates are anchored by mechanisms that are independent of the system's liquidity, as central banks publicly announce some form of target for the short-term interest rate, letting quantities adjust endogenously. The idea that liquidity management has lost most of its signaling value for monetary policy has therefore recently become relatively popular. According to Akhtar (1997), it holds true for the US since February 1994, when the Fed began to announce its federal funds rate target. Demiralp and Jordà (2002a, 2002b) call this way of controlling the overnight rate the "announcement effect" and show it to be relevant in the US since 1994. Evidence of this effect

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1 The paper draws on Angelini and Silipo (2000). I am indebted to Leonardo Bartolini, Ulrich Bindseil, Fabio Fornari, Eugenio Gaiotti, Oscar Jordà, Antonio Scalia, Luca Silipo and Livio Tornetta for useful comments on previous drafts.

2 Gilchrist (2001) points out that the high-frequency phenomenon discussed in this literature may have little in common with the liquidity effect discussed in the theoretical literature on dynamic general equilibrium models or in the structural VAR literature. However, views on this issue differ (see e.g. Thornton, 2001b).

is also available for New Zealand, where the central bank steers rates by means of "open mouth operations" (McCallum, 1995; Guthrie and Wright, 2000), and for a large number of industrialized countries (Borio, 1997).

This paper investigates these issues within the context of the euro-area monetary policy framework and money market. A test of the martingale hypothesis for the Eonia (the area interbank overnight rate) is performed, to check for the presence of the effects that can be grouped under the heading "market frictions".[3] The hypothesis is rejected, implying that, in principle, a liquidity effect must exist. An estimate of the effect is then derived, and an attempt is made – to my knowledge for the first time – to separately assess its signaling and market frictions components. Specifically, the paper attempts to answer the question: following a liquidity shock, how large is the overnight rate reaction due solely to market frictions? How large is it instead if the shock is perceived as having some signaling value for the monetary policy stance? To this end, following the suggestion by Taylor (2001), an area-wide reserves demand equation is estimated in which both the current overnight rate and a proxy for its expected value appear among the regressors. The paper exploits the basic intuition that if a liquidity shock is perceived as carrying some signal, it should cause the spot overnight and its expected value to move in the same direction and by roughly the same amount, whereas a temporary shock, carrying no signal, should affect the current overnight level but leave its expected value unaffected. In either case, the liquidity effect can be directly inferred from the slope of the demand curve.

As pointed out by Taylor (2001), the central bank should be able to affect the current rate even without open market operations to the extent that its credibility allows it to affect the expected value of the short-term rate, which is a demand curve shifter. The magnitude of the elasticity of demand to the latter should therefore represent a measure of the potential importance of the announcement effect. The proxies for the expected short-term rate used in the empirical analysis are based on futures contracts on overnight funds, which have been found to be good measures of monetary policy expectations (see e.g. Kuttner, 2001).

To retrieve an area-wide demand for reserves, separate equations for the eleven national segments of the euro-area interbank market are estimated. This analysis is relevant per se, as it sheds light on the degree of integration of the euro-area interbank market – a key issues in the new single monetary policy environment – and allows an assessment of the efficiency in liquidity management by the individual national banking systems. The specification search is guided by the

3 These include several factors that may prevent the full working of arbitrage mechanisms: limits on credit lines and transaction costs (Hamilton, 1996; Clouse and Dow, 1999), the role of reserves for the interbank payment system (Furfine, 2000), risk-aversion on the part of money market operators (Angelini, 2000).

predictions derived from a simple theoretical model of reserve management behavior within the holding period, which is able to reproduce some well-known results of existing models and to suggest a few new insights.

The rest of the paper is organized as follows. Section 2 briefly describes the main features of the euro-area interbank market. Section 3 presents the model and summarizes its main predictions. Section 4 illustrates the dataset. Section 5 presents the empirical results concerning the time series properties of the overnight rate and the estimated demand functions at the national and area-wide level. Section 6 concludes.

2. The euro-area interbank market

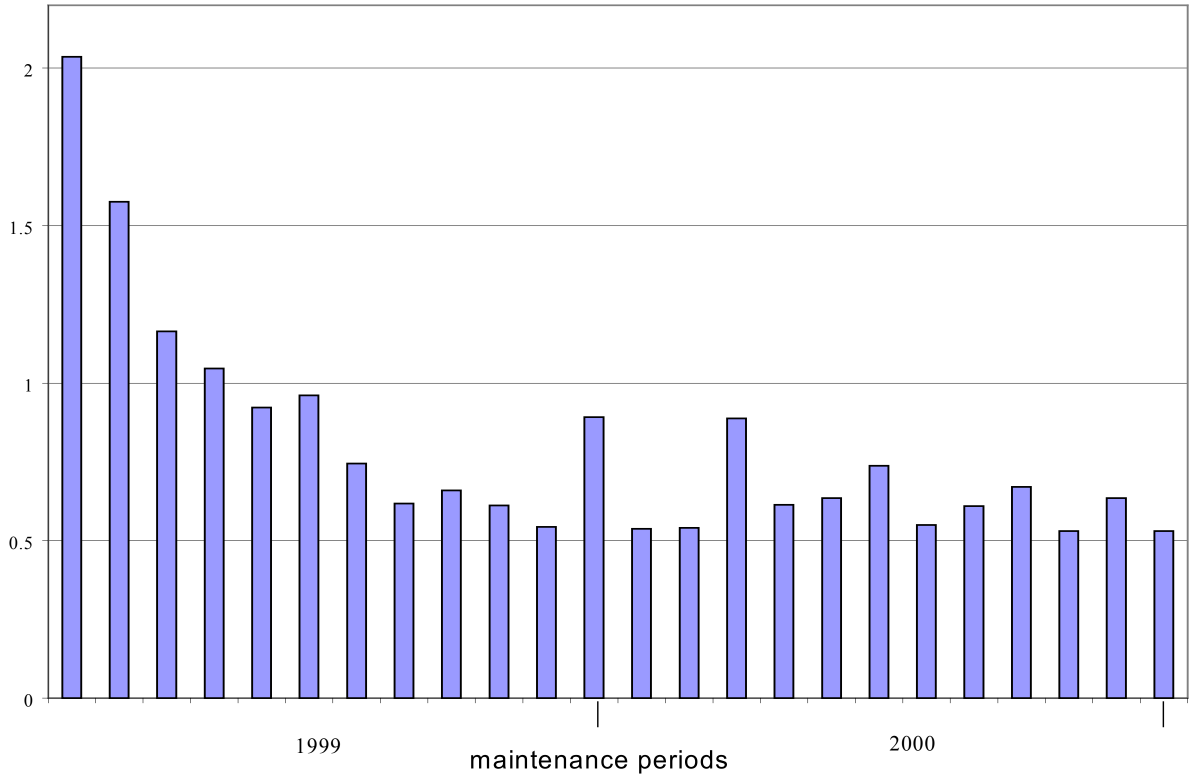
The market comprises virtually all the euro-area commercial banks (over 8,000). A 2 per cent reserve ratio is applied to selected bank liabilities, based on amounts outstanding at the end of month k; the requirement must be met on average over the maintenance period, which runs from the 24th of month k+1 to the 23rd of month k+2 (lagged system). On average over the sample period, required reserves in the euro area totaled about 107 billion euros (Table 1). Excess reserves, relatively high in the first half of 1999, were stable around 0.6-0.8 per cent of required reserves from September 1999 onwards (Figure 1).

The Eonia, the reference interbank overnight rate for the euro area, generally displays a low volatility. The large swings towards the end of the maintenance period (Figure 2), typical of systems with averaging provisions, are also due to the operational framework chosen by the Eurosystem, which features weekly open market operations and little if any fine-tuning of liquidity towards the end of the period. The Eonia is bounded above and below by the "official rates corridor", fixed by the ECB: banks may borrow against collateral at the rate on the marginal lending facility (the ceiling) or deposit funds at the rate on the overnight deposit facility (the floor). Within the available sample, the behavior of the Eonia over the maintenance period displays no clear seasonal pattern (Figure 3). The pattern of reserves accumulation over the holding period is relatively homogeneous across national banking systems (Figure 4). Although the curves, computed as averages of daily data over the 24 periods comprising the sample, do differ, the related standard deviations, particularly at the beginning of the period, are very large.[4]

[4] Italian banks typically start the maintenance period with very low reserve balances (on average, almost 35 per cent less than the amount due) and then gradually make up for the shortfall over the period. This pattern appears related to the timing of fiscal receipts of the Italian government, which come due on the 23rd of each month.

Figure 1: End-of-period excess reserves

(percentage deviation from required reserves)



Source: Eurosystem data.

Table 1: Reserves held at the central bank in the euro area [(1)]

(millions of euro and percentage points)

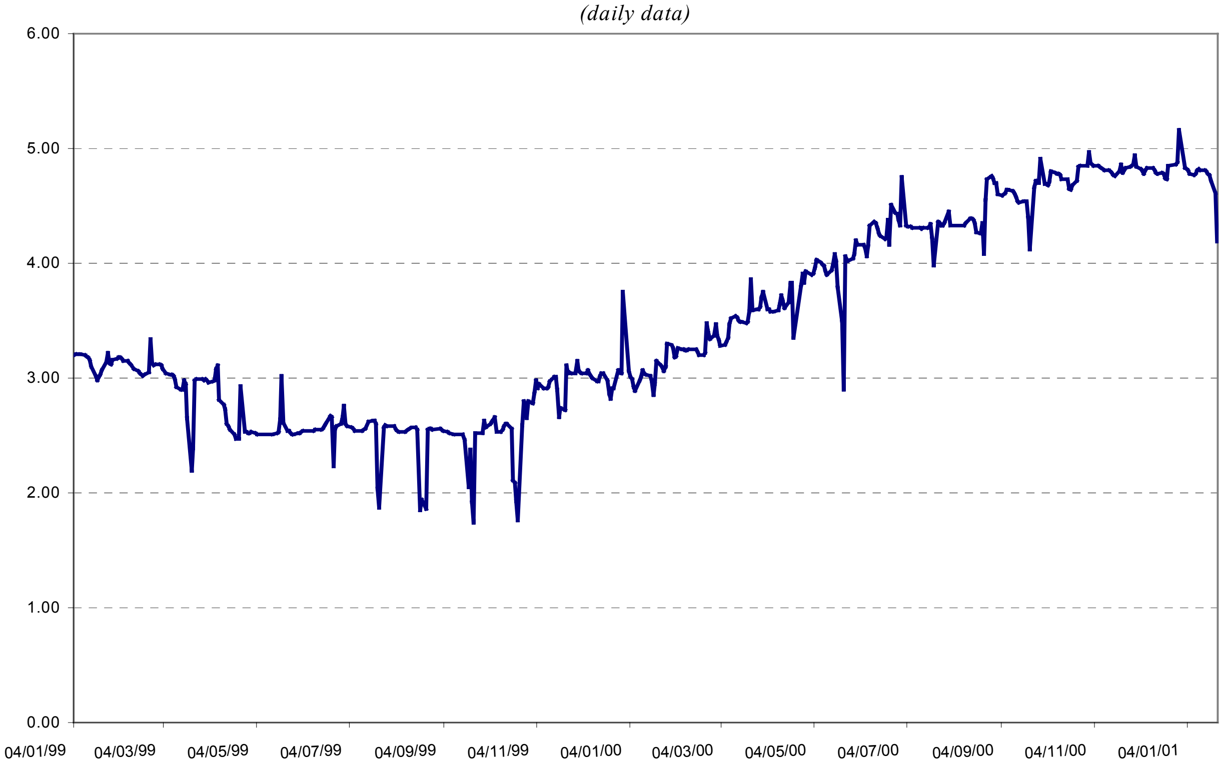
	AUT	BEL	FIN	FRA	GER	IRE	ITA	LUX	NET	POR	SPA	AREA
Required reserves (a)	3,590	7,253	1,582	18,837	32,628	3,090	12,116	6,445	10,407	2,763	8,588	107,298
Excess reserves (b)	41.0	13.8	6.8	268.0	315.7	11.9	64.8	32.3	32.8	8.4	52.8	848.2
(b)/(a) %	1.14	0.19	0.43	1.42	0.97	0.39	0.53	0.50	0.32	0.30	0.61	0.79

Source: Eurosystem data.

(1) Required and excess reserves are computed as an average over the entire sample period (4 January 1999 – 23 January 2001).

Figure 2: Euro-area overnight interest rate (Eonia)

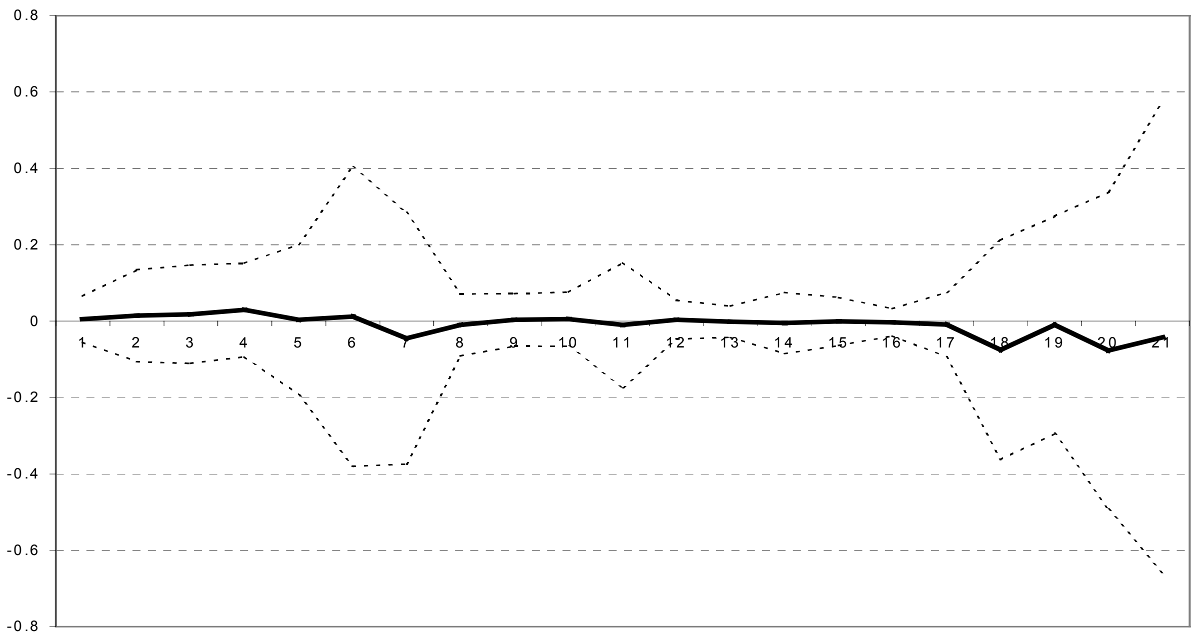
(daily data)



Source: Telerate.

Figure 3: Pattern of the Eonia over the maintenance period (1)

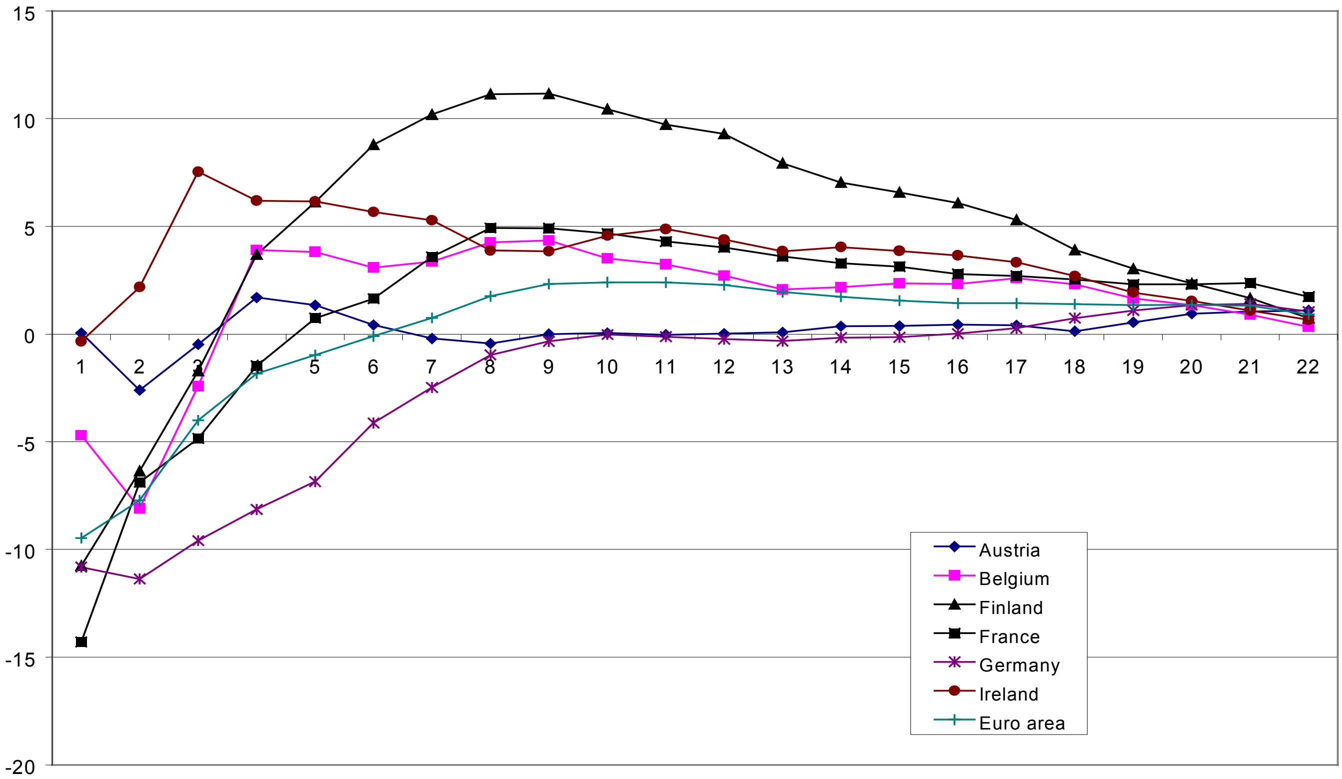
(first differences; averages of daily data over 24 maintenance periods)

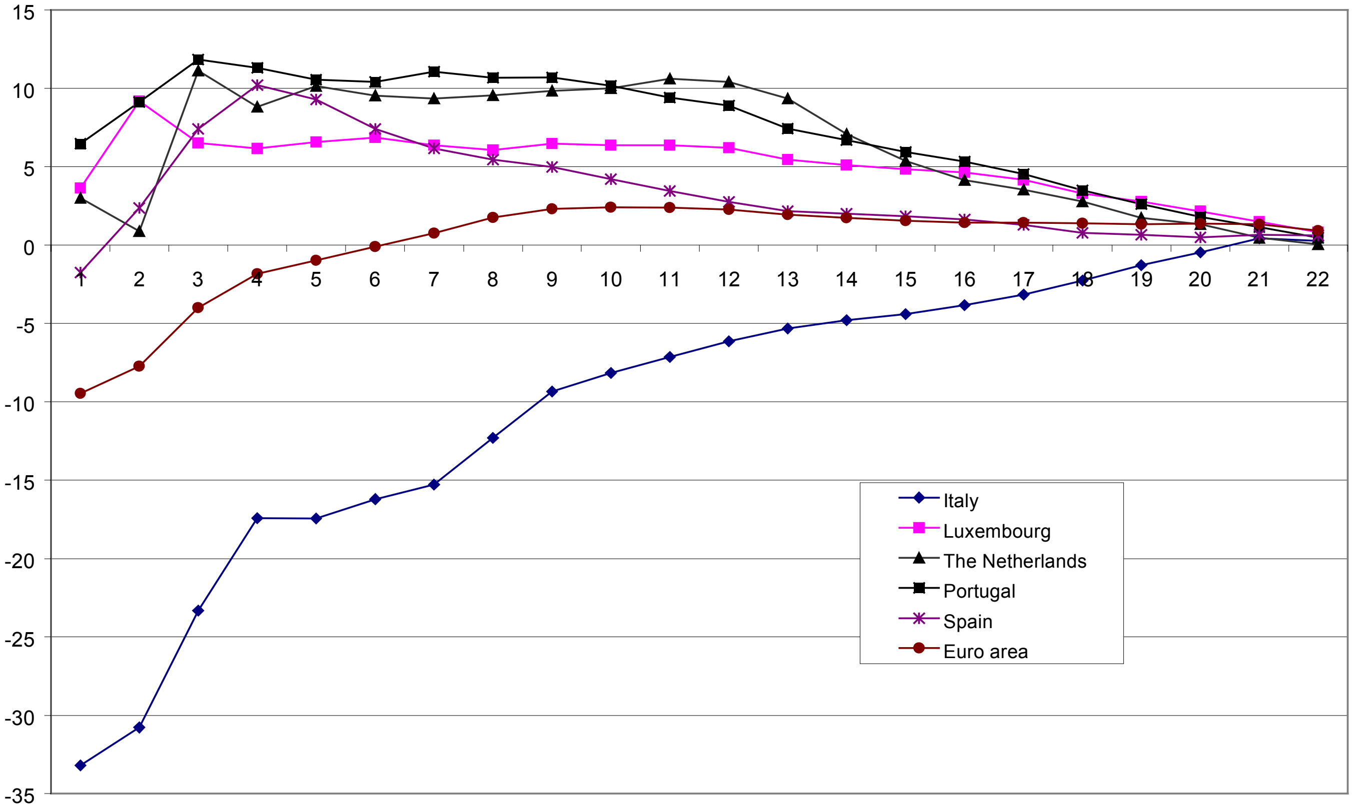


Source: Telerate.

(1) Dotted lines delimit a confidence band computed as ± 2 standard deviations of the series. The horizontal axis reports the working days of the maintenance period. The last day is always plotted under the label "21" of the horizontal axis; however, since the length of the period is not constant, under the label "1" are reported observations pertaining to the longest periods only. The first 15 observations of the maintenance period 1 January – 23 February 1999 were eliminated. First differences of the Eonia are computed within each maintenance period.

Figure 4: Progressive balance over the maintenance period (1)
(percentage deviation from the amount due)





Source: Eurosystem data.

(1) The horizontal axis reports the working days of the maintenance period. The last day is always plotted under the label "22" of the horizontal axis; however, since the length of the period is not constant, under the label "1" are reported observations pertaining to the longest periods only.

Main refinancing operations (MROs), repos with a two-week maturity normally auctioned every Tuesday and settled the following day, are the principal instrument for liquidity regulation. Longer-term refinancing operations are held monthly and have a three-month maturity. Fine-tuning operations are available to the ECB, but were used only twice during the sample period covered by this study. Until 27 June 2000, MROs were auctioned at a fixed rate, which was explicitly meant to signal the monetary policy stance; afterwards, they were conducted as variable rate tenders with the announcement of a minimum bid rate, which has replaced the fixed rate as a signaling device. Since April 1999 the fixed/minimum rate has been set at the midpoint of the official rates corridor. A second institutional change was introduced on 16 June 2000, when the ECB began releasing its own forecasts of the liquidity needs of the banking system.

3. Motivation

Adopting an extremely simplified approach, the behavior of a liquidity manager when averaging provisions are in place can be modeled as a two-day problem. On the first day intertemporal arbitrage is possible; the second day, when the reserve requirement becomes binding, can be thought of as the latter part of the holding period – at the limit, just its final day. This modeling option, relatively common in the literature (e.g. Campbell, 1987; Clouse and Dow, 1999; Bartolini, Bertola and Prati 2002; Quiros and Rodriguez-Mendizabal, 2000), is warranted when the analysis focuses on qualitative aspects rather than on realism.

While the treasurer faces uncertainty at the daily frequency concerning stochastic inflows and outflows of reserves, it can be assumed that the role played by such uncertainty over the entire holding period is modest. Accordingly, since the only reason for treasurers to hold excess reserves is related to payments uncertainty, excess reserves are assumed to be zero, so that the reserve requirement is met with strict equality (as mentioned in the previous section, this assumption is realistic for the euro area):

(1) $$(R_1 + R_2)/2 = \overline{R}\ ,$$

where R_k is the reserve balance on day k and $\overline{R}$ is the average stock of reserves to be held over the period. Denoting by i_t the short term interbank interest rate in period t, and overlooking discounting, given the short horizon considered, the two-period problem solved by the treasurer can be laid out as follows:

(2) $$\underset{R_1,\, R_2}{Min} \quad E_1\left\{(i_1 R_1)^2 + (i_2 R_2)^2\right\}$$

subject to constraint (1). The quadratic formulation of the problem (variants of which are relatively common in the literature; see e.g. Campbell, 1987) captures the fact that banks are unwilling to let their daily balance deviate too far from a target, for the reasons briefly mentioned in footnote 3.

Concerning the information structure and the timing of decisions, I assume that in the first period the bank observes i_1. Under a lagged reserve requirement system $\overline{R}$ is known in the first period, as it is directly computed from outstanding deposits at the end of the previous month. Thus, the expectation refers to i_2, which is the only unknown at the time the decision on R_1 is made. The standard backward solution technique can be used to derive an expression for R_2 directly from (1):

$$R_2 = 2\overline{R} - \hat{R}_1 \qquad (3)$$

where a hat denotes realized values. Substituting (3) into (2), solving for R_1 and rearranging yields:

$$R_1 = \frac{2\overline{R}\left[s_{i_2}^{2} + (E_1 i_2)^2\right]}{i_1^2 + s_{i_2}^{2} + (E_1 i_2)^2} \qquad (4)$$

where $s_{i_2}^{2}$ is the variance of i_2. As in Campbell (1987), Furfine (2000), Taylor (2001), today's demand for funds depends on both the current overnight rate and its expected value with a finite elasticity. This implies that within the maintenance period the short-term interest rate cannot be determined simply by the interaction of demand and supply of reserves, as there is a continuum of values for i_1 and $E_1(i_2)$ coherent with a given value of R_1. To determine the rate, some additional condition must be introduced, e.g. a signaling device (the federal funds target rate used by the Fed or the fixed/minimum tender rate used by the Eurosystem). As pointed out by Taylor (2001), this feature of the model rationalizes an announcement effect: the mere release of information about a policy decision, if credible, causes a shift in the demand curve because $E_1(i_2)$ changes, independently from variations in the supply of funds (the traditional liquidity effect).

Standard comparative static exercises performed on (4) show that in the first period reserve holdings increase: if r_1 decreases; if interest rates in the second period are expected to rise; if the volatility of interest rates in the second period rises. In addition, equation (3) shows that there is an inverse relationship between the demand for funds in the first and second period, as any excess (shortfall) of reserves relative to the requirement day must be eventually worked off. It also shows that R_2 is completely inelastic to interest rates, capturing the well-known fact that the interest rate elasticity of the demand for reserves tends to diminish as the end of the holding period approaches.[5]

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[5] Borio (1997) provides a qualitative description of the phenomenon. Bartolini, Bertola and Prati (2000) derive the same results within a multiperiod model, and provide supporting empirical evidence from the US federal funds market. Bartolini, Bertola and Prati (2001) provide analogous evidence for the G7 countries.

Finally, an upward shift of equal magnitude affecting both current and future interest rates should in general depress the current demand for reserves, as long as there is uncertainty concerning tomorrow’s rate. This can be seen by computing the total differential of (4) and assuming a unit increase in i_1 and $E(i_2)$, which yields:

$$dR_1 \approx -\frac{4\bar{R}i_1\left[s_{i_2}^2 + E_1 i_2 (E_1 i_2 - i_1)\right]}{\left[i_1^2 + s_{i_2}^2 + (E_1 i_2)^2\right]^2}. \qquad (5)$$

Under the assumption that the term $(Ei_2 - i_1)$ is negligible, the right-hand side of (5) is negative. The intuition underlying this result is that when $E_1(i_2)$ increases for given $s_{i_2}^2$, the relative uncertainty concerning tomorrow’s interest rate decreases. Other things being equal, a risk-averse bank should therefore be more willing to hold reserves tomorrow.

Two qualifications of the above analysis are in order. First, the dependence of the current demand for reserves on $s_{i_2}^2$ in equation (4) depends on the quadratic terms in the interest rate in the loss function (2). Using Campbell’s (1987) specification for (2) the result disappears, leaving all other results unchanged.[6] Second, following Campbell (1987), but departing from much of the existing literature, the model assumes that uncertainty concerning reserve inflows and outflows plays no role. It is well known that in the presence of transaction costs, banks facing unexpected liquidity shocks have an incentive to trade on the final day of the maintenance period (see e.g. Bartolini, Bertola and Prati, 2002), which may in principle offset the negative effect of interest rate volatility on the demand for funds in the second period. A full-fledged model should in principle account for both these effects; whether the former or the latter prevail is an empirical matter.

4. The data

The dataset comprises daily time series from the eleven EMU countries over the period 4 January 1999 – 23 January 2001. End-of-day settlement balances are reported by each national central bank of the Eurosystem. The Eonia is a volume-weighted average of effective rates on unsecured lending transactions in the interbank market, reported by a sample of large banks broadly representative of the euro-area countries; it is published daily on Telerate. The Italian screen-based interbank deposit market MID is the data source for the tom- and spot-next interbank futures rates, and the one and two-week spot rates; proxies for $E_1(i_2)$ based on these rates will be described and used in the next sections. A bank that agrees to borrow tom-next (spot-next) funds at a given rate on day t acquires a

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6 Campbell (1987) assumes the following period loss function on day k: $i_k R_k + (q/2)(R_k - R^*)^2$, where R^* represents a daily reserve target.

right to take delivery of the funds on day *t*+1 (*t*+2) and a commitment to reimburse them plus interest on *t*+2 (*t*+3); this makes these rates ready-to-use proxies for expectations about the overnight rate one or two days from the current date.

As is standard practice (see e.g. Hamilton, 1996, 1997), days on which the market was closed – when TARGET was not operational, Saturdays and Sundays – were eliminated from the sample. For the analysis in Section 5.2 different sample periods are used, depending on the country. In particular, the following four sub-periods are treated as special: *i*) 1 January 23 February 1999, the first maintenance period of the sample, characterized by some turbulence related to the start of the single monetary policy and by a non standard length;[7] *ii*) 27 December 1999 - 4 January 2000, heavily affected by the so-called "millennium bug"; *iii*) 26 June 2000 - 10 July 2000, which was affected by the move from fixed to variable rate tenders and by the publication of forecasts of liquidity needs by the ECB, briefly described in section 2; *iv*) 27 December 2000 - 4 January 2001. For each country a sensitivity analysis was performed by excluding these periods (one at the time as well as jointly) from the estimation sample. In most cases results are fairly robust to whether or not these sub-samples are included in the regression, although the magnitude and significance of the coefficients can be somewhat affected. Details about the sample adopted for each country are reported in a footnote to Table 3. Finally, the sample does not include the first day of each holding period, which is used to compute lagged values.

Two linear trends, denoted *T* and *t*, are used in the following sections. *T* takes values from zero to one over the entire sample period, comprising 530 observations; *t* takes values from zero to one over each maintenance period and is introduced to capture possible seasonal patterns over the period.

5. The empirical analysis

5.1 Is the Eonia a martingale?

To test the martingale hypothesis for the Eonia, the series of regressions reported in Table 2 were run. Autocorrelation of the dependent variable is accounted for up to the fifth order; a series of zero-one dummy variables should capture seasonal patterns: day-of-the-week effects, days before and after three or four-day holidays, year-end, quarter-end, month-end, settlement day.[8] To control

7 Gaspar, Perez-Quiros and Sicilia (2001) argue that there is clear evidence of learning behavior by commercial banks during this period.

8 Dummies for days before or after a one-day holiday (used e.g. by Hamilton, 1996) are not included as there are no such days within the available sample period.

for possible seasonal patterns over the maintenance period, a polynomial in *t* is introduced.[9] OLS regression results are reported in column *(a)*. The coefficient of the first lag of the dependent variable is very close to one and highly significant, whereas all other lagged values are not different from zero. On the first day of a new maintenance period the first order autocorrelation disappears almost completely (the coefficient drops from 0.98 to 0.04), whereas a strong fifth-order autocorrelation materializes. As noted by Hamilton (1996), this does not have any implication for the martingale hypothesis, as no arbitrage is possible between *k* and *k*+1 if *k* is the final day of a period. The set of calendar dummies is not significant, with the exception of the end-of-month effect: the estimated coefficient indicates that the rate on the final day of the month is 8 basis points higher than average. The end-of-quarter and end-of-year dummies are significant at the 10 per cent level. These increases may reflect a temporary shift in the interbank loan supply schedule induced by the regulation on capital adequacy.[10] Also, in line with the evidence of Figure 3, the hypothesis that the coefficients of the terms in the linear trend are equal to zero is not rejected, implying that no clear seasonal pattern characterizes the data over the averaging period (analogous results were obtained introducing higher order terms).

[9] This method is adopted because the number of working days in the maintenance periods is not constant, which rules out creating a meaningful set of dummies for each day of the period, as is generally done in studies on the US system.

[10] In particular, the consistency of banks' capital with the Basel requirements is checked on end-of-quarter outstanding risk assets. Thus, at the end of the quarter bank treasurers have an incentive to reduce very-short-term loans, in order to "absorb" less capital. Anecdotal evidence suggests that the effect is also observed at the monthly frequency, because end-of-month data, sent to the central bank for supervisory reasons, are also often used by commercial banks for their internal monitoring procedures whereby the profits produced by each department are adjusted to account for the capital absorbed. These phenomena result in increased short-term interest rate volatility around the end of the month, which is clearly visible in the peak displayed by the standard deviation of the first difference of the Eonia around the sixth working day of the maintenance period (see Figure 3).

Table 2: Dependent variable: Eonia rate [1]

(daily data; sample period: 4 January1999 – 23 January 2001)

	OLS (a)		Robust [2] (b)		P-GARCH GED [3] (c)	
	Coeff.	σ	Coeff.	σ	Coeff.	σ
$Eonia_{(t-1)}$	0.98**	0.07	1.03**	0.01	1.00**	6.7e-6
$Eonia_{(t-2)}$	-0.03	0.05	-0.03*	0.01	-4.8e-3**	3.3e-5
$Eonia_{(t-3)}$	0.01	0.03	2.1e-3	0.01	6.4e-5	8.4e-5
$Eonia_{(t-4)}$	-0.02	0.03	-3.1e-3	0.01	2.2e-6	6.3e-5
$Eonia_{(t-5)}$	0.05	0.03	1.5e-3	0.01	-6.2e-6	7.6e-5
$Eonia_{(t-1)}$*dummy for first day of period	-0.94**	0.09	-0.87**	0.03	-0.85**	3.6e-3
$Eonia_{(t-2)}$*dummy for first day of period	0.09	0.12	-0.07	0.05	-0.10**	6.4e-3
$Eonia_{(t-3)}$*dummy for first day of period	0.22	0.12	0.11	0.06	0.07**	0.01
$Eonia_{(t-4)}$*dummy for first day of period	-0.25*	0.11	-0.20**	0.07	-0.16**	0.01
$Eonia_{(t-5)}$*dummy for first day of period	0.92**	0.09	1.05**	0.05	1.06**	6.0e-3
Zero-one dummies for:						
Day before a 3 or 4 day holiday	-0.08	0.16	0.07**	0.02	0.03	0.03
Day after a 3 or 4 day holiday	-0.21	0.12	-0.04*	0.02	-0.03**	4.4e-3
Monday	-9.8e-3	0.01	7.4e-3	4.4e-3	-6.0e-7	1.6e-5
Tuesday	0.02	0.01	7.8e-3	4.4e-3	-4.0e-7	1.5e-5
Thursday	-1.0e-3	0.01	1.3e-3	4.4e-3	-3.1e-7	1.6e-5
Friday	4.4e-3	0.01	-2.2e-3	4.4e-3	-3.3e-7	1.7e-5
end of month	0.08**	0.02	0.04**	8.4e-3	0.01**	5.3e-5
end of quarter	0.10	0.06	0.04*	0.02	0.10**	4.3e-3
end of year	0.42	0.23	0.00	0.03	0.14**	0.04
Settlement day	0.01	0.07	0.06**	8.4e-3	0.09**	0.01
linear trend over maintenance period	0.07	0.08	0.03	0.02	1.8e-5	2.8e-4
$(\text{linear trend over maintenance period})^2$	-0.12	0.08	-0.03	0.02	-1.5e-5	2.4e-4
Constant	0.02	0.03	-9.7e-3	8.1e-3	-3.8e-6	8.5e-5
N° observations	525		525		525	
R^2	0.99		-		-	

(1) Eonia, an acronym for Euro OverNight Index Average, is the reference overnight rate for the euro area. Week-ends and holidays were excluded from the dataset. Both "Robust" and OLS regressions report White heteroskedasticity-robust standard errors. One or two asterisks denote significance at the 5 and 1 percent levels, respectively.

(2) The column headed "robust" reports regression results obtained with the rreg command available in the Stata software. An initial OLS regression is run and outliers are detected according to Cook's statistic. These outliers are excluded from the sample. Subsequently a regression is run, in which observations are assigned a weight that is inversely related to the magnitude of the residual. The regression is iterated until no change in the weights occurs.

(3) Estimates from a power GARCH model in which the errors z_t are assumed to have a GED distribution. The following equation for the conditional variance was used:
$\sigma_t^{\delta} = k_1 + k_2(|z_{t-1}| + k_3 z_{t-1})^{\delta} + k_4\sigma_{t-1}^{\delta} + \bar{\lambda}D$, where the vector D comprises the zero-one dummies reported in the table and the two terms in the linear trend. Estimated values for these parameters are not reported.

As is typical for regressions of this kind (see e.g. Hamilton, 1996, 1997), OLS residuals turn out to be heteroskedastic and with fat tails. A Cook-Weisberg test yields a chi square of 19.3 with one degree of freedom, allowing us to reject the null of homoskedasticity at any significance level. Whereas these features do not affect the consistency of the estimates, within a finite sample large errors may well bias the parameters. To account for this problem the equation was re-estimated using two additional methods. The first employs an iterative routine that drops the most severe outliers and subsequently assigns each observation a weight inversely related to the magnitude of the attached residual (additional details are provided in the footnote to the table). The results, reported under the heading "Robust", are broadly similar to those obtained with OLS.[11] The second method consists in adding a power GARCH model for the variance to the above specifications and estimating it with pseudo-maximum likelihood, assuming a generalized error distribution (GED) for the error term (the coefficients of the equation for the variance, as well as those of the GED, are not reported).[12] Whereas this method allows a proper modeling of the heteroskedasticity and of the fat tails, the errors have an unknown distribution. Since the focus here is on assessing the potential bias of the OLS estimates, significance levels based on *t* statistic critical values are reported; they should therefore be interpreted with caution. Again, the results broadly confirm the lack of bias in the OLS estimates, although the magnitude of some calendar effects is somewhat different.[13] These results are broadly in line with the evidence available for other industrialized countries, where deviations of the overnight rate from martingale behavior are statistically significant although quantitatively small.[14]

5.2 The demand for settlement balances

The analysis in Section 3 yields a series of testable propositions that can be used to guide the specification search. The current demand for daily settlement balances should be: *i)* negatively

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[11] The significance of the coefficients of the dummies for the end of the maintenance period should be looked at with some suspicion, given that on these days the variance of the interest rate is typically high, increasing the probability that the estimation procedure drops or assigns a low weight to these observations. A similar caveat applies to the finding that rates are lower than average on days preceding or following a three or four-day vacation.

[12] The GED, also adopted by Bartolini, Bertola and Prati (2000) for the same purpose, is a very general model of a distribution with fat tails (alternatively, Hamilton, 1996, adopts a mixture of normal p.d.f.s). The two parameters controlling the peakedness and the fatness of the tails of the GED estimated in Table 2 turn out to be significant and equal to .44 and .62, respectively, in line with the a priori (both parameters should be equal to 2 in the case of normality).

[13] Hamilton (1998) also finds the OLS estimates to be broadly adequate for the US federal funds rate.

[14] However, few common cross-border patterns seem to emerge concerning calendar effects and seasonality. Hamilton (1996) finds that on days preceding (following) a 3-days holiday the federal funds rate is significantly lower (higher) than average (3 and 17 basis points, respectively). Confirming the results of previous literature, he also shows that the rate follows a declining pattern over the maintenance period and then spikes on the last day. However, such spike disappears after 1998, possibly due to the change from a contemporaneous to a lagged reserve system (Demiralp and Jordà, 2002b; Taylor, 2001). More generally, Bartolini, Bertola and Prati (2001) document the difficulty of identifying common patterns in the overnight market across G7 countries.

related to the average balance accumulated up to the previous day; *ii)* negatively related to the current overnight rate and positively related to the rate expected to prevail tomorrow; and *iii)* inversely related to the volatility of tomorrow's interest rate. In addition, *iv)* the interest rate sensitivity should decline over the holding period, possibly reaching zero at its end; *v)* the semi-elasticity to current rate changes should be larger than that to expected rate changes.

Based on these a priori, the following demand for end-of-day balances was estimated for each country:

$$(5) \qquad r_t = g + b_1 t^a \tilde{r}_{t-1} + b_2 r_{t-1} + (b_3 + t^a b_4) i_t + (b_5 + t^a b_6) E_t(i_{t+1,S}) + b_7 t^a + b_8 T + b_9 s^2_{i_{t+1}} + \sum_{i=1}^{6} j_i D_i + e_t$$

where $r \equiv \ln(R)$, $\tilde{r}_t$ is the percentage deviation of the progressive average of reserve balances from the amount due in the current maintenance period.[15] With a slight change of notation relative to Section 3, let $E_t(i_{t+1,S})$ be the overnight rate expected to prevail over the rest of the holding period and let subscripts t index the t^{th} day of the period. Two empirical counterparts for $E_t(i_{t+1,S})$ are used: the tom-next, which is a good proxy for the overnight expected to prevail tomorrow, and an alternative measure, described below, which should span the entire holding period. A lagged dependent variable is included to allow for the strong autoregressive behavior of daily balances. i_t is the Eonia, whereas several proxies for $E_t(i_{t+1,S})$ are used, as discussed below. The linear trends over the maintenance period and over the entire sample period described in Section 4 are denoted by t and T, respectively.[16] The interaction of t^a with the interest rate variables allows for within-period time-varying semi-elasticities, whereas the interaction with the progressive balance captures the fact that the rate at which accumulated reserves imbalances must be worked off increases as the end of the maintenance period approaches. The conditional volatility estimated from the GARCH process of the previous subsection are used as a measure of interest rate volatility. D is a vector comprising a subset of the zero-one calendar dummies used in the previous subsection.

In principle, estimation of an equation such as (5) poses a simultaneity bias problem, as quantities R_t and prices i_t are determined by the interplay of supply and demand. Nevertheless, the least squares estimation method can be deemed appropriate for three reasons. First, the simultaneity problem is emphasized in the literature dealing with the US market owing to the presence of a publicly announced target for the federal funds rate, which the Fed normally pursues on a daily

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15 The definition used is: $\tilde{r}_t \equiv \ln(\frac{1}{t-1}\sum_{j=1}^{t-1} R_j) - \bar{r}$, where $\bar{r}$ stands for the log of required reserves.

16 Specifications featuring time-varying parameters within the maintenance period are relatively common (see e.g. Hamilton, 1997; Demiralp and Jordà, 2002b).

basis via open market operations. By contrast, the ECB does not try to stabilize the Eonia. As mentioned in Section 2, the ECB's MROs are conducted on a weekly basis, and fine-tuning operations were used only twice during the sample period. Thus, on any given day other than Wednesday (when open market operations are settled), the total supply of reserves changes only because of autonomous factors, which do not react in any systematic way to movements in short-term interest rates (Bindseil and Seitz, 2001). Second, the dependent variable in (5) is not exogenously determined, either at the euro-area level or at the country level, because it incorporates the recourse to the standing facilities, which is freely determined by banks; use of the standing facilities is negligible on average but can reach large peak values. Third, given the relatively large number of national segments of the euro-area interbank market (11), the hypothesis of price-taking behavior (i.e. of exogeneity of the Eonia) in each segment may be expected to hold.

Table 3 reports parameter estimates and heteroskedasticity robust standard errors for the 11 countries comprising the euro area within the sample period. Owing to the presence of the term t^a, nonlinear least squares are used. Area-wide estimates, in the last column, are obtained as averages of their country-specific counterparts. Pesaran and Smith (1995) show that this aggregation method provides consistent, although inefficient, results. Standard errors retrieved via this method are correct as long as parameters are independent across countries.

Figure 5 shows the shape of t^a, the trend capturing the evolution of the elasticities over the holding period. Estimated as are relatively heterogeneous across countries, ranging from a maximum of 6.2 for Italy to a minimum of 1.5 for Luxembourg. On average in the euro area, no significant decline in the elasticities occurs for the first half of the period.

Proposition *i)* (the current demand for daily settlements should be inversely related to the average balance accumulated up to the previous day) is readily verified: coefficients are negative and significant at the 1 per cent level for all countries. The effect is time-varying within the maintenance period; for example, on settlement days a 1 per cent cumulated deficit would cause daily balances to increase by a minimum of 3.3 per cent up to a maximum of 13.0 per cent for German and Italian banks, respectively (in principle, to completely offset the deficit the increase should be about 30 per cent), whereas at the beginning of the period the effect is negligible, regardless of the country.

Table 3: Dependent variable: log of balances held at the central bank [(1)]

(daily data; sample period: 4 January 1999 – 23 January 2001)

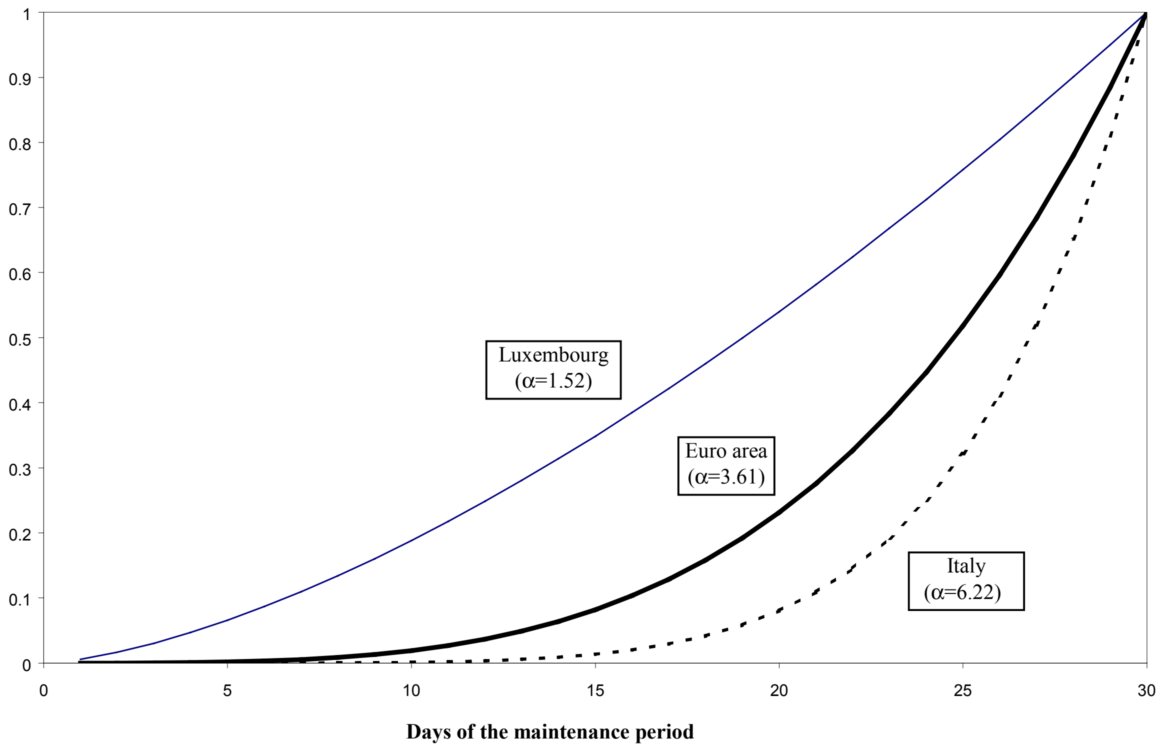
	AUT	BEL	FIN	FRA	GER	IRL	ITA	LUX	NET	POR	SPA	AREA [(3)] weighted average	AREA [(3)] simple average
Constant	6.31**	5.90**	6.09**	7.40**	6.39**	6.11**	5.38**	4.74**	6.82**	4.90**	7.29**	6.12**	6.40**
	0.40	*0.40*	*0.36*	*0.44*	*0.52*	*0.41*	*0.35*	*0.43*	*0.40*	*0.30*	*0.45*	*0.40*	*0.44*
ln(progr. balance$_{t-1}$)*t^{α} [(2)]	-8.59**	-8.85**	-4.85**	-5.00**	-3.29**	-6.35**	-12.96**	-3.09**	-8.14**	-6.96**	-9.99**	-7.10**	-6.45**
	1.50	*2.11*	*1.08*	*1.21*	*0.74*	*1.56*	*2.03*	*0.55*	*1.78*	*1.17*	*1.67*	*1.40*	*1.29*
ln(balances$_{t-1}$)	0.22**	0.33**	0.19**	0.25**	0.38**	0.22**	0.43**	0.47**	0.25**	0.38**	0.18**	0.30**	0.33**
	0.05	*0.04*	*0.05*	*0.05*	*0.05*	*0.05*	*0.04*	*0.05*	*0.04*	*0.04*	*0.05*	*0.05*	*0.05*
ΔEonia$_t$ (β_3)	-1.15**	-0.87**	-0.66	0.12	-0.56*	-0.10	-2.32**	-1.14**	-0.59**	-0.68**	-0.36*	-0.76**	-0.70**
	0.28	*0.27*	*0.36*	*0.14*	*0.23*	*0.26*	*0.32*	*0.20*	*0.18*	*0.20*	*0.18*	*0.24*	*0.22*
ΔEonia$_t$*t^{α} (β_4)	1.37**	0.96**	1.01*	0.09	0.56*	0.34	2.45**	1.16**	0.79**	0.87**	0.45*	0.91**	0.81**
	0.30	*0.30*	*0.41*	*0.18*	*0.25*	*0.28*	*0.34*	*0.23*	*0.24*	*0.25*	*0.21*	*0.27*	*0.25*
Δtom-next$_t$ (β_5)	1.00**	0.91**	0.58	0.04	0.42*	0.42	1.05**	0.96**	0.04	0.41*	0.33*	0.56*	0.47*
	0.27	*0.33*	*0.31*	*0.08*	*0.18*	*0.31*	*0.33*	*0.23*	*0.16*	*0.21*	*0.13*	*0.23*	*0.20*
Δtom-next$_t$*t^{α} (β_6)	-0.93**	-1.22**	-0.96*	-0.30*	-0.56**	-0.46	-0.95**	-1.05**	-0.14	-0.36	-0.45**	-0.67*	-0.60*
	0.30	*0.37*	*0.39*	*0.14*	*0.20*	*0.33*	*0.35*	*0.24*	*0.29*	*0.25*	*0.15*	*0.27*	*0.24*
t^{α} (holding period trend)	0.06	0.02	-0.05	0.07	0.10**	-0.02	-0.03	-0.05	-0.17*	-0.10*	0.01	-0.01	0.02
	0.05	*0.06*	*0.05*	*0.04*	*0.03*	*0.05*	*0.06*	*0.03*	*0.07*	*0.04*	*0.03*	*0.05*	*0.04*
α	4.59**	5.50**	2.11**	2.44**	2.30**	2.63**	6.22**	1.52**	3.67**	3.97**	4.75**	3.61**	3.40**
	0.79	*1.11*	*0.37*	*0.58*	*0.56*	*0.49*	*0.94*	*0.31*	*0.57*	*0.49*	*0.85*	*0.64*	*0.66*
T (sample period trend)	3.4e-4**	1.2e-4**	1.2e-4**	9.1e-5**	1.6e-4**	8.0e-4**	9.1e-5	1.8e-4**	4.4e-4	3.8e-4**	2.8e-4**	2.7e-4**	2.0e-4**
	6.0e-5	*6.3e-5*	*7.4e-5*	*4.8e-5*	*3.5e-5*	*7.5e-5*	*4.8e-5*	*5.1e-5*	*9.1e-5*	*5.0e-5*	*4.5e-5*	*5.8e-5*	*5.1e-5*
Volatility of eonia$_t$	-0.02	-0.06	-0.34**	-0.10	-0.16**	-0.01	-0.06	-0.24**	0.08	-0.03	0.14	-0.07	-0.08
	0.10	*0.14*	*0.11*	*0.08*	*0.06*	*0.10*	*0.12*	*0.07*	*0.17*	*0.09*	*0.08*	*0.10*	*0.09*
Zero-one dummies for:													
month-end	-0.10*	-0.11	0.04	0.06	0.11**	0.00	-0.21**	-0.07	0.03	-0.04	-0.05	-0.03	0.00
	0.05	*0.07*	*0.10*	*0.04*	*0.03*	*0.05*	*0.06*	*0.04*	*0.08*	*0.04*	*0.04*	*0.05*	*0.05*
quarter-end	-0.14	0.04	0.13	0.10	0.13*	-0.02	0.07	0.01	0.10	-0.09	0.02	0.03	0.07
	0.08	*0.11*	*0.13*	*0.10*	*0.06*	*0.12*	*0.15*	*0.05*	*0.12*	*0.08*	*0.10*	*0.10*	*0.09*
Monday	0.03	0.06*	0.09**	-0.01	0.01	0.01	-0.03	-0.03	0.05	0.02	0.05	0.02	0.01
	0.02	*0.03*	*0.03*	*0.02*	*0.02*	*0.03*	*0.03*	*0.02*	*0.05*	*0.02*	*0.02*	*0.03*	*0.02*
Tuesday	0.03	0.02	-0.02	-0.01	0.01	-0.02	0.00	-0.01	-0.01	-0.01	0.03	0.0005	0.00
	0.02	*0.03*	*0.03*	*0.02*	*0.02*	*0.03*	*0.03*	*0.02*	*0.05*	*0.02*	*0.02*	*0.03*	*0.02*
Thursday	0.00	0.06*	0.07*	-0.02	0.00	0.02	-0.03	0.00	0.00	0.01	-0.01	0.01	0.00
	0.02	*0.03*	*0.03*	*0.02*	*0.02*	*0.03*	*0.02*	*0.02*	*0.05*	*0.02*	*0.02*	*0.03*	*0.02*
Friday	0.06**	0.07*	0.01	-0.02	-0.01	-0.03	0.03	-0.01	0.11**	0.03	-0.02	0.02	0.01
	0.02	*0.03*	*0.03*	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*	*0.04*	*0.02*	*0.02*	*0.02*	*0.02*
F-test of H$_0$: β_3=-β_5, β_4=-β_6	*2.40*	*0.83*	*0.10*	*0.48*	*3.47**	*2.63*	*27.23***	*0.84*	*1.82*	*2.65*	*0.12*		
F-test of H$_0$: β_3=-β_4, β_5=-β_6	*2.99*	*2.06*	*5.18***	*5.14***	*2.51*	*2.18*	*1.36*	*0.45*	*0.60*	*2.94*	*1.12*		
SER	0.16	0.21	0.21	0.14	0.10	0.19	0.17	0.13	0.31	0.14	0.12		
N° obs.	446	456	446	465	483	493	483	456	496	483	462		

(1) Estimation by non-linear least squares, providing starting values for the coefficients. White heteroskedasticity robust standard errors are reported in italics below each coefficient. One or two asterisks denote significance at the 5 and 1 percent levels, respectively. All quantity variables are in natural logarithms. See Section 5 for details about the construction of t and T, and for the estimation period, which differs across countries for the following sub-periods: *i*) 1 January - 23 February 1999; *ii*) 27 December 1999 - 4 January 2000; *iii*) 26 June 2000 - 10 July 2000; *iv*) 27 December 2000 – 4 January 2001. Specifically, *i*) is dropped for Austria, Belgium, Finland, France, Luxembourg and Spain; *ii*) is dropped for all countries with the exception of France and the Netherlands; *iii*) is dropped for Austria, Finland, Germany, Italy and Portugal; *iv*) is dropped for all countries except Spain.

(2) The variable is defined as [*ln*(progressive average balance $_{t-1}$) - *ln*(required reserves$_{t-1}$)] * t^{α}.

(3) Following the methodology in Pesaran and Smith (1995), euro area coefficients and their standard errors are computed as simple averages of the national estimates presented in the table, assuming parameter independence across countries. Corresponding weighted averages are also presented; weights are the share of deposits by each national banking system on the euro area total over the available sample period (Austria: 0.033; Belgium: 0.068; Finland: 0.015; France: 0.179; Germany: 0.306; Ireland: 0.027; Italy: 0.116; Luxembourg: 0.063; Netherlands: 0.093; Portugal: 0.025; Spain: 0.079).

Figure 5: Time-varying patterns within the maintenance period for the interest rates semi-elasticities (1)



(1) Only the curves corresponding to the minimum, maximum and euro area (weighted average) estimated alphas are reported (estimates from table 3). The 30th day is the last of the holding period, when *t*=1. The period includes weekends and holidays, as they are included in the progressive average used to check the fulfillment of the requirement.

Proposition *ii)* (a higher current overnight rate or a lower expected rate should depress the current demand for daily balances) is broadly confirmed by the estimates. The coefficient of the Eonia, β_3, is negative in 10 countries out of 11 and significant in 9. As a proxy for the expected Eonia the tom-next rate (described in Section 4) is used here; its coefficient β_5 is positive in all countries, as predicted, and significant in 7. Note that interest rates enter as first differences; the related coefficients, in particular the area-wide averages, remain broadly unchanged if analogous regressions with levels are run.[17]

[17] In particular, for Finland both the absolute value and the significance of the interest rate semi-elasticities increase remarkably; for Italy, the Netherlands, Portugal and Spain, the significance of these coefficients record a slight deterioration, whereas their magnitude remains broadly unchanged. Analogous terms in levels were also added to the specification, thereby doubling the number of interest rate regressors (from 4 to 8). This yields mixed results: for some countries levels are mainly significant, for others the same conclusion holds for first differences, in still others some levels and some differences are relevant. Whereas the results of a country-tailored specification search would have been different from those reported, this strategy would have complicated the derivation of area-wide averages and the presentation of the regressions results and was therefore not pursued.

The time-varying nature of the interest rates semi-elasticities (proposition *iv*) is generally verified. The Eonia coefficient b_4 is positive in all countries and significant in 9; the analogous coefficient for the tom-next is negative in all countries and significant in 8. Table 3 reports F-statistics for the null hypothesis $b_3 = -b_4$, $b_5 = -b_6$. The hypothesis is rejected for Finland and France; however, the interest rate coefficients for the latter country are scarcely statistically significant. Overall, this can be interpreted as evidence that towards the end of the period the true value of the elasticities is actually zero.

Proposition *iii)* (the current demand for balances should be inversely related to the volatility of the interest rate) finds relatively scant support; the coefficient is of the expected negative sign in 9 countries, but it is significant in only 3.

Proposition *v)* (the absolute value of the semi-elasticity to current rate changes should be larger than to expected rate changes) is verified for eight countries and at the area level. However, a formal test of the hypothesis $b_3 = -b_5$, $b_4 = -b_6$ yields rejection in only two cases, Italy and Germany. Overall, given the importance of these two countries for the whole area, this evidence can be viewed as inconclusive.[18]

One potential problem with the discussion so far is that the tom-next rate is a good proxy for $E_t(i_{t+1})$, but it may not necessarily be a good measure for $E_t(i_{t+1,S})$. For instance, since auctions for the MROs are conducted by the European Central Bank once a week, they may have an impact on the tom-next without necessarily affecting maturities beyond the week. To account for this problem, the regressions in Table 3 were re-run with an alternative proxy for $E_t(i_{t+1,T})$.[19] The results, reported in the appendix (table A1), are remarkably similar to those reviewed so far; the main difference is that the semi-elasticities to the expected rate are now larger in absolute value, casting further doubts on the validity of proposition *v*).

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[18] In a mimeo version of Furfine (2000) the hypothesis $b_3 = -b_5$ is not rejected for the US federal funds market.

[19] Specifically, letting *T* denote the settlement day, the proxy was set equal to the tom-next on *T* and *T*-1; to the spot-next on *T*-2 through *T*-5; to the 6-day forward rate derived from the overnight and the one-week rates on *T*-6 through *T*-10; to the 13-day forward rate derived from the overnight and the two-week rates on *T*-11 through the beginning of the holding period. Similar results (not reported) were obtained with the one week forward rate derived from the one and two-week spot rates. In general, forward-based measures of expectations, such as the ones used in this paper, are not problem-free, as they may incorporate systematic variations across months and trading days unrelated to monetary policy. However, Söderström (2001) shows that futures contracts on US federal funds rates are a relatively good measure of market expectations of changes in the Federal Reserve target even without adjusting for these factors. Futures-based measures of policy expectations are also used by Kuttner (2001). Also, there is evidence that the predictive power of forward rates for short-term rates is quite good in the initial segment of the term structure (see e.g. Rudebusch, 1995; Longstaff, 2000).

5.3 Robustness checks

Several additional robustness checks of the estimates presented in Table 3 were performed, without detecting significant qualitative changes (results not reported). First, levels rather than logs of quantity variables were used. Also, $\tilde{r}_{t-1}$ (in addition to $t^a \tilde{r}_{t-1}$) was added to the set of regressors. Second, the time-varying interest rate terms were omitted, and regressions were re-estimated after dropping the final 7 days of each maintenance period. Third, to check for the possibility that the official interest rates corridor distorts the estimated interest rate semi-elasticities, days on which the Eonia was close to the floor or to the ceiling were dropped from the sample. Finally, I tried to assess the sensitivity of the results to the key assumption of exogeneity of the interest rates appearing on the right-hand side of equation (5). In the previous sub-section several arguments in favor of this assumption were given. However, the supply-driven changes in reserves on Wednesdays, when the main refinancing operations are settled, could in principle bias the estimates. Thus, the regressions in Table 3 were augmented with weekly fixed effects (dummies equal to one for the period Wednesday through Tuesday) and with extra terms to allow for differences in the key slope coefficients on Wednesdays. In this case the precision of the estimates is somewhat reduced, but the signs and magnitudes of the coefficients remain broadly unchanged.

5.4 Liquidity and announcement effects

To identify the signaling and the "market frictions" components of the liquidity effect, I rely on the distinction between "temporary" and "permanent" shocks. Assume a liquidity shock equal to 1 per cent of the current stock of reserves occurs. If the shock is believed to be purely temporary (to affect liquidity conditions only today), then $\Delta i_t \neq 0$ and $\Delta E_t(i_{t+1,S})=0$ should hold; inverting equation (5), its interest rate impact should be $1/(b_3 + b_4 t^a)$. By contrast, if the shock is perceived as "permanent" (i.e. if the market believes that the central bank will not fully offset it in subsequent days of the holding period), then $\Delta i_t = \Delta E_t(i_{t+1,S}) \neq 0$ holds, and the interest rate impact is $1/[(b_3 + b_5) + (b_4 + b_6)t^a]$.

In Table 4 the estimated bs from Tables 3 and A1 are used to gauge the order of magnitude of temporary vs. permanent liquidity shocks over the maintenance period. Several points are worth noting. First, the effect tends to grow as the holding period progresses, due to the diminishing absolute value of the interest rate semi-elasticities. On the last day of the period the shock is permanent by definition (it cannot be offset by the central bank within the period), so that it causes the Eonia to move by ±100 basis points, hitting the ceiling or the floor of the corridor. Second, the effect is positively related to the perceived degree of persistence of the shock. At the beginning of the period a 3 per cent drain in total bank reserves (currently amounting to 3.5 billion euros), if perceived by market operators as purely temporary, causes the Eonia to rise by about 4 basis points; one week from the end of the period, the effect is still modest but about twice as large, 7 to 8 basis points, depending on whether simple or weighted average coefficients are used. Since a purely temporary shock cannot convey any policy signal, these figures should give a measure of the liquidity effect due to "market frictions" (limits on credit lines, transaction costs, market operators risk-aversion, etc.).

Table 4: Liquidity and announcement effects in the euro area[(1)]

(effect of a 3 percent reserves drain on the Eonia; basis points)

	Perceived nature of liquidity shock		
	Temporary	"Permanent"	
Shock is occurring:	(shock lasts only today)	(shock lasts at least until tomorrow)	(shock lasts for rest of holding period)
At beginning of holding period	4	13-*15*	25-100
After 2 weeks from beginning	*4*-5	14-*17*	25-100
After 3 weeks from beginning	*7*-8	20-*26*	25-100
End of holding period	100	100	100

(1) The ranges in the first two columns are derived from the area-wide coefficients reported in Table 3, using the procedure described in section 5.4. In practice, temporary effects (first column) are computed as $1/(b_3 + b_4 t^a)$, permanent effects as $1/[(b_3 + b_5) + (b_4 + b_6)t^a]$. Figures in italics (standard type) are derived from weighted (simple) average coefficients; when no range is reported estimated effects coincide. The range reported under the third column is 25-100 basis points because based on the area-wide estimates in table A1 the denominator of $1/[(b_3 + b_5) + (b_4 + b_6)t^a]$ is zero. This implies an infinite reaction of interest rates to a monetary shock. In practice, the reaction is likely to range between 25 basis points (the typical minimum size of an official interest rate change) and 100 points (the typical difference between the Eonia and the official rates corridor).

When the perceived degree of persistence of the liquidity shock increases, the effect is much larger: a shock believed to last at least through the following day moves the Eonia by 13-15 basis points at the beginning of the period and by 20-26 points one week from the end (second column of the table, derived using the coefficients in Table 3). The effect is even larger when it is believed that the shock will "permanently" affect liquidity conditions: the semi-elasticities of the demand for reserves to the current and expected overnight rate reported in Appendix become undistinguishable, so the interest rate sensitivity becomes in principle infinite and the Eonia hits the official interest rates corridor (±100 basis points; the lower bound of 25 basis points reported in the third column of

Table 4 is the typical minimum size of an official interest rates change).[20] In the initial part of the period this can be interpreted as a case in which the shock has some signaling content for the monetary policy stance. Alternatively, the estimates may be capturing a pure announcement effect. Following a change in official interest rates, the market knows that from that day liquidity will be offered by the ECB at the new rate. It also knows that the announcement is credible, as the central bank has the power to drive short-term rates to the new desired level via liquidity management; thus, both the current Eonia and its expected value adjust by the full amount of the change, whereas the demand for reserves remains unchanged.

Table 5 helps shed some light on the practical importance of these effects over the available sample period. The shaded lines report data relating to days in which official interest rate changes became effective (8 in total). The other lines relate to selected MRO days. Specifically, out of the 101 days on which MROs were held, those falling within the last five working days of the maintenance period were discarded; from the remaining 80 observations, those days were selected on which: *i*) Δi_t, $\Delta E_t i_{t+1}$ and $\Delta E_t i_{t+1,T}$ all have the same sign and are larger than one basis point in absolute value; *ii*) the change in the system's aggregate liquidity on day t+1, when the MRO is settled, has the opposite sign. The latter condition restricts attention to those operations whose tightening/expansionary effect is consistent with the movement in interest rates.[21] Overall, this leaves 11 observations.

[20] This sensitivity is higher than reported by Bindseil and Seitz (2001) for the euro-area, or by Hamilton (1998) for the US. Bindseil and Seitz (2001) find that on the last day of the period a cumulated reserve surplus equal to 10 billion euros (almost 10 per cent of the stock of reserves) would trigger a mere 13 basis points decrease in the spread between the Eonia and the fixed tender rate. According to Hamilton's estimates, a 3 per cent reserve drain raises the federal funds rate by 7 basis points on settlement days, by 3 on other days; the corresponding estimates in Hamilton (1997) are 23 and 1 to 3 basis points, respectively. More recently, Thornton (2001a) has argued that no liquidity effect at all can be detected outside Hamilton's sample period. The low reactivity of interest rates in the US can at least in part be explained by the presence of carryover provisions: banks with accumulated reserve imbalances in a given period are allowed to offset them over the next period, reducing pressures on the interest rate.

[21] Ideally, the selection should fall on those days when the amount of liquidity injected or drained by the MRO significantly deviated from expectations; however, measures of expectations are not available in the dataset.

Table 5: Liquidity and announcement effects in practice[1]

(shaded lines: official interest rate changes; other lines: selected main refinancing operations)

Date (2)	Δi_t *(% points)* (3)	$\Delta E_t(i_{t+1})$ *(% points)* (3)	$\Delta E_t(i_{t+1,T})$ *(% points)* (3)	ΔR_{t+1} *(eur mln)*	ΔR_t *(eur mln)*	Official interest rate change *(% points)*	
9 April 1999	-0.27	-0.27	-0.34	2010	2334	-0.5	Announcement effect
13 April 1999	-0.04	-0.09	-0.04	30623	1294	-	
5 October 1999	0.02	0.02	0.02	-2648	1060	-	
27 October 1999	-0.03	-0.13	-0.01	35618	-551	-	
2 November 1999	0.09	0.09	0.14	-8728	1179	-	MRO carried some signal?
5 November 1999	-0.03	0.03	0.04	496	-16886	+0.5	Policy move fully expected
11 January 2000	0.03	0.08	0.03	-40321	-194	-	MRO carried some signal?
4 February 2000	0.08	0.08	0.09	1087	1647	+0.25	Announcement effect
7 March 2000	0.02	0.03	0.03	-16116	-1163	-	MRO carried some signal?
17 March 2000	-0.01	-0.01	-0.03	4578	-7275	+0.25	Policy move fully expected
11 April 2000	0.05	0.05	0.03	-6097	-88	-	MRO carried some signal?
28 April 2000	0.02	-0.01	0.00	19403	-15754	+0.25	Policy move fully expected
30 May 2000	0.04	0.07	0.02	-6293	962	-	MRO carried some signal?
9 June 2000	0.27	0.26	0.22	-191	-1543	+0.25	Announcement effect
14 June 2000	-0.04	-0.04	-0.04	5123	1035	-	
29 August 2000	-0.02	-0.02	-0.05	12732	2891	-	
1 September 2000	-0.10	-0.16	-0.10	-269	2274	+0.25	Larger increase was expected
6 October 2000	0.12	0.15	0.14	-1545	465	+0.25	Announcement effect
5 December 2000	-0.02	-0.02	-0.01	21090	-7622	-	

(1) Over the available sample period main refinancing operations (MROs) were held by the Eurosystem on 101 days. The white lines report data relating to the 11 cases in which: *i*) Δi_t, $\Delta E_t i_{t+1}$ and $\Delta E_t i_{t+1,T}$ all have the same sign and are larger than one basis point in absolute value; *ii*) the change in the system's aggregate liquidity on the following day – when the MRO is settled – has the opposite sign. The last five working days of each maintenance period were always discarded. The shaded lines report data for all the days in which changes in official interest rates were observed.

(2) Shaded lines: day in which the official interest rate change became effective. Other lines: day when the auction of the MRO was held, and related results were published (settlement took place on the following day).

(3) i_t is the Eonia, $E_t(i_{t+1})$ is proxied by the tom-next, $E_t(i_{t+1,\ T})$ is the proxy described in footnote 19. The differences reported in the shaded lines are computed as i_t-i_{t-2}. This is done because the rate change effective on day *t* is announced on day *t*-1 around 2:00 p.m.; thus, in general the interest rate data on day *t*-1, computed as volume weighted averages over the entire day, partly incorporates the announcement effect.

The picture emerging from the table is relatively complex. On certain days there is clear evidence of an announcement effect; in particular, on 8 April 1999 a 0.5 percentage points rate cut was announced, which, based on anecdotal evidence from the economic press of the time, was largely unexpected. On the following day spot and expected short-term rates adjusted downwards by over 30 basis points. On other days the announcement of a monetary policy tightening triggered a zero or even negative reaction of market rates, signaling that the increase was fully expected (e.g. 17 March 2000) or smaller than expected (1 September 2000). Few observations are consistent with the hypothesis that MROs may have been interpreted as carrying some signal (e.g. 7 March, 30 May 2000), but the magnitude of the effect is generally small and cannot be deemed convincing. A possible exception took place on 2 November 1999, when a liquidity-draining MRO was followed by a rate increase of 10 basis points (one week later the Eurosystem announced a 25 basis point hike, which turned out to be fully expected); however, several important economic news items released on 2 November could also explain the rate increase.[22]

6. Conclusions

According to the theory, under the assumption of no frictions or imperfections in the money market, the overnight interest rate should obey the so-called martingale hypothesis: today's value of the rate should be the best predictor of tomorrow's value. In line with the evidence available for other industrialized countries, modest deviations of the euro-area overnight interest rate (Eonia) from martingale behavior are detected. In particular, systematically higher-than-average rates characterize the last day of the month (from 1 to 12 basis points, depending on the estimation method) and of the quarter (from 8 to 18 basis points).

As rejection of the martingale hypothesis is a sufficient condition for the presence of a liquidity effect, the paper then seeks to gauge the magnitude of the latter by separately assessing its "market frictions" and "monetary policy signaling" components. To this end, area-wide reserve demand equations are estimated in which both the current overnight rate and various measures of its expected value appear among the regressors, and the liquidity effect is inferred directly from the slope of the curve. In general, the absolute magnitude of the effect is found to be positively related to the perceived degree of persistence of the liquidity shock.

At the beginning of the period a shock amounting to 3 per cent of outstanding reserves, if perceived by market operators to be purely temporary (i.e. to last only for one day) causes the Eonia to move by about 4 basis points. The paper argues that this is the order of magnitude of the "market frictions" component of the liquidity effect. When the perceived degree of persistence increases, the effect is much larger: a similar shock believed to last at least through the following day moves the Eonia by 13-15 basis points.

[22] In particular, the euro-area purchasing managers confidence index for October, released on that day, turned out to be 57.1 (against a Standard and Poor's survey-based expectation of 55.2); in addition, positive inflationary surprises in producer prices were released for Italy and France.

When the shock is believed to be truly permanent (i.e. to last through the rest of the maintenance period), the semi-elasticities of the demand curve with respect both to the current and to the expected overnight rate become statistically equal in absolute value. This implies that the liquidity effect becomes, in principle, infinite. In practice, this can happen in two distinct cases: *(i)* the end of the holding period is close. In the last three days a shock, regardless of its signaling content, is permanent, according to the definition adopted in the paper (it cannot be offset within the period); thus, it causes the Eonia to hit the floor or the ceiling of the official rates corridor, moving by roughly plus or minus 100 basis points from its normal level; *(ii)* the liquidity shock is perceived as a monetary policy signal; the rates may adjust by up to the full amount of the expected policy move, typically 25 or 50 basis points. Only instances of effect *(i)* seem to be clearly present in the two-year period covered by this study.

The equality of the semi-elasticities of the demand curve with respect both to the current and to the expected overnight rate also provides evidence in line with the announcement effect, the ability of the central bank to influence short-term rates without any need for open market operations. As soon as the central bank announces an official rate change, or just signals — e.g. via a speech of one of its officials — that a change may be forthcoming, the market reacts by instantaneously revising expectations about the overnight rate. By the standard arbitrage argument underlying the martingale hypothesis, the spot overnight rate also immediately adjusts by the same amount. The adjustment to the new level may be partial (e.g. if the signal is conveyed via a relatively ambiguous speech, so that there is a probability that no move will take place) or full; it may also be reverted at a subsequent time, if expectations prove wrong. In any case, since the semi-elasticities are equal in absolute value, an identical move of the spot and the expected rates will leave the demand for reserves completely unaffected. Thus, short-term rates can be changed without resorting to open market operations.

The euro-area demand for reserves used in the analysis is derived from separate regressions for the eleven national segments of the money market. Several differences are found in demand patterns across countries. For a majority of countries the theoretical a priori are confirmed: on any given day of the maintenance period, liquidity demand is negatively related to the average balance held up to the previous day and to the current overnight rate, whereas a rise in tomorrow's expected rate tends to increase it; these elasticities tend to diminish nonlinearly throughout the period. However, for some countries the demand for reserves appears completely interest rate-inelastic, suggesting that further efficiency improvements may be achieved in the future.

Appendix: Dependent variable: log of balances held at the central bank [(1)]

(daily data; sample period: January 4, 1999 – January 23, 2001)

	AUT	BEL	FIN	FRA	GER	IRL	ITA	LUX	NET	POR	SPA	AREA [(3)] weighted average	AREA [(3)] simple average
Constant	6.37**	5.77**	6.14**	7.40**	6.45**	6.12**	5.24**	4.78**	6.82**	4.91**	7.09**	6.38**	6.10**
	0.39	*0.40*	*0.37*	*0.45*	*0.52*	*0.40*	*0.33*	*0.43*	*0.39*	*0.30*	*0.45*	*0.44*	*0.40*
ln(progr. balance$_{t-1}$)*t^{α} [(2)]	-8.07**	-9.00**	-4.79**	-4.74**	-2.98**	-6.33**	-12.15**	-3.16**	-8.21**	-7.02**	-4.64**	-5.79**	-6.46**
	1.50	*2.22*	*1.10*	*1.15*	*0.69*	*1.56*	*1.86*	*0.55*	*1.79*	*1.18*	*1.08*	*1.20*	*1.33*
ln(balances$_{t-1}$)	0.21**	0.35**	0.19**	0.25**	0.38**	0.22**	0.44**	0.47**	0.25**	0.37**	0.21**	0.33**	0.30**
	0.05	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.03*	*0.05*	*0.04*	*0.04*	*0.05*	*0.05*	*0.05*
ΔEonia$_t$ (β_3)	-0.83**	-0.97**	-0.44	0.10	-0.60**	-0.03	-2.65**	-0.93**	-0.68**	-0.72**	-0.42*	-0.75**	-0.74**
	0.28	*0.24*	*0.35*	*0.14*	*0.22*	*0.24*	*0.26*	*0.22*	*0.19*	*0.17*	*0.21*	*0.21*	*0.23*
ΔEonia$_t$*t^{α} (β_4)	1.06**	1.05**	0.71	0.11	0.59*	0.26	2.73**	0.96**	0.86**	0.90**	0.55*	0.85**	0.89**
	0.29	*0.27*	*0.40*	*0.18*	*0.24*	*0.26*	*0.28*	*0.24*	*0.25*	*0.22*	*0.24*	*0.24*	*0.26*
ΔE_t(Eonia$_{t+1,S}$) (β_5)	0.87*	1.54**	0.39	0.10	0.80**	0.44	2.19**	0.88*	0.60**	0.76**	0.65*	0.85**	0.84**
	0.38	*0.38*	*0.54*	*0.18*	*0.27*	*0.32*	*0.29*	*0.35*	*0.21*	*0.24*	*0.32*	*0.28*	*0.32*
ΔE_t(Eonia$_{t+1,S}$)*t^{α} (β_6)	-0.86*	-1.87**	-0.72	-0.37	-0.99**	-0.49	-2.24**	-0.96**	-0.77*	-0.77**	-0.81*	-1.02**	-0.99**
	0.41	*0.43*	*0.61*	*0.22*	*0.29*	*0.34*	*0.31*	*0.36*	*0.33*	*0.29*	*0.35*	*0.31*	*0.36*
t^{α} (holding period trend)	0.06	0.04	-0.06	0.07	0.10**	-0.02	-0.01	-0.05	-0.17*	-0.09*	-0.04	0.02	-0.02
	0.05	*0.06*	*0.05*	*0.04*	*0.02*	*0.05*	*0.06*	*0.03*	*0.07*	*0.04*	*0.03*	*0.04*	*0.05*
α	4.36**	5.64**	2.09**	2.27**	2.04**	2.62**	6.03**	1.57**	3.71**	4.01**	2.08**	3.07**	3.31**
	0.81	*1.13*	*0.37*	*0.53*	*0.51*	*0.49*	*0.85*	*0.31*	*0.57*	*0.48*	*0.42*	*0.59*	*0.59*
T (sample period trend)	3.3e-4**	1.0e-4**	1.3e-4**	9.0e-5	1.6e-4**	8.0e-4**	9.0e-5	1.8e-4**	4.4e-4**	3.8e-4**	3.1e-4**	2.0e-4**	2.7e-4**
	6.0e-5	*6.3e-5*	*7.4e-5*	*4.8e-5*	*3.5e-5*	*7.5e-5*	*4.7e-5*	*5.1e-5*	*9.1e-5*	*5.0e-5*	*4.5e-5*	*5.0e-5*	*5.8e-5*
Volatility of eonia$_t$	-0.01	-0.10	-0.37**	-0.10	-0.17**	-0.01	-0.10	-0.24**	0.09	-0.04	0.12*	-0.09	-0.08
	0.10	*0.14*	*0.12*	*0.08*	*0.06*	*0.10*	*0.12*	*0.07*	*0.17*	*0.08*	*0.06*	*0.09*	*0.10*
Zero-one dummies for:													
Month-end	-0.15**	-0.12*	0.01	0.06	0.10**	-0.01	-0.21**	-0.11*	0.03	-0.05	-0.06	-0.01	-0.05
	0.05	*0.06*	*0.10*	*0.04*	*0.03*	*0.04*	*0.05*	*0.05*	*0.08*	*0.04*	*0.04*	*0.04*	*0.05*
Quarter-end	-0.22**	-0.01	0.10	0.10	0.10*	-0.06	0.04	-0.08	0.12	-0.11	-0.02	0.05	0.00
	0.07	*0.09*	*0.13*	*0.09*	*0.05*	*0.13*	*0.13*	*0.06*	*0.11*	*0.07*	*0.09*	*0.08*	*0.09*
Monday	0.03	0.06*	0.09**	-0.01	0.01	0.01	-0.03	-0.02	0.04	0.02	0.06	0.01	0.02
	0.02	*0.03*	*0.03*	*0.02*	*0.02*	*0.03*	*0.03*	*0.02*	*0.05*	*0.02*	*0.02*	*0.02*	*0.03*
Tuesday	0.03	0.03	-0.02	-0.01	0.01	-0.02	0.01	-0.01	-0.01	-0.01	0.03	7.4e-03	4.2e-03
	0.02	*0.03*	*0.03*	*0.02*	*0.02*	*0.03*	*0.02*	*0.02*	*0.05*	*0.02*	*0.02*	*0.02*	*0.03*
Thursday	0.00	0.07*	0.08**	-0.02	0.00	0.02	-0.03	0.00	0.00	0.01	0.00	-1.8e-03	0.01
	0.02	*0.03*	*0.03*	*0.02*	*0.02*	*0.03*	*0.02*	*0.02*	*0.04*	*0.02*	*0.02*	*0.02*	*0.03*
Friday	0.06**	0.08**	0.01	-0.02	-0.01	-0.03	0.04*	-0.01	0.11**	0.03	-0.01	0.01	0.02
	0.02	*0.03*	*0.03*	*0.02*	*0.02*	*0.03*	*0.02*	*0.02*	*0.04*	*0.02*	*0.02*	*0.02*	*0.02*
F-test of H$_0$: β_3=-β_5, β_4=-β_6	1.95	2.50	0.10	0.60	3.55*	2.42	52.17**	0.20	0.03	1.38	0.61		
F-test of H$_0$: β_3=-β_4, β_5=-β_6	2.71	2.51	3.64*	5.48**	4.27*	2.08	23.81**	0.38	2.53	2.15	2.54		
SER	0.16	0.21	0.21	0.14	0.10	0.19	0.16	0.13	0.31	0.14	0.12		
N° obs.	448	458	448	465	483	493	483	458	496	483	464		

(1) The regressions differ from those in Table 3 only because Δtom-next$_t$ is replaced by ΔE_t(Eonia$_{t+1,S}$), constructed as follows: Specifically, letting *T* denote the settlement day, the proxy was set equal to the tom-next on *T* and *T*-1; to the spot-next on *T*-2 through *T*-5; to the 6-days forward rate derived from the overnight and the one week rates on *T*-6 through *T*-10; to the 13 days forward rate derived from the overnight and the two week rates on *T*-11 through the beginning of the holding period. Estimation by non-linear least squares, providing starting values for the coefficients. White heteroskedasticity robust standard errors are reported in italics below each coefficient. One or two asterisks denote significance at the 5 and 1 percent levels, respectively. All quantity variables are in natural logarithms. See section 4 for details about the estimation period, which differs across countries for the following sub-periods: *i*) 1 January - 23 February 1999; *ii*) 27 December 1999 - 4 January 2000; *iii*) 26 June 2000 - 10 July 2000; *iv*) 27 December 2000 – 4 January 2001. Specifically, *i*) is dropped for Austria, Belgium, Finland, France, Luxembourg and Spain; *ii*) is dropped for all countries with the exception of France and the Netherlands; *iii*) is dropped for Austria, Finland, Germany, Italy and Portugal; *iv*) is dropped for all countries except Spain.

(2) The variable is defined as [*ln*(progressive average balance $_{t-1}$) - *ln*(required reserves$_{t-1}$)] * t^{α}.

(3) Following the methodology in Pesaran and Smith (1995), euro area coefficients and their standard errors are computed as simple averages of the national estimates presented in the table, assuming parameter independence across countries. Corresponding weighted averages are also presented; weights are the share of deposits by each national banking system on the euro area total over the available sample period (Austria: 0.033; Belgium: 0.068; Finland: 0.015; France: 0.179; Germany: 0.306; Ireland: 0.027; Italy: 0.116; Luxembourg: 0.063; The Netherlands: 0.093; Portugal: 0.025; Spain: 0.079).

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