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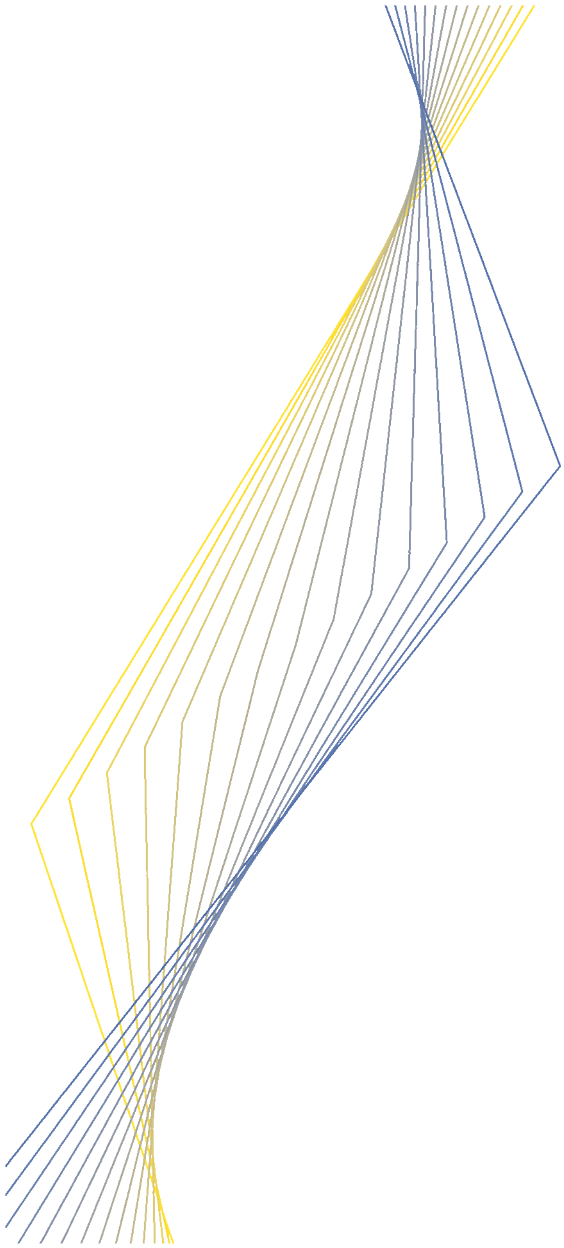

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BY FLEMMING REINHARDT WÜRTZ[2]

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Contents

Abstract

This paper presents a comprehensive model on the spread between the euro overnight rate and the key policy rate of the ECB. It is shown that the most important variables driving the level and the volatility of this spread are expectations about changes of the key policy rate and the projected liquidity conditions at the end of the reserve maintenance period. The model allows for an assessment of how these variables impact differently on the spread according to the different open market operating procedures and the liquidity management policy of the ECB. It is found that a fixed rate tender procedure effectively limits the downward potential of the spread, while, however, no evidence is identified that it should be more effective than a variable rate tender procedure in keeping overall the overnight rate close to the key policy rate.

JEL Classification numbers: C32, E43, E52

Key Words: overnight rate, open market operating procedures, liquidity management

Non-technical summary

The overnight rate constitutes the very starting point of the yield curve and is normally perceived as being within the control of the central bank, for whom it is thus also important to understand its dynamics. This paper proposes a comprehensive empirical model on the euro overnight rate, or more precisely on the spread between the EONIA (Euro OverNight Index Average) and the key policy rate of the ECB. The latter has been the rate applied to fixed rate tenders or the minimum bid rate applied to variable rate tenders. Although the model, which is estimated on daily data in the sample period ranging from 26 April 1999 to 23 April 2002, also contains time series elements, its main purpose is to explain the spread via structural explanatory variables by use of a non-linear set-up which also takes into account that the spread is capped by the corridor set by the standing facilities.

The various explanatory variables are mainly introduced on the back of the celebrated martingale hypothesis (in its simplest form), according to which the overnight rate on any point in time is equivalent to the expected overnight rate at the end of the maintenance period. Otherwise, market participants could perform intertemporal arbitrage by either postponing or advancing their reserve holdings. The expected overnight rate on the last day of a reserve maintenance period depends on 1) the expected accumulated liquidity imbalance of the relevant reserve maintenance period, which in turn determines the likelihood that recourse to the deposit facility or to the marginal lending facility will be necessary on a net basis, and 2) expectations about the key policy rate, which determines the rates at which any such accumulated liquidity imbalance ultimately need to be disposed.

Several variables are used for measuring expectations about the accumulated liquidity conditions, which in principle are not observable. The by far most relevant variable in terms of explanatory power is the ex-post accumulated net recourse to standing facilities in the remaining days of a reserve maintenance period. This rational liquidity measure, which according to the balance sheet identity is equivalent to the actual accumulated liquidity imbalance after the last open market operation of the reserve maintenance period, only impacted significantly on the spread on the two last trading days of a reserve maintenance period. This confirms that the market generally has expected the ECB to offset any liquidity shocks until the last main refinancing operation of the reserve maintenance period. On the last day of the maintenance period, a recourse to the marginal lending facility (deposit facility) of EUR 10 billion is found to approximately imply a 40 basis point increase (decrease) of the spread.

However, expectations about the accumulated liquidity conditions have, in case of rate cut expectations (i.e. expectations of a reduction of the key policy rate), also impacted indirectly on the spread before the last days of a reserve maintenance period. This relates to the fact that the ECB has normally not fully compensated liquidity shortages resulting from the fact that counterparties are not bidding sufficiently to the main refinancing operations when anticipating a rate cut later in the same reserve maintenance period. Accordingly, the risk of underbidding has to a large extent prevented the spread from becoming negative, such that the downward impact of interest rate cut expectations has been almost simultaneously offset by an upward impact resulting from the risk of cut expectations. Evidence of a similar countering of rate hike expectations by a perceived risk of loose liquidity conditions at the end of the reserve maintenance period was not identified. This reflects that expectations of market rates falling below the minimum bid rate (or the fixed tender rate) at the end of the reserve maintenance period are not rational, because banks will not be willing to bid sufficiently in the last main refinancing operation of the maintenance period such that market rates would afterwards fall systematically below the minimum tender rate.

The interest rate change expectations are measured from the forward rate implied by the one and two month EONIA swap rates, assuming that the spread between this forward rate and the prevailing key policy rate only reflects expectations about future changes of the latter. Furthermore, the likelihood that the rate change discounted into this forward spread actually takes place in the prevailing reserve maintenance period is assumed to decline linearly throughout a reserve maintenance period and hence to not depend on the meeting schedule of the Governing Council of the ECB. On average a spill-over of around 22% from the forward spread to the overnight spread is identified for the first day of a reserve maintenance period under interest rate hike expectations, which is almost twice as high as the estimated spill-over under interest rate cut expectations. This supports the above mentioned hypothesis that cut expectations to a large extent have been balanced by expectations of tight accumulated liquidity conditions.

Also the marginal rates of the previous MROs, which determines the rate of remuneration of bank's reserve holdings, are found to impact significantly on the spread. This is in line with anecdotal evidence from market participants suggesting that marginal rates from previous MROs are seen as a "fair price for liquidity", which, however, is in obvious contrast to the marginal behaviour foreseen by the martingale hypothesis. On the other hand it can not be ruled out that the significance of previous marginal rates also reflects the fact that they constitute a parsimonious representation of the interest rate change expectations for the prevailing reserve maintenance period. A more obvious violation of the martingale hypothesis stems from the calendar effects, which, as identified over the whole sample period, comprises an increase of the spread up to and after an end of month, when the spread, excluding end of semesters and end of years, reached a level of around 9 basis points. Also the spread tended to decline on the last two business days of a reserve maintenance period. No other important violations of the martingale hypothesis are identified.

Finally, the spread is found to be more noisy during fixed rate tenders than during variable rate tenders in the sense that the standard deviation of the residuals, all other equal, has been 36% lower during the variable rate tender than during the fixed rate tender. Also the fixed rate tender is not found to be more efficient than the variable rate tender in preventing interest rate change expectations from spilling over to the mean of the overnight spread.

1 Introduction

As the shortest inter-bank interest rate, and hence the starting point of the term structure, the overnight rate plays a crucial role in the implementation of the monetary policy. In particular, as the operational target of many central banks, the overnight rate is normally perceived as being controlled by the central bank and hence to have signalling content as regards the monetary policy stance. For instance, ECB [2002b] illustrates that also the ECB considers the overnight maturity to play a certain role in its implementation of monetary policy. The benchmark status of the overnight rate, is further evident from the outstanding liquidity of the overnight swap market, and in relationship to this, from the fact that the overnight rate is the only rate for which a true reference rate, the "Euro OverNight Index Average" (EONIA), is calculated in the euro area.[2] Consequently, it is crucial for the central bank to understand how the overnight rate may react to its monetary policy decisions and operations as well as to other exogenous variables under the relevant operational framework. Naturally, the more comprehensive is the central banks model of the overnight rate, the more it will actually be able to identify the adequate policy measures in order to control it to the possible and desired extent.

While due to the length of the history, the literature on the empirical characteristics of the overnight rate is rather comprehensive for the US market (including for instance Hamilton [1996], Bartolini et al. [2002]), the literature does still not cover all aspects of the euro overnight market (Bindseil & Seitz [2001], Perez-Quiros & Rodriguez [2001], Hartmann et al. [2001], Gaspar et al [2001], Prati et al. [2002], Angeloni & Bisagni [2002]). Most of the literature concentrate on specific time series properties of the overnight rate. For instance Prati et al. [2002] finds that the euro overnight rate drops towards the end of the reserve maintenance period, although only statistically significant on the second last trading day, and hence does not appear to satisfy the celebrated martingale hypothesis. It is argued that this might give the central bank some leeway in affecting the overnight rate on specific days via its liquidity management. Perez-Quiros & Rodriguez [2001] finds in contrast to Prati et al. [2002] evidence that the overnight rate in the euro area increases systematically on the last trading day of a reserve maintenance period.[3] Perez-Quiros & Rodriguez [2001] relate this to (risk neutral) banks' preferences for fulfilling reserve requirements late in the maintenance period in order to maintain the possibility to buffer out liquidity shocks via the reserve holdings on the last days of the period. Gaspar et al [2001] find that changes of the ECB's key policy rates have normally been fully discounted into the overnight rate, which obviously suggests that interest rate change expectations to a large extent are affecting the latter. In contrast to the

[2] The EONIA-rate is an average, calculated on a daily basis, of the (lending) turnover in the unsecured overnight market of the 49 panel banks.

[3] Prati et al. [2002] finds, however, also that the overnight rate in Germany, before the EMU, increased significantly on the last day of the reserve maintenance period. However, since the end of the reserve maintenance period in Germany at that time coincided with the end of month, it remains a question mark whether in fact these increases reflect the well-known window-dressing activities at end of the month.

above mentioned studies, Bindseil & Seitz [2001] models the overnight rate as a function of structural explanatory variables, like interest rate change expectations and liquidity conditions, and not purely from its time series properties. In line with Angeloni and Bisagni [2002], they find evidence that the liquidity conditions only impact on the overnight rate in the last days of a reserve maintenance period – i.e. from after the last main refinancing operation [*MRO*] has been allotted. However, while Bindseil & Seitz [2001] find that the impact of liquidity shocks increases exponentially until the very last day of the reserve maintenance period, Angeloni and Bisagni [2002] finds that the impact is strongest immediately after the last MRO and actually almost reverses on the last two days.

This study proposes a comprehensive empirical model on the EONIA in the period from 26 April 1999 to 23 April 2002, covering a total of 767 trading days and 35 intact reserve maintenance periods. The model, which includes mostly structural explanatory variables but also time series elements, is comprehensive in the sense that it covers several aspects of the overnight rate at the same time and no information appears to be left in the innovations. It assesses how the tender procedures applied by the ECB, i.e. the fixed rate tender (from 1999 to mid 2000), and the variable rate tender with a minimum bid rate (mid 2000 onwards), which actually becomes a quasi fixed rate tender under rate cut expectations, have affected the formation of the overnight rate. The identification of a (presumably) rather complete set of variables driving the overnight rate also allows for a somewhat different approach for assessing the extent to which the martingale hypothesis holds for the euro area. Indeed, instead of only testing the time series properties of the overnight rate, this study assesses whether the identified explanatory variables conflict with the "economic substance" behind the martingale hypothesis.

It is found that the Eurosystems supply of liquidity (i.e. central bank deposits) appears to only directly affect the level of the EONIA to a notable extent on the last two trading days of a reserve maintenance period. However, the finding that the spread between the EONIA and the midpoint of the corridor [*the spread*], set by the standing facilities, appears to be more positive in times of interest rate hike expectations than it is negative in times of cut expectations, suggests an indirect impact of the expected liquidity supply, in the sense that, already at an early stage of a reserve maintenance period, expectations of possibly tight liquidity conditions resulting from underbidding appears to have countered the impact of cut expectations. The fact that a corresponding countering of hike expectations could not be identified illustrates the finding in Bindseil [2002], that in fact expectations of a loose liquidity supply are not rational as long as counterparties bidding in the main refinancing operations is subject to either a fixed or a minimum bid rate.

In addition it is shown that the volatility of the residuals decreased significantly after the introduction of the variable rate tender and the publication of the ECB's autonomous factors forecast, indicating that both may have contributed to lower the noise in the overnight rate. Also no evidence is identified that a fixed or a quasi fixed rate tender should be more efficient than a pure variable rate tender in keeping the mean of the EONIA close to the ECB's key policy rate.[4] Finally, the only identified clear violation of the martingale hypothesis is the systematic peaks at the end-of-months, although some indications are found that the market may not behave as rational as foreseen by this hypothesis. In contrast to the existing literature (including Prati et al [2002] , and Gaspar et al [2001]), the end of month effect was found to also spill significantly over to the previous and the subsequent days.

The paper is organised as follows: Section 2 shortly presents the spread data series, and section 3 introduces the framework of the model, the explanatory variables and the estimates. In section 4, the parameterisation and the estimate of the model are interpreted and discussed, while section 5 concludes.

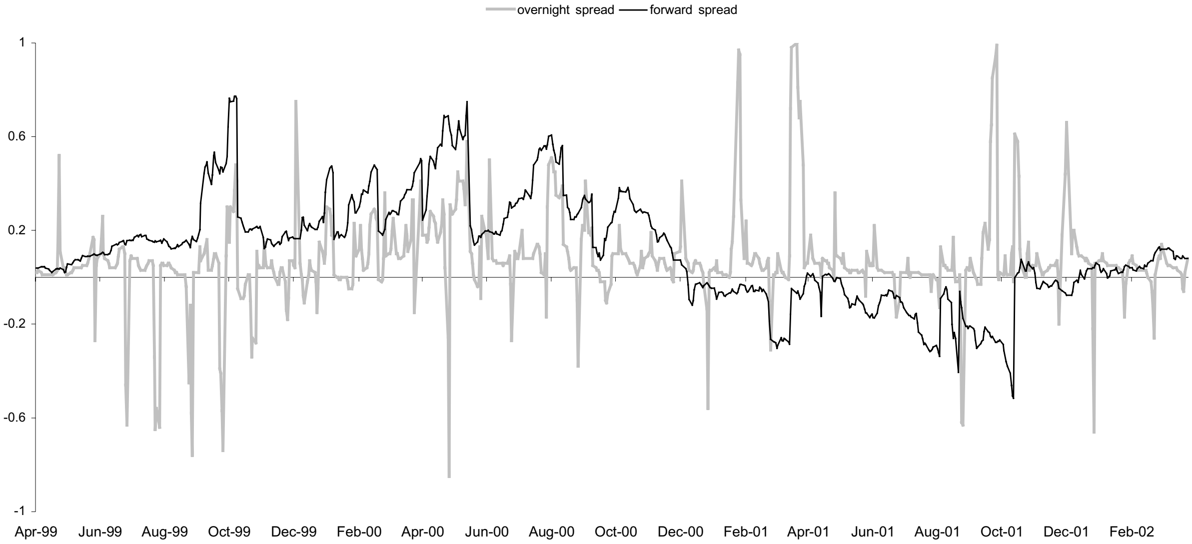
2 A brief look at the data

Since this study aims at explaining deviations of the EONIA from the key policy rate, and not the actual level of the latter, the key policy rate is treated as an exogenous variable in the sense that only the spread between the key policy rate and the EONIA is modelled. The key policy rate has been either the minimum bid rate of variable rate tenders or the rate applied to fixed rate tenders, and has, in the sample period, been equivalent to the mid point of the corridor set by the rates of the standing facilities. Thus the terms "key policy rate" and "mid point of the corridor" are used simultaneously.

The time series of the spread is shown in Chart 1. The sample period omits the first three reserve maintenance periods, in which the market was adapting to the new operational framework, and starts thus on 26 April 1999. It ends on the 23 April 2002, the last day of the fourth reserve maintenance period in 2002, and contains hence two complete circles of interest rate hike and cut expectations as is illustrated in Chart 1, where interest rate change expectations are quantified via the forward rate implied by the one and two month swap rates.

[4] Throughout this paper, a "quasi fixed rate tender" refers to a variable rate tender with minimum bid rate under interest rate cut expectations, where the minimum bid rate effectively restricted the bidding. A "pure variable rate tender" refers to a variable rate tender with minimum bid rate during interest rate hike expectations, where the bidding to the individual MROs is not effectively restricted by the minimum bid rate, although as it will be discussed below it still has a bearing on the bid rate.

Chart 1
The overnight spread and the spread between the forward rate [1] and the mid point of the corridor
(percent per trading day)



1) Calculated from the one and two month EONIA swap rates

The mean and the standard deviation of the spread over the whole sample period amounts to 7.5 and 20 basis points respectively. The regular peaks of the spread towards the end of a reserve maintenance period, when the overnight rate approaches the rate of one of the two standing facilities, evidence the rather well established fact that the volatility increases at the end of a reserve maintenance period. In the model presented below, this is accommodated by introducing both non-stationary explanatory variables as well as conditional volatility.[5] Furthermore it follows from a visual inspection of Chart 1, that the spread has been positive on most of the days covered by the sample period. In fact the spread has only been negative on 6% (38 days) out of the 624 days falling before the allotment of the last MRO of the reserve maintenance period, while it conversely has been negative on 48% (69 days) of the remaining 143 days of the sample period falling after (and including) the last MRO allotment of the reserve maintenance period. Finally, the chart shows that the spread has never exceeded one, or put differently that the EONIA has always remained inside the corridor set by the standing facilities. This suggest that an adequate model should cap the maximum possible spread, and thus rules out a simple linear relationship between the explanatory variables and the spread.

3 The model

3.1 The overall structure

The following model on the spread, s, is estimated:

(3.1) $$s_t = f(x_t, \alpha, \beta_t) + \varepsilon_t ,$$

[5] A dickey fuller test gives overwhelming support to the hypothesis that the spread is indeed stationary over time [i.e. it is not I(1)], and thus that the regression model presented below should generally not rely on spurious relationships.

where x_t is a 42×1 vector of explanatory variables, α a scalar parameter and β_t a time-varying 42×1 vector of parameters. ε_t represents an independently distributed error term with zero mean and conditional variance $\sigma_t^2(x_t, \beta_t, v_t)$ with v_t being a 16×1 vector of parameters. The distribution $g(\varepsilon_t)$ of the error term is, as in Hamilton[1996], assumed to be given by a mixture between two normal distributions, whereby problems with significant kurtosis are effectively accommodated:

$$(3.2) \qquad g(\varepsilon_t) = \frac{p}{\sqrt{2\pi\sigma_t^2}} exp\left(\frac{-\varepsilon_t^2}{2\sigma_t^2}\right) + \frac{1-p}{\sqrt{2\pi\overline{\sigma}_t^2}} exp\left(\frac{-\varepsilon_t^2}{2\overline{\sigma}_t^2}\right), \quad \text{where } p \in [0:1].$$

The variance of ε_t, given by $E(\varepsilon_t^2) = p \cdot \sigma_t^2 + (1-p) \cdot \overline{\sigma}_t^2$, is normalised by imposing the restriction that $\sigma_t^2 = \lambda \cdot \overline{\sigma}_t^2$, such that it can be written as a function of the parameters p and λ and the conditional volatility σ_t^2:

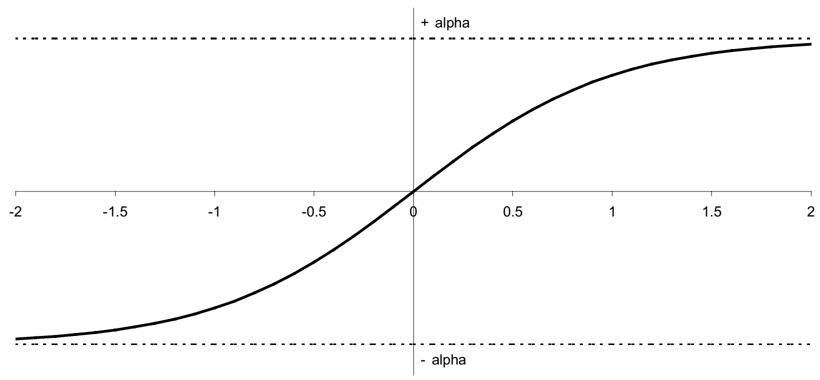
$$(3.3) \qquad E(\varepsilon_t^2) = \sigma_t^2(x_t, \beta_t, v_t) \cdot (p + (1-p) \cdot \lambda)$$

Finally, the function $f(x_t, \alpha, \beta_t)$ is defined as

$$(3.4) \qquad f(x_t, \alpha, \beta_t) = \alpha\left(\frac{2}{1+e^{-2\beta_t' x_t}} - 1\right)$$

Intuitively, one can think of the function $f(x_t, \alpha, \beta_t)$ as capping the *linear impact* of the explanatory variables, $L_t = \beta_t' x_t$, such that the estimated spread will always be within $[-\alpha;+\alpha]$. Knowing that the width of the corridor, set by the standing facilities, is 2 percentage points, it follows that α should indeed be close to one.

Chart 2
The relationship between the linear impact of the explanatory variables (L_t) and the mean of the spread
(x-axis: linear impact of the explanatory variables, i.e. L_t; y-axis: impact on the spread)



3.2 The variables

The main motivation for the included explanatory variables, stems from the celebrated martingale hypothesis, which, in spite of its rather strong underlying assumptions, appears to successfully describe the key dynamics of the overnight rate in the euro area.[6] By assuming perfect substitutability of reserve holdings on any day within a reserve maintenance period, the hypothesis claims that the overnight rate is always equivalent to its expected level in the remaining days of the reserve maintenance period, from which it follows that it should always equalise its expected level on the last day of the reserve maintenance period. If not, banks could exploit the averaging mechanism and perform intertemporal arbitrage by substituting reserve holdings on expensive days with reserve holdings on cheap days. On the last day of the reserve maintenance period, when any accumulated liquidity imbalance ultimately needs to be offset via the standing facilities, the overnight rate is given by the rates of the latter weighted by the probability that they, on a net basis, will actually be accessed. In the following, *s* denotes the spread between the overnight rate, *r*, and the mid point, r^m, of the corridor set by the rates, r^d and r^l, of the deposit and the marginal lending facility respectively, while P^d and P^l represent the probabilities for an aggregate net recourse to the respective facility on the last day, *T*, of the maintenance period. The martingale hypothesis then suggests the following equation for the spread when, consistent with the sample period, also taking into account that r^l-r^m = r^m-r^d = 1.

$$r_t = P^l \cdot E_t\left(r_T^l\right) + P^d \cdot E_t\left(r_T^d\right)$$

(3.5) whereby (when applying the definition of s_t)

$$s_t = r_t - r_t^m = \underbrace{P^l - P^d}_{\text{Liquidity expectations}} + \underbrace{E_t\left(r_T^m\right) - r_t^m}_{\text{Interest rate change expectations}}$$

As indicated in the subscripts of the equation, the probabilities P^d and P^l reflect the market's expectations regarding whether the liquidity supplied by the central bank makes an aggregate recourse to any of the standing facilities at the end of the maintenance period necessary. The second component, $E_t\left(r_T^m\right) - r_t^m$ expresses the extent to which the market expects the central bank to change its key policy rate before the end of the prevailing maintenance period. Hence, the martingale hypothesis suggests that variables which are perceived to either contain information about the accumulated liquidity conditions of the maintenance periods, i.e. the net recourse to standing facilities at the end of the reserve maintenance period, or possible changes of the monetary policy stance, should play an important role in explaining the spread. The extent to which other variables, like for instance calendar effects, which can not be related to the expected accumulated liquidity conditions or to interest rate change expectations, appear to be significant, the martingale hypothesis in the form of equation (3.5), does not adequately describe the spread.

[6] It should, however, be stressed that the motivation for which explanatory variables to include in x_t does not rely on a single specific theoretical model, like for instance the "pure" martingale hypothesis or the model presented in Perez-Quiros & Rodriguez [2001]. Instead it includes aspects of several more or less advanced theories, which do not necessarily need to be fully consistent with a rational behaviour of market participants.

Overall the variables contained in x_t can be divided into eight categories.

- The **first** category contains variables affecting the market's expectations regarding the accumulated liquidity conditions over the complete reserve maintenance period, which, as explained above, affects the spread via P^d and P^l. The most interesting variables in this category are 1) the ex post realised accumulated net recourse to the marginal lending facility (i.e. recourse to the marginal lending facility minus recourse to the deposit facility) in the remaining days of the reserve maintenance period, which assumes a *perfect* liquidity forecast of market participants, and 2) a *simple* liquidity forecast, where the information made available on a daily basis by the ECB via wire services is simply extrapolated up till the end of the maintenance period. However, this category also contains the net recourse to the standing facilities on the preceding day, which on the last trading days is probably also seen as an indicator of the overall liquidity conditions of the reserve maintenance period. That is, net recourse to the marginal lending (deposit) facility is seen as indicating tight (loose) liquidity conditions.
- The **second** category aims at measuring the availability of central bank deposits on each day, and does thus not aim at describing the expected accumulated liquidity conditions over the whole maintenance period, although the two issues are inevitably connected.
- The **third** category comprises variables relevant for measuring the prevailing interest rate change expectations, i.e. $E_t\left(r_T^m\right)-r_t^m$. These are simply measured from the forward rate implied by the one and two month EONIA swap rates, which are hence assumed to be exogenous, only driven by interest rate change expectations.
- The **fourth** category spans variables describing the outcome of the preceding main refinancing operations in terms of marginal rates and allotment volumes. Here, the most interesting variables are probably a weighted average of the marginal MROs rates realised earlier in the prevailing reserve maintenance period, and the marginal rate of the last MRO of the previous reserve maintenance period. As will be further discussed below, market participants are some times referring to previous marginal rates as a fair price for liquidity.
- The **fifth** category contains variables covering the different impacts of over- and underbidding. Overbidding refers to those MROs where disproportionately large bids were submitted, while the term underbidding refers to MROs in which the Eurosystem did not receive sufficient bids in order to allot its so-called benchmark allotment (see ECB[2002b]). Although the impact of the latter of course is closely related to the ECB's subsequent tight allotments, which as such are quantifiable, the four rounds of underbidding are insufficient to measure any systematic relationships between allotments and the spread, because the market's perception about the ECB's possible reactions to underbidding has clearly not been stable. As a consequence, the impact of underbidding is only modelled via a set of dummy variables. In contrast, overbidding prevailed over a longer period of time - in principle during most of the fixed rate tender - and it is somewhat easier to relate the spread directly to the extent of overbidding, which is here simply measured by the amount of bids submitted to the fixed rate tenders.

- The **sixth** category comprises dummy variables for the measurement of possible calendar effects, like the rather well established end of month effect (including end of quarters, semesters and years), and dummy variables for specific days within the maintenance period. The latter aim at revealing any systematic patterns of the spread (either in terms of levels or volatility) across a reserve maintenance period.
- The **seventh** category contains constants and possible impacts of changes of the key policy rates.
- Finally the **eighth** category comprises time series components, such as a moving average of the residuals from the previous 5 business days.

Table 1 provides a detailed overview and an exact definition of the vector, x_t, of explanatory variables. The first two columns order the variables by the above categories, while the third column defines the specific variables chosen for the relevant category. The references in brackets refer to annex A, where some supplementary explanations about the relevant variables can be found. The fourth and the fifth columns indicate on which days (out of the days for which the explanatory variable is defined) the corresponding coefficients in the mean and the volatility equation are *different* from zero (controlled via dummies), i.e. when the entries in the vectors β_t and v_t, respectively, are different from zero. Finally, the sixth column shows the entry in x_t (and β_t) to which the variable refers, while the relevant entry in v_t, which can not necessarily be interpreted as a linear coefficient in the same way as β_t, is shown in brackets. In order to limit the size of the table, it only contains the most important of those variables which appeared insignificant and hence were excluded from the final model (these variables have no entry number). All monetary quantities are in EUR billions, while interest rates are in percentages. Furthermore, κ_t denotes the number of trading days which (at time t) have already taken place since the beginning of the prevailing reserve maintenance period, while τ_t represents the number of trading days up till the end of the reserve maintenance period.[7] The latter is for convenience abbreviated as RMP.

[7] The convention that κ_t and τ_t are equal to one on the first and the last trading day of the reserve maintenance period, respectively, is adapted, whereby $\kappa_t+\tau_t$ equals the number of trading days in the reserve maintenance period plus one.

Table 1, explanatory variables (x)

Main category	Sub category	Specific variables	β_t	σ_t	Entry in x_t (v_t)
1. Expectations regarding accumulated liquidity conditions (over the complete RMP)	1. Rational liquidity expectations	Perfect forecast: Accumulated net recourse to the standing facilities (realised ex post) from time t up till the end of the RMP. Defined as recourse to marginal lending minus recourse to deposit facility.	$\tau \in \{1,2\}$	$\tau \in \{1,2\}$	1 (1)
		Simple forecast: Extrapolation of the liquidity key figures made available on a daily basis by the ECB via wire services. (See A 1).	All	All	2 (1)
		The net recourse (marginal lending minus deposit facility) to standing facilities realised on the preceding trading day.	$\tau=1$	$\tau=1$	3 (1)
		The accumulated reserve surplus. (See A 2).			
	2. Adaptive liquidity expectations	The average spread experienced on the last days of the previous RMP (i.e. after the last MRO of the previous RMP).	All		4
		Dummy variable equal to one if the spread on the last trading day of the two previous RMPs exceeded 25 basis points.	All		5
2. Daily liquidity conditions		Daily reserve surplus, i.e. current account holdings minus reserve requirements.	All		6
3. Rate change expectations		The difference between the forward rate implied by the one and two month EONIA swap rates and the mid of the corridor. (See A 3)	All	All	7 (2)
4. Tender outcomes	1. Marginal rates in previous MROs	The marginal rate of the most recent MRO.			
		The marginal rate of the second most recent MRO.			
		The marginal rate of the last MRO in the previous RMP.	$\kappa \in \{1,2\}$		8
		Weighted average of the marginal rates, realised since the beginning of the RMP less the prevailing mid point of the corridor. Can be seen as an indication of what will be the remuneration of banks' reserve holdings in the relevant RMP. (See A 4)	All		9
	2. MRO allotment volumes	The change (on the settlement day) of the total outstanding MRO-volume.	All		10
		Difference between the actual and the benchmark allotment as defined in ECB [2002].			
5. Bidding behaviour in the MROs	1. Underbidding	A dummy variable for each of the four rounds of underbidding in 2001 (Feb, Apr, Oct, and Nov respectively), equal to one after the settlement day of the underbidding MROs and up till the end of the RMP. (See A 5)	All	All	11,12,13,14 (3)
		A dummy variable equal to one on the allotment days (10 April, 9 October, 6 November) of the three last underbidding events in 2001.	All		15
	2. Overbidding	The amount of bids submitted to the at time t most recent MRO. Is only defined for the intensive phase of overbidding (See A 6).	All		16
6. Calendar effects	1. End of month peaks	Dummy variable equal to one on end of months.	All	All	17 (4)
		Dummy variable for the days leading up to an end of month, defined as the first 6 trading days of a RMP.	All		18
		Dummy variable equal to one on the day falling after an end of month.	All		19
		Dummy variable equal to one on end of quarters.			
		Dummy variable equal to one on end of semester.	All		20
		Dummy variable for the end of each year.	All		21, 22, 23
		The residual from the previous end of month.	$x_{17}=1$		24
	2. Day of the week	Dummy variables for each weekday.			
	3. Holiday	Dummy variables for trading days falling before and after holidays.			
	intra-maintenance period pattern	Dummy variable for the first trading day of a RMP		All	25 (5)
		Dummy variable for each of the three last trading days of a RMP (i.e. for $\tau=3$, $\tau=2$, $\tau=1$ respectively).		All	26 ,27, 28 (6,7,8)
		Dummy variable equal to one on the last 2 trading days of a RMP.	All		29
		Dummy variable equal to one after the allotment of the last MRO of a RMP.		All	30 (9)
7. Other	1. Adjustment to new key policy rate	The difference between the key policy rate on time t and the key policy rates on time t-1 and t-2. Quantified as $x_{31} = r_t^m - 0.5 \cdot \left(r_{t-1}^m + r_{t-2}^m\right)$.	All		31
		Dummy variable equal to one after a rate change, i.e. if $r_t^m \neq r_{t-1}^m$.			
	2. Irregular days due to the terrorist attacks in the US	Dummy variable equal to one on 12 September 2001, when the financial markets were heavily influenced by the terrorist attacks in the US.	All		32
		Dummy variable equal to one from 13 September to 21 September 2001 (i.e. the end of the RMP).		All	33 (10)
	3. Constants	Dummy variable equal to one over the whole sample period.	All	All	34 (11)
	4. Tender regime	Dummy variable equal to one from 26 June 2000 onwards, when the variable rate tender was introduced simultaneously with the publication of the ECB's forecast of autonomous factors.		All	35 (12)
		Dummy variable equal one in the first week with the variable rate tender		All	36 (13)
8. Time series components	1. Previous residuals	The residual on each of the previous trading days supplemented by the impact of x_8, x_{18} and x_{19}: $x_{33+j_t} = \varepsilon_{t-j} + u_{t-j}$, where $u_t = \beta_{8_t} x_{8_t} + \beta_{18_t} x_{18_t} + \beta_{19_t} x_{19_t}$. Dummies ensure **no** spill-over between different RMPs.	$j \in \{1 \ldots 5\}$ $\kappa>j$	$j \in \{1,2\}$ $\kappa>j$	37,38,39,40, 41 (14,15)
		The residual from the previous trading day, scaled by the increase of its estimated standard deviation: $x_{42} = x_{35}\sigma_t / \sigma_{t-1}$	$\kappa > 1$		42
	2. Previous levels / volatility	The previous day's volatility: $x_{43} = \sigma_{t-1}^2$.		$\kappa > 1$	43 (16)

Table 2 gives an overview of the variables which, on top of x_{17}, κ and τ, are used for controlling how the coefficients in β (the entries, β_1, β_2, and β_7, $\beta_{37\text{-}42}$) are changing.[8]

Table 2, additional dummy variables

Reference	Definition	Symbol
Rate change indicator	Equal to one under interest rate hike expectations. (i.e. when $x_7>0$)	I_{hike}
Indicator of a possible rate change in the prevailing RMP	Equal to one if there is a prescheduled meeting of the Governing Council (and an MRO) before the end of the RMP. Only meetings at which the market perceives it likely that there will be a rate change are counted. (See A 7)	I_{GC}
Indicator of a possible rate change before the next MRO	Equal to one if one of the above defined meetings of the Governing Council takes place before the allotment of the next MRO. (See A 7)	$I_{GC<MRO}$
Indicator for the last trading days of a RMP	Equal to one when there are z trading days left in the prevailing RMP.	$I_{\tau=z}$

3.3 The time varying entries in the parameter vector β

The coefficient for the "perfect liquidity forecast", x_1, is allowed to change from the second last to the last day of the reserve maintenance period, while the coefficient for the "simple liquidity forecast", x_2, increases towards the end of the maintenance period:

(3.6) $$\beta_{1_t} = \beta_1^1 I_{\tau=1} + \beta_1^2 I_{\tau=2}$$

(3.7) $$\beta_{2_t} = \frac{\beta_2^1}{\tau_t}$$

The coefficient, β_{7_t}, for the forward rate, x_7, i.e. the measure for interest rate change expectations, is defined such that it in principle varies according to three dimensions: 1) whether there are expectations of an interest rate hike or a cut, controlled by the dummy variable I_{hike}, which is simply equal to one whenever F_t is positive, and 2) whether there is still a meeting of the Governing Council left before the end of the reserve maintenance period, controlled by the dummy I_{GC}, and the number, τ, of remaining trading days in the prevailing reserve maintenance period, which together can be seen as a measure for the likelihood that the rate change discounted into the forward rate will actually take place in the prevailing reserve maintenance period.[9] 3) whether there is a meeting of the Governing Council before the allotment of the next MRO. This dimension, which appeared to be only statistically significant under interest rate cut expectations, is controlled by the dummy, $I_{GC<MRO}$, (see table 2). In sum the following parameterisation of β_{7_t}, which will be elaborated further below, was chosen:

[8] Obviously, the distinction between explanatory variables, i.e. those contained in x_t, on the one hand, and the variables allowing the coefficients for the latter to change over time, on the other hand, is somewhat arbitrary. The distinction chosen here aims at making the presentation of the model as transparent and simple as possible.

[9] Various parameterisations in which the likelihood of a rate hike within the prevailing reserve maintenance period was modelled via the meeting schedule of the GC only complicated the model without improving the goodness of fit.

$$(3.8)\qquad \beta_{7_t} = \left(\beta_7^1 \cdot I_{GC} + \beta_7^2 \cdot (1 - I_{GC})\right) \cdot \tau \cdot I_{hike} + \left(\beta_7^3 \cdot \tau + \beta_7^4 \cdot I_{GC<MRO}\right) \cdot I_{GC} \cdot (1 - I_{hike})$$

Finally, the spill-over of the residuals realised on end of months is reduced, since the subsequent day's overnight rate is somewhat less dependent hereof than is "usually" the case: [10]

$$\forall j \in \{37,...,42\}:\ \beta_{j_t} = \frac{\beta_j^2}{\beta_{37}^1 \left(1 + x_{17_t}\right)}$$

All other entries in the parameter vector, β, are constant (i.e. on those days, where they, in accordance with table 1, are different from zero).

Relevant for both the parameterisation of the equation for the volatility, in the next subsection, as well as for the decomposition of the spread into the various categories defined above, I will define the *linear* impact of x_{i_t} as $l_{i_t} = \beta_{i_t} x_{i_t}$. In the same vein the linear impact of the j,k[th] (main,sub) category of explanatory variables is defined as $L_{j,k_t} = \sum_{i \in Cat_{j,k}} l_{i_t}$ such that $\sum_{k \in Main_j} L_{j,k_t} = L_{j_t}$ and $\sum_j L_{j_t} = \beta_t' x_t$. For instance $L_{1,1}$, the linear impact of category 1,1 (rational expectations regarding accumulated liquidity conditions) is given by $\sum_{k=1}^{3} \beta_k x_k$.

3.4 The conditional volatility

The equation for the conditional volatility, σ_t^2, contains a GARCH component as well as several of the structural explanatory variables which are relevant for describing the mean of the spread. It can be written conveniently as a function of three (positive) components, V_{1_t}, V_{2_t} and V_{3_t} in which I^{UB} is an indicator function equal to one, whenever one of its arguments is greater than zero:

$$(3.9)\qquad \sigma_t^2 = \left(V_{1_t} + V_{2_t}\right) \cdot V_{3_t}$$

$$V_{1_t} = v_{16}\sigma_{t-1}^2 + v_{14}\left(\frac{x_{37_t}}{1 + \beta_{37}^1 \cdot x_{17_{t-1}}}\right)^2 + v_{15} \cdot \left(\frac{x_{38_t}}{1 + \beta_{37}^1 \cdot x_{17_{t-2}}}\right)^2 + v_3 I^{UB}\left(x_{11_t}, x_{12_t}, x_{13_t}, x_{14_t}\right) + v_{10} x_{33_t}$$

$$(3.10)\qquad V_{2_t} = exp\left(v_{11} + v_5 x_{25_t} + v_9 x_{30_t} + v_6 x_{26_t} + v_7 \cdot x_{27_t} + v_8 x_{28_t} + v_4 x_{17_t}\right)$$

$$V_{3_t} = exp\left(v_{12} x_{35_t} + v_{13} x_{36_t} + v_2 \cdot \left|L_{3_t}\right| + v_{16} \cdot \left|L_{1.1_t}\right|\right)$$

[10] Put differently, surprises about the end of month effect do only to a small extent spill over to the subsequent days.

3.5 The estimates

Positive values of the parameters v_3, v_{10}, v_{14}, v_{15}, v_{16}, λ have been ensured by replacing these with $exp(v'_3), exp(v'_{10}), exp(v'_{14}), exp(v'_{15}), exp(v'_{16}), exp(\lambda')$ and instead estimating $v'_3, v'_{10}, v'_{14}, v'_{15}, v'_{16}, \lambda'$. Likewise a value of p between 0 and 1 have been obtained by substituting p with $p = \frac{e^{p'}}{1+e^{p'}}$ and instead estimating p'.

Although the dimension of x is 43, β only yields a total of 40 parameters, whereby the total number of estimated parameters is 59. The estimate of these were obtained by maximisation of the log likelihood function:

(3.11)
$$logl(\alpha, p', \lambda', \beta, v'_{3,10,14,15,16}, v_{1,2,4-9,11-13}) = -\tfrac{1}{2}log(2\pi\sigma_t^2) + log\left(p \cdot exp\left(\frac{-\varepsilon_t^2}{2\sigma_t^2}\right) + \frac{1-p}{\sqrt{\lambda}} exp\left(\frac{-\varepsilon_t^2}{2\beta\sigma_t^2}\right)\right)$$

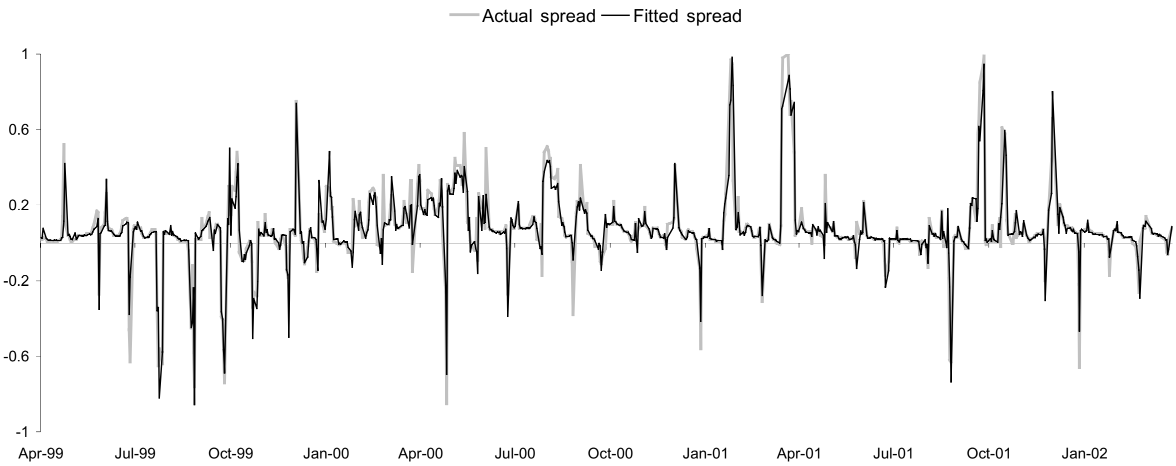
After having found reasonable starting values by only changing subsets of the parameters, the final estimates were obtained by allowing all parameters to change simultaneously. Insignificant variables were for the purpose of numerical stability left out. On the background of the 767 observations in the period from 26 April 1999 to 23 April 2002 the estimates shown in table 3 were obtained, yielding a *logl*-function value of 1695.4.[11]

[11] The overall robustness of the parameters has been roughly assessed by estimating the complete model (all parameters but α) on different subsets of the complete sample period. The quality, however, of this exercise is strongly affected by the inferior sample size of these sub periods as compared to the number (59) of estimated parameters. Nevertheless it was in general found that the only parameters which do not appear to be robust are those related to the measurement of interest rate hike expectations (mainly β_7^1, and β_9 [see below]) and the calendar effects β_{18} and β_{29}. (i.e. the decline on the last two days and the increase on the first 6 calendar days of a reserve maintenance period). The changing impact of rate change expectations is, however, not surprising (when taking into account the small sample period), because their intensity, i.e. the likelihood that they really occur in the prevailing maintenance period, is highly cyclical. Likewise the changing calendar effects may also reflect changing perceptions in the market, which are related to specific events, such as the cash changeover, 11-september effect, etc, which are almost impossible to model specifically without "dummying" it all out. Various attempts to capture these changing perceptions via parsimoniously changing coefficients have not been successful, which is probably also related to the relative small number of observations. Accordingly, for the remainder of the paper, it should be kept in mind that the identified non-robust parameters expresses *the average behaviour of the EONIA over the whole sample period*, which may have been biased by perceptions prevailing in specific sub periods. Since, however, the sign of the parameters remain robust (the sign changes, however, for the two relevant calendar effects to levels not significantly different from zero), the qualitative assessments in the remainder of the paper are broadly unaffected.

α	Maximum spread		1.07	7.15E-03		
p' (p)	Probability for drawing from the normal distribution with variance σ_t^2		-1.10 (0.25)	0.16		
λ (λ')	Difference in volatility between the two normal distributions		-2.40 (0.091)	0.14		
β_1^1	Expected recourse to marginal lending according to perfect forecast	On the last day of a RMP	0.036	3.99E-03	2.29	0.00
β_1^2		On the second last day of a RMP	4.24E-03	1.86E-03	8.53	0.02
β_2	Expected recourse to marginal lending according to simple forecast		2.81E-04	5.09E-05	-5.52	0.00
β_3	Net recourse to marginal lending on the second last trading day of a RMP		0.041	-4.85E-03	8.53	0.00
β_4	Average spread in the last days of the previous RMP		0.016	4.46E-03	3.67	0.00
β_5	systematic drop on the last 4 trading days of a RMP, if the previous RMPs ended sufficiently loose.		-0.38	0.02	-21.11	0.00
β_6	Daily reserve surplus		-2.24E-04	5.82E-05	-3.85	0.00
β_7^1	Hike expectations when there is still a GC-meeting left	Multiplied by the number of remaining trading days in the RMP	9.84E-03	6.46E-04	15.24	0.00
β_7^2	Hike expectations when there is no GC meeting left		9.80E-03	1.08E-03	9.07	0.00
β_7^3	Cut expectations when there is still a GC-meeting left		5.27E-03	8.38E-04	6.28	0.00
β_7^4	Cut expectations when there is a GC-meeting before next MRO		0.036	9.57E-03	3.79	0.00
β_8^1	Marginal rate from prev. RMP, on first trading day	Also spilling over via moving average	0.58	0.07	8.54	0.00
β_8^2	Marginal rate from prev. RMP, on second trading day		0.19	0.05	3.89	0.00
β_9	Weighted average of previous marginal rates		0.20	0.02	9.96	0.00
β_{10}	Change of outstanding MRO-amount		-1.55E-04	3.72E-05	-4.15	0.00
β_{11}	Underbidding in 2001	February	0.084	0.033	2.57	0.01
β_{12}		April	0.80	0.10	7.59	0.00
β_{13}		October	0.21	0.063	3.24	0.00
β_{14}		November	0.071	0.100	0.71	0.48
β_{15}		Allotment day	0.10	4.87E-03	20.86	0.00
β_{16}	Overbidding		1.47E-05	2.83E-06	5.19	0.00
β_{17}	Increase on end of month		0.044	6.23E-03	7.02	0.00
β_{18}	Increase on first 6 trading days	Also spilling over via moving average	3.63E-03	9.34E-04	3.88	0.00
β_{19}	Increase on first day after an end of month		4.16E-03	2.03E-03	2.05	0.04
β_{20}	Additional increase on end of semester		0.076	0.018	4.27	0.00
β_{21}	End of 1999		0.65	0.014	47.06	0.00
β_{22}	End of 2000		0.15	6.38E-03	23.64	0.00
β_{23}	End of 2001		0.40	0.077	5.13	0.00
β_{24}	Residual from previous end of month		0.23	0.079	2.92	0.00
β_{29}	Decline on the last 2 trading days		-0.0415	1.36E-02	-3.05	2.26E-03
β_{31}	Difference between new and old policy rates		-0.17	2.04E-02	-8.35	0.00
β_{32}	Increase after the terrorist attacks on 11 Sept.		0.12	7.68E-03	15.23	0.00
β_{34}	Constant		0.0217	1.72E-03	12.64	0.00
β_{37}^1	Scaling of the end of month residual		5.29	1.65	3.21	0.00
β_{37}^2	MA(1), mean		0.80	0.069	11.61	0.00
β_{38}^2	MA(2), mean		0.81	0.038	21.36	0.00
β_{39}^2	MA(3), mean		0.56	0.033	17.20	0.00
β_{40}^2	MA(4), mean		0.35	0.025	14.18	0.00
β_{41}^2	MA(5), mean		0.13	0.015	8.34	0.00
β_{42}^2	MA(1), mean, standardised residuals		0.20	0.046	4.34	0.00
v_1	Decrease under liquidity expectations		-3.37	1.17	-2.89	0.00
v_2	Increase under rate change expectations		13.87	2.19	6.33	0.00
v_3' (v_3)	Increase after underbidding		-2.42 (0.09)	0.42		
v_4	Increase on end of month		2.99	0.40	7.49	0.00
v_5	Increase on the first day of a RMP		2.09	0.30	6.97	0.00
v_6	Increase on the third last trading day of a RMP		2.46	0.41	5.97	0.00
v_7	Increase on the second last trading day of a RMP		3.21	0.45	7.18	0.00
v_8	Increase on the last trading day of a RMP		5.46	0.43	12.70	0.00
v_9	Increase after the last MRO of a RMP		2.22	0.26	8.68	0.00
v_{10}' (v_{10})	Increase after the terrorist attacks on 11 Sept.		-1.71 (0.18)	1.00		
v_{11}	Constant		-7.74	0.22	-35.19	0.00
v_{12}	General decrease after introduction of the variable rate tender		-0.89	0.10	-8.65	0.00
v_{13}	Increase in the first week with the variable rate tender		1.17	0.59	1.98	0.05
v_{14}' (v_{14})	MA(1), variance		0.63 (1.88)	0.25		
v_{15}' (v_{15})	MA(2), variance		0.0784 (1.08)	0.27		
v_{16}' (v_{16})	AR(1), variance		-2.75 (0.06)	0.46		

Chart 3 shows the actual and the fitted spread, while annex B summarises other measures for the goodness of fit, confirming that the standardised residuals appear to be well in line with the distributional assumptions.

Chart 3
The actual and the fitted spread
(percent per trading day)



4 Possible interpretation of the results

It is almost needless to say that the above model is the final result of a process where numerous other parameterisations have been tested for. In the following, some possible explanations of the chosen parameterisation and of the estimated parameters are provided. Although it is a key issue to also model the volatility correctly in order to obtain efficient and unbiased estimates, the following will mainly focus on the level of the spread, from which the most important conclusions are drawn.

4.1 Interpretation of the equation for the mean

In the non-linear model given by (3.4) the marginal impact of the explanatory variables depends on the level of $\beta_t' x_t$, whereby some assumptions are needed for quantifying and interpreting the impact of the various explanatory variables on a uniform basis. In general, when referring to the *impact* of a certain explanatory variable, x_i, I will refer to the partial derivative of f evaluated in some value of x_t for which the total linear impact is zero: $\partial f(x_t, \alpha, \beta_t) / \partial x_{i_t} \big|_{\forall x_t : \beta_t' x_t = 0} = \alpha \beta_{i_t}$. In so far that the expected value of $\beta_t' x_t$ is normally close to zero this should provide a good assessment of the relevance of the various variables contained in x_t.

Likewise, the non linear set-up prevents an unambiguous decomposition of the spread into *contributions,* c_{i_t}, from each of the specific variables on time t without also making further assumptions about the relative timing of the changes of the various explanatory variables as well as about the extent to which they, when occurring, affect the impact of those changes which have already taken place. In this context, I will make the practical assumption that $\forall i : \Delta l_{i_t} = l_{i_t} - l_{i_{t-1}}$ is occurring simultaneously on day t, without affecting the impact of previously realised changes and thus the total change of f, i.e. $\Delta f(x_t) = f(x_t) - f(x_{t-1})$, is allocated to the different variables in proportion to their linear contribution (Δl_{i_t}). In addition, in order to avoid potential accumulation of the noise resulting from these assumptions, the contributions of each variable is initialised on the first day of each reserve maintenance period. This assumption accords well the construction of the model which assumes only a very limited spill-over between different reserve maintenance periods. On the background of these practical assumptions the *contribution* of the j,kth sub category of explanatory variables across time can be defined as:

$$C_{j,k_t} = \begin{cases} C_{j,k_{t-1}} + \dfrac{\Delta f(x_t)}{\Delta L_t} \Delta L_{j,k_t} & \text{for } \kappa_t > 1 \\ \dfrac{f(x_t)}{L_t} L_{j,k_t} & \text{for } \kappa_t = 1 \end{cases}$$

Chart 4 and 5 summarise the relative and absolute importance of the various categories of explanatory variables across time.

Chart 4
Average relative contributions to the spread per reserve maintenance period
(average contribution to the spread per reserve maintenance period as a percentage; averages for the whole sample period are shown next to the legend)

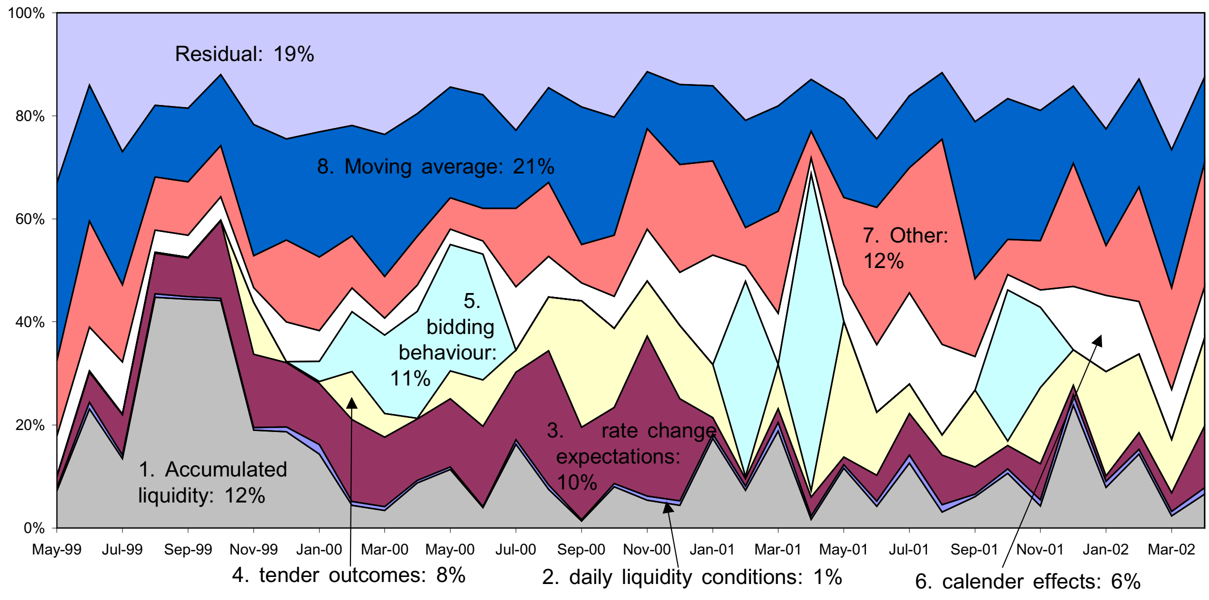
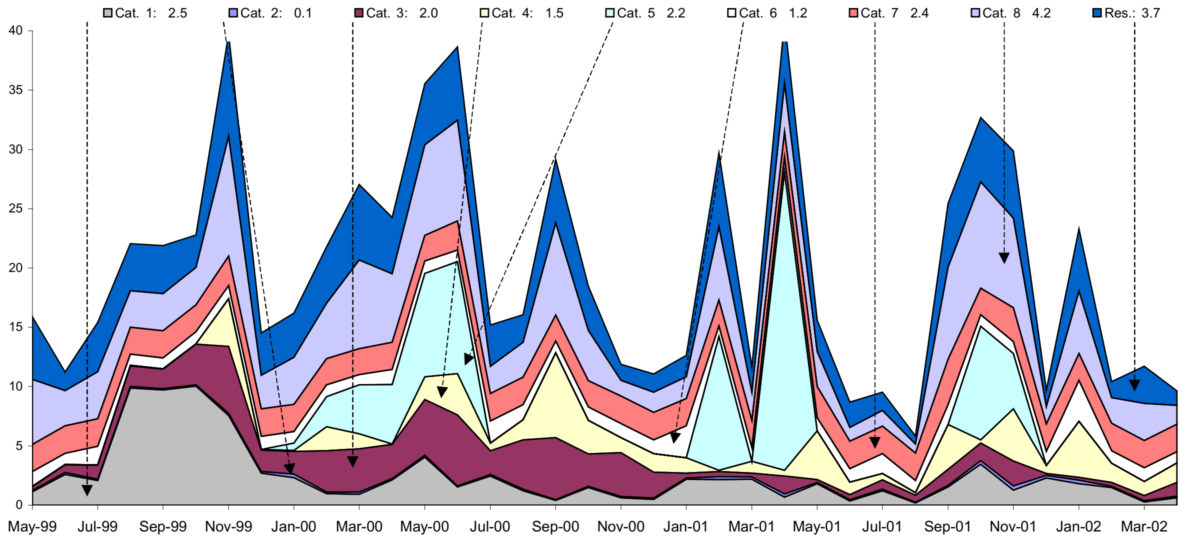


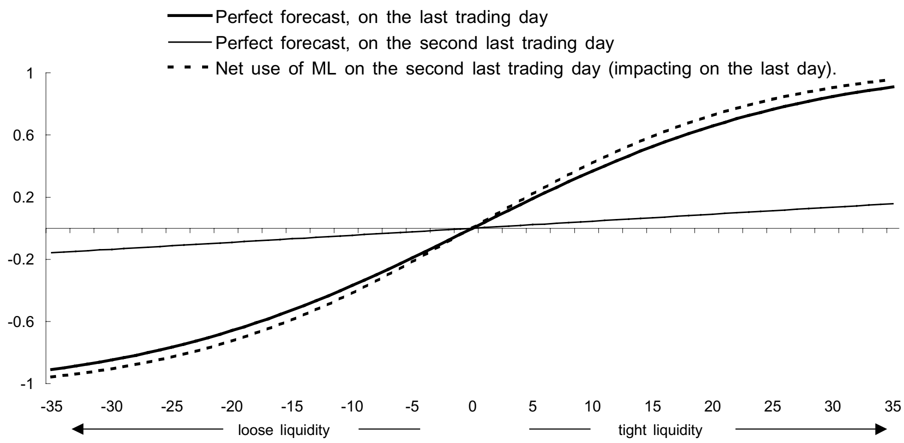
Chart 5
Average absolute contributions to the spread per reserve maintenance period
(average absolute contribution per mainteancenance period in basis points; averages for the whole sample period are shown next to the legend)



4.1.1 Liquidity effects

Firstly, it is interesting that variables measuring the expectations regarding the accumulated liquidity conditions over the complete reserve maintenance period, i.e. category 1, were only found to impact importantly on the spread on the last two days. The "perfect forecast"-variable and the net recourse to standing facilities on the preceding day, i.e. x_1 and x_3, contributed in absolute terms a maximum of around 60 basis points and averages of 16 and 3 basis points on the last and the second last day, respectively, of the reserve maintenance periods.

Chart 6
Estimated impact of the perfect forecast of accumulated liquidity conditions (i.e. x_1), and of the use of standing facilities on the previous trading day (i.e. x_3)
(x-axis: Accumulated net recourse to the marginal lending facility in the remaining (one or two) days of the MP in EUR billions; y-axis: impact on the spread as a percentage)



Also if the spread had been sufficiently low (less than 25 basis points) on the last trading day of the two previous reserve maintenance periods, adaptive liquidity expectations lead to a decline of the spread by an average of 39 basis points, however, only in the last 4 trading days of the reserve maintenance period. This variable was only relevant for the August, September, October, and November reserve maintenance periods of 1999, when a perception, that the ECB should favour loose accumulated liquidity conditions, emerged. This is probably related to the fact that all of the six maintenance periods from May to October 1999 ended with loose accumulated liquidity, such that in October 1999 seven out of the nine first maintenance periods of stage III had ended with net recourse to the deposit facility.

Within a reserve maintenance period, the expected accumulated liquidity conditions only impacted statistically significant on the spread through the simple forecast, x_3, the impact of which was found to increase linearly towards the end of the reserve maintenance period. This variable contributed a mere maximum of 2 basis points and an absolute average of less than 0.2 basis points. Since this variable takes on extreme values when large daily and accumulated liquidity chocks prevail at the same time, it can not be ruled out that its (modest) significance also reflect an unwillingness to buffer out daily liquidity chocks if they occur at the same time as large accumulated liquidity chocks. The impact of the daily liquidity shock (i.e. daily reserve surplus, category 2), when not combined with the accumulated chock, shall probably mostly be seen as a measure of counterparties willingness, given the ECB's so far broadly neutral liquidity management policy (see ECB[2002b]), to buffer out daily liquidity shocks via the averaging mechanism. The estimate of β_6 implies that a daily reserve deficit of around EUR 10 billion leads to an almost negligible increase of the spread by around 0.23 basis point, indicating that counterparties to a large extent are indeed willing to buffer out daily liquidity chocks without requiring significant premiums.[12] This also confirms that the ECB, given its broadly neutral and quantity oriented liquidity management policy, has very limited leeway to affect the spread by steering the *daily* availability of liquidity.

Deviations of the ECB's allotment decisions from the so-called benchmark allotment, defined in ECB[2002b], can, in particular in the last MRO of a reserve maintenance period, be seen as an indicator for the accumulated liquidity conditions of a reserve maintenance period. However, since, as explained above, the underbidding episodes, in which the spread indeed reacted strongly to deviations from the benchmark amount, are here modelled via dummy-variables, these deviations appeared to be insignificant. The MRO allotment amount was only found to impact marginally on the spread (in the same magnitude as the daily reserve surplus) when it deviated from the maturing amount.

The very modest impact of variables contained the first two main categories, together with the generally negligible reactions in the spread to the ECB's allotment decisions in the MROs, confirm that the broadly neutral liquidity management policy of the ECB has been well understood by the market. That is, before the last MRO of a maintenance period, counterparties have, as suggested by Bindseil & Seitz [2001] and Angeloni & Bisagni [2002], generally trusted that the ECB would offset any liquidity imbalances, apart from those resulting from underbidding, in the last MRO of the reserve maintenance period.

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[12] The mean and the standard deviation of the daily reserve surplus, as defined in table 1, amount to EUR 0.9 and 9.7 billion respectively.

The above also supports the finding in Bindseil [2002], that a central bank in a rational expectations model only have limited possibilities for steering the overnight rate by influencing the markets' expectations about the accumulated liquidity conditions of the reserve maintenance period. Under a fixed (or a quasi fixed) rate tender, this relates to the fact that the central bank cannot via its allotment policy push P^d significantly above 0.5, since counterparties then, all other equal, would not be willing to pay the fixed tender rate for liquidity in the MROs, and hence would not bid more than the benchmark amount. Although, with a discretionary allotment policy, the central bank on the other hand indeed can push P^d below 0.5, in both fixed and variable rate tenders, like the ECB for instance managed to do after the occurrences of underbidding, Bindseil[2002] questions the credibility and overall efficiency of such a liquidity management, which is mostly relevant if the central bank would want to counteract interest rate cut expectations. However, since, indeed – credible or not – tight accumulated liquidity conditions is in principle capable of pushing the overnight rate above the mid point of the corridor, while the opposite is not possible for ample liquidity conditions, apart from after the last MRO of the reserve maintenance period, one could imagine an asymmetric impact of ample and tight liquidity conditions on the spread. However, several parameterisations in which tight and ample liquidity conditions were allowed to impact differently on the spread before the last MRO of the reserve maintenance period, turned all out to be insignificant. On the other hand, the fact that the very strong increases of the spread, generated by the ECB's tight liquidity management in those reserve maintenance periods where underbidding occurred, were not matched by corresponding declines under the rather ample liquidity management during the intensive phase of overbidding, clearly supports the idea of an asymmetric impact of expectations of loose and tight accumulated liquidity (see ECB[2001] and ECB[2002b]).[13] Indeed the estimates of the underbidding-dummies show that the spread increased by an average of 6 to 79 basis points in the days after an underbidding, leaving aside any doubt that expectations of *tight* accumulated liquidity conditions have impacted on the spread, before the last MRO of a reserve maintenance period. In the overbidding phase, the relatively ample liquidity policy of the ECB appears to have only generated strong declines of the spread after the last MRO, which in the present model is captured via the rational and the adaptive liquidity expectations.

4.1.2 Rate change expectations

Also the impact of interest rate change expectations was significantly asymmetric in the sense that the estimated time varying coefficient for the "forward-spread" was more than twice as high during interest rate hike expectations than it was under cut expectations.[14] Furthermore, while interest hike expectations were found to still impact significantly on the spread after the last GC-meeting of the reserve maintenance

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[13] However, it should also be kept in mind that most probably the policy of tight liquidity after an underbidding has been better understood by the market, than the policy of ample liquidity as a response to overbidding (see for instance the ECB [2001] and the ECB [2002b]). This may relate to the fact that it is more difficult to define overbidding than underbidding, since in fact the ECB's discretionary allotment policy relies on some overbidding.

[14] Although the parameter, β_7^1, for the forward rate under rate hike expectations appeared to be not completely robust over the whole sample period it remained in all circumstances higher than the corresponding coefficient, β_7^3, for cut expectations.

period, cut expectations were not found to impact on the spread after the last GC-meeting.[15] Indeed, under hike expectations the time varying coefficient, β_7, for the spread between the forward rate and the mid point of the corridor amounted to around 0.22 in the beginning of reserve maintenance periods, which compares to only around 0.12 under cut expectations.[16] These estimates imply that the maximum impact of interest rate hike expectations, as measured directly from the forward rates, amounted to around 14 basis points, while for cut expectations the maximum (negative) impact was only around 5 basis points over the complete sample period. Probably, again this finding relates to the fixed or (quasi fixed) rate tenders, which throughout the sample period have been applied in times of cut expectations, together with the ECB's policy against underbidding. The latter has clearly increased the expected costs, incurred by those using the averaging provision as a mean to speculate against expected rate cuts by, in relative terms, "under" fulfilling (or "back-loading") reserve requirements up to a possible rate cut. Obviously these increased costs have dampened, although not eliminated, market participants' willingness to supply funds in the overnight market below the minimum bid rate even in times of rather strong cut expectations. Putting this into the terminology of the martingale hypothesis, i.e. (3.5), it is the same as saying that the downward pressures on the spread resulting from cut expectations have been more or less simultaneously offset by increases of the probability for ending the reserve maintenance period with recourse to the marginal lending facility. Equivalent increases of the probability for ending the reserve maintenance period with recourse to the deposit facility in times of hike expectations have, however, not taken place to the same extent, since, as already mentioned, a policy of ample liquidity cannot, in a credible way, change the markets expectations about the accumulated liquidity conditions.

Furthermore, under cut expectations, when, in the sample period, only fixed or quasi fixed rate tenders have been applied, the coefficient β_7 increased by an estimated amount of 0.036 ($=\beta_7^3$) on those days where no MRO was going to be allotted before the next meeting of the Governing Council. This reflects that there on these days was a lower likelihood of underbidding before the next possible interest rate cut (i.e. the next GC meeting), and hence a smaller risk associated with "speculating" against it by back-loading the reserve requirements. Hereby the above described balancing of cut expectations, by possibly tight liquidity conditions, becomes less effective.

All in all, the above gives good support to the hypothesis that expectations of tight accumulated liquidity conditions to a large extent have offset the impact of cut expectations, while equivalent expectations of loose liquidity conditions have not offset the impact of hike expectations.

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[15] One should generally expect the likelihood that a rate hike takes place after the last GC-meeting to be zero, and it is thus somewhat striking that rate hike expectations indeed were found to still affect the spread, though to a much less extent, after the last GC-meeting. Probably this relates to the fact that there after the last GC-meeting still exists a residual likelihood for the rate hike to take place outside a prescheduled meeting, and that the market to some extent may expect the ECB to "prepare" the rate hike by aiming at relatively tight accumulated liquidity conditions of the relevant reserve maintenance period.

[16] It is recalled that the coefficient declines proportionally with the number of remaining trading days in the reserve maintenance period, as the likelihood for a rate change in the prevailing reserve maintenance period vanishes. The coefficients for the beginning of the reserve maintenance period are thus obtained by multiplying the estimates of β_7^1 and β_7^3 (0.0098 and 0.0052 respectively), by α (1.07) and the approximate number of trading days in a reserve maintenance period (21).

Yet, the spill-over of rate change expectations into the overnight rate does in the present model not only come from the direct correlation with the forward rate. Also the variables contained in category 4.1, previous marginal MRO rates, and category 5, bidding behaviour, are largely dependent on interest rate change expectations, and their explanatory power does hence, to some extent, reflect an indirect impact hereof. Indeed the previous marginal rates to a large extent reflect the interest rate change expectations that prevailed at the time the bids to the relevant MRO were submitted. Likewise over and underbidding can also generally be seen as a response to interest rate hike expectations.

4.1.3 Marginal rates in previous MROs

As explained in annex A, the most important variable, x_9, in category 4.1 is calculated such that it after the last MRO of a reserve maintenance period is equivalent to the difference between the prevailing mid point of the corridor and the rate of remuneration of the reserve holdings in that reserve maintenance period (which is a weighted average of the marginal MRO rates realised in that reserve maintenance period). Before the last MRO of the reserve maintenance period, when the rate of remuneration of the reserve holdings is still uncertain, the most recent marginal rate is given more weight, such that x_9 reflects what would be the remuneration of the reserve account, if the marginal rates in the remaining MROs of the reserve maintenance period would be the same as the most recent one. The estimate of $\beta_9=0.20$ implies that a 5 basis points difference between the previous marginal rates and the prevailing mid point of the corridor, approximately leads to a one basis point increase of the spread. Also the spread, x_8, between the current mid point of the corridor and the marginal rate in the last MRO of the previous reserve maintenance period, leads to significant increases of the spread in the first days of the next reserve maintenance period. On the first day of a reserve maintenance period, 62% of this spread spills over to the overnight rate, while on the second day 20% spills over. Furthermore x_8 also spills over on the next 5 business days via the moving average filter. Under the fixed rate tender, when the marginal rate by definition was identical to the mid point of the corridor, the variables in category 4.1 has only contributed to the spread after a rate change. However, under the variable rate tender with minimum bid rate, when the marginal rate has normally been larger than the minimum bid rate, in particular during interest rate hike expectations, the variables contributed somewhat more to the spread. Indeed the previous marginal rates have in absolute terms contributed a daily average of 0.9 basis points to the spread during the fixed rate tender, an average of 1.2 basis points during the quasi fixed rate tender, and an average of 2.5 basis points during the variable rate tender.[17] The peak (joint) contributions of x_8 and x_9 amount to approximately –10 and +25 basis points.

The rather strong statistical significance of the previous marginal rates might partly relate to the fact that they, under the variable rate tender, constitute a nice parsimonious representation of the latest average interest rate change expectations. This is consistent with anecdotal evidence indicating that some

[17] This ranking of when the previous marginal rates impact most on the spread appear to be robust, in spite of the tendency of the parameter β_9 to change over time.

counterparties also perceive previous marginal rates, and not only the fixed tender rate or the minimum bid rate, as signals of the monetary policy stance, which, however, has recently been excluded by the ECB (see ECB[2002b). Yet, other anecdotal evidence clearly suggests that previous marginal rates also constitutes a "fair price" for liquidity - both in their capacity as the rate of remuneration of the reserve account and as the average price paid for central bank liquidity. For instance traders have been quoted for saying: (Börsen-Zeiting, *"Geldmarkt",* 10 May 2002): *"Those who have paid the ECB 3.29%, are hardly willing to give away their funds at a lower rate"*. It goes without saying that this "fair price"-hypothesis contradicts the martingale hypothesis, and other rational models, because it foresees that the average and not the marginal value of liquidity determines the overnight rate.

4.1.4 Over and underbidding

The level of bids submitted to the fixed rate tender in the period of "severe overbidding", here defined as ranging from January 2000 to the introduction of the variable rate tender in June 2002, also explains an important part of the spread. Indeed the estimate of β_{16} implies that overbidding (in EUR billions) contributed a maximum of approximately 13 basis points in May 2000, when bids for around EUR 8500 billion were submitted to a single MRO.[18] As also suggested by Bindseil[2002], this can be seen as the costs of overbidding, which to an increasing extent lowered market participants willingness to supply reserves in the overnight market against an expectation of being able to raise the same amount of reserves in the next fixed rate tender. That is, the accelerating overbidding made it increasingly difficult to predict the allotment ratios, whereby the MROs could no longer be regarded as a "secure" source of funding and a general reluctance to supply funds in the overnight market emerged. In particular this implied that it became more and more risky to "arbitrage out" the spill-over of the rather strong interest rate hike expectations to the overnight rate (i.e. the fixed rate tenders "ability" to maintain a small spread diminished). [19] In any event, it follows from ECB [2002b] that the ECB in fact conducted a relatively loose liquidity management during most of the fixed rate tender and hence that the significance of overbidding can not a priori be explained by any correlation with tight liquidity conditions, as discussed in, for instance, Ayuso & Repullo [2001].

4.1.5 Rate change expectations under the variable rate and the fixed rate tender

The above suggests that it is not clear-cut which of the two tender procedures, i.e. a fixed or a quasi fixed rate tender, on the one hand, and a pure variable rate tender on the other hand, have been most efficient in preventing interest rate change expectations from spilling over to the overnight rate. While the fixed (and quasi fixed) rate tender leads to a smaller direct spill-over of cut expectations into the spread and to a

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[18] The total bid amount was trending significantly upwards together with the spread and interest rate hike expectations in the period from January till June 2000, suggesting that the correlation between overbidding and the spread could be spurious. However, fitting simple trends together with the bid amount confirmed the robustness of the identified relationship.

[19] This suggests that overbidding leads to a higher spread, which again should increase the incentives to overbid. However, if assuming, for instance, that the overbidding costs are a linear function of the amount of bids submitted there will exist an equilibrium where the overbidding costs balance the increase of the spread, since the latter is limited by the corridor.

smaller impact through the previous tender rates, it suffers from the over and underbidding problem. When tentatively interpreting both the impact of previous marginal rates and the bidding behaviour as indirect consequences of rate change expectations, it follows from table 4, that the fixed rate tender has not been more successful than the variable rate tender in preventing rate change expectations from spilling over to the spread. Only if one ignores the impact of over and underbidding this has been the case.[20]

Table 4, Average absolute contributions (in basis points) under different tender procedures

explanatory variable \ tender procedure	**quasi fixed rate [1]**	**fixed rate**	**variable rate [2]**
rate change expectations (category 2)	0.89	2.94	2.20
previous marginal rates (category 4.1)	1.41	0.88	2.84
over/under bidding (category 4.2)	4.42	2.16	0.33
Total	6.72	5.98	5.37

[1] *variable rate tender with minimum bid rate under rate cut expectations (i.e. when $F_t<0$)*
[2] *variable rate tender with minimum bid rate under rate hike expectations (i.e. when $F_t>0$)*

4.1.6 Calendar effects

The constant, β_{34}, and the variables contained in the 6th category adds up to the total average calendar effect in the course of a reserve maintenance period illustrated by the black line in Chart 7. The calendar effect, as identified over the whole sample period,[21] increases gradually up to the end of month (which typically falls on the 5th or the 6th trading day) when it, on account of "window dressing activities", peaks at around 9 basis points on a "regular" end of month and at around 17 basis points on an end of semester.[22] Hereafter it decreases relatively smoothly down to the level of around 2.3 basis points,[23] before it on the last two trading days declines further to around minus 2 basis points, which, however, is not significantly less than zero.[24]

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[20] These results are indeed robust , in spite of the tendency of β_7^1 and β_9 to change over time.

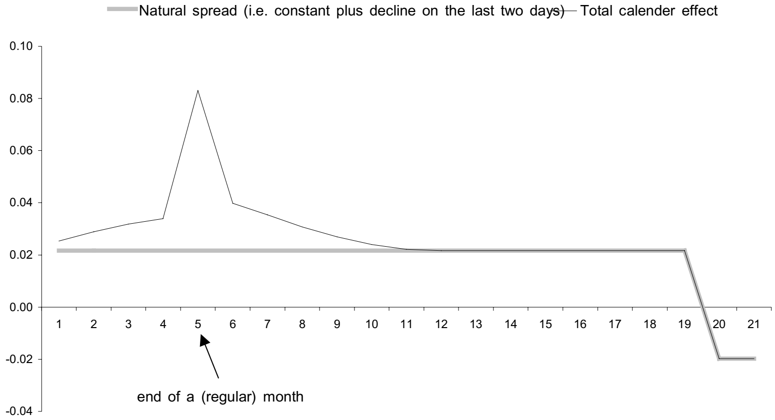
[21] It is recalled from footnote 11 that the parameters, β_{18} (measures increase on the first 6 calendar days of a reserve maintenance period) and β_{29} (measures decrease on the two last business days) was somewhat none-robust and therefore should be interpreted with care.

[22] Gaspar et al [2001] does not identify a systematic increase of the mean of the spread on the end of month, but only an increase of the volatility. This, however, contrasts with the finding in Bindseil et at [2002], where indeed the overnight rate is found to increase systematically on the end of month. Furthermore, apart from the end of April 2000 which coincided with a change of the key policy rate, the spread (in the sample period from April 1999 to March 2002) has always been higher on the end of month than its average value on the previous and the subsequent trading day.

[23] The gradual increase and subsequent decrease is obtained by letting the dummy variables, x_{18} and x_{19}, impact also through the moving average filter

[24] According to a t-test, the hypothesis that $\beta_{29} > -\beta_{34}$ can not be rejected at a 10% level of significance.

Chart 7
Average calendar effect in the course of a reserve maintenance period
(x-axis: trading days gone, when assuming a RMP of 21 days ; y-axis: systematic impact on the spread as a percentage)



To the extent all other explanatory variables are unbiased, which by construction of the model appears to be a rather fair assumption, the constant, β_{34}, of 2.2 basis points (multiplied by α=1.07) and the decline on the last two business days to a level not significantly different from zero, can be interpreted as the so-called natural spread, i.e. the spread at which the market settles when all other effects are zero (the grey line in Chart 7). The fact that the natural spread is generally positive can tentatively be interpreted as a consequence of

1) the cost of collateral, in the sense that market participants require a premium to give away funds which they have obtained in the MROs against eligible collateral, or
2) the fact that the EONIA is an "offer-rate", i.e. it is only calculated from the panel banks' *lending*, or
3) the asymmetry of possible movements of the spread as discussed above. That is, if the central bank has a "tight" target for the accumulated liquidity conditions (i.e. recourse to marginal lending), this will have an upward impact on the spread which is greater than the downward impact resulting from an equivalent loose liquidity target, because the latter will be balanced by market participants lower bidding at the fixed (or quasi fixed) tender rate. Thus, if there for some reason is uncertainty about the central bank's liquidity target, this will lead to a positive spread.

The third explanation also accounts for the overall declining tendency of the spread on the last days of the reserve maintenance period, as the ECB's liquidity target becomes more certain because, for instance, the risk for underbidding vanishes. In fact, the "asymmetry" should disappear completely after the last MRO, because market participants' bidding behaviour at this stage of the reserve maintenance period can no longer balance potentially loose liquidity conditions. It is interesting to note that this explanation of the declining tendency on the last days of a reserve maintenance period in fact is the same as saying that the probability for an aggregate recourse to marginal lending, P^l, is declining in the course of a reserve maintenance period, which does not constitute a violation of the martingale hypothesis, as put in (3.5), although of course it implies that the spread does not follow a martingale from a time series perspective. However, when also taking into account the apparent none-robustness of this identified average decline on the last two days of the reserve maintenance period, one can not rule out that it rather reflects a general perception among market participants that the ECB should favour loose ends of reserve maintenance periods. At least this explanation finds some anecdotal support that in turn can be justified by the fact that 23 out of the 36 reserve maintenance periods in the sample have indeed ended with recourse to the deposit facility.[25]

Nevertheless, it is interesting to note, consistent with Prati et al. [2002], but contrary to Perez-Quiros & Rodriguez [2001], that no systematic increase of the spread on the last trading day of the reserve maintenance period was identified. This probably relates to the relatively high level of reserve requirements in the Euro area, which implies that the risk of being "locked in", i.e. fulfilling the reserve requirements before the last day of the reserve maintenance period, and thus loosing the option to buffer out liquidity chocks via the reserve holdings, is rather limited.

Finally, the moving average of the last 5 business day's residuals explains an important part of the spread. The moving average is constructed such that residuals from one reserve maintenance period do not spill-over to the next reserve maintenance period. Probably it captures changing perceptions in the market about how the above identified structural explanatory variables impact on the spread. For instance, as already discussed in footnote 12, the perceived likelihood that a rate change will actually take place in the prevailing reserve maintenance period does in reality not only reflect the number of remaining trading days, as assumed in this model, but also other issues, like the true macro economic conditions. These "other issues" will, unless modelled explicitly, inevitably lead to correlated residuals. Likewise, towards the end of the maintenance period the "market mood" (rumours, perceptions of the monetary policy stance, etc.) some times leads to persistent perceptions about the probabilities, P^l and P^d , which also lead to correlated residuals, unless the perceptions are supported by the rationally expected liquidity conditions. However, it can not be ruled out that the very significant moving average also reflects a sluggishness, i.e. an auto regressive element, of the spread, which could indicate that the willingness/possibility to perform the intertemporal arbitrage foreseen by (3.5) are somewhat limited.[26]

4.2 Interpretation of the equation for the volatility

The volatility is mainly driven by the GARCH(1,2)-element and the systematic increases towards the end of the maintenance period, contained in V_1 and V_2 respectively. The latter implies that the standard deviation increases from the "all other equal level" of around 2 basis points to around 6 basis points after the allotment of the last MRO and further to 35 basis points on the last day of a reserve maintenance period. Although all variables (and several others), which were found significant for the mean, were also tested for in the volatility, only the end of month, the interest rate change expectations, summarised in L_3,

[25] It is recalled that these perceptions are in fact modelled via the variable l_6, which, however, was only relevant in the fall of 1999, when the perceptions of loose endings of the reserve maintenance period were particularly strong.

[26] It is recalled that the arbitrage argument underlying the martingale hypothesis assumes that reserve holdings are either front- or back loaded against a willingness to use the standing facilities with the probabilities P_L and P_D at the end of the maintenance period. Indeed the professional segment of counterparts that might exploit such arbitrage opportunities is limited to only do this to the extent the size of their unfulfilled reserve requirements allows it.

and the variables for the rational expectations about the accumulated liquidity conditions, summarised in $L_{1,1}$, were identified as significant structural explanatory variables for the volatility. While increasing interest rate change expectations leads to increasing volatility, the opposite is true for an increasing impact of the expected accumulated liquidity conditions; indeed an increase of the absolute value of L_3 of approximately 10 basis points all other equal leads to a doubling of the standard deviation, while an increase of the absolute value of $L_{1,1}$ of approximately 41 basis points leads to a halving of the standard deviation. The latter reflects the fact that strong liquidity expectations at the end of a reserve maintenance period decreases the uncertainty about which of the two standing facilities will actually need to be accessed and thus also the rather broad band, in which the spread is normally fluctuating at the end of a reserve maintenance period.

The most interesting element in the equation for the volatility, from a monetary policy point of view, is probably the estimated rather strong decline from 24 July 2000 onwards, when the variable rate tender and the weekly publication of liquidity needs were introduced. Indeed the estimate of v_{13} at –0.89 implies that the standard deviation since then has been on a 36% lower level, when disregarding the estimated 29 basis points increase after an occurrence of underbidding. Towards the end of a reserve maintenance period, this structural decline of the volatility could be partially explained by a less noisy extraction of the actual accumulated liquidity conditions, i.e. of x_1, which, as also argued in Bindseil[2000], is easier to predict by the market when the liquidity needs are published. The structural decline could also be due to the rather significant contribution of the previous marginal MRO rates, which after the introduction of the variable rate tender, to a larger extent, has allowed the interest rate hike expectations to be reflected in the overnight rate, and hence may have established an equilibrium spread which is perceived more natural, and hence less volatile, by the market. However, it could also partially reflect a learning process, in the sense that the equilibrium overnight rate was less obvious to the market through most of the fixed rate tender period, because it was possibly still adapting to the Eurosystem's operational framework.

Finally, it is also interesting to note that no significant increase of the volatility after a change of the key policy rate was identified, supporting the finding in Gaspar et al [2001] that changes of the key policy rates have generally been well discounted into the spread. Only on the first two days after a rate change a gradual adjustment of the mean of the spread was identified. Possibly, this gradual adjustment to new key policy rates could be related to the fair price considerations discussed above.

5 Conclusion

The overnight rate is not only the starting point of the term structure of interest rates, but is also often viewed as the operational target of central banks. It is hence an essential aim of any central bank to understand all factors affecting its evolution. Especially deviations of the overnight rate from the level, which may appear to be "normal", such as, in the case of the ECB, the middle of the corridor set by standing facilities or the key open market operation policy rate, are of major interest.

This paper dealt with this issue in the case of the euro area by presenting a complete empirical model on the spread between the EONIA rate and the middle of the corridor set by standing facilities, and reached the following main conclusions about the spread in the sample period from April 1999 to April 2002.

First, with the exception of days falling after an underbidding, the measurable expected accumulated liquidity conditions of a reserve maintenance period impacted only strongly on the spread on the last two days of a reserve maintenance period. For instance, on the last day of the maintenance period a recourse to the marginal lending facility (deposit facility) of EUR 10 billion leads to approximately a 40 basis point increase (decrease) of the spread. This confirms that the market, until the last main refinancing operation of the reserve maintenance period, has generally expected the ECB to offset any liquidity shocks, apart from those resulting from underbidding, through the subsequent operations.

Second, before the end of a reserve maintenance period, expectations about the accumulated liquidity conditions have, however, in case of rate cut expectations, impacted indirectly on the spread. Specifically, the risk of underbidding has to a large extent prevented the spread from becoming negative, implying that the direct effect of rate cut expectations on the market rate was offset by its indirect impact through expectations of underbidding. Evidence of a similar countering of rate hike expectations by a perceived risk of loose liquidity conditions at the end of the reserve maintenance period was not identified. This reflects that expectations of market rates falling below the minimum bid rate (or the fixed tender rate) at the end of the reserve maintenance period are not rational, because banks will not be willing to bid sufficiently in the last main refinancing operation of the reserve maintenance period such that market rates afterwards fall systematically below the minimum tender rate.

Third, accordingly interest rate hike expectations impacted almost twice as much as cut expectations on the EONIA spread. For instance, at the beginning of a reserve maintenance period, expectations of a 50 basis points rate hike taking place within the same or the two next reserve maintenance periods increased the spread by 11 basis points, while corresponding rate cut expectations only decreased the spread by 6 basis points. Both were declining proportionally in the course of the reserve maintenance period, reflecting the vanishing likelihood for a rate change before the next period.

Fourth, somewhat surprisingly, the marginal MRO rates realised previously in the same reserve maintenance period had an independent strong impact on the spread. Although this can be interpreted as another "channel" for interest rate hike expectations to enter into the spread, anecdotal evidence suggests that it could also reflect that previous MRO rates are seen as a "fair price" for liquidity in the interbank market.

Fifth, when viewing the sample period as a whole, the spread was higher in the days before and after an end-of-month, when it, excluding end of semesters and end of years, was on average 9 basis points. In addition, the "all other equal" spread of around 2.3 basis points tends to decline to a level not significantly different from zero on the last two trading days of a reserve maintenance period. This could be related to a vanishing of the perceived risk of underbidding and hence increased certainty about the ECB's liquidity target towards the end of the reserve maintenance period.

Sixth, the equilibrium spread has been more noisy during the fixed rate tender and the quasi fixed rate tender period, than it has been during the pure variable rate tender period (i.e. the period when hike expectations prevailed during the variable rate tender with minimum bid rate).

Finally, in sum, most of the identified factors driving the spread can be related to expectations about the key policy rate and the liquidity conditions at the end of the reserve maintenance period. This supports, in spite of the identified calendar effects and the possible interpretation of previous marginal MRO rates as representing a "fair price" for liquidity, the martingale hypothesis.

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Annex A, supplementary explanations to the definitions of the variables in table 1 and 2.

A 1. Formally x_{2_t} is defined as follows: $x_{2_t} = AccRs_{t-1} + (T-t)\cdot Rs_{t-1} - AccEr$, where $AccRs_{t-1}$ represents the reserve surplus (current account holdings less the reserve requirements) that has accumulated since the beginning of the prevailing maintenance period up till day t-1, while Rs_{t-1} represents the reserve surplus realised on day t-1. Both are made available by the ECB via wire services on day t between 9.00 and 9.15 a.m. AccEr denote the excess reserves (simply assumed to be equal to EUR 21 billion per maintenance period), which are subtracted such that x_{2_t} in principle becomes an unbiased predictor of the accumulated liquidity conditions of the maintenance period (i.e. the expected net recourse to standing facilities).

A 2. The accumulated reserve surplus (AccRs) is, as explained in A 1, defined as the sum of the daily reserve surpluses (i.e. current account holdings minus reserve requirements) that have been experienced since the beginning of the maintenance period.

A 3. The forward rates are calculated as $f\left(r_t^{1m}, r_t^{2m}\right) = \frac{1 + r_t^{2m}\cdot\frac{61}{36000}}{1 + r_t^{1m}\cdot\frac{30}{36000}}\cdot\frac{36000}{31}$, where r_t^{1m} and r_t^{2m} are the one and two months EONIA swap rates. These are extracted from the Kliemm Frankfurt Reuters page at 9.30 AM on a daily basis. However, in order to better align these swap rates with the EONIA rate (which reflects the average overnight rate over the whole trading day), the average of the swap rates on the current and the subsequent trading day is used.

A 4. It follows from the "General documentation", ECB(2002a), that the remuneration of the reserve account is calculated as a weighted average of the marginal rates of the MROs, which have been settled within or immediately before the prevailing reserve maintenance period. x_{9_t} is here defined in a similar way, following the assumption that the at time t most recent marginal rate will also prevail in the remaining MROs of the maintenance period: $x_{9_t} = \frac{1}{n}\sum_{i=1}^{n_t} MR_{t-i} + (n - m_t)\cdot MR_t - M_t$

where m_t is the number of calendar days in the prevailing maintenance period that at time t have already passed by (excluding day t), n is the total number of calendar days in the maintenance period, and MR_t is the at time t most recent marginal rate of an MRO.

A 5. The dummy variable for the initial round of underbidding in February 2001 allows for a linear increasing impact. Specifically this dummy, i.e. x_{11}, is multiplied by the term "t – 13/02/2001", i.e. the number of days since the underbidding MRO was allotted.

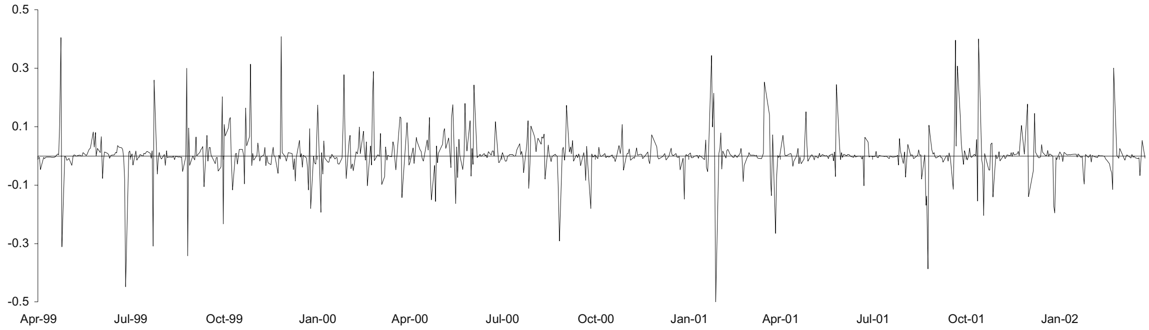
A 6. The intensive phase of overbidding is, in accordance with ECB [2001], defined to range from the start of 2000 to the introduction of the variable rate tender in the July maintenance period of 2001.

A 7. In the period up till 16 March 2000, I_{GC} and $I_{GC<MRO}$ only counts meetings with a prescheduled press conference, since the market in this period, according to the financial press, only expected the Governing Council to possibly change the key policy rate on these meetings. Likewise, from 9 November 2001 onwards, when the Governing Council announced to only discuss the monetary policy stance on its first monthly meeting (which is followed by a press conference), only these meetings are counted.

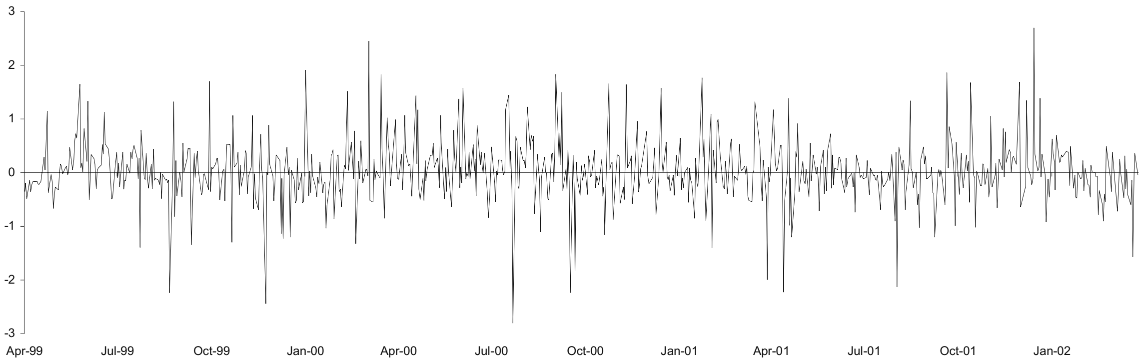
Annex B, Goodness of fit

The actual residuals

(percent per trading day)

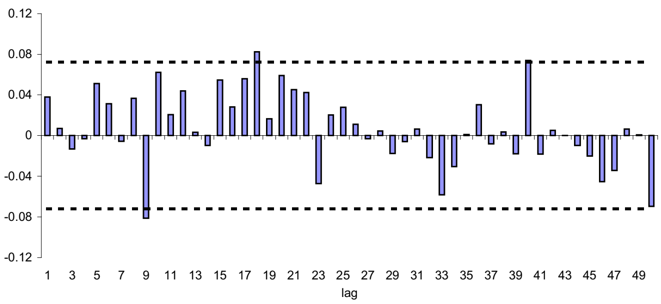


The standardised residuals



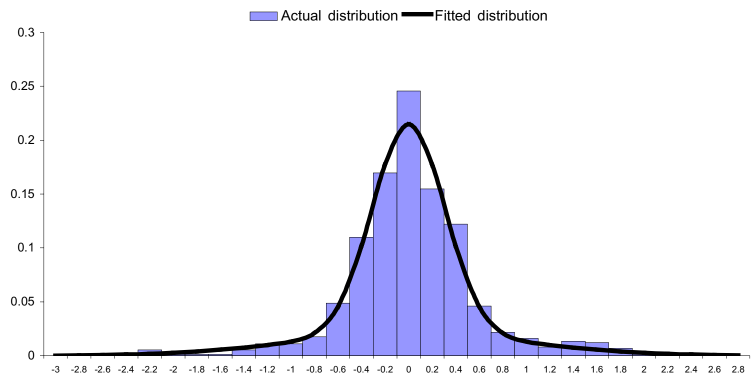
Correlogram of the standardised residuals

(The dotted lines indicate the 95% confidence interval, under the hypothesis of zero correlation)



Ljung-Box tests				
Lag	standardised residuals		squared standardised residuals	
	Q-stat	Significance	Q-stat	significance
10	13.2	0.21	8.3	0.60
20	28.9	0.09	11.1	0.94
30	35.0	0.24	17.3	0.97
40	44.3	0.30	32.4	0.80
50	51.6	0.41	41.5	0.80
75	67.4	0.72	74.2	0.50
100	81.6	0.91	100.2	0.48

The actual and the fitted distribution of the standardised residuals



Mean:	0.0306
Standard Error of mean	0.0204
Standard Error	0.5650
Skewness	0.0433
Kurtosis	7.2713

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