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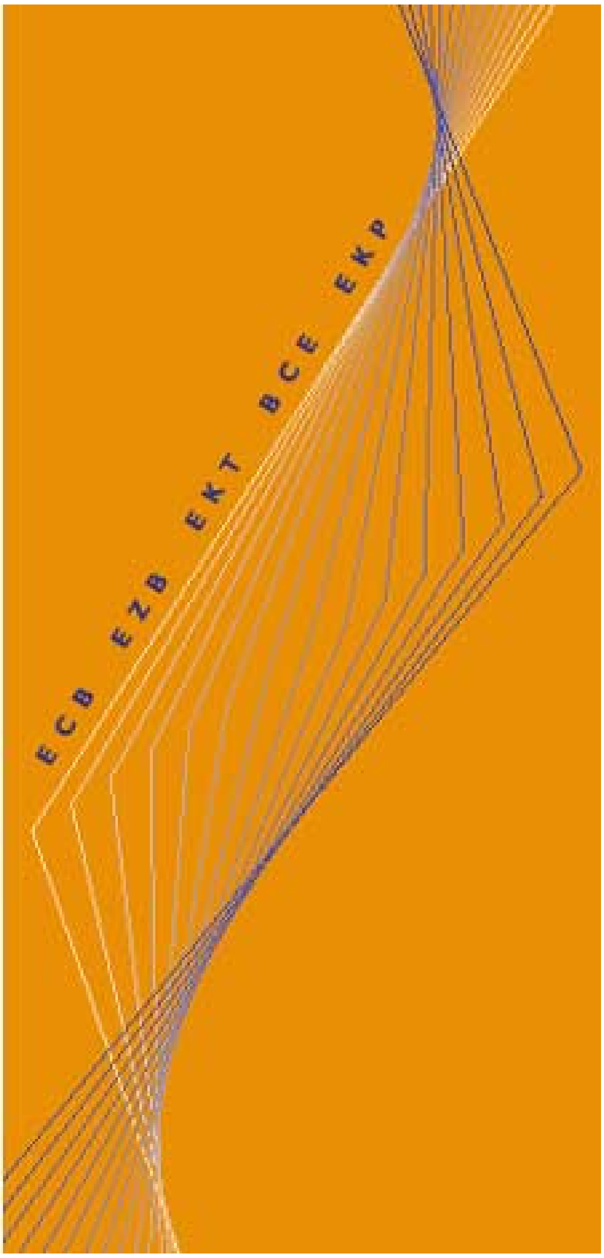

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THE SUPPLY AND DEMAND FOR EUROSYSTEM DEPOSITS THE FIRST 18 MONTHS

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* *Ulrich Bindseil: European Central Bank, Directorate General Operations, Kaiserstrasse 29, D-60311 Frankfurt am Main, Germany; e-mail: ulrich.bindseil@ecb.int. Franz Seitz: University of Applied Sciences Amberg-Weiden, Hetzenrichter Weg 15, D-92637 Weiden, Germany; e-mail: f.seitz@fh-amberg-weiden.de.* *We thank Juergen von Hagen, James Hamilton, Dieter Nautz, Hans-Eggert Reimers, participants of seminars at the Center for European Integration Studies at University of Bonn and at the WHU in Koblenz, and an anonymous referee for valuable comments. The paper reflects the personal views of the authors and not necessarily those of the European Central Bank.*

Address	**Kaiserstrasse 29**
	D-60311 Frankfurt am Main
	Germany
Postal address	**Postfach 16 03 19**
	D-60066 Frankfurt am Main
	Germany
Telephone	**+49 69 1344 0**
Internet	**http://www.ecb.int**
Fax	**+49 69 1344 6000**
Telex	**411 144 ecb d**

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Contents

Abstract

This paper describes the demand and supply factors affecting the amounts of deposits held by banks with the Eurosystem in the first 18 months of Stage Three of EMU and differences to the years before. The paper starts from the methodology adopted in a recent study by James Hamilton on "The supply and demand for Federal Reserve deposits". While the treatment of the autonomous liquidity factors is in principle similar, the modelling of open market operations and of the recourse to standing facilities diverge. These differences stem from different institutional settings, but also from somewhat different views on the accurate model. In a second part, the paper turns to prices by providing a simple econometric model capturing a large part of the variability of the difference between the EONIA rate (the price for daily funds) and the rate charged for the main refinancing operations.

JEL Classification numbers: E52, E58
Keywords: Monetary policy instruments, money markets, money market rate

1 Introduction

The purpose of this paper is to describe the factors affecting the amounts of deposits held by banks with the Eurosystem in the first 18 months of Stage Three of EMU. The primary instrument of monetary policy is the control of the supply of deposits of banks with the central bank through open market operations. The supply and demand for deposits determines the overnight interest rate, i.e. the inter-bank interest rate for deposits with a one-day maturity. This rate is of crucial importance since it may be considered as the "monad" of the yield curve.

The paper starts from the methodology adopted by Hamilton [1998][1] who undertakes a similar analysis of the demand and supply of factors of Federal Reserve deposits and their dynamic interaction. As far as possible, we follow Hamilton's line of reasoning. Nevertheless, some substantial differences emerge which partially result from different institutional settings in the euro area (especially: much higher reserve requirements with averaging, lower frequency of open market operations, symmetric standing facilities), but also from some diverging views on the appropriate modelling of some of the relationships.

In a second step we cover the interaction between supply and demand factors for deposits and their price in the form of the spread between the overnight rate and the main refinancing rate of the Eurosystem. In treating the quantity and price side sequentially we claim that indeed, such a separation is useful since there is no significant causality from prices to quantities in this market.[2]

The first 18 months of Stage Three of EMU were of course a special period which was at least partially influenced by an ongoing learning process. However, it appears that the properties of the time series analysed have been relatively stable for the entire period of analysis. It should be noted that the first 18 months of Stage Three was at the same time the (first) period of application of the fixed rate tender in the ECB's weekly tender operations, which may also justify to consider this period as one specific episode.[3]

The paper proceeds as follows: section 2 describes the consolidated balance sheet of the Eurosystem which may be interpreted as the representation of all supply and demand factors for deposits (reserves) with the Eurosystem. At the same time, it provides a brief introduction to the logic of central bank liquidity management and to the determinants of the key balance sheet items (i.e. the key supply and demand factors on the market for deposits). Section 3 then explores the time series properties and the dynamic interaction of the so called "autonomous" liquidity factors, i.e. those balance sheet items that can be considered as purely exogenous both from the point of view of the central bank's liquidity management and from the point of view of the market. There should not be any causality running from the other factors to these autonomous ones, which are government deposits (section 3.1), banknotes in circulation (section 3.2), the net float (section 3.3) and the residual sum of all other autonomous factors (section 3.4). In the case of banknotes in circulation and government depositswe were able to use data starting in 1994 and 1995, respectively. Section 4 focuses on the *endogenous* balance sheet items and their dynamic interaction, namely outstanding open market operations of the Eurosystem (section 4.1), the net recourse to standing facilities (section 4.2), and the banks' deposits (section 4.3). Section 5 provides a basic theoretical, and specifically an econometric model of the price of reserves in the form of the spread between the EONIA rate and the main refinancing rate of the Eurosystem. Finally, section 6 summarises and draws some conclusions.

1 *See also Hamilton [1996], [1997]. A related analysis can be found in Lee [1999] who compares the federal funds market with the overnight eurodollar market.*

2 *Hamilton [1998] also treats the relationship between quantities and prices on the market for deposits, but also does not model any causality from prices to quantities.*

3 *The ECB switched to the variable rate tender procedure in its main refinancing operations in its last operation of June 2000. To be more precise, our sample ends with the end of this fixed rate period on 27 June 2000. This period is also analysed for instance by Ayuso and Repullo [2000] in an attempt to show that the ECB has an asymmetric loss function penalising more heavily interbank rates below a certain target rate.*

2 The Eurosystem's balance sheet, the supply and demand for deposits, and the logic of the ECB's liquidity management[4]

The natural starting-point for any description and analysis of central bank liquidity management is the balance sheet of the central bank. The European Central Bank (ECB) publishes the balance sheet for the Eurosystem, which comprises the ECB and the national central banks (NCBs) of the EU Member States which have adopted the euro, on a weekly basis, as a rule every Tuesday in respect of the preceding Friday (see the ECB's Web site at http://www.ecb.int).[5] Table 1 constitutes a simplified version of the Eurosystem's balance sheet of 26 November 1999, which shows all the individual items which are relevant to understand the ECB's current liquidity management.

Table 1

The Eurosystem's stylised balance sheet of 26 November 1999 (€ bn)

Assets			Liabilities		
1.	Main refinancing operations	143.0			
2.	Longer-term refinancing operations	65.0			
3.	Marginal lending facility	0.4	4.	Deposit facility	0.1
5.	Net float	1.2	6.	Banknotes in circulation	343.3
7.	Other autonomous factors	301.6	8.	Liabilities to general government	61.7
			9.	Current accounts (incl. min. reserves)	106.1

From the point of view of central bank liquidity management, a distinction should be made between the following four categories of items:

– Open market operations, namely the main and longer-term refinancing operations (items 1 and 2), both of which are reverse liquidity-supplying operations. The trend in the evolution of outstanding open market operations in the period under review is shown in Chart 1.[6] In principle, the ECB can also conduct various types of fine-tuning operation, but it did not do so in 1999. In the first half of 2000, the ECB conducted two fine tuning operations.[7]

4 *See also Bindseil [2000] for a general introduction into Central Bank liquidity management.*

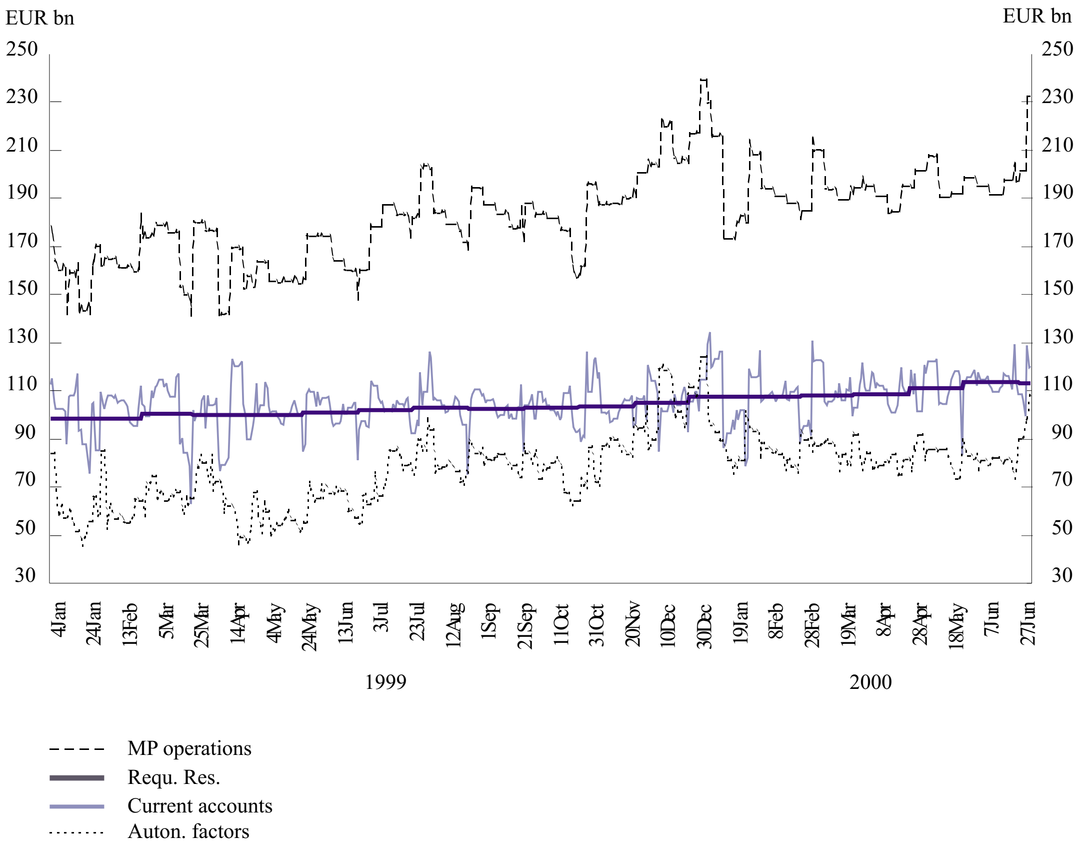
5 *Selected balance sheet items are also published on a daily basis by the ECB through wire services, namely the current account holdings, the use of the marginal lending facility and the use of the deposit facility. Publication of data for the previous day normally takes place by 9.30 a.m. The ECB has furthermore started to publish explicitly the sum of autonomous factors and estimates of the future average evolution of autonomous factors in July 2000, so after the period under consideration here.*

6 *Note that the "MP operations" ("Monetary Policy Operations") time series in chart 1 also contains the liquidity effect of the recourse to standing facilities, which is however negligible on most days compared to the outstanding open market operations.*

7 *A collection of fixed term deposits to mop up excess liquidity after the transition to the year 2000 and an overnight reverse operation in June 2000. Further details may be found in the Monthly Bulletin of the ECB.*

Chart 1

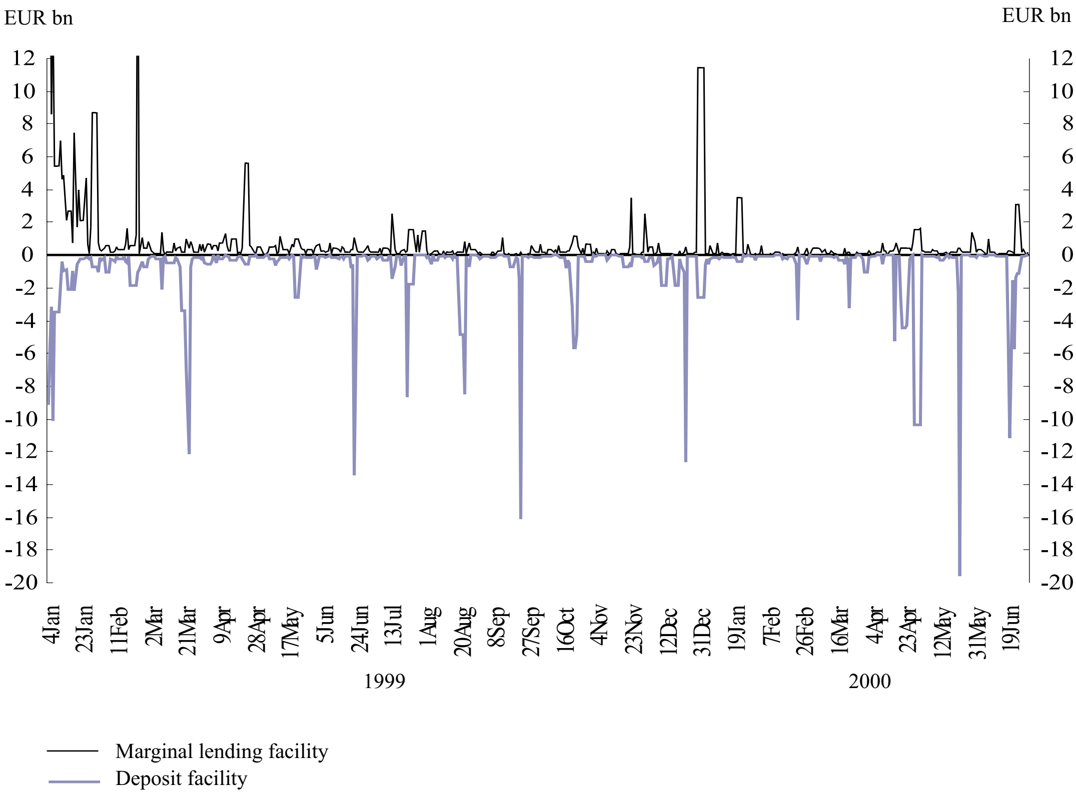
Liquidity factors



– The standing facilities (items 3 and 4) are, in contrast to open market operations, monetary policy operations, which are conducted *on the initiative of counterparties*. The marginal lending facility enables the counterparties of the Eurosystem to cover their end-of-day liquidity needs at a rate of interest above the market rate. There are no credit limits or other restrictions on counterparties' access to the facility (with the exception of the requirement that sufficient collateral must be available). The deposit facility enables counterparties to place their surplus end-of-day liquidity with the Eurosystem at a rate below the market rate. The interest rates on the two facilities form the ceiling and the floor of a corridor within which the rate for the main refinancing operations lies and within which money market rates move. Chart 2 shows that, except for the beginning of the year and a few other exceptions, the main recourse to the standing facilities has always taken place at the end of the maintenance period, i.e. around the 23rd of each month.

Chart 2

Recourse to the standing facilities



– Autonomous liquidity factors such as items in course of settlement (net float) (item 5), banknotes (item 6), other autonomous factors (item 7; the sum of various items the biggest of which is foreign exchange assets), and Government deposits (item 8) relate to central bank activities or services determined neither by the central bank's liquidity management nor by counterparties. As the underlying transactions involve central bank money, transactions affecting these items have exactly the same liquidity-providing or liquidity-absorbing effect as monetary policy-related transactions. As shown in Chart 1, the liquidity effects of autonomous factors are considerable. In the case of the Eurosystem, the most volatile autonomous factor is government deposits with the national central banks. Chart 1 reveals that day-to-day changes in autonomous factors in the order of €10 billion are relatively frequent. In order to be able to allot an adequate amount of liquidity in its weekly main refinancing operations, the Eurosystem prepares a forecast of all major autonomous factors with a minimum forecasting horizon of ten business days on a daily basis.

– The current account holdings ("reserves") of counterparties with the Eurosystem (item 9) can be considered a residual position, which balances the balance sheet. All operations of the Eurosystem ultimately affect the banks' current accounts (as long, of course, as they do not net out). By transforming the balance sheet identity, it can be seen that the current accounts can always be determined from the following equation:

current accounts

= (main refinancing operation + longer-term operation) + (marginal lending facility - deposit facility) + (net float + other autonomous factors - banknotes - government deposits)

= open market operations + use of standing facilities + autonomous factors (expressed as assets)

This equation is reflected in Chart 1, in which the current accounts curve corresponds to the difference between the monetary policy ("MP") operations curve and the autonomous factor curve. One may also interpret this equation as the supply function of the Eurosystem of current account holdings ("reserves") of counterparties with the central bank.

To complete a model of the market for banks' reserves with the central bank, the demand side has to be added. Reserves of counterparties can take two forms, required reserves and excess reserves, but the average volume of the latter component amounted to only around 0.7% of total reserves in the case of the Eurosystem in 1999. Reserve requirements have to be fulfilled by counterparties in the euro area on average over a maintenance period of one month, which starts on the 24th of each month and ends on the 23rd of the following month. They have been increasing most of the time in the period under consideration, starting at around € 100 and reaching around € 113 billion in June 2000. They are broadly determined by applying a factor of 2% to liabilities of banks with a maturity of less than two years, and are regarded as exogenous from the point of view of liquidity management.

The logic of the ECB's liquidity management in terms of the described four types of balance sheet items can be summarised very roughly as follows: The ECB attempts to provide liquidity through its open market operations in a way that, after taking into account the effects of autonomous liquidity factors, counterparties can fulfil their reserve requirements. If the ECB provides more (less) liquidity than this benchmark, counterparties will use on aggregate the deposit (marginal lending) facility.

The balance sheets of central banks of industrialised countries are generally relatively similar, and the logic of liquidity management is also basically the same everywhere, even though the types of monetary policy operations diverge to a considerable extent. This homogeneity allows taking a comparable approach to Hamilton [1998]. The following table gives a broad comparison of the treatment of balance sheet items in Hamilton [1998] and in our paper:

Table 2

A comparison of the simplified balance sheets in Hamilton [1998] and in the present study

Balance sheet items	Hamilton [1998] – FED	Present study – Eurosystem
Net float; banknotes; government deposits	Autonomous factor variables	Autonomous factor variables
Assets denominated in foreign currency	Assigned to the variable representing open market operations of central bank	Assigned to "other autonomous factors"
Outright holdings of securities	Variable representing open market operations of central bank (endogenous variable)	Autonomous factor included in "other autonomous factors" (exogenous variable)
Reverse central bank operations	Assigned to the variable representing open market operations of central bank	Variable representing open market operations of central bank
Standing facilities	Discount window loans	Two symmetric facilities
Bank deposits	Deposits of banks with the Federal Reserve System	Deposits of banks with the Eurosystem

The main differences between the two stylised balance sheets can thus be summarised as follows:

1) Outright holdings of securities constitute the variable capturing open market operations in the US, while it is an autonomous factor in the Eurosystem, since outright operations have so far never been used by the Eurosystem for monetary policy purposes.
2) Foreign exchange assets are included in Hamilton's variable for open market operations, while we regard it as an autonomous factor. For us, foreign assets are not really a policy variable in liquidity management.
3) Access to standing facilities is symmetric in the case of the Eurosystem, i.e. there is not only a facility to cover shortages, but also one allowing to deposit surpluses.

In terms of data set, Hamilton uses daily balance sheet data for three years (1992-1994), while we analyse mainly the first 18 months of the Eurosystem (1 January 1999 to 27 June 2000). For two of the autonomous factors, for which a longer time series is available, we also analyse a longer time span in order to allow for a more reliable estimation of seasonal patterns , which can, by definition, not be easily identified within an 18 months period.

3 The autonomous liquidity factors[8]

This section presents a descriptive as well as an econometric time series analysis of the four autonomous factors defined in the previous section. In all cases, it is claimed that the autonomous factors are exogenous in the sense that they are not influenced by the endogenous balance sheet items (i.e. open market operations and the recourse to standing facilities). This is not only confirmed by liquidity management practices of central banks but also by Granger causality tests (not reported here, but available on request). None of these endogenous variables, either individually or taken as a group, do Granger cause the value of the relevant autonomous liquidity factor. Moreover, the correlation between the residuals of the different equations of the autonomous factors is negligible (in every case the respective correlation coefficient is below 0.07 in absolute terms).[9] We try to explain the development of the different autonomous items through institutional and seasonal factors as well as day-of-the-week effects which we capture through different dummy variables (see annex 1). The standard regression equation applied to the autonomous factors can be represented as follows:

$$y_{i,t} = c_i + x'_{i,t}\,\beta_i + Ly_{i,t}\delta_i + \varepsilon_{i,t}$$

where $y_{i,t}$ is the amount of autonomous factor i (e.g. banknotes) on day t, c_i is a constant term, $x'_{i,t}$ is the vector of dummy variables on day t, β_i is the vector of coefficients of the dummy variables to be estimated, *L* is the lag-operator, δ_i is the vector of coefficients of the autoregressive terms, and $\varepsilon_{i,t}$ is the residual. In the case of banknotes a deterministic time trend is included in the regression (see section 3.2). To get consistent estimates in the presence of heteroskedasticity and autocorrelation the Newey-West procedure is applied to all estimations.

Note that because of the adding-up condition of the balance sheet, all equations are estimated in levels rather in logs (in line with Hamilton [1998]). For instance, a one-Euro increase in an autonomous factor, if not offset elsewhere on the balance sheet, would result in a one-Euro decrease in banks' reserves. By contrast, the effects of a 1-percent increase in an autonomous factor depend on the current levels of the respective autonomous factor and reserves. The purpose of the paper is to develop a complete description of the dynamic links between the different balance sheet items, which are linked by the accounting identity mentioned above. This is

8 See also ECB [2000a, 40-41] for a short presentation of the main autonomous liquidity factors affecting the euro area.

9 Therefore it seems to be justified to use a single equation estimation and not a system estimation, e.g. a SUR model. See for the same argumentation Hamilton [1998].

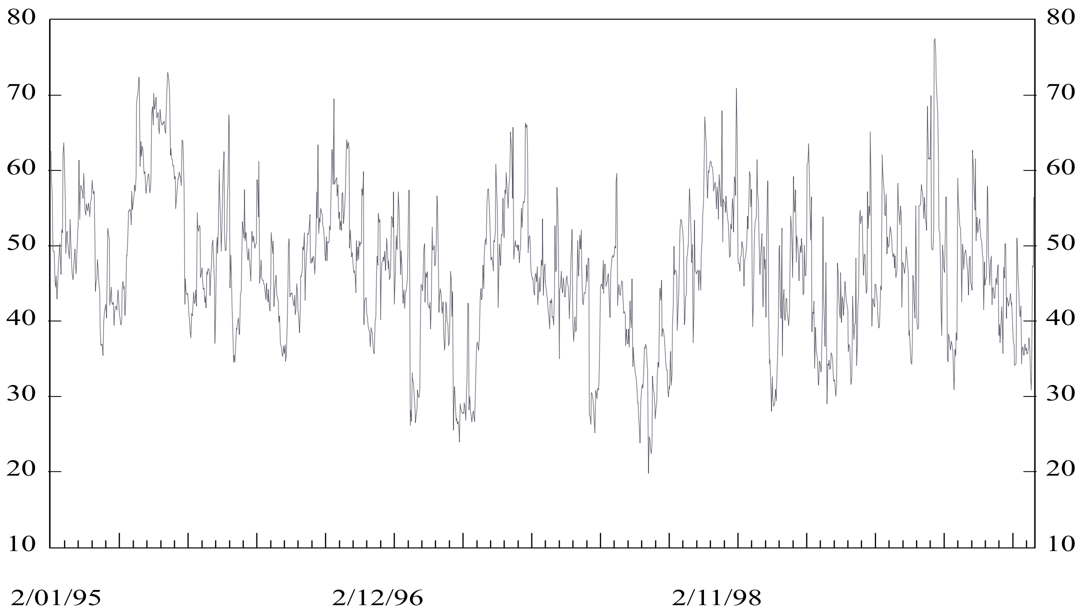
also the reason why we do not report too much diagnostic statistics of the different equations (again, in line with Hamilton [1998][10]). The data are taken from the daily balance sheet of the Eurosystem (see table 1). Weekends are excluded from the data set. The first observation corresponds to the 1 January 1999 which was the beginning of the first maintenance period. The last observation corresponds to the 27 June 2000. We restrict our analysis to the fixed-rate period since this period may be substantially different in terms of several aspects treated in this paper, compared to the period of the use of variable rate tenders in main refinancing operations.[9] Therefore, we have a total of 388 observations. In the case of banknotes and government deposits we were able to expand the sample period back until 1994 (1692 observations) and 1995 (1432 observations), respectively.

3.1 Government deposits

Chart 3 shows the evolution of Government deposits with EU 11 central banks from 2/01/1996 – 27/06/2000.

Chart 3

Government deposits (in € bn)



10 *For instance, it is natural that the OLS requirement of normality of residuals and absence of heteroskedasticity is not respected in case of an estimation in levels for time series that are subject to trend growth.*

11 *For instance, the allotment strategy of the ECB may have changed, as well as the behaviour of inter-bank overnight rates. Only autonomous factors should not be affected by the change of the tender procedure.*

Even though some monthly regularities are obvious, large parts of the changes also appear to be without regularity. The volatility of Treasury deposits in fact generally stems only from a few NCBs, namely, since the beginning of EMU, those of Spain, France, Ireland, Italy, and Portugal. The other NCBs have adopted arrangements that provide incentives to the Treasury to target very low or at least stable levels of deposits. For instance, if deposits are not remunerated, Treasuries normally transfer all funds at the end of the day to the banking sector to obtain interest. In the mentioned group of NCBs, Treasury deposits are affected by any operation conducted by the Treasury, such as debt issuance, redemption and coupon activity, the collection of tax and social security contributions, the acquisition of goods and services, the payment of wages, pensions and other social security benefits (see ECB [2000b] and for instance Grittini [1999]). Surprisingly, government deposits with the Eurosystem usually rose dramatically at the end of the reserve maintenance period (the 23rd of each month). However, this is not due to any causal relationship between the fulfilment of reserve requirements and Treasury activities: by mere coincidence, the Italian Government collects on the 23rd of each month a major amount of funds due to tax and social security payments.

Table 3

Estimated model for government deposits

Explanatory variable	Coefficient	t-value (absolute)
constant	5.27	9.0
gd_{t-1}	0.80	36.6
gd_{t-2}	0.06	2.7
dumjan1	-4.06	8.7
dum2	1.74	5.1
dum3	0.91	2.7
dum6	1.54	3.4
dum7	2.37	5.8
dum8	2.33	5.1
dum9	1.85	4.6
dum10	0.88	2.1
dum11	1.53	3.6
dum12	1.21	2.7
dumit	3.57	4.8
dumsp	-0.46	2.2
dumfi	-14.22	13.8
dumla	3.10	4.8
dum95	0.93	3.6

Notes: Newey-West correction for heteroskedasticity and autocorrelation; adj. R^2 = 0.87 (adjusted coefficient of determination); SE = 3.46 (standard error of regression); included number of observations: 1430. For dummy variable definition see annex 1.

Table 3 shows the results of the estimation procedure. One clearly recognises the calendar effects with government deposits being higher at the end of the year and on the last business day of the months but lower on the first business day of the months. The Treasury activities in Spain and Italy are especially significant.

In those central banks, which have traditionally volatile Government accounts, considerable resources are devoted to estimate the net liquidity flows resulting from all transactions of the Government with the private sector. Therefore, our simple econometric approach only allows for forecasts which are worse than those the Eurosystem actually has, and possibly also worse than those of the larger money market players. This shows up in the relatively large standard error of the estimate.

For the liquidity management of the ECB, the important measure for the quality of autonomous factor forecasts is the quality with which changes of the series can be forecast within time horizons derived from the frequency of operations and other parameters of the operational framework. The most important forecasting horizon is thus normally the T+5 (in terms of business days) one, since this is the period from one main refinancing operation to the next, assuming that fine-tuning operations are preferably avoided by the Eurosystem. Further important horizons are the very short term one (T+1), for instance in the case of fine-tuning, and the T+10 one, since this is the normal maturity of the main refinancing operation. The following table provides the standard deviation of changes in Government deposits of the original time series for these three lags, and compares them with the standard error of forecasts at the corresponding forecasting horizons.[12] It emerges that over all forecasting horizons the dummy variable approach is able to capture between one third and one half of the variability of the time series.[13]

Table 4

Variability and forecast quality for Government deposits using our simple regression approach during EMU (in € billion)

Government deposits	T+1	T+5	T+10
(1) Std. deviation of changes of the underlying time series	5.50	9.60	10.42
(2) Std. errors of forecasts (RMSE)	3.51	4.64	4.64
(3) predicted share =(1)-(2)/(1), in %	36%	52%	55%

One could suggest analysing the time series with regard to whether monetary union implied a structural break at the beginning of 1999. However, from a theoretical point of view, some reservations with regard to the conjecture of a structural break are warranted. On the one hand, the introduction of the euro itself in January 1999 should have had no unambiguous effects on Government deposits, since these are determined to a very large extent by inflows (e.g. tax and social security payments, debt issuance) and outflows (e.g. payment of salaries and pensions; debt redemption) of the Treasury which are not affected by the irrevocable fixing of the exchange rates between the euro area currencies. The introduction of monetary union only impacted indirectly and with a time lag on the time series properties of Government deposits in so far as (1) the time series properties of the spread between the remuneration rate (as far as applicable) of the deposits and market rates changed, which incited some Treasuries after a while to modify their liquidity management correspondingly; (2) in the course of the first 18 months, some national central banks revised their arrangement with their Treasury, also in view of the effects that the volatility of Treasury deposits had on the euro area liquidity conditions. The fact that all these changes occurred only over time, and also only affected a part of the national time series, suggests to be cautious in the interpretation of any test for a structural break. Having these reservations in mind, it may be reported that a Chow breakpoint test seemed to reject the null hypothesis of no structural break on 1 January 1999 in the Government deposits time series.

3.2 Banknotes

The banknote time series displayed in chart 4 shows a rather regular weekly, monthly and seasonal pattern (the latter indeed corresponds to a large extent to the pattern observed in previous

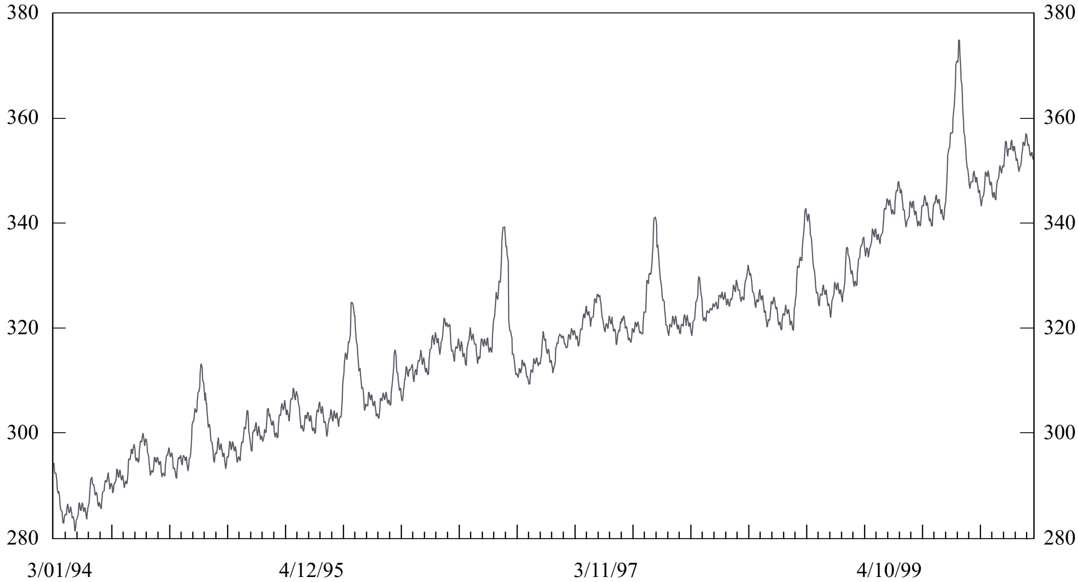
12 In order to compare the results for all the autonomous factors with each other, we do this forecast evaluation only for the time of EMU. This also takes into account the instability problems encountered for the autonomous factors for which a longer time series is analysed.

13 Naturally, out of sample forecasts, especially for the time of EMU, would be preferable. However, we felt that due to the special situation in 1999 and the structural break with the beginning of EMU this improvement would require the availability of more data.

years). Moreover, in contrast to the other 3 autonomous time series, this series displays a general upward trend, rising for instance from € 294 bn to € 352 bn at the end of June 2000[14]. It covers all banknotes issued by the Eurosystem no matter where they are circulating. Especially in the case of the German mark it has been argued that a large portion of DM currency is held outside EMU (see Seitz [1995]).[15]

Chart 4

Banknotes issued by EU 11 central banks (in € bn)



The volatility of changes of this time series is considerably lower than the one of Government deposits (the corresponding standard deviations are € 1.01 and € 4.51 bn, respectively). The regularities of the changes guarantee that the changes of the banknotes in circulation can be forecast to a relatively large extent through an econometric approach. This is indeed done by some central banks (see e.g. Cancelo and Espasa [1987] for the case of Spain). Others use more intuitive methods as for instance graphical approaches. The regularities in the circulation of banknotes reflect social patterns in the use of banknotes such as consumption behaviour, holidays, the role of the Christmas shopping season, but also parameters of the banking system such as the number of ATMs. This implies corresponding differences between the patterns across countries. Such different patterns can be observed both within the euro area and for instance when comparing the euro area with the US.

14 One may estimate that around 3% of banknotes in circulation at the end of 1999 can be assigned to the Y2K effect.
15 Rogoff [1998] projects this also for the Euro.

Table 5

Estimated model for EU 11 banknotes

Explanatory variable	Coefficient	t-value (absolute)
constant	5.87	4.0
time	0.00	4.0
n_{t-1}	1.33	15.6
n_{t-2}	-0.23	1.8
n_{t-3}	-0.12	2.5
dum1	-0.34	4.7
dum7	0.20	4.5
dum12	0.52	4.4
dummo	-0.72	13.1
dumtu	-0.42	4.6
dumth	1.27	30.6
dumfr	0.40	4.6
$dumfi_{t+2}$	0.41	4.6
$dumfi_{t+3}$	0.32	4.3
$dumfi_{t+4}$	0.22	4.7
dumla	0.40	4.2
$dumla_{t-1}$	0.33	3.9
$dumla_{t-2}$	0.28	4.0
$dumla_{t-3}$	0.20	2.9
dumhol	0.33	5.8

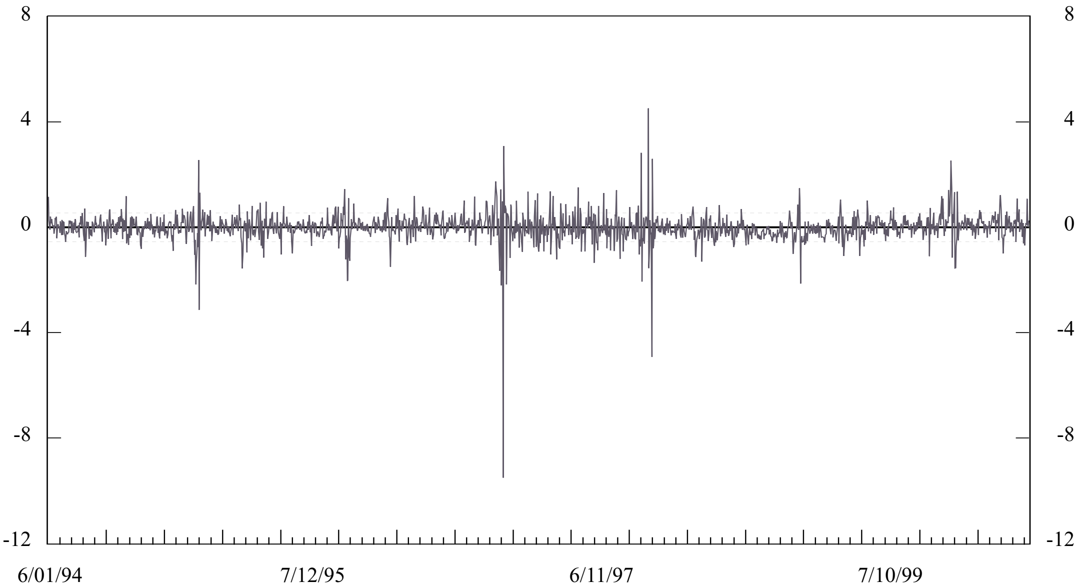
Notes: Newey-West correction for heteroskedasticity and autocorrelation; adj. R^2 = 0.99; SE = 0.55; included number of observations: 1689. For dummy variable definition see annex 1.

We apply an elementary univariate method to forecast the circulation of banknotes in the euro area. It estimates the weekly, monthly, and seasonal pattern of the banknotes in circulation by an OLS regression on corresponding dummy variables (see annex 1), a time trend (time) and autoregressive terms (see table 5). We find a clear tendency for banknotes to be lower at the beginning of the year and to be higher in July and at the end of the year and the beginning and end of each month. Furthermore, we got significant day-of-the-week effects with lower amounts of currency at the beginning of the week and higher levels at the end of the week. Especially big and significant are the positive effects on Thursday. Furthermore, the demand for cash increases prior to the main euro area holidays. Neither the other autonomous factors nor other balance sheet items are useful in explaining the development of banknotes.

The calendar factors appear to be the strongest and most significant patterns of daily changes. However, the monthly and seasonal factors are also clearly significant. An analysis of the residuals of the equation (see chart 5) reveals that the time series was rather predictable in the period considered. The few large outliers always occur at the turn of the years. The difficulty to capture the evolution in these periods is probably related to the ever-changing interplay of the day-of-the-week-, the calendar- (day-of-the-month), and holiday-effects.

Chart 5

Residuals from Banknotes equation (in € bn)



As in the case of Treasury deposits, one may wonder whether the introduction of the euro on 1 January 1999 had a structural impact on the time series. Once again, a Chow breakpoint test seems to reject the null of structural stability since the beginning of EMU. However, again as in the case of Government deposits, one may argue that this result should be treated with care since it lacks a convincing economic explanation. On the one hand, one might argue that the changed inflation outlook in several countries related to the transition to Stage Three also changed the willingness to hold banknotes. However, on the other hand, it can hardly be argued that the corresponding effect should have taken place precisely on 1 January 1999, since it could have had gradual effects both years before the actual transition to Stage Three, as well as within the first years after the transition to the single currency.

Finally, we turn again to the quality of liquidity forecasts for banknotes at the horizons that should be most relevant for the ECB, as displayed in the following table 6. The uncertainty with regard to this autonomous factor can be reduced through our simplistic forecasting approach by more than half for the short and long forecasting horizon and by about 40% for the medium-term forecasting horizon.

Table 6

Variability and forecast quality for banknotes using our simple regression approach during EMU (in € bn)

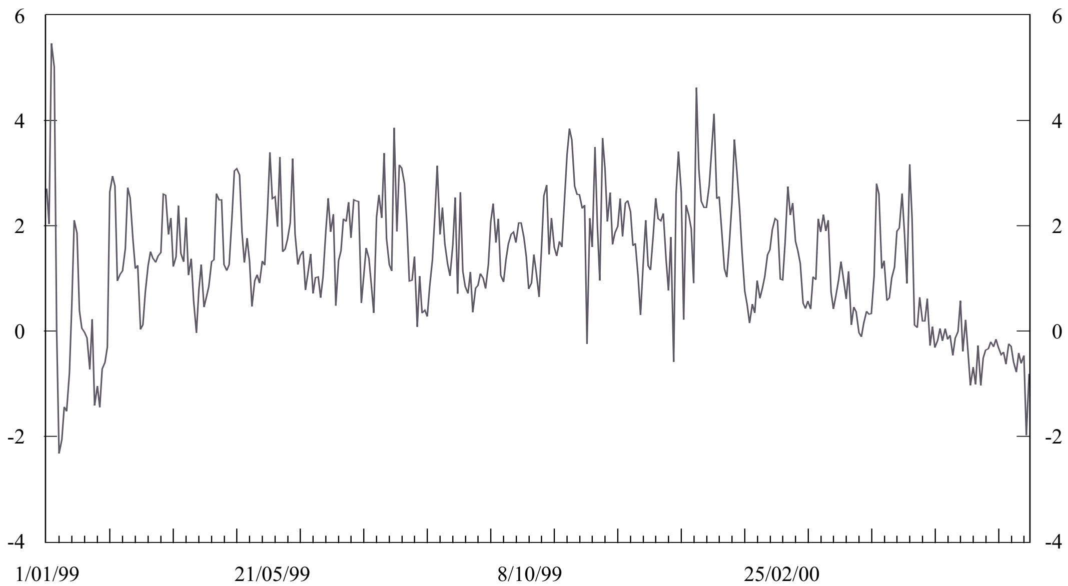
	T+1	T+5	T+10
(1) Std. deviation of changes of the underlying time series	1.03	3.39	5.56
(2) Std. errors of forecasts (RMSE)	0.42	2.16	2.17
(3) predicted share =(1)-(2)/(1), in %	59%	36%	61%

3.3 Net float ("items in course of settlement")

Payment system float is created whenever the crediting and the debiting of accounts do not occur simultaneously. It can both be liquidity providing (appear on the asset side of the central bank balance sheet) or liquidity withdrawing (appear on the liability side of the balance sheet). For instance, cheques which are credited before being debited inject liquidity. The relevance of float thus depends on the specification of the payments system. Indeed, in the euro area, a majority of national central banks do not exhibit any float while the volatility in the aggregate time series mainly stems from a few central banks (see e.g. Deutsche Bundesbank [1997]). As chart 6 reveals, this time series seems to be stationary even in a short term horizon. The augmented Dickey-Fuller test statistic is 4.5 compared to a 1-percent-critical value of 3.4. This is also illustrated by table 7 in which the volatility of the time series grows barely when the time lag for which the net float is calculated increases from 1 to 5. It even seems to decrease from lag 5 to lag 10.

Chart 6

Net float of Eurosystem since 1999 (in € bn)



Our model of net float is summarised in table 6. The sum of the coefficients of the lagged endogenous variable is the smallest under the items cosnidered, indicating that there is not too much serial correlation in this series. In accordance to Hamilton [1998] we do find strong day-of-the-business-week effects (the dummy variables for Wednesday and Thursday are significant). Furthermore, net float was typically lower around the turn of the month, after the main holidays, between Christmas and New Year's Day and shortly before the last day of the maintenance period. On the other side, net float is higher in april, October and November. In contrast to Hamilton [1998] we do not find that lagged values of banknotes are useful in forecasting float.[16] This again justifies the single equation approach. In the US, if banks needed more cash yesterday, then net float tended to be higher. Such a pattern would be plausible, for instance, if people ask for currency when depositing a cheque. But this pattern does not seem to be relevant for EMU.

16 This would be the case if we solely concentrated on 1999.

Table 7

Estimated model for net float (f)

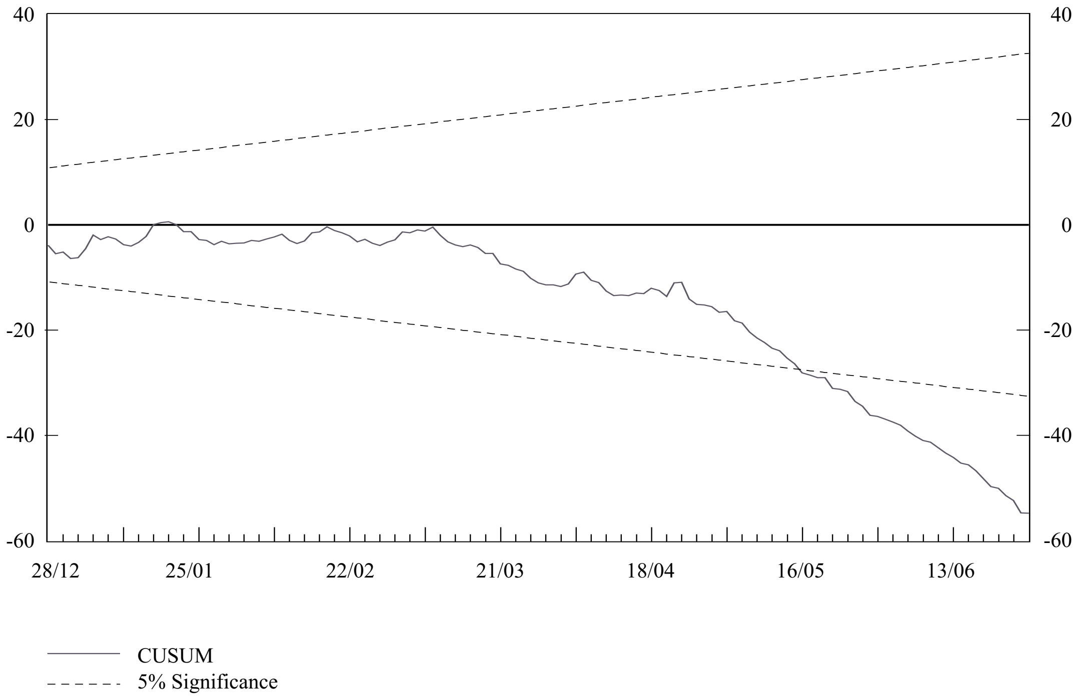
Explanatory variable	Coefficient	t-value (absolute)
Constant	0.53	5.5
f_{t-1}	0.67	14.5
dum4	0.21	2.2
dum10	0.41	2.9
dum11	0.29	2.6
dumwe	-0.23	2.1
dumth	-0.19	1.7
dumfi	-0.24	2.1
$dumfi_{t+2}$	-0.36	2.4
dumla $m_t = m_{t-1}$	-0.33	3.0
$dumchri_{t-1}$	0.93	2.7
$dumsum_{t-2}$	-0.63	7.1
$dumsum_{t-3}$	0.77	10.6
$dummpl_{t-1}$	-0.72	4.8
dumhol1	-0.17	1.9

Notes: Newey-West correction for heteroskedasticity and autocorrelation; adj. R^2 = 0.54; SE = 0.79; included number of observations: 387. For dummy variable definition see annex 1.

To conduct a stability analysis we performed a CUSUM-test. The cumulative sum of the recursive calculated residuals is displayed in chart 6a. It shows that there were instability problems in the second quarter of 2000. Eliminating this period seems to restore rather stable relationships (see the evolution of the test statistic). As chart 6 indicates there is a sharp downward shift in the level of the items in course of settlement from April 2000 onwards. This extraordinary evolution cannot be captured by our simple regression approach. It would be interesting to know whether this development is a lasting and permanent shift or more a temporary phenomenon. To investigate this question further observations are necessary.

Chart 6a

CUSUM-test for net float



The Eurosystem itself also generally cannot forecast the net float to a very precise degree. However, the interference with liquidity management is normally limited since the volatility in the net float is generally of a rather transitory nature. Only at the very end of the reserve maintenance period, transitory liquidity shocks at the order of magnitude exhibited by the net float may be disturbing. The following table 8 displays the predictive power of our regression at the forecasting horizons relevant for the ECB. It shows that around one quarter of the variability of net float can be captured by our estimation approach for the 2 longer forecasting horizons, but only slightly more than 10% for the short forecasting horizon. This may be due to the rather erratic day-to-day movements in net float.

Table 8

Variability and forecast quality for the net float using our simple regression approach during EMU (in € bn)

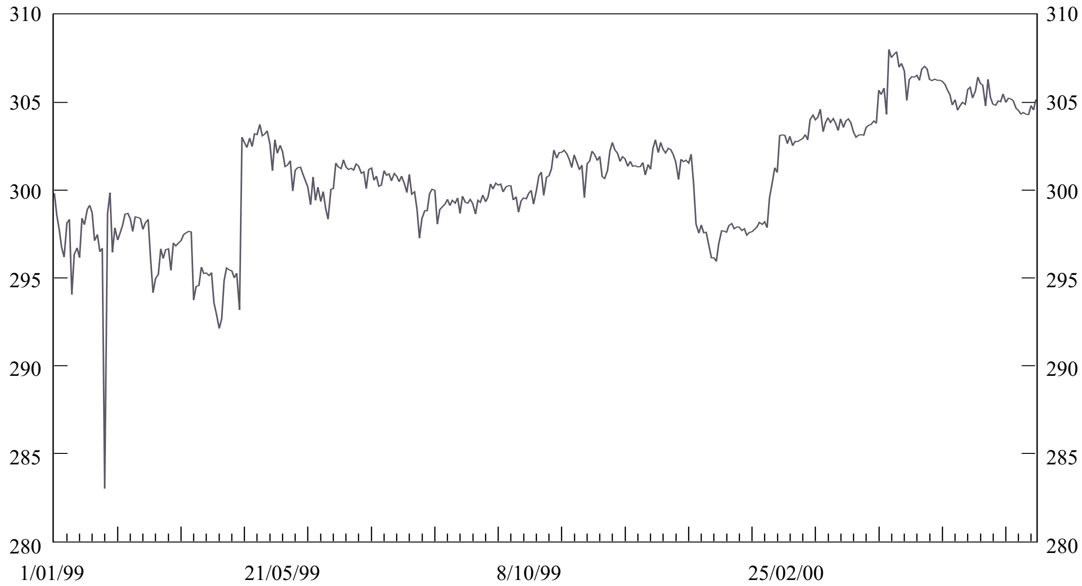
	T+1	T+5	T+10
(1) Std. deviation of changes of the underlying time series	0.89	1.40	1.30
(2) Std. errors of forecasts (RMSE)	0.78	1.02	0.96
(3) predicted share =(1)-(2)/(1), in %	12%	27%	26%

3.4 Other autonomous factors

The other autonomous factors are a residual containing various balance sheet items such as foreign exchange reserves, domestic securities, revaluation accounts, and capital and reserves. In the case of the Eurosystem, the largest component in absolute terms are by far the foreign exchange reserves. In small monetary areas, the foreign exchange assets are normally rather volatile and may reflect intervention activities of the central bank. This was not the case for the Eurosystem in the fixed rate tender period under consideration here, where changes of foreign exchange reserves normally reflected customer-related transactions or the desire to adjust the amount of foreign exchange reserves due to investment or portfolio considerations.

Chart 7

Other autonomous factors of Eurosystem since 1999 (in € bn)



The overall stability of the other autonomous factors appears both in chart 7 and in table 9. Because of 2 large outliers at the end of January and mid-April 1999 we introduce a further dummy variable to capture these anomalies. The first outlier is due to the failure of one national TARGET component on the 29 January. Consequently, some interbank transactions could not be settled on this date. The second outlier is due to the transfer of the Bundesbank profit to the German Treasury on 15 April 1999. These events were booked in a way to affect the balance sheet item "Other Liabilities" in the balance sheet of the Eurosystem, which is assigned to other autonomous factors in our study.

Table 9

Estimated model for other autonomous factors

Explanatory variable	Coefficient	t-value (absolute)
Constant	15.88	3.0
o_{t-1}	0.70	10.5
o_{t-2}	0.12	2.0
o_{t-3}	0.12	2.8
o_{t-5}	-0.05	1.8
n_{t-5}	0.04	1.9
Time	0.00	3.0
dum4	0.22	1.8
dum12	-0.50	2.2
dumtu	0.28	2.3
dumth	0.18	1.8
dumfr	0.19	2.2
dumjan1	1.58	11.6
dumhol	-0.19	2.3
dumother1	-13.7	99.4
$dumother1_{t+1}$	0.12	0.7
$dumother1_{t+2}$	-0.7	4.8
$dumother1_{t-1}$	11.71	12.4
$dumother1_{t-2}$	3.24	3.4
dumother2	8.79	30.4
$dumother2_{t-1}$	1.79	3.2
$dumother2_{t-2}$	0.99	2.4
$dumother2_{t+1}$	-2.36	13.6
dumother3	-3.93	53.5

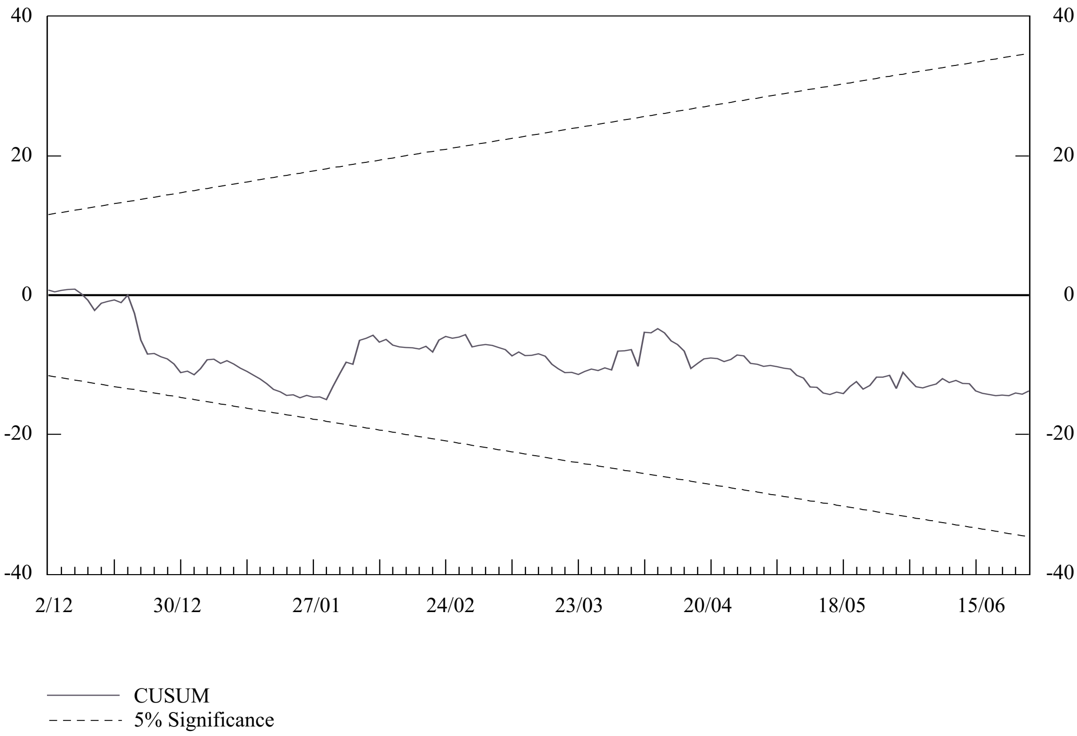
Notes: Newey-West correction for heteroskedasticity and autocorrelation; adj. R^2 = 0.95; SE = 0.70; included number of observations: 383. For dummy variable definition see annex 1.

Chart 7 suggests that the forecasting of this item is rather difficult, at least through the simple time series approach proposed here. Our econometric results are summarised in table 9. Up to five lags of other autonomous factors are included in the estimation indicating strong serial correlation. The results show clearly the increase of these items at the beginning and the decrease at the end of 1999. Three business day dummies help to explain the other autonomous factors. Around the holiday seasons including Christmas, the levels of these factors are smaller than usual. Moreover, balance sheet anomaly indicators exert a significant influence. One further dummy variable is included which captures the strong decrease in the other autonomous factors on March, 19.

The CUSUM test now indicates that the equation for the other autonomous factors does not exhibit signs of instability in 2000 (see chart 7a). The test statistic does not move outside the 5% critical lines which would be suggestive of coefficient instability.

Chart 7a

CUSUM-test for other autonomous factors



It should be noted that the forecast quality of the Eurosystem for this time series is generally considerably better than our results obtained through simple time series processes. This is due to the prior information the Eurosystem has on various operations. For instance, foreign exchange transactions are in general settled only on T+2, such that any liquidity effects are perfectly known at least two days in advance. The quality of our forecasts at the relevant time horizons is summarised in the following table 10:

Table 10

Variability and forecast quality for other autonomous factors using our simple regression approach during EMU (in € bn)

	T+1	T+5	T+10
(1) Std. deviation of changes of the underlying time series	1.42	1.94	2.43
(2) Std. errors of forecasts (RMSE)	0.68	1.20	1.19
(3) predicted share =(1)-(2)/(1), in %	52%	38%	51%

It appears that around 50% of the variability of other autonomous factors can be captured for the short and long time horizons, and around 40% for the medium-term time forecast horizon by our simple dummy variable approach.

4 The endogenous liquidity factors

Both the outstanding amounts of open market operations and the net recourse to standing facilities has to be considered as being endogenous variables to any model of liquidity management of a central bank. They are determined by the two acting agents of the model, the central bank (open market operations, section 4.1) and banks (standing facilities, section 4.2) after observing ex post values and forecasting future values of the autonomous liquidity factors. Hence, the deposits banks hold with the Eurosystem (section 4.3), which have to be interpreted as the residual item of the balance sheet (see also Hamilton [1998]), are also endogenous.

4.1 Outstanding open market operations of the Eurosystem

A central bank normally follows some kind of *liquidity management strategy* in the implementation of its open market operations. A liquidity management strategy is defined as a function mapping relevant information available to the central bank (on the evolution of autonomous factors within the maintenance period and of reserve holdings, on its overnight rate target, etc.) into a liquidity supply through open market operations. The strategy may be distinct for different days of the maintenance period or for different days during the week.

The idea of a liquidity management strategy does not imply a total pre-commitment of the central bank, i.e to opt totally for "rules" instead of for "discretion" in the implementation of monetary policy. It reflects the concept that there are systematic elements in each liquidity management approach. If all these systematic components that relate the liquidity management decisions of the central bank to specific "information" variables are translated into a strategy, the residual components of the liquidity supply should be non-correlated (orthogonal) to those specific variables. In other words, counterparties should be able to predict the liquidity management decisions, except for some unpredictable element that can be considered as "white noise" for outside observers.

In the following, we will model the liquidity supply through the Eurosystem's *main* refinancing operations, and not through its *longer* term refinancing operations. The latter are not used for active liquidity management but only as a structural device of liquidity supply (ECB [1998]). During the period under review, the provision of liquidity through longer-term refinancing operations amounted to between € 45 and € 75 bn. The allotment amounts in longer term refinancing operations are usually set for several months in advance and never reflect the acute liquidity conditions around the tender date. Therefore, they can be treated as exogenous from the point of view of the central bank deciding how much liquidity to provide via its main refinancing operation. The problem for the ECB then is to estimate the systematic liquidity part of the autonomous factors to decide the concrete allotment.[17]

Assume the following terminology: *t=1…T* are the (normally 30 or 31) days of the maintenance period; m_t is the amount of liquidity outstanding on day t of the maintenance period through main refinancing operations of the Eurosystem; a_t is the value of autonomous factors on day t of the maintenance period, including the longer term refinancing operation; R is the reserve requirement; $E^{cb}(X)$ is the central bank's estimate of the excess reserves X which amounted in the second half of 1999 to around 0.7% of required reserves, and D_t are the deposits of banks with the Eurosystem. Finally, $E_t^{cb}(q_\tau)$ is the value of variable *q* that the central bank expects based on ex post data available on day t to prevail on day t, with t < t.

17 This is in sharp contrast to Hamilton [1998, 29ff.] who models the optimal reaction of the FED to the unsystematic part of the autonomous factors, i.e. the residuals of the estimated equations in section 3.

The allotment strategy shown in Box 1 is a kind of simple benchmark strategy from which the ECB may start its considerations with regard to the optimal allotment amount in its main refinancing operations. To understand the time indices correctly, it should be noted that allotment decisions in tender operations are normally made by the ECB on Tuesday, based on forecasting data making use of Monday's ex post figures, and that settlement normally takes place on Wednesday. There were only few exceptions in the period under consideration in terms of the settlement day. It is assumed in the strategy that on the allotment day the Eurosystem has a perfect liquidity forecast for the allotment day.[18]

Box 1

A benchmark allotment strategy for main refinancing operations

If day t is a weekday other than a main refinancing settlement day, i.e. normally a Wednesday, then:

$$m_t = m_{t-1} \tag{A}$$

If day t is a settlement day and if t+6<T:

$$m_t = R + E^{cb}(X) + \left(-\sum_{j=1}^{t-1} (R + E^{cb}(X) - D_j) + \sum_{j=t}^{t+6} E^{cb}_{t-2}(a_j) \right) / 7 \tag{B}$$

If day t is a settlement day and if t+6>T:

$$m_t = R + E^{cb}(X) + \left(-\sum_{j=1}^{t-1} (R + E^{cb}(X) - D_j) + \sum_{j=t}^{T} E^{cb}_{t-2}(a_j)) \right) /(T - t + 1) \tag{C}$$

In words: Whenever the central bank does not settle a new open market operation, as on all days except settlement days, the volume of liquidity provided through main refinancing operations remains constant (A). This volume changes on every settlement day ((B), (C)). The central bank always allots an amount of liquidity such that in the average of the following tender week (case B) or until the end of the reserve maintenance period (case C), banks can fulfil their reserve requirements, correcting for the deficit or surplus that has accumulated since the start of the maintenance period. The days relevant for the allotment decisions are always within the current maintenance period, which is the relevant horizon for the liquidity analysis. This strategy of the central bank has a forward and a backward looking part. The backward looking part is the one contained in the first sum, while the forward looking part is contained in the second sum.[19]

To test whether this strategy is indeed able to describe a substantial part of the allotment volumes in the ECB's main refinancing operations, it was applied to the period under consideration here in five variants, whereby the variants differ regarding (1) the expectations of the central bank with regard to autonomous factors and (2) the attention paid to previous errors. The five variants are summarised in the following table.

18 Indeed, T+1 forecasts of the Eurosystem are usually very good. This assumption also supports the simplicity of the representation of the allotment strategy.

19 Note that the backward looking part can also be written differently, making use of the balance sheet identity. For instance, part (B) of the strategy would take the following form, whereby : l_j, e_j are the recourse to the marginal lending and deposit facility, respectively:

$$m_t = R + E^{cb}(X) + \left(-\sum_{j=1}^{t-1} (R + E^{cb}(X) + a_j - m_j - l_j + e_j) + \sum_{j=t}^{t+6} E^{cb}_{t-2}(a_j) \right) / 7$$

Table 11

Summary of the five different variants of the basic allotment strategy

		Assumption regarding autonomous factor forecast of NCB		
		Perfect forecasts	No forecasts at all	Forecasts based on models of section 3
Assumption regarding the correction of past forecast errors	Past non-anticipated liquidity effects (same MP) have no impact on allotment	MP4	MP3	
	Past non-anticipated liquidity effects (same MP) are neutralised in following allotment	MP1	MP2	MP5

MP1: This specification assumes that the ECB is able to forecast autonomous factors perfectly, such that in the formula above, one can substitute $E_t^{cb}(a_j) = a_j, \forall j > t$, i.e. one simply uses the ex post figures collected afterwards as forecasts.

MP2: This specification assumes that the ECB is unable to forecast autonomous factors at all, or at least does not make use of the forecasts in its allotment decisions of main refinancing operations. Therefore, one can substitute in the formula above the forecasts with the latest ex post value available to the central bank $E_t^{cb}(a_j) = a_{t-1}, \forall j > t$.

MP3: Here, it is assumed that the ECB is unable to forecast autonomous factors, and that it does not care about the accumulated liquidity surplus or deficit, such that for instance (B) takes the following form: $m_t = R + E^{cb}(X) + a_{t-1}$. Under this strategy, the central bank is not backward looking in its allotment policy of main refinancing operations.

MP4: This variant assumes that the ECB is again not backward looking, but that it has perfect autonomous factor forecasts and makes use of them.

MP5: Finally, this specification makes use of the autonomous factor models estimated in section 3 to derive hypothetical forecasts by the ECB.[20]

Chart 8 displays the outstanding amounts of liquidity through main refinancing operations (MROs) on the 75 MRO settlement days of the period under review, together with the estimated amounts based on the five alternative allotment strategies of the central bank presented above.[21]

20 *Ideally, this would require relying exclusively on out of sample forecasts. As the actual forecasts of the Eurosystem may be closer to perfect forecasts than to forecasts generated by simple time series methods as used in section 3, it seems justified to use the model we estimated for the whole period under consideration.*

21 *We excluded the allotment of April, 7 1999 because on this date the allotment was determined by counterparties due to expectations of a rate cut by the Eurosystem. Furthermore, in interpreting chart 8 one has to take into account that there was no MRO on January, 5 2000.*

Chart 8

Allotment Decisions in Main Refinancing Operations: Actual and Estimated (bn €)

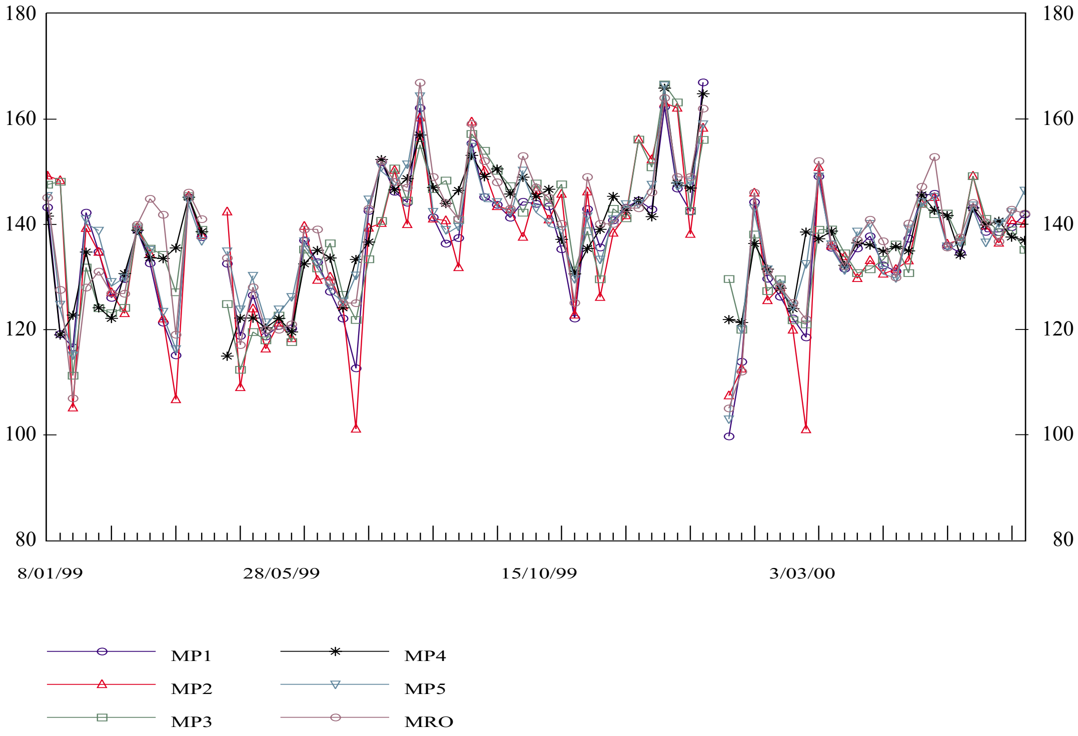


Table 12, which shows the standard errors of the estimations, indicates that a relevant part of the fluctuations of outstanding volumes can well be explained by each of the proposed models of allotment decisions, but that significant unexplained elements remain. The table provides both figures for the entire period (first 18 months), for 1999 alone, and of the last 12 months sub-period, to allow detecting possible effects stemming from the particular conditions in the first 6 months of Stage Three.

Table 12

Standard deviation of allotments and standard errors of estimates (in € bn)

Standard deviation of allotment volumes	Standard errors of estimates				
	MP1	MP2	MP3	MP4	MP5
	Jan 1999 – June 2000[22]				
12.5	4.5	7.3	7.2	6.7	4.7
	1999				
12.9	5.2	8.1	6.9	6.3	5.0
	July 1999-June 2000				
11.6	2.7	6.1	7.5	6.0	3.7

One can conclude that the strategy including both an ex post and an ex ante part performs best, i.e. that the ECB cared both about accumulated imbalances with regard to the banks' fulfilment of the reserve requirement and about autonomous factor forecasts (MP1 and MP5). For 1999 the best performing assumption was the one where the ex ante part was estimated with a time series regression (MP5). But this specification ceases to outperform MP1 when the sample is extended to include the year 2000. It is especially noteworthy that MP1 improves much more than the other assumed strategies when one restricts the analysis to the last 12 months of the period under analysis. This suggests that the actual strategy of the ECB may has converged to some extent with this strategy, or that the assumption of perfect autonomous factor forecasts has come at least closer to reality than it had been at the beginning of Stage Three.

To compare the significance of the forecast accuracy of our 5 variants we applied a test procedure proposed by Diebold [1998, ch. 12]. This test shows that for the whole period considered as well as for the period excluding the first 6 months of 1999 the forecasts of MP1 and MP5 do not differ in a significant way, but that they are both significantly better than the other forecasts.
There are several factors to explain why even the best performing strategies did not succeed to explain even more of the variability of MRO allotment volumes:

- First, the assumptions with regard to the autonomous factor forecast are not fully appropriate. The best performing assumption, i.e. both the forecasts estimated in this paper, and perfect forecasts, may still be relatively far away from the actual ones of the ECB. The assumption that the excess reserves of the relevant maintenance period are fully known to the ECB is also too optimistic. At least in the first maintenance periods, the uncertainty with regard to excess reserves was large. Note that an estimation error of € 0.3 bn for the average excess reserves implies an allotment error of € 6 bn for an operation settled on the last day of the maintenance period (or for instance of € 1 bn for an operation settled on T-6).

- Secondly, the actual allotment strategy of the ECB is likely to take into account various other considerations, even if the strategy presented here would be an appropriate description of the benchmark from which the ECB starts its discussion about the allotment decision. For instance, in the second half of 1999, the ECB had the tendency to provide systematically more liquidity than strictly required for the fulfilment of reserve requirements (and excess reserves), implying a larger average use of the deposit facility at the end of the maintenance period than of the marginal lending facility. This asymmetry is not captured in the simple strategy described above. Furthermore, other factors, such as overbidding in the fixed rate auctions, taking into account the subsequent maintenance period, the level of the EONIA rate and the size of overlapping MRO's may also play a role.

We end this section with a brief comment on the way Hamilton [1998] estimates in his equation 5 (see his section 7, p. 29) the relationship between autonomous factors and open market operations. Hamilton [1998] basically makes an OLS regression taking into account as only forward looking component the residuals from the OLS regressions of autonomous factor estimations. He concludes that these residuals, which he calls "shocks", are highly significant and that their coefficients represent the partial insulating of the banking sector from the autonomous factor shock. We think that the forward-looking part of this equation reflects a misunderstanding and only by chance leads to significant results. It appears unclear why the Fed should only react to the part of autonomous factors that cannot be explained by simple regression models, i.e. not "shocks" should be the explanatory variable in the open market operation equation, but

22 *It may also be of interest to look at the means and mean absolute errors of the forecasts. For the entire period, the mean of the errors amounted to EUR 2.40; 2.56; 0.90; 0.73; 0.54 billion, for the five strategies, respectively. The mean absolute errors amounted to EUR 3.60; 5.40; 5.60; 4.90; 3.40 billion, respectively.*

expected changes, including those that can be forecast through simple OLS regressions. If the variables used by Hamilton are significant, this is due to the fact that the power of the econometric forecasts is indeed limited and that the Fed has considerable additional ex ante information, such that the residuals from the econometric forecasts and the changes of the variables themselves are correlated. One other major difference of Hamilton's open market operation equation to ours is that his forward looking component only concerns the current day, while our forecasting horizon is normally one week. However, this can indeed be justified by the fact that the Fed operates normally on a daily basis. It would have been nevertheless interesting to check whether longer forecasting horizons are still significant.

4.2 The recourse to standing facilities

In contrast to the discount window of the Federal Reserve System, the recourse to the Eurosystem's marginal lending and deposit facilities is governed exclusively through the price mechanism, and not by administrative or regulatory disincentives. Furthermore, the Eurosystem's facilities are symmetric, i.e. there is not only a facility to cover urgent liquidity needs at high rates (a marginal lending facility) but also one to get rid of excess liquidity at relatively low rates (a deposit facility).[23]

Under the assumption of *perfect inter-bank markets*, recourse to standing facilities should take place in principle only at the end of the last day of the maintenance period and should reflect the *aggregate* lack or surplus of liquidity relative to reserve requirements (including excess reserves). During the maintenance period, the buffers provided by the reserve requirement system with averaging are always sufficient to allow the aggregate banking sector to average out transitory reserve deficits or surpluses (see chart 1 illustrating that the aggregate deposits never fell below around • 70 bn, leaving still a large aggregate liquidity buffer).

If the assumption of perfect inter-bank markets is dropped, then further recourse to standing facilities may occur at a non-aggregate level at any point of time of the maintenance period. This recourse has nothing to do with the aggregate liquidity situation, but mainly reflects transaction costs in the payment systems and especially non-anticipated end of day payment flows which occur too late to still allow a correction via the inter-bank market and which cannot be averaged out by the individual counterparty.

Reflecting the different nature of the two types of the recourse to standing facilities, we separate their analysis correspondingly.[24]

(a) Recourse reflecting a deficit or surplus relative to aggregate reserve requirements at the end of the maintenance period

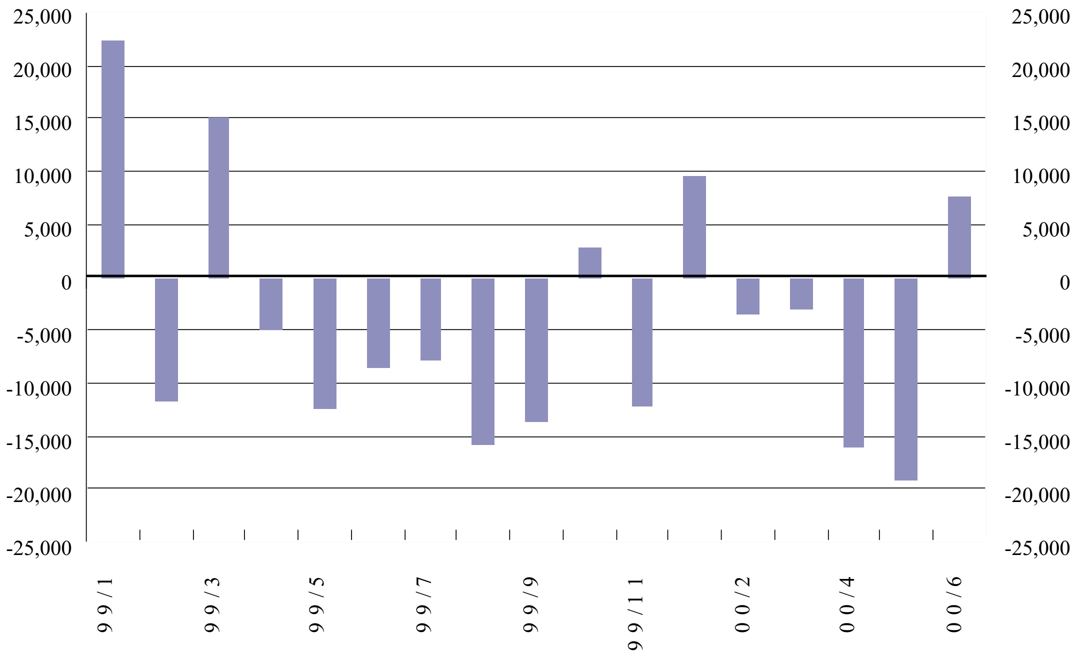
The end of maintenance period aggregate recourse to standing facilities allows that average reserve holdings correspond to required reserves plus excess reserves. This motivation to use standing facilities is symmetric for the two facilities: an aggregate surplus of accumulated deposits with the Eurosystem over accumulated reserve requirements implies a recourse to the deposit facility, an aggregate deficit of the same magnitude implies a corresponding recourse to the marginal lending facility. It is hence possible to just talk of the "net recourse to standing facilities", defining a net recourse to marginal lending (depositing) as a positive (negative) net recourse to standing facilities. Note for chart 9 that whenever the end of the maintenance period fell on a Friday or a weekend

23 *For the US, Bartolini et al. [2000] show that depository institutions tend to hold more reserves during the last few days of each reserve maintenance period. They explain this "stylised fact" by uncertain liquidity flows and transaction costs.*

24 *The distinction may be a bit blurred for the days preceding the last business day of the maintenance period. Still, if inter-bank markets would strictly be perfect and free of any transaction costs, no recourse should take place. In practice, often some considerable recourse takes place that already reflects an anticipated aggregate liquidity imbalance at the end of the maintenance period.*

Chart 9

Net recourse to standing facilities on the last day of the maintenance period (€ mn)



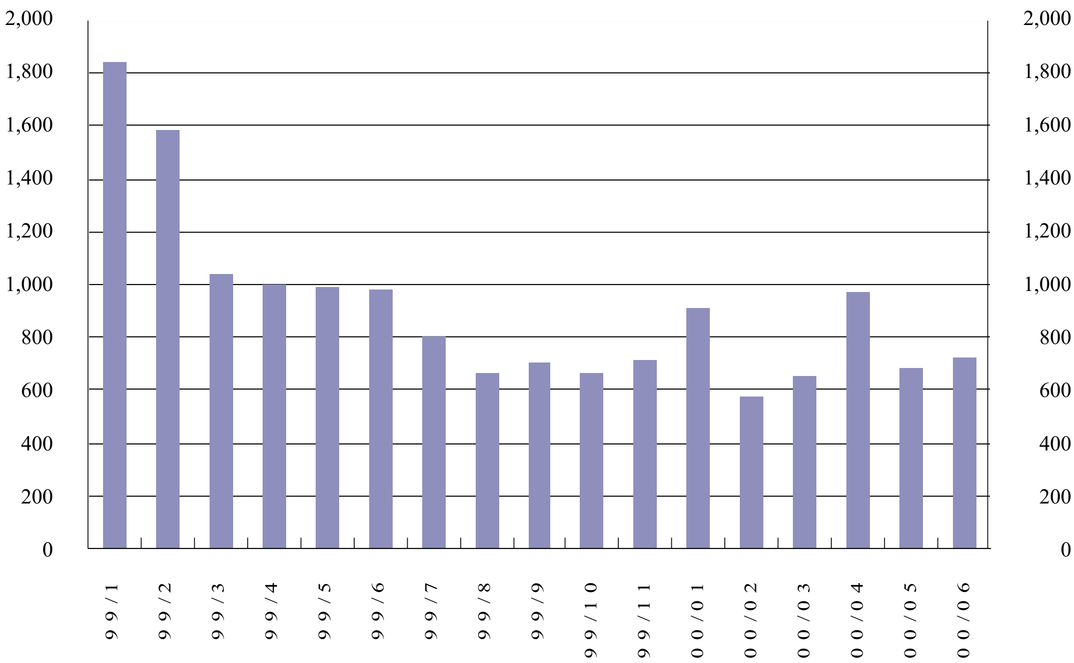
day, the recourse to standing facilities on Friday had to be counted three times to obtain the required net liquidity injection or absorption at the end of the relevant maintenance period to allow counterparties to achieve their current account target. Chart 9 indicates the Eurosystem's tendency to provide ample liquidity in the second half of 1999.

The biggest challenge in modelling the net recourse to standing facilities at the end of the maintenance period lies in the excess reserves. These are simply defined as the average daily difference over the maintenance period between deposits with the Eurosystem and reserve requirements. Although these were relatively stable and converged in the course of the 18 months to around 0.7% of the reserve requirement (see chart 10), they introduce a further stochastic moment into the end of maintenance period recourse to standing facilities. It should be noted that in an operational framework with a deposit facility, the existence of (non-remunerated) excess reserves cannot be justified through the non-perfection of the inter-bank market, but requires transaction costs at the level of using the deposit facility by the individual bank. After all, the amount of excess reserves is not surprising in view of the large number of counterparties of the Eurosystem (around 8000) and the relatively low costs of leaving small amounts of excess reserves overnight on a non-remunerated account. For instance, if 1000 banks, which do not have to fulfil (any longer) any reserve requirements leave every day € 500,000 on their account with the Eurosystem, this implies an average amount of excess reserves of € 0.5 bn. The costs for the single bank of not transferring this amount to the deposit facility under the assumption that the latter is remunerated at 3.00% is only € 41.7, and therefore does hardly justify to leave one staff member for one more hour in the office, if this would be required.

In the case of the Eurosystem for the fixed-rate period with its rather stable interest rates, it would be

Chart 10

Excess reserves per maintenance period (€ mn)



misleading to make excess reserves a function of interest rates. At least, this would not explain any of the variability of excess reserves in the period under review. The variations of excess reserves are determined by the (1) more and more efficient liquidity management of banks in the course of the year and (2) calendar day effects such as the location of weekends relative to the end of the maintenance period.

The fact that excess reserves are stochastic also implies that after all, the net recourse to standing facilities at the end of the maintenance period does not only follow mechanically from reserve requirements and the liquidity supplied through the net effect of open market operations and autonomous factors ("non-borrowed" deposits, to use the FED's terminology). In fact, excess reserves represent a further exogenous variable to the model, which is, as the required reserves, a not directly observable balance sheet item (in contrast to autonomous liquidity factors).[25]

(b) **The intra-maintenance period recourse related to the non-perfectness of the interbank market**

The intra-maintenance period recourse to standing facilities is due to the non-perfection of the inter-bank market for liquidity (including the payment system on which it is based). It is in a certain way exogenous to liquidity management, since it should in principle not be affected by aggregate liquidity conditions (if the aggregate buffer provided by reserve requirements is large as in the case of the Eurosystem).

In what follows we exclude the end-of-the maintenance period effects, the window dressing effects appearing on the end of half-years and the first maintenance period. The latter could be justified because the inter-bank market still worked less smoothly in the first maintenance period due to

25 *The sum of required and excess reserves are by definition the deposits of the banks with the Eurosystem, which is naturally a balance sheet item.*

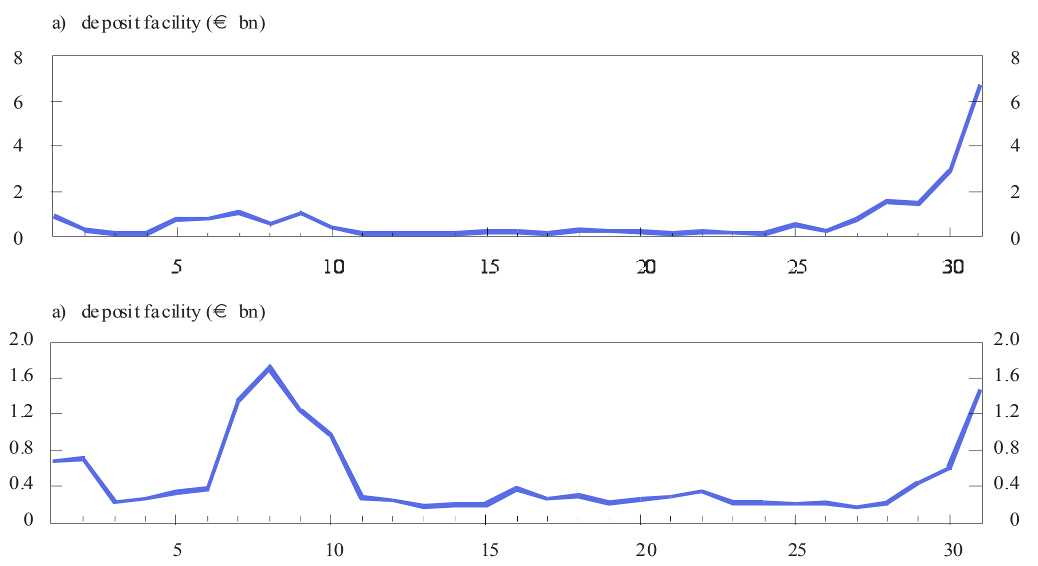
the starting phase of Stage 3 of EMU and because in the first 20 days of it the interest rate corridor set by the standing facilities was particularly narrow, making the recourse to the facilities rather cheap. Usually, there should be no serial correlation in the development of the two standing facilities, i.e. they should have no memory. However, in the period under review this could not be detected in general but depends on the sample and the facility considered. For the whole period there is clear indication of serial correlation up to lag 3 for the deposit facility and up to lag 7 for the marginal lending facility. For the deposit facility this picture was rather unchanged during the whole sample. Because the series drops to zero after only 3 lags this is a sign that it obeys a low-order moving average process. But, the observed serial correlation in the use of the marginal lending facility disappeared nearly completely for the second half of 1999. Beginning in 2000, the serial correlation restarted to be significant up to lag 3. This autocorrelation structure seems to be the "equilibrium one" for the marginal lending facility (as for the deposit facility). In this sense the year 1999 should be treated as special as far as the marginal lending facility is concerned.

How do the means of the two facilities evolve over time during the maintenance period? As chart 11 shows there is a clear day-of-the-maintenance-period effect for the deposit facility at the end of the reserve period. This is plausible because the recourse to the deposit facility should increase in the course of the maintenance period since it becomes more and more likely that counterparties have already fulfilled their reserve requirement. The marginal lending facility showed no such clear-cut pattern. It increased somewhat at the end of the maintenance period, but in general the swings were not as large as in the case of the deposit facility. The hikes in the evolution of the 2 facilities on the 7th to 9th day of the reserve maintenance period, especially of the marginal lending facility, are due to some special outliers of the series (end of April and beginning of May 2000).

Next to chart 12 which shows the histograms of the 2 facilities, we present some descriptive statistics which help to understand the recourse to the two standing facilities. The mean and standard deviation of the deposit facility (marginal lending facility) are € 0.44 (0.58) and € 1.31 (1.92) bn, respectively. Different equality tests show that the means and the variances of the two

Chart 11

Mean recourse to the two standing facilities over the days of the maintenance period

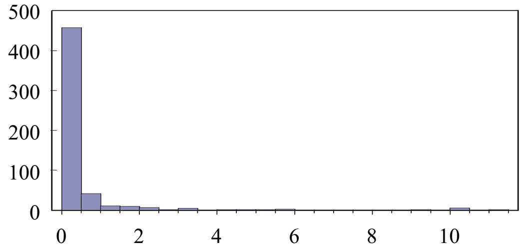


time series differ in a statistically significant way. This points to an asymmetry in the recourse to the facilities. At end-of-day, counterparties' intraday debit positions on their settlement account with the Eurosystem are automatically considered to be a request for recourse to the marginal lending facility. Access to the deposit facility is granted if a request is sent to the relevant national central bank, which should only be done if reserve requirement are already fulfilled. Furthermore, the charts show that the two distributions are leptokurtic (long tailed) and positively skewed. Chart 12.c plots the quantiles of the deposit facility against that of the marginal lending facility. It shows that the two distributions are different, but also, that there are "areas" where they are not too different. If the quantiles plot lies on a straight line the 2 distributions are completely the same.

Chart 12

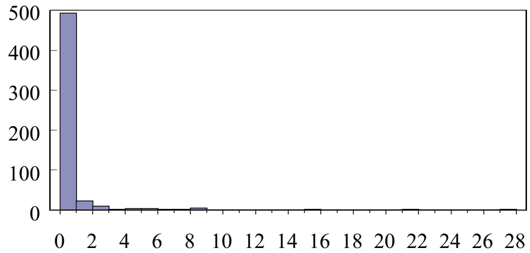
Histograms and descriptive statistics of the deposit and marginal lending facility

a) deposit facility



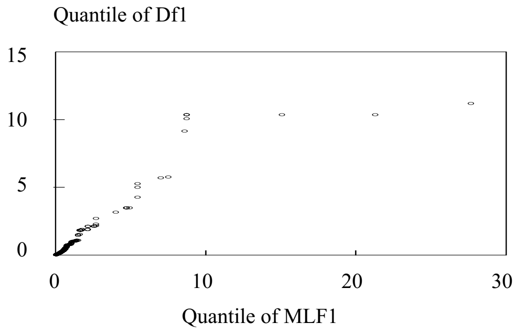
Observations 541	
Mean	0.438416
Median	0.105000
Maximum	11.20700
Minimum	0.002000
Std. Dev.	1.311642
Skewness	6.113729
Kurtosis	43.87405
Jarque-Bera	41030.31
Probability	0.000000

b) marginal lending facility



Observations 541	
Mean	0.575403
Median	0.188000
Maximum	27.68700
Minimum	0.001000
Std. Dev.	1.917151
Skewness	9.260288
Kurtosis	108.8207
Jarque-Bera	260154.1
Probability	0.000000

c) distribution graph



Finally, let us comment briefly on Hamilton's [1998] analysis of discount window lending. We think that his analysis may be misleading for the following reasons (which are closely related):

- Hamilton does not distinguish between the motivations for discount window borrowing within the maintenance period (that would not occur if inter-bank markets would work perfectly), and at the end of the maintenance period (which also occurs if inter-bank markets work perfectly).

- The averaging facility inherent in the reserve requirement system of the Federal Reserve system does not play any role in Hamilton's model, which also explains that he does not see a need to model the intra- and end of maintenance period recourse differently. Even though reserve requirements were smaller in the US in the period considered by Hamilton, than in the euro area, the averaging they allowed for is still crucial in the US in the period in question to limit the intra-maintenance period recourse to standing facilities.

- Hamilton explains the more intense use of the discount window at the end of maintenance periods by a lower non-pecuniary cost of this recourse on these days, which is somewhat difficult to understand since the higher recourse comes from the different *demand* factors on these days. Doubts may therefore be raised whether Hamilton's optimisation model is a model of the actual factors determining the recourse to standing facilities.

4.3 Deposits

Deposits of banks with the Eurosystem are the third endogenous variable of our model. From the point of view of liquidity management, it makes most sense to interpret this endogenous variable as the residual derived from the balance sheet identity, since each of the two other endogenous variables can be assigned clearly to one actor: open market operations to the central bank, and the recourse to standing facilities to banks. Although banks' deposits with the Eurosystem are the topic of this paper, the analysis of the factors shaping them is in principle completed at the moment where we finally get to them.

To summarise the relationships after having made the tour of all factors: Autonomous items are affecting the available liquidity in a purely exogenous way. The central bank normally wants to achieve a certain average overnight rate in line with its monetary policy stance. For this, it has to make sure that the demand for deposits in order to fulfil reserve requirements and to hold excess reserves is matched with an accurate supply. The allotment decisions in the central bank's open market operations are guided by this objective, taking into account the past and forecast evolution of autonomous factors. The volume of outstanding open market operations can thus be regarded as an endogenous variable. At the end of the maintenance period, the banks will take recourse to standing facilities in order to fine-tune the availability of deposits. Even though the recourse to standing facilities is costly, it is still cheaper than under-fulfilling reserve requirements or to leave funds unremunerated. At the end of the maintenance period, average current account holdings will correspond to reserve requirements plus excess reserves.

It should be highlighted that this logic applies only to an operational framework with considerable liquidity buffers provided by reserve requirements with averaging, such as the one of the Eurosystem. The analysis should become blurred and more complex in case of a system with relatively low reserve requirements and averaging, such as the US.

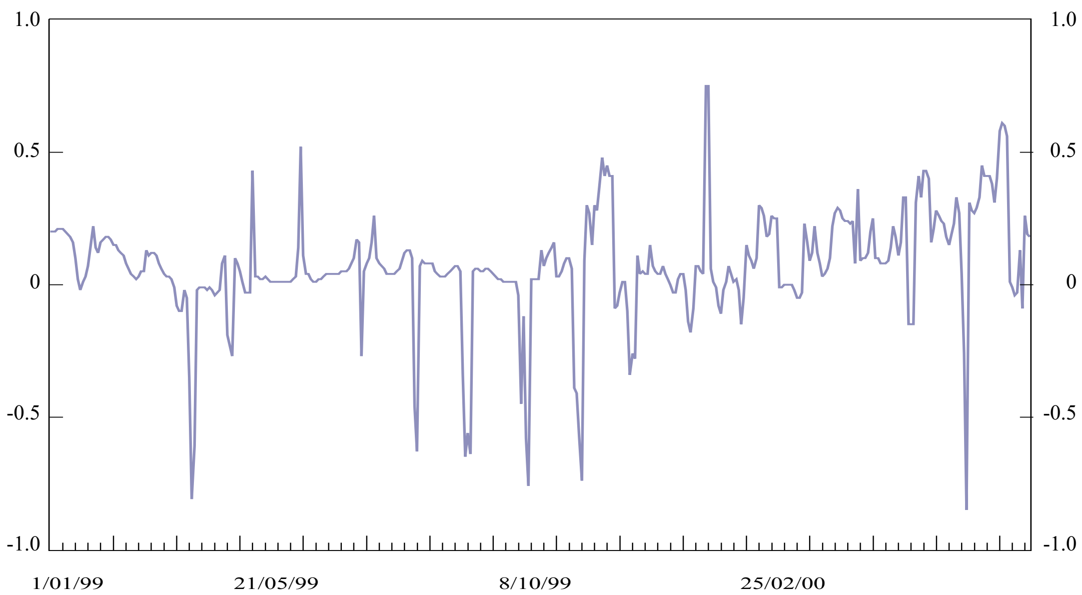
5 The evolution of the eonia rate – a regression approach

So far, this paper dealt with quantities, namely with the supply and demand for Eurosystem deposits. Now, we turn to the analysis of prices, i.e. to the overnight interest rate for Eurosystem deposits. The widely used reference rate for overnight euro deposits is the *Euro Over Night Index Average* (EONIA) rate, an effective overnight rate computed as a weighted average of all overnight unsecured lending transactions in the interbank market, initiated within the euro area by 52 contributing panel banks. On average, the calculation of the EONIA rate is based on overnight transactions with a daily total volume of around EUR 40 billion. It should be highlighted that the EONIA rate is the only *effective* reference rate for the euro money markets: for instance EURIBOR rates are only posted rates. Interestingly, it will appear in the following that during most of the reserve maintenance period, namely during the first three quarters of it, quantities (i.e. supply and demand) actually do not have a strong impact. Instead, expectations regarding possible changes of the standing facility interest rates before the end of the reserve maintenance period dominate the evolution of the price for Eurosystem deposits. Only towards the end of the maintenance period, when on the one side, the interest rates of the standing facilities can no longer change before the end of the maintenance period, and, on the other side, the ECB can no longer compensate liquidity shocks through an adjustment of subsequent tenders, quantities start to play a dominant rule.

Chart 13 plots the evolution of the spread between the EONIA rate and the rate of the main refinancing operation of the Eurosystem in the period under review. The standard deviation of this spread is 20 basis points. Its volatility is however concentrated mainly on the last days of the maintenance period when the averaging mechanism of reserve requirements can by definition play less and less the role of a liquidity buffer.[26] The mean spread is 7.0 basis points with the biggest positive spread of 75 basis points at the end of 1999 and the biggest negative spread of 81 basis points at the end of the March 1999 maintenance period.

Chart 13

The spread between EONIA and the main refinancing rate



26 See Perez-Quiros and Rodriguez [2000] for more statistical evidence regarding this day of the maintenance period effect.

The econometric approach presented below is motivated by the following simple theory of the relationship between liquidity and overnight rates. Like many other markets, the market for reserves is interesting owing to its *uncertainty*. In a system of minimum reserve requirements with averaging, such as that of the Eurosystem, banks face an inter-temporal optimisation problem when minimising the cost of holding required reserves over the maintenance period. The opportunity cost of holding reserves on one day is the inter-bank overnight rate on that day. Banks will thus have an incentive to hold reserve surpluses (or accumulate reserve deficits) whenever the market rate is low (high) in relation to future expected overnight rates within the maintenance period. This behaviour on the part of banks will tend to stabilise market rates as, in order for the daily market to clear, overnight rates will tend to be aligned with future expected overnight rates within the maintenance period. Overnight rates will, thus, be determined not only by current or past conditions, but also by expectations with regard to expected liquidity conditions in the remainder of the reserve maintenance period.

We shall now assume for a moment that there is no uncertainty concerning either autonomous factors or the liquidity supply through monetary policy operations in the remainder of the reserve maintenance period. In this setting, reserves are obviously either short or long in relation to reserve requirements, in which case the marginal utility of funds obtained in the inter-bank market, and therefore their price, either rises to the marginal lending rate, or drops to the deposit rate. In the entire maintenance period, the overnight rate would therefore correspond, under the assumption of perfect foresight with regard to liquidity conditions, to one of the standing facility rates relevant at the end of the maintenance period.

Denote in the following by a_t the sum of all autonomous factors minus the longer term refinancing operation (which can be treated as an autonomous factor in the case of the Eurosystem) on a given day t of the reserve maintenance period and by *A* the corresponding sum over the maintenance period. Denote similarly by M the sum over the maintenance period of the daily amounts of funds outstanding as main refinancing operations, m_t. Then, one may call (M-A) the accumulated amount of "non-borrowed" reserves over the reserve maintenance period, to use a term applied usually in the US. Furthermore, denote by i_d the rate of the deposit facility and by i_{ml} the rate of the marginal lending facility, with $i_d < i_{ml}$. The only interest rate elastic elements of the market equilibrium condition for bank deposits with the central bank, the standing facilities, have the following functional form, assuming perfect interbank markets (where *L* is the total recourse to the marginal lending facility and *D* is the total recourse to the deposit facility over the maintenance period):

$$\forall i < i_{ml}: \quad L(i) = 0 \qquad \forall i > i_d: \quad D(i) = 0$$

$$\forall i > i_{ml:}: \quad L(i) = \infty \qquad \forall i < i_{d:}: \quad D(i) = \infty$$

$$i = i_{ml}: \quad L(i) = A - M \qquad i = i_d: \quad D(i) = M - A$$

The overnight interest rate that clears the market for central bank deposits is then determined by:

$$M + (L(i) - D(i)) - A = V + X$$

where V are the (cumulative) reserve requirements and X are the (cumulative) excess reserves.
Now, we shall consider the more interesting case in which the liquidity supply and the rates of the standing facilities are uncertain in the sense that the banking sector assumes a certain density function for the relevant liquidity factors. Denote now with i_t the overnight rate on day t. The

basic relationship between quantities and prices (overnight rates) under the assumptions made above (especially the one of perfect inter-bank markets and large reserve requirements) is then described by the following equation, in which f^t_{M-A} is the density function the money market participants assign on day t to the random variable $M-A$:

$$i_t = E_t(i_{t+1}) = ... = E_t(i_T) = E_t(i_{ml})P("short") + E_t(i_d)P("long")$$
$$= E_t(i_{ml})(\int_{-\infty}^{V+X} f^t_{M-A}(z)dz) + E_t(i_d)(\int_{V+X}^{\infty} f^t_{M-A}(z)dz)$$

In words: the overnight rates on any day will correspond to the weighted expected rates of the two standing facilities, the weights being the respective probabilities that the market will be short or long at the end of the maintenance period before having recourse to standing facilities. *Ex ante*, rates are constant within the maintenance period, i.e. the expected overnight rates for the remainder of the maintenance period are all identical. *Ex post*, rates do not have to be constant since news about the expected end of maintenance period standing facilities rates and the net liquidity supply may occur at any moment in time.

Obviously, expectations, i.e. the subjective density functions the banking sector assigns to the non-borrowed reserves, *M-A,* and the expectations with regard to standing facility rates, are the major challenge for a calibration of this equation. Neither expectations with regard to standing facility rates, nor expectations with regard to autonomous factors, nor expectations concerning open market operations can be measured directly.

Specifically, the spread between the EONIA rate and the rate of the main refinancing operation (which was most of the time equivalent to the mid point of the corridor set by standing facilities) was chosen as explained variable of our simple regression model. The model above suggests that the mid point of the corridor should be a natural level for the EONIA rate as long as liquidity conditions are perceived as "neutral", i.e. as long as the probability of a liquidity shortage at the end of the reserve maintenance period is considered to be identical to the probability of an excess of liquidity.[27] Intuitively, the time series exhibits a marked volatility at the end of reserve maintenance period.[28] Any model which is supposed to achieve an explanation of a significant part of the deviation of this spread will therefore have to focus first on capturing the end of maintenance period volatility. In search of an adequate model, starting from the basic theory outlined above, various explanatory variables were examined but only a few of them proved to contribute significantly to explain the evolution of the EONIA rate. The selection of variables confirmed the predictions of the theory with regard to what factors should be relevant.

Both the spread and the chosen explanatory variables are stationary, as revealed in table 13. However, both the explained variable and the non-dummy explanatory variables exhibit significant auto-correlation. Hence, an estimation of relationships in levels is adequate, while possibly introducing auto-regressive terms to reduce the auto-correlation of the residuals.

27 *Of course this is only an approximation in so far as the effective cost of the use of the marginal lending facility are somewhat higher than the rate of the facility, since the use of the facility requires the depositing of collateral.*

28 *This volatility pattern could suggest to use an ARCH specification, as is done for instance by Peres-Quiros and Rodriguez [2000]. We did not model the ARCH process explicitly, but corrected our OLS estimates with the Newey-West procedure to get consistent estimates in the presence of autocorrelation and heteroskedasticity. This yielded rather satisfactory results.*

Table 13

Unit root-Phillips-Perron-tests of the non-dummy variables

Variable	Lag truncation	t-value (abs.)	1% critical value
spread	5	8.8	3.4
fp	5	6.2	3.4
sf	5	8.5	3.4
acc	5	11.3	3.4

Dummy variables that are tested for significance include the end and the beginning of month, the end of maintenance period, the day of the week, the settlement day of main refinancing operations, the end of half years, the different months of the year, the different tax indicators listed in annex 1, and a Y2K dummy, which takes the value 1 on 30 and 31 December 1999. Moreover, chart 13 indicates the presence of end-of-the-month-effects on the spread. Therefore we also included one monthly indicator dummy (dum6 for end of June) and a dummy for the beginning and end of the month (the latter only relevant in 2000). Other tested dummies appeared to be insignificant. This is to some extent due to the fact that our non-dummy variables (discussed below) also capture the effects of the dummy variables.[29] Thus, only these dummy variables were retained in the estimations.

Four non-dummy variables were used.

(fp) Possible ECB rate hike in the current maintenance period. This variable is assumed to capture the expectations of counterparties with regard to a change of ECB rates before the end of the current maintenance period. To construct this variable, we calculated first the difference between the implied forward one month Euribor deposit rate (calculated using simple arithmetic averages) and the current MRO rate (mror). This variable has the advantage that it is *not* affected by present liquidity conditions and therefore allows separating conceptually counterparties' assessment of the liquidity situation from their assessment of the likelihood of a rate hike. In a second step, the variable is then set to zero whenever there is no longer any meeting of the Governing Council with a press conference in the same maintenance period. This specification proved to be preferable to two alternative specifications, namely (1) leave the variable as obtained after the first step, or (2) set the variable to zero only if there is no longer *any* meeting of the Governing Council in the current maintenance period. Apparently, counterparties in many cases, especially in 1999, expected changes of ECB rates to take place only in meetings of the Governing Council with a pre-scheduled press conference. Indeed, the three first changes of rates took place at such meetings. In summary, this variable is defined as follows, whereby *r* is a dummy that takes the value 1 only on days before a meeting of the Governing Council with pre-scheduled press conference in the same maintenance period:

$$fp_t = [(2Euribor^{2months} - Euribor^{1month}) - mror]r$$

(sf) Expectation of end of maintenance period recourse to standing facilities based on observations of previous end of maintenance periods. This and the following variable are supposed to capture the expectations of counterparties with regard to the end of maintenance period liquidity situation, i.e. the likely recourse to each of the two standing facilities. Counterparties try to extract the strategy of the ECB with regard to the end of maintenance period recourse to standing facilities to

29 *In the case of the end-of maintenance dummies, for instance, the insignificance is due to the simultaneous presence of the synthetic non-dummy variables that also focus on the end of the maintenance period.*

anticipate the liquidity conditions at the end of the current maintenance period. These liquidity conditions have an impact on the overnight rate within and especially at the end of the maintenance period. Denote by *Z* the index for the maintenance periods, by W_Z the net recourse to the marginal lending facility at the end of maintenance period, and by 0 < l < 1 a constant which was set to 0.8 after experimenting with different values. It is assumed that counterparties form adaptive expectations. Furthermore, it is assumed (after having tested alternative assumptions) that this variable becomes relevant only at the end of the maintenance period, whereby the weight of the variable decreases exponentially when moving away from the end of the maintenance period. Eventually, the variable is defined as follows:

$$sf_t = \left(\frac{\sum_{i=1}^{Z-1} \lambda^{Z-i} W_i}{\sum_{i=1}^{Z-1} \lambda^{Z-i}} \right) \alpha^{(T-t)}$$

With α < 1 and $sf_t = 0$ for (T-t) > 6. The best value of a was calculated through iterations. It was found that a value of 0.7 performed reasonably well in all regressions.

(acc) Accumulated reserve surplus at end of maintenance period. On days close to the end of the maintenance period, the accumulated reserve surplus should contain further relevant information on the likely end of maintenance period liquidity situation. Different assumptions on the increased relevance of this variable towards the end of the maintenance period were tested. For instance, it was assumed that this variable is relevant only on days after the last tender of the maintenance period. However, the following simple exponential weighting of the accumulated reserve surplus appeared to lead to the best explanatory contribution of the variable:

$$acc_t = \left(\sum_{j=1}^{t} (c_j - v - x) - l_t + d_t \right) \beta^{(T-t)}$$

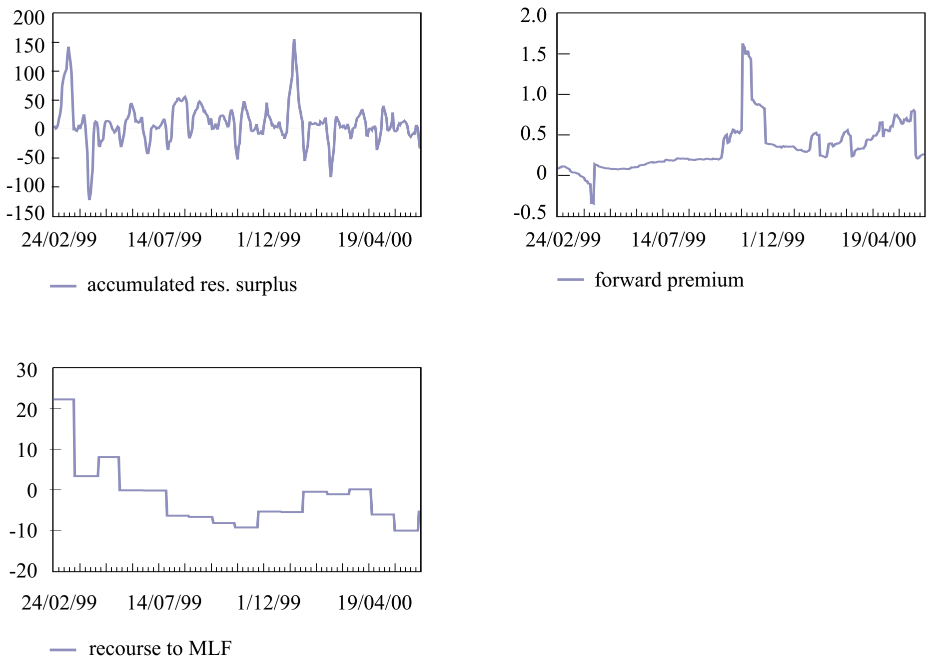
Note that accumulated reserve surpluses are defined relative to reserve requirements plus actual excess reserves in the relevant maintenance period, i.e. it is assumed that forecasts of excess reserves are perfect. Furthermore, they are defined as *before the same day's recourse to standing facilities,* i.e. end of day positions are cleaned from the contributions of the recourse to standing facilities. The best value of the constant 0 < ß < 1 is again calculated through iterations. A value of 0.4 performed reasonably well in all regressions. Finally, $acc_t = 0$ for (T-t) > 6.

It should be noted that autonomous factors play a role in the regression as they enter into this variable. The fact that this variable had to be defined in a way that it is actually relevant only on the last days of the reserve maintenance period illustrates that the ECB had the reputation to compensate any liquidity shock stemming from autonomous factors through the subsequent allotment, if any within the same maintenance period, which also confirms the result obtained in the econometric analysis.

Chart 14 shows the 3 basic variables to construct the regressors fp, sf and acc. These are the forward premium for fp, the expectation of a recourse to the standing facility for sf and the accumulated reserve surplus for acc. One clearly recognises the jumps in the forward premium and in the accumulated reserve surplus due to Y2K.

Chart 14

The basic non-dummy variables to estimate the spread.



(*ar*) *Auto-regressive term*. The equations estimated contain as explanatory variable the explained variable lagged by one business day. This makes sense since the explained variable exhibits auto-correlation. However, this variable was set to zero on the first day of the maintenance period, since on these days, the auto-correlation to the previous business day (the last day of the previous maintenance period) should be fundamentally different from the one on normal days.

The variables fp, sf and acc are generated regressors, properties of which are discussed, inter alia, by Pagan [1984] and Kennedy [1993, ch. 9]. Specifically, Pagan [1984] has shown that the standard errors in such equations estimated with OLS (such as those reported in table 14) are consistent estimates of the true standard errors if the true coefficient is zero (see also Hamilton [1998, 30]). This is the null to be tested here. Moreover, there would be a simultaneity problem if the spread enters the allotment decision of the ECB. However, there does not seem to be any clear evidence for such an assumption.

In the estimations we excluded the first maintenance period. Therefore the sample ranges from 24/02/1999 to 27/06/2000 (348 observations). We analyse a further sample starting on April, 26, the beginning of the May reserve maintenance period (305 observations). In this period the MRO rate had been precisely in the mid of the corridor set by the two standing facilities of the Eurosystem. Table 10 summarises the regression results for the two alternative estimation periods. In each period we further included a time trend in the regressions. To get consistent estimates in the presence of heteroskedasticity and autocorrelation we applied the Newey-West procedure in the estimations.

Table 14

Regression results to explain EONIA rates with liquidity conditions*

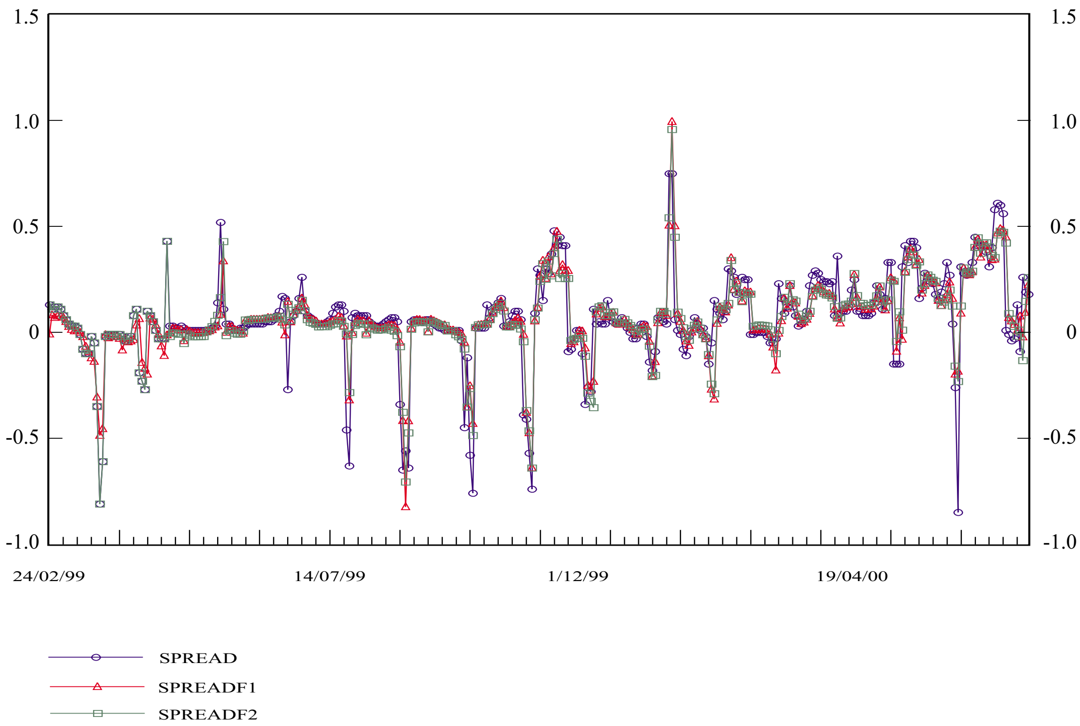
	Estimation period	
Explanatory variables	24/02/1999 – 23/06/2000	26/04/1999 – 23/06/2000
Constant	-0.02 (1.5)	-0.054 (-0.3)
Time	0.000 (1.7)	0.000 (3.2)
Y2K	0.432 (6.0)	0.459 (7.3)
dum6	0.040 (2.2)	0.058 (2.9)
fp 1m forward 1 m Euribor	0.090 (4.0)	0.095 (4.4)
sf (ML recourse in previous MPs)	0.005 (0.8)	0.022 (1.9)
acc (Accumulated reserve surplus)	-0.020 (-3.4)	-0.013 (-1.7)
ar	0.689 (9.4)	0.587 (6.8)
Dumfi	-0.059 (-2.0)	-0.050 (-1.9)
Dumla2k	0.084 (4.1)	0.084 (4.3)
R^2	0.66	0.66
SE	0.124	0.1123
ARCH(5)	0.22	0.26
DW	1.87	

** Newey-West correction for heteroskedasticity and autocorrelation; t-values in brackets below coefficients. SE: standard error of regression; ARCH(5): Lagrange multiplier test for autoregressive conditional heteroscedasticity in the residuals with 5 lags; the number shown is the p-value that there are no such arch effects; DW: Durbin-Watson test statstic.*

About 65% of the variation of the spread is explained by the regressions. The table suggests an acceptable stability of coefficients across the 2 different samples.This is also confirmed by a Cusum test. But the variable sf capturing the expectation of end of maintenance period recourse to standing facilities based on past behaviour is only significant in the shorter sample. Perhaps expectations have changed. Chart 15 plots the two fitted spreads together with the actual spread, showing that most of the end of maintenance period changes of the spread and most of the changes related to expectations of an ECB rate change within the same maintenance period are broadly captured by the regressions. But, as chart 16 shows, again and again there are large outliers in the residuals of the estimated equation.

Chart 15

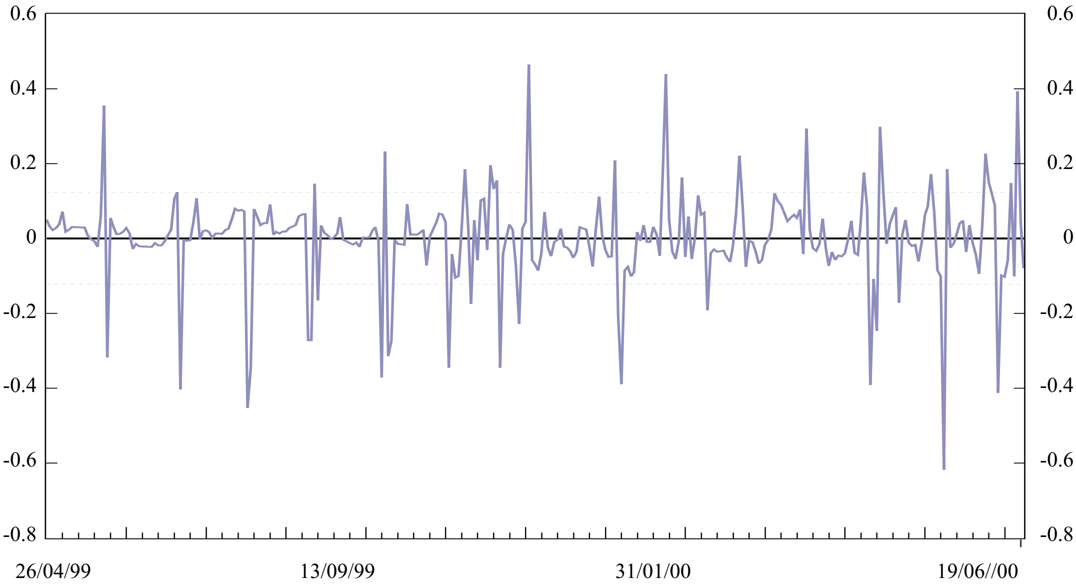
Actual and estimated spreads



For a brief interpretation of regression coefficients, consider for instance the second equation. The coefficient of the forward rate premium of 0.095 indicates that if the implied one month forward rate for the one month Euribor rate is 100 basis points above the current MRO rate, this would, before a meeting of the Governing Council with press conference in the same maintenance period, drag the EONIA-MRO spread upwards by around 10 basis points. The coefficient of the expectation of a net recourse to marginal lending associated with experience in preceding maintenance periods of 0.022 indicates that if the expectation regarding the end of maintenance period net recourse to marginal lending is € 10 billion, this would drag up the spread relative to a neutral former experience on the last day of the maintenance period by 22 basis points, on the preceding day by 15 basis points, on T-2 by 11 basis points, etc. The coefficient of the accumulated reserve surplus, -0.013, indicates that if the accumulated reserve surplus on the last day of the maintenance period amounts to € 10 billion, this would drag down the spread on that day by 13 basis points, while the same accumulated surplus on T-1 would imply a 10 basis point fall of the spread relative to a neutral accumulated liquidity balance, etc. Furthermore, at the end of the months in 2000 the spread is typically lower, while at the beginning of the months over the whole period the spread increases. All coefficient values have the right sign and seem to be of a reasonable order of magnitude.

Chart 16

The Residuals of the spread equation (sample: 26/04/1999–27/06/2000)



6 Conclusions

In this paper we presented an analysis of the demand and supply of Eurosystem deposits in the first fixed rate tender period of Stage 3 of EMU. Subsequently, we applied this analysis together with some basic theory to the price of these deposits, the overnight rate, by estimating a regression model for this time series. The methodology applied is similar to that of Hamilton [1998], while taking due account of the specific institutional settings of the Eurosystem, the operating procedures and monetary policy instruments, as well as of different views on the adequate modelling approach. The main differences to Hamilton as regards the quantity relations are the following: First, we are interested in the systematic forecast of the autonomous liquidity factors as input for the ECB in the allotment decision of its main refinancing operation. In our view, it does not make sense to relate open market operations to the unexplained component of the autonomous factors. Second, we distinguish four autonomous factors – Government deposits, banknotes, net float and other autonomous factors whereas Hamilton only considers the first three items and includes all other positions in them (or in the variable capturing open market operations). Third, there are - unsurprisingly - some differences in the institutional, seasonal and day-of-the-week effects on the autonomous factors. Fourth, the recourse to standing facilities in the Eurosystem is symmetric in the sense that there is the possibility for banks to deposit surpluses and to satisfy liquidity shortages. In the case of the FED, Hamilton rightly only recognises the discount window. Fifth, we took due account of the averaging provision for required reserves in the discussion of the recourse to standing facilities. We therefore distinguish between the recourse reflecting a deficit or surplus relative to aggregate reserve requirements at the end of the maintenance period and the intra-maintenance period recourse related to the non-perfection of the interbank market. Even though reserve requirements are lower in the US, we feel that this distinction would also have been relevant there. Sixth, we exactly specify the time pattern of the main refinancing operation which is only offered once a week with a maturity of 2 weeks, taking again into account explicitly the averaging mechanism on which the allotment decisions of the ECB relies.

With regard to the econometric modelling of autonomous liquidity factors, the following findings may be highlighted: (1) the evolution of Government deposits in the euro area since 1995 can be explained to a significant extent by a series of seasonal and monthly dummy variables that capture tax payment and other says of systematic public transfers. The hypothesis that the properties of this time series has changed with the transition to the euro could not be rejected. (2) The same result (change of time series properties in January 1999) was obtained for banknotes in circulation, for which euro area data was available since 1994. Again, a series of dummy variables (seasonal, day-of the month, day of the week) could explain a significant share of the variability of the series. (3) The net float in the euro area, for which data was available only from the start of Stage Three on, could also be explained to some extent by dummy variables, but to a lesser degree.

With regard to the outstanding open market operations, several alternative simple allotment rules where tested to capture the systematic part of the ECB's main refinancing operations. The best explanatory power (explaining at least 50% of the variability in allotment amounts) could be achieved through a specification under which the ECB was assumed (1) to fully compensate any liquidity shocks that occurred in the course of the previous tender week (2) to derive its autonomous factor forecast on the basis of the simple univariate approach presented in section 3 or to have perfect forecasts. It is noteworthy that the assumption of perfect forecasts performs best if one only considers the last 12 months of the sample period. This suggests that the ECB could improve its autonomous factor forecasts in the course of the first 6 months of 1999.

Finally, with regard to the explanation of the evolution of the EONIA rate, a simple regression approach, derived from some basic theoretical considerations and using only a few explanatory variables was able to explain about two thirds of the variations in the spread. Especially the large jumps of the spread at the end of the maintenance periods were well captured. Liquidity conditions, i.e. the supply and demand of deposits, did not appear to be relevant in the first three quarters of the reserve maintenance period, illustrating that the averaging facilities inherent in the ECB's reserve requirement system was well used and that the ECB built up a reputation to compensate, as far as possible, the liquidity effects of autonomous factor shocks through subsequent allotment decisions in the same reserve maintenance period. In the first three quarters of the reserve maintenance period, the only significant (non-dummy) explanatory variable of the spread were the expectations of a change of ECB rates within the same reserve maintenance period.

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Annex 1: List of dummy variables#

Calendar indicators

dummo = 1	if day t falls in month mo (mo = 1,...,12)
dumbu = 1	if day t falls on business day bu of the week (bu = Monday mo, Tuesday tu, Wednesday we, Thursday th, Friday fr)
dumx = 1	if day t falls in year x (x = 1994, 1995, 1996, 1997, 1998)
dumsasu = 1	if day t falls on a weekend
dumwin = 1	if day t falls on 30 June and 31 December
dumjan1 = 1	if day t falls in the first business week of January
dumfi = 1	if day t falls on the first business day of the month
dumla = 1	if day t falls on the last business day of the month
dumla2k = 1	if day t fallls on the last business day of the month in year 2000

Holiday indicators

dumhol = 1	if day t is 1, 2, 3, 4 or 5 business days before the main holidays in EMU (Epifania, Easter Friday, Easter Monday, Labour Day, Ascension, Monday of Pentecost, Corpus Christi, Immac. Conception, Tag der deutschen Einheit, Toussaint, First Christmas Day, Second Christmas Day)
dumhol1 = 1	if day t is 1, 2, 3, 4, or 5 business days after the main holidays in EMU (see definition of dumhol)
dumchri = 1	if day t is between 24 and 31 December 1999
dumsum = 1	if day t falls between 23 and 31 August (indicator for summer holidays)

Reserve maintenance period indicators

dummp(j) = 1	if day t is the jth day of the maintenance period
dummr = 1	if day t falls in the first maintenance period (01/01/99-23/02/99)
dummpl = 1	if day t is the last business day of the maintenance period

Tax indicators

dumit = 1	if t is the 23rd or the following business day or if t is the first business day of the month or if t falls within the first ten business days and on the last day of December (liquidity effects of Treasury activities in Italy)
dumsp = 1	if t falls on the last working day of the month or in the middle of February, August and November or if t falls on a Friday (liquidity effects of Treasury activities in Spain)
dumf = 1	if t falls on the 15th of February, March, April, June, September, November and December (or the nearest business day before the 15th) (liquidity effects of Treasury activities in France)
dumf1 = 1	if t falls in the months since May 1999 (since the beginning of May 1999 interest has been paid on the French Treasury's balances with the Banque de France above a given threshold at a rate below the market rate)

Balance sheet anomaly indicators

dumother1 = 1	for t = January, 29 1999 (a national TARGET component was cancelled)
dumother2 = 1	for t = April, 15 1999 (Bundesbank profit of 8 bn EUR was transferred to the Treasury).
dumother3 = 1	for t = March, 19 1999(drop in other autonomous factors by about € 4 bn due to an unusual increase in liabilities to non-euro area residents denominated in euro and intra-ESCB liabilities.

All dummy variables take on the value zero except under the conditions indicated in the table.

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