

# THE EUROSISTEM'S EXPERIENCE WITH FORECASTING AUTONOMOUS FACTORS AND EXCESS RESERVES

## ARTICLES

The Eurosystem's experience with forecasting autonomous factors and excess reserves

*The Eurosystem's reserve requirements, together with its forecasts of autonomous factors and excess reserves, form the basis for the calibration of the liquidity supply through its open market operations and hence for the steering of short-term money market interest rates close to the minimum bid rate in main refinancing operations determined by the Governing Council. This article analyses the properties of autonomous factors and excess reserves, the Eurosystem's forecasting procedures and the related forecast errors. From the perspective of the Eurosystem's liquidity management, the most important individual autonomous factors in terms of their size and variability are banknotes in circulation and government deposits. Although the fluctuations in autonomous factors and excess reserves are not stable over time (especially over the year end), and this may occasionally lead to increased forecast errors (outliers), the article shows that overall the forecasting methodology employed leads to unbiased estimates of the banking system's liquidity needs.*

## I INTRODUCTION

When determining the allotment amount in main refinancing and fine-tuning operations (MROs and FTOs, respectively), the European Central Bank (ECB) takes into account a forecast of the liquidity needs of the banking sector, usually for a horizon of up to one week. These liquidity needs stem from three different sources: reserve requirements, excess reserves and autonomous factors. While reserve requirements are determined with a high degree of precision at the beginning of the reserve maintenance period, the forecasts for excess reserves and autonomous factors are subject to uncertainty over the horizon of up to one week. Autonomous factors denote all items in the balance sheet of the Eurosystem that are not monetary policy instruments denominated in euro. Excess reserves are defined as the average difference between banks' current account holdings and their reserve requirements.

An underestimation of liquidity needs usually implies that the ECB has allocated insufficient funds in open market operations. Particularly in the last week of the reserve maintenance period, when banks have limited scope to postpone the fulfilment of their reserve requirements, there may be an upward drift in the spread between short-term money market interest rates and the minimum bid rate. Conversely, an overestimation may lead to a downward drift. Hence, the better the forecasts of autonomous factors and excess reserves, the better the ECB can calibrate its open market operations and

meet the objective of steering short-term money market rates close to its policy rate, namely the minimum bid rate in MROs.

It is particularly important for the Eurosystem's liquidity forecasts to be unbiased from a statistical point of view and for this to be well understood by market participants. If the liquidity needs of the banking sector were systematically underestimated, the ECB would regularly allocate insufficient liquidity in open market operations, and market participants would, in the course of time, make frequent recourse to the marginal lending facility in order to satisfy their liquidity needs. Very short-term money market interest rates would display an upward drift towards the marginal lending rate. In contrast, a systematic overestimation of banks' liquidity needs would lead to a downward drift towards the deposit rate.

This article reviews the main properties of autonomous factors and excess reserves, and assesses the degree of unbiasedness of the Eurosystem's liquidity forecasts. For the statistical analysis of the forecast errors, the period from January 2003 to October 2007 is used in order to exclude the effects from the cash changeover in 2002. Section 2 describes the size, variability and feasibility of forecasting the various autonomous factors distinguished in the Eurosystem's balance sheet. Section 3 discusses the properties of the forecast errors for the aggregate autonomous factors. Section 4 provides a similar analysis for excess reserves. Section 5 examines statistics

on the same-day error of the total liquidity forecast – i.e. the sum of the forecast errors of the aggregate autonomous factors and excess reserves – on the last day of the maintenance period. This forecast, and its unbiasedness, is of particular importance for the calibration of the end-of-period fine-tuning operation and for the steering of the interbank overnight rate earlier in the maintenance period. Section 6 concludes.

## 2 AUTONOMOUS FACTORS

### 2.1 OVERVIEW

As mentioned above, aggregate autonomous factors impose a liquidity need on the banking system and thus have a net liquidity-absorbing effect. However, individual autonomous factors can be both liquidity-providing and liquidity-absorbing, depending on which side of the central bank's balance sheet they appear. An increase in an autonomous factor on the asset side is, *ceteris paribus*, liquidity-providing, because it reflects the fact that the central bank has purchased assets against liquidity – i.e. current account holdings – and has therefore reduced banks' need to obtain liquidity via refinancing operations in order to fulfil their reserve requirements. Conversely, an increase in an autonomous factor on the liability side is liquidity-absorbing, because it reflects the fact that the banking system has bought a claim on the central bank against a reduction in their current account holdings, which need to be replenished through increased refinancing operations.

The simplified Eurosystem balance sheet in Chart 1 distinguishes four autonomous factors: “government deposits”, “banknotes in circulation”, “net foreign assets” and “other factors net”. Government deposits and banknotes in circulation are the largest liquidity-absorbing autonomous factors, while net foreign assets is the largest liquidity-providing autonomous factor. Refinancing operations constitute the largest item on the asset side. The ECB adjusts these to the total sum of autonomous factors

Chart 1 Simplified Eurosystem balance sheet, as at 30/10/2007



Source: ECB.

plus reserve requirements and excess reserves, as described above, in order to keep short-term money market rates close to the minimum bid rate. The item “other factors net” is a net residual representing three autonomous factors of minor importance on both the asset and the liability sides (see below).

Banknotes, government deposits and other factors net display considerable variation (see Chart 2). Despite their large size, net foreign assets show only small fluctuations, while other factors net and government deposits show relatively large fluctuations compared with their size.

Autonomous factors are forecast on a daily basis for a horizon of up to the end of the current maintenance period or at least the next two weeks. The forecast procedure is generally decentralised in the sense that the national central banks (NCBs) forecast the autonomous factors in their domestic balance sheets, which are then aggregated by the ECB to provide a euro area forecast. In this process, a variety of approaches – such as econometric models, expert judgement and knowledge about cash flows from specific transactions – are applied, taking into account the properties of the individual factors mentioned below. In addition to this decentralised procedure, a

**Chart 2 Standard deviation of the main balance sheet items for 2007**

(EUR billions)

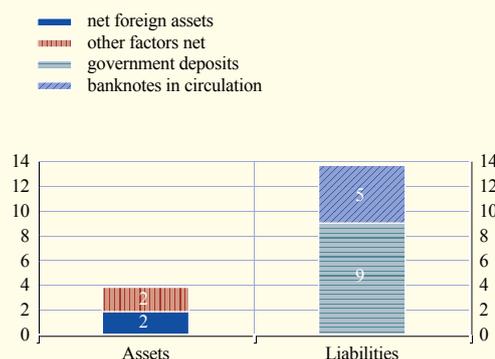


Source: ECB.

Note: The total sum of standard deviations on the asset and liability sides in the simplified balance sheet does not match owing to non-linearity and correlations between various items.

**Chart 3 Predictability of autonomous factors (measured as the standard deviation of the eight-step ahead accumulated forecast error)**

(EUR billions)



Source: ECB.

Note: The accumulated forecast error denotes the sum of the differences between this forecast and the realised value for each day over the week (from one allotment decision to the other).

centralised structural time series model is applied for banknotes in circulation.<sup>1</sup>

While the large fluctuations in government deposits and banknotes in circulation mentioned above are also associated with large forecast errors (see Chart 3), the same is not true for other factors net, which shows small forecast errors of the same magnitude as those calculated for net foreign assets.

These statistics show that government deposits and banknotes in circulation are by far the most important autonomous factors for the Eurosystem's liquidity management, causing the largest fluctuations and forecasting errors in liquidity needs. Net foreign assets and other factors net are relatively large in size, but show limited variability and forecast errors.

## 2.2 SPECIFIC PROPERTIES

### BANKNOTES IN CIRCULATION

Banknotes are issued by the NCBs of the Eurosystem and the ECB. Since vault cash does not count towards reserve requirements, no distinction is made between banknotes within the banking sector and those outside. Demand for banknotes is mainly determined by the share of cash transactions in the economy and store

of value motives. In particular, there may be a large demand for euro banknotes from outside the euro area, mainly for store of value motives.

The evolution of banknotes in circulation is characterised by an upward trend, which has been particularly strong since the cash changeover in 2002 (see Chart 4) and by clearly

<sup>1</sup> The model is based on the aggregate time series for banknotes (i.e. the Eurosystem total) in terms of components, such as trends, seasonality and patterns with a direct interpretation (see next subsection). Seasonal components include intra-year effects; intra-month effects; and moving and fixed calendar effects. The forecast of the structural time series model and the decentralised forecasts by NCBs are combined, taking into account the past performance of the two techniques, as well as expert judgement. The model is estimated in state space form using a Kalman filter technique.

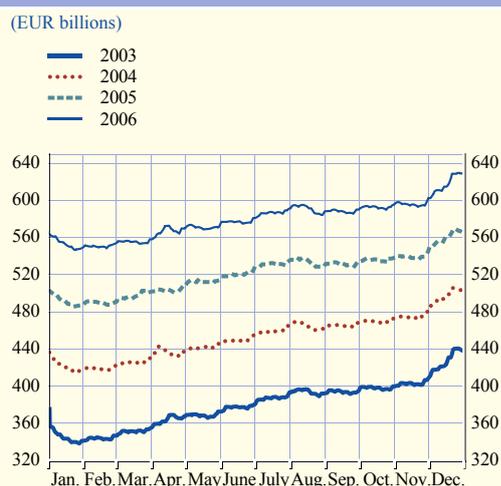
**Chart 4 Evolution of banknotes in circulation**

(EUR billions)



Source: ECB.

**Chart 5 Intra-year evolution of banknotes in circulation**



Source: ECB.

discernible intra-week, intra-month and intra-year patterns (See Chart 5).

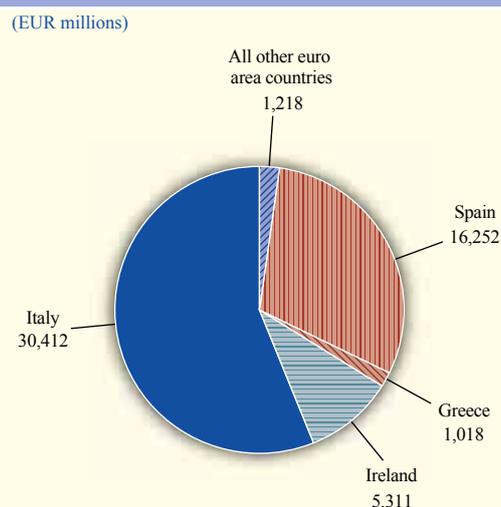
In the structural time series model used to forecast banknotes in circulation in combination with the decentralised procedure, a distinction is made between intra-week seasonality (mainly related to weekend shopping activities), intra-month seasonality (mainly related to salary and pension payments) and, most importantly, intra-annual seasonality (reflecting important public holiday periods like Christmas/New Year and summer holidays). Important one-off special events affecting banknotes include the changeover to the new millenium and the aforementioned euro cash changeover.

### GOVERNMENT DEPOSITS

Some NCBs have traditionally fulfilled the role of “fiscal agent” for their domestic government and have continued to do so in Economic and Monetary Union. Within the Eurosystem there are significant variations between countries with regard to government deposits and their volatility, which mainly relate to institutional features inherited from the past (see Chart 6).

Aggregate government deposits do not display a clear trend (See Chart 7). However, some NCBs

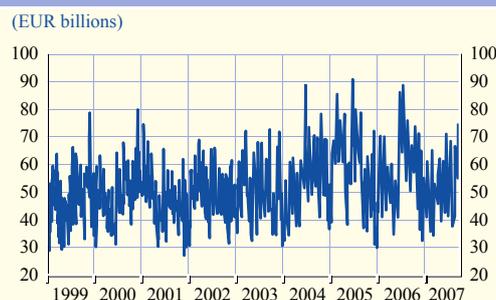
**Chart 6 Countries use of government deposits (average from 2003 to 2007)**



Source: ECB.

show a muted monthly pattern, which is mainly related to the use of the treasury accounts. For the Banca d’Italia, for example, the most significant monthly variations reflect payments relating to the collection of taxes (between the 19th and the 23rd of each month) and social security contributions. Payments of salaries, pensions and social benefits (mainly at the beginning of the month), payments related to debt management and payments related to the settlement of foreign exchange transactions are also significant. In close cooperation with their respective treasuries, most NCBs have implemented measures to reduce volatility and enhance the predictability of government deposits.

**Chart 7 Evolution of government deposits**



Source: ECB.

### NET FOREIGN ASSETS

The net foreign assets of the Eurosystem consist mainly of foreign exchange reserves and holdings of gold, which are held for investment purposes and the preparation of foreign exchange interventions. Given the very exceptional nature of the latter, movements in the net foreign assets are mainly driven by portfolio reallocations, which are usually known at least three business days before settlement and can thus be forecast relatively easily.

### OTHER FACTORS NET

The net residual "other factors net" shown in the above simplified balance sheet consists of the net sum of the following three less significant autonomous factors, which are treated separately in the Eurosystem's daily forecasting procedure.

#### Items in course of settlement

To the extent that payments between commercial banks are settled using current accounts held by the central bank, a time difference between credit and debit operation will have an impact on liquidity provision. Therefore, the importance of this autonomous factor depends largely on the design of the payment system (mainly clearing of cheques) and varies from country to country. However, owing to the advanced state of development of payment systems, this autonomous factor is usually rather small in terms of size, variability and forecast errors.

#### Net assets denominated in euro

The NCBs generally hold euro portfolios to meet pension obligations, invest (and build up) capital buffers, or increase monetary income. In practice, most changes in these portfolios are driven by investment transactions which, as foreign exchange transactions, are usually known at least three days in advance. The TARGET accounts of ESCB central banks outside the euro area are another possible source of movement in this autonomous factor.

#### Other autonomous factors

The central bank capital and reserves, as well as revaluation accounts make up a large part of

other autonomous factors, which is the residual item identified in the Eurosystem's daily liquidity forecasting procedure. Usually, changes in this residual are relatively limited and for the most part simply mirror developments in other net assets denominated in euro and/or net foreign assets.

### 3 FORECAST ERRORS FOR AGGREGATE AUTONOMOUS FACTORS

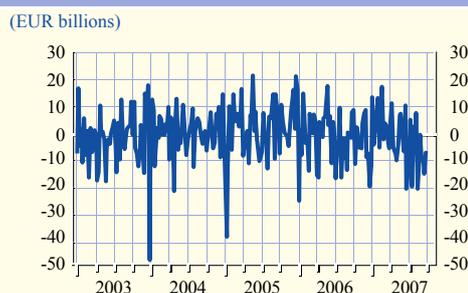
As already mentioned, the quality of the forecasts and, in particular, their unbiasedness, is of utmost importance. An overview of the statistical properties of the forecast errors for autonomous factors is provided in this section, distinguishing between weekly accumulated errors and same-day errors. The former are important for assessing the precision of the calibration of the weekly MRO allotments, while the latter are important for end-of-period FTOs.

#### WEEKLY ACCUMULATED AGGREGATE FORECAST ERRORS FOR AUTONOMOUS FACTORS

The weekly accumulated aggregate forecast errors<sup>2</sup> for autonomous factors on the MRO allotment days fluctuated around a mean of €-200 million (median €-14 million). However, the standard deviation of slightly more than €9 billion

2 The one week ahead forecasts on each MRO allotment day are usually conducted from Tuesday to Tuesday, inclusive. The accumulated error denotes the sum of the differences between this forecast and the realised value for each day over the relevant week. Negative values denote an underestimation of autonomous factors.

Chart 8 Accumulated forecast errors for total autonomous factors over the week



Source: ECB.

renders this figure insignificantly different from zero, indicating an absence of statistical bias. Errors fluctuated between extremes of €21 billion and €-46 billion in the weeks ending 24 May 2005 and 30 December 2003, respectively (see Chart 8).

Chart 8 also illustrates that the period of increased market volatility since August 2007 has been associated with a slightly increased frequency of large forecast errors. These were caused, in particular, by government deposits and other factors net. However, overall, the forecasting feasibility has not significantly deteriorated in this period.

An analysis of the average monthly variance of the forecast errors reveals that autonomous factors (notably banknotes in circulation) display greater variance in December and January. Controlling for two large outliers occurring as a result of this,<sup>3</sup> the forecast errors closely resemble a normal distribution (see Chart 9). Overall, the forecast errors for the accumulated weekly autonomous factors are unbiased<sup>4</sup>, including during the recent period of increased market volatility.

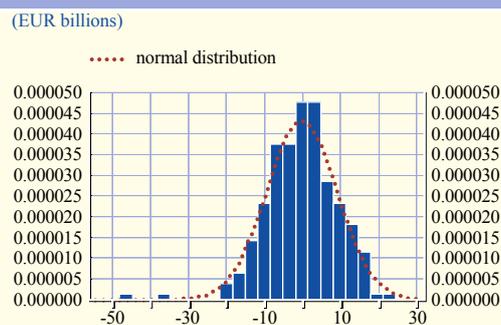
#### SAME-DAY AGGREGATE FORECAST ERRORS FOR AUTONOMOUS FACTORS

The forecast errors for the same-day aggregate forecast underlying the calibration of any end-of-period fine-tuning operations display properties very similar to the weekly accumulated aggregate forecast errors for autonomous factors (see Chart 10). Two large negative outliers were observed, which both fell in the periods with the highest variance in December and January.<sup>5</sup>

#### 4 EXCESS RESERVES

In comparison with autonomous factors and reserve requirements, excess reserves are a tiny, but equally important liquidity need at the margin. In contrast to the reserve requirements, excess reserves are not remunerated by the Eurosystem and are therefore costly to banks. Nevertheless, a variety of reasons for holding excess reserves

**Chart 9 Histogram showing forecast errors for accumulated autonomous factors**

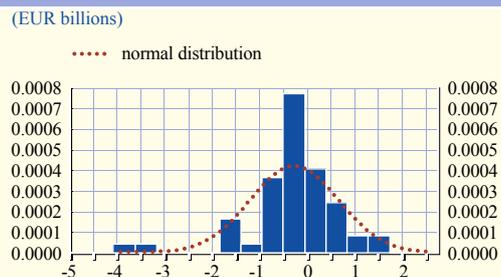


Source: ECB.  
Note: The dashed curve represents the fitted normal distribution (s=€9 billion).

have been identified,<sup>6</sup> which include avoiding operative and administrative costs, maintaining buffers to insure against liquidity shocks late in the day, inactive management of bank's current accounts, fulfilling liquidity requirements under national laws, and missing access to the deposit facility of the Eurosystem.

- 3 €-46 billion (government deposits) observed on 30 December 2003 and €-38 billion (banknotes in circulation) observed on 11 January 2005.
- 4 Formal tests do not reject normality of forecast errors. Furthermore, there is no evidence of serial correlation.
- 5 €-3.8 billion (government deposits) occurred on 23 December 2003 and €-3.2 billion (banknotes) occurred on 18 January 2005.
- 6 See Box on excess reserves in the October 2005 issue of the Monthly Bulletin.

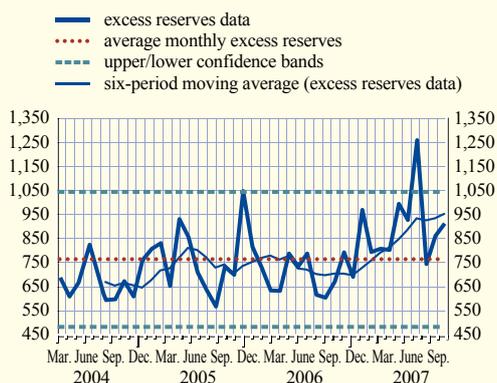
**Chart 10 Histogram showing forecast errors for same-day autonomous factors**



Source: ECB.  
Note: The dashed curve represents the fitted normal distribution (s=€900 million).

**Chart 11 Average excess reserves per maintenance period (March 2004-September 2007)**

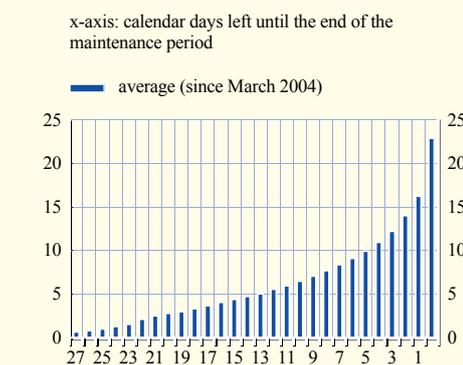
(EUR millions)



Source: ECB.

**Chart 12 Accumulated excess reserves: intra-maintenance period pattern**

(EUR billions)



Source: ECB.

In the period from March 2004 (when the operational framework was amended)<sup>7</sup> to September 2006, the average daily excess reserves amounted to €710 million (median €727 million), while they have been somewhat higher since October 2006, with a daily average of €896 million (median €836 million). In July 2007 a maximum daily average of €1,251 million<sup>8</sup> was reached (see Chart 11).

Daily excess reserves rise exponentially during a maintenance period, because the likelihood increases day by day that credit institutions have fulfilled their reserve requirements. The possible use of excess reserves as a buffer against non-compliance with reserve requirements (for instance, in case of not receiving an expected payment) implies that a particularly high share of total excess reserves is held on the last day.

### FORECASTING PROCEDURES

Excess reserves for a given maintenance period are forecast at three different points in time as information on actually accumulated excess reserves becomes available to the Eurosystem, following the pattern in Chart 12. First, at the beginning of the maintenance period, when no or very little information is available, a forecast is made exclusively on the basis of observations from previous maintenance periods. Second, on the allotment day of the last MRO of the maintenance

period, part of the excess reserves will already have accumulated (usually around one third of the total amount for the maintenance period), which provides a basis for a revised forecast. Finally, on the last day of the maintenance period, information on actually accumulated excess reserve holdings up to the penultimate day of the maintenance period is obtained (usually around two thirds of excess reserves of the total amount for the maintenance period). This information significantly improves the forecast<sup>9</sup> and is an important input in the calculation of the expected liquidity imbalance on the last day of the maintenance period, which is used to calibrate the possible end-of-period FTOs.

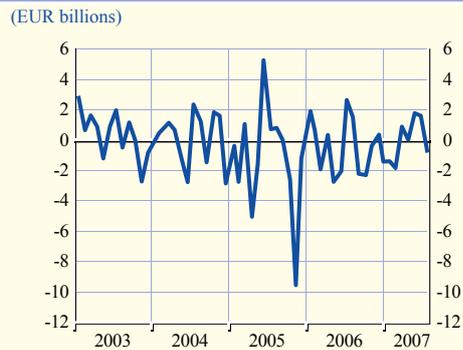
The abovementioned three forecasts of excess reserves are based on time series models, which take into account the most recent available cumulative figure on excess reserves. Complementary sources of information, which include forecasts by NCBs of their domestic excess reserves and anecdotal evidence, are used to improve the forecast quality.

7 For a detailed description of the changes to the framework, see the article entitled "Initial experience with the changes to the Eurosystem's operational framework for monetary policy implementation" in the February 2005 issue of the Monthly Bulletin.

8 Here one individual bank used its current account holdings for liquidity needs for securities settlement.

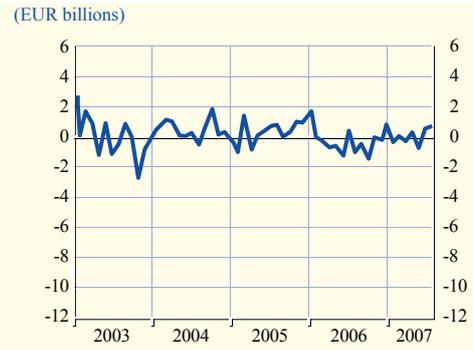
9 A fractional integrated ARIMAX model is used, which improves forecast performance measured by root mean square errors by a factor of four compared with trivial methods (e.g. assuming values of the previous maintenance period as forecasts).

**Chart 13 Forecast errors for accumulated excess reserves over a maintenance period on the last MRO allotment day**



Source: ECB.

**Chart 14 Forecast errors for accumulated excess reserves over a maintenance period at the end of the maintenance period**



Source: ECB.

Charts 13 and 14 display the errors in the Eurosystem's forecast of excess reserves (expressed in accumulated terms over a maintenance period) on the day of the last MRO (thus with a one-week horizon) and on the last day of the maintenance period (with a one-day horizon), respectively.

#### SAME-DAY FORECAST ERRORS

The histogram of the series of same-day errors<sup>10</sup> shows that errors are centred around zero with a statistically insignificant mean (the average amounts to €3 million). Furthermore, the forecast errors for excess reserves show no time dependence, either on the last MRO allotment or on the last day of the maintenance period, indicating that errors do not follow a systematic pattern. Interestingly, neither the absolute level of excess reserves, nor the forecast errors, have been significantly affected by the increased financial market volatility since August 2007. Overall, there are no indications that the forecast errors for excess reserves are biased.

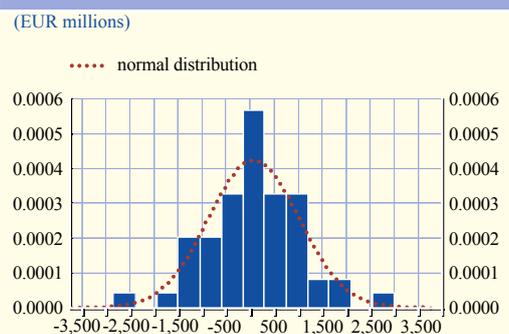
### 5 FORECAST ERRORS FOR THE LIQUIDITY IMBALANCE ON THE LAST DAY OF A MAINTENANCE PERIOD

The last day of every maintenance period has a special significance, since liquidity imbalances can no longer be addressed via a MRO allotment or a FTO. Unavoidably, therefore,

recourse is made to standing facilities, leading to volatility in the overnight rate. As a result of the changes made to the operational framework in 2004, the time between the allotment of the last MRO and the last day of the maintenance period increased to seven calendar days. The resulting longer forecast horizon increased the size of the liquidity imbalances. To counter the effect on short-term interest rates, the ECB frequently uses FTOs, conducted on the last day of the maintenance period with a maturity of one day.

<sup>10</sup> The analysis only regards the same-day errors, since these are relevant for the liquidity imbalance on the last day of the maintenance period.

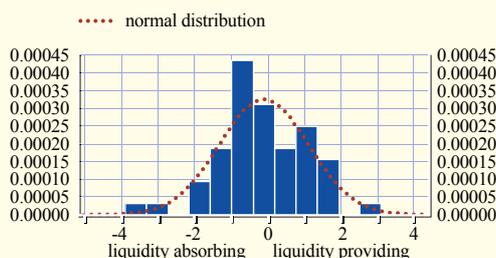
**Chart 15 Histogram showing forecast errors for accumulated excess reserves**



Source: ECB.  
Note: The dashed curve represents the fitted normal distribution ( $s = €940$  million).

Chart 16 Histogram showing the sum of the same-day forecast errors for autonomous factors and the forecast errors for accumulated excess reserves at the end of the maintenance period

(EUR billions)



Source: ECB.

Note: The dashed curve represents the fitted normal distribution ( $s = \text{€1 billion}$ ).

When deciding on the need for and the scale of the FTO, the main part of the expected liquidity imbalance for the last day are already known, consisting of the forecast errors for autonomous factors realised up to the last day. The remaining uncertainty stems from two sources: the same-day aggregate error in the autonomous factor forecast for the last day of the maintenance period and the difference between the most recent excess reserves forecast and the realised excess reserves, which were assessed in the preceding sections. Since both of these sets of errors appear to be random (around a zero mean, i.e. the forecast is unbiased), the same applies to the sum of the two errors.

The joint errors of the two forecasts are concentrated around a small, insignificant mean (see Chart 16). The recent period of market volatility did not lead to additional outliers in forecasting the end-of-period imbalances.

## 6 CONCLUSION

This article has provided information on the properties of individual and aggregate autonomous factors and excess reserves. It has explained how the Eurosystem forecasts these liquidity factors in order to determine the adequate allotment amounts in open market operations and has reviewed the errors made in these forecasts in order to check that they are unbiased.

The findings of the article can be summarised as follows. From the perspective of the Eurosystem's liquidity management, the most significant individual autonomous factors are government deposits and banknotes in circulation, which both exhibit relative large fluctuations and forecast errors. Excess reserves is a tiny, but significant liquidity need at the margin, which can be predicted with a high degree of precision on the last day of the maintenance period. The variance in both the aggregate autonomous factors and excess reserves shows some seasonality, increasing in December and January, meaning that large forecast errors occasionally occur in this period of the year. However, an assessment of the forecast performance for the period from January 2003 to October 2007 shows that the forecasting procedures led to unbiased estimates for both liquidity factors. Although the recent period of increased market volatility has been associated with some large autonomous factor forecasting errors, it has not led to a significant deterioration in the forecast performance for either aggregate autonomous factors or excess reserves. This identification of the forecast errors as statistically unbiased also holds for weekly accumulated errors, as well as same-day error on the last day of the maintenance period.