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„A Monetary Real-Time Conditional Forecast of Euro Area Inflation“

A monetary real-time conditional forecast of euro area inflation

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Abstract

Based on a vector error correction model we produce conditional euro area inflation forecasts. We use real-time data on M3, HICP, and include real GPD, the 3-month EURIBOR and the 10-year government bond yield as control variables. Real money growth and the term spread enter the system as stationary linear combinations. Missing and outlying values are substituted by model-based estimates using all available data information. In general, the conditional inflation forecasts are consistent with the European Central Bank's assessment of liquidity conditions for future inflation prospects. The evaluation of inflation forecasts under different monetary scenarios reveals the importance of keeping track of money growth rate in particular at the end of 2005.

JEL classification: C11,C32,E31,E37,E52
Key words: Bayesian forecast, vector error correction, inflation forecast, missing values, real-time data.

1 Introduction

The structural break in the money demand relationship apparent in the data after 2001 and the surge of nominal M3 yearly growth rates soaring well above the reference value of 4.5% triggered an intense discussion about the usefulness of the European Central Bank's (ECB) two-pillar approach. In particular the need and contribution of monetary analysis to assess conditions for future inflation prospects was questioned. The standard New Keynesian approach to monetary policy setting assigns absolutely no role to monetary developments in defining optimal monetary policy. Woodford (2007) shows that the New Keynesian model can be extended to include a money demand relationship in which the stock of money is determined endogenously when the monetary authority is committed to the inflation target. In these models, future inflation is optimally predicted by the actual inflation rate and by the output gap. Given that the inflation rate contains the same stochastic trend as money growth there is no improvement in inflation forecasts to be expected when including money growth besides inflation in the forecasting equation.

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[‡] The paper contains the views of the authors and not necessarily those of the OeNB.

Rather, forecast improvements are to be expected when a better measurement of short-term deviations of inflation from its stochastic trend is included.

This is precisely what we exploit in the present paper. If both money growth and inflation share the same stochastic trend, i.e. if they are cointegrated, then it is not only the current level of inflation that contains information about future inflation. Rather, the level of inflation in relation to money growth contains additional information about future inflation. In other words, deviations of real money growth from the long-run average imply error correction dynamics to restore the long-run stable growth path. If inflation is not (weakly) exogenous, a real money growth rate higher than average indicates inflationary pressures in the future. Although we do not work with a full structural model, which includes the real and the monetary side of the economy, we want to exploit the information contained in a small reduced system of variables, to assess the impact of monetary developments on future inflation prospects.

Based on the results we present in Kaufmann and Kugler (2008), we use the same Markov-switching vector error correction model (MS-VECM) to produce conditional, "monetary" HICP inflation forecasts for the euro area. We call the conditional forecasts "monetary" because they are basically produced by exploiting the information contained in real money growth, in the term spread, in the real GDP growth rate, and nothing else. In that sense, they may complement the Eurosystem's Staff Macroeconomic Projections published in the Monthly Bulletin of the ECB, which mainly take into consideration the economic stance for future inflation prospects.

An additional contribution of the paper is to derive model-based estimates of missing end-of-sample values in a real-time context. We work with the real-time database released on the Euro Area Business Cycle Network's website (EABCN) to produce inflation forecasts in real-time. Conditional on the implied structure of the MS-VECM and on all information contained in the data, we estimate the missing end-of-sample values. In our small model, this not only concerns GDP, but also actual M3 and HICP are sometimes missing. The conditional forecasts thus also include uncertainty about missing end-of-sample values.

As a by-product, we can use the estimation method to assess the impact of different monetary and financial scenarios on future inflation. In one case for instance, we show that M3 growth, in addition to monetary policy tightening represented in interest rate increases, has to significantly contract in order to bring down monetary inflation pressures. These results are consistent with and provide an empirical complement to the simulation experiments of Beck and Wieland (2008) which show that money growth contains useful information to be cross-checked with when misperceptions of real data like the output gap and the real interest rate prevail. Substantial improvement in inflation control is achieved when a cross-check with monetary developments is included in the policy rule.

Although we use the raw data in the sense of unfiltered data, the paper is also related to studies using filtered data, like Assenmacher-Wesche and Gerlach (2006), Bruggeman et al. (2005) and Neumann and Greiber (2004). These authors find that "core" money growth influences "core" inflation, whereby the "core" measures are extracted by filtering the low-frequency of the data. Finally, additional support for the present analysis is provided in the extensive studies of Hofmann (2006), Carstensen (2007) and Scharnagl and Schumacher (2007), which evaluate and document the improvements in inflation forecasts relative to naive and simple autoregressive models when monetary and/or real variables are included in the forecasting models.

We proceed in the following way. In section 2 we present the MS-VECM with which we work. Section 3.1 derives the posterior distribution of the missing values conditional on the error-correction structure and all information of actually available data. We show that released data lie within the end-of-sample first estimates of the interquartile range for real money growth most of the time. There are three periods out of the fourteen that we evaluate in which the model-based estimate significantly departs from released data. We interpret these periods as those where monetary developments contain additional information about future inflation prospects. We demonstrate this in section 4, in which we use the model to produce inflation forecasts conditional on the short-term interest rate frozen at the actual level. We compare the conditional forecasts to the inflation projections published in the June and December issue of the Monthly Bulletin of the ECB. It turns out that so far, the long-term forecast, the ECB's first release of two-years ahead projected inflation rate has been biased downwards. The long-term conditional MS-VECM forecast, although being more volatile, displays so far no systematic bias. On the other hand, the ECB's short-term inflation projections, the current year's inflation projections published in the June Bulletin, clearly outperform the MS-VECM conditional forecasts and deliver a very precise estimate of actual inflation.

In section 5 we choose three periods, the turn of 2001/2002, 2005/2006 and 2007/2008, to show how the MS-VECM can be used to evaluate the effects of different monetary conditions on conditional inflation forecasts. This exercise reveals that keeping track of the M3 growth rate was particularly crucial at the turn of 2005/2006. This is consistent with the ECB's internal assessment of liquidity conditions for future inflation prospects at that time (Fischer et al., 2007, p.32). We conclude in section 6 that all these findings provide evidence in favour of the two-pillar approach of the ECB's policy strategy.

2 Data and model specification

We work with real-time data provided on the Euro Area Business Cycle Network's website[1]. In the empirical model, we include M3 growth (Δm), HICP inflation (Δp), the 3-month EURIBOR rate (r), the 10-year government bond yield (R) and real GDP (yr). All data are available at a monthly frequency except for GDP, which is observed at a quarterly frequency. We transform monthly to quarterly observations by taking averages. Finally, the HICP quarterly data are seasonally adjusted by the Census-X12 procedure implemented in EViews. The starting date of the vintages differs between the series. Therefore, to obtain a longer and consistent estimation sample, we complete the quarterly series with data from the euro area wide model (EAWM), also available on the EABCN website. The interest rates are simply linked. M3 and HICP are chained by growth rates.

Given the unit root and cointegration results in Kaufmann and Kugler (2008), interest rates enter the VECM in differences and real GDP in growth rates. Given that M3 and the HICP appear to be integrated of order 2, both are included in second differences. The error correction terms define a stationary term spread ($R - r$) and a stationary real money growth rate ($\Delta m - \Delta p$). To account for the dynamics in the data, we include three autoregressive lags of the endogenous variables, $p = 3$. Formally, if we define the vector

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[1] www.eabcn.org

y_t to include all variables in period t, $y_t = (\Delta r_t, \Delta R_t, \Delta^2 m_t, \Delta^2 p_t, \Delta yr_t)$,[2] the model is:

$$y_t = \nu_{S_t} + \sum_{j=1}^{p} A_{j,S_t} y_{t-j} + \alpha_{S_t} \beta Y_{t-1} + \varepsilon_t, \quad t = 1974Q3, \ldots, T \tag{1}$$

with ε_t i.i.d multivariate $N(0, \Sigma)$ and with T equal to the end date of the vintage. The matrix β contains the cointegration vectors which define two stationary relationships, the term spread and real money growth, $\beta = \begin{bmatrix} -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \end{bmatrix}$. The subscript S_t indicates that we estimate a model with state dependent intercept term ν, dynamic coefficients A_j and error correction coefficients α. The unobservable, and hence estimated, state indicator S_t can take on two values, $k = 1, 2$ and is assumed to follow a Markov process with transition probabilities $P(S_t = j | S_t - 1 = k) = \xi_{kj}$.

The state variable S_t is relevant to account for two periods, from end-1977 to 1981 and from end-1980 to end-1981, during which interest rates were very volatile. These are related to the period when Paul Volcker became Chairman of the US Federal Reserve and enacted a policy change towards reserve targeting to bring down inflation rates. This resulted in very volatile interest rates which spilled over to Europe. The empirical model confirms that much of the error correction and dynamic adjustments went through interest rates in these times (see Kaufmann and Kugler, 2008). Although we do not observe such a high level of volatility in interest rates for the rest of the sample period (and hence do not switch back into this state), we keep the Markov switching specification to be able to capture a potentially recurrent state of high interest rate volatility.

3 Model-based estimates of missing values

3.1 Estimation

We estimate the model by Markov chain Monte Carlo (MCMC) methods, see Kaufmann and Kugler (2008) and Kaufmann and Valderrama (2008) for more details, and given that we condition on the cointegrating vectors, we can use the Gibbs sampler involving the following steps:

(i) $\pi\left(S | y_{\backslash \tilde{y}}, \beta, \tilde{y}, \theta\right)$
(ii) $\pi\left(\theta | y_{\backslash \tilde{y}}, \beta, \tilde{y}, S\right)$
(iii) $\pi\left(\tilde{y} | y_{\backslash \tilde{y}}, \beta, S, \theta\right)$

The vector of data $y_{\backslash \tilde{y}}$ collects all observed variables, while $\tilde{y}$ contains the missing values. The state vector $S = (S_T, S_{T-1}, \ldots, S_0)$ is simulated in one sweep using the multi-move sampler described in Chib (1996). The vector of parameters θ is additionally blocked to sample from standard distributions like the Normal, the inverse Wishart and the Dirichlet distributions. We use conjugate priors, and while sampling, we exclude parameter draws for A_{j,S_t}, α_{S_t} which imply roots larger than 1 in the process for the level variables.

Each sweep of the sampler is completed by drawing the missing and outlying values $\tilde{y}$ from their joint conditional posterior distribution, given the model structure and all available observations. Hence, the estimation of the model not only yields a posterior

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[2] The vector Y_t will denote the vector of the variables in levels, $Y_t = (r_t, R_t, \Delta m_t \Delta p_t, yr_t,)$

inference of the model parameters and the state indicator, but yields also an inference on the posterior distribution of the missing values.

Real-time data usually display the feature of ragged ends, which means that end-of-sample observations of time series are missing and only released with a time-lag. In our case this concerns GDP and sometimes M3 and HICP. The approach we follow is to estimate the model for the longest sample period of the data vintage, thereby replacing missing values by a draw from their joint posterior conditional distribution given the model and all available information, i.e. all observed data at the release date of the data vintage. We describe the approach in general to show that it can also be used to sample missing or outlying values within the sample.

In model 1, let y_t denote the $N \times 1$ vector of data which all are observed in period t, and let $\tilde{y}_t$ denote the vector of data in which some observations are missing. Given a prior distribution $\pi(\tilde{y})$, which will be defined later, the conditional posterior $\pi(\tilde{y}|y_{\backslash \tilde{y}}, \beta, S, \theta)$ is derived in the following way.

Define the $N \times Np$ state-dependent matrix $\Phi_{S_t} = [A_{p,S_t} \; \cdots \; A_{1,S_t}]$ and rewrite the system (1) as

$$0 = \begin{bmatrix} \Phi_{S_{p+1}} & -I_N & 0 & \cdots & \cdots \\ 0_{N\times N} & \Phi_{S_p+2} & -I_N & 0 & \cdots \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ \cdots & 0 & \Phi_{S_{T-1}} & -I_N & 0 \\ \cdots & \cdots & 0 & \Phi_{S_T} & -I_N \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_{T-1} \\ y_T \end{bmatrix} + \begin{bmatrix} \nu_{S_{p+1}} \\ \nu_{S_{p+2}} \\ \vdots \\ \nu_{S_{T-1}} \\ \nu_{S_T} \end{bmatrix} +$$

$$\begin{bmatrix} \alpha_{S_{p+1}} & 0 & \cdots & 0 \\ 0 & \alpha_{S_{p+2}} & 0 & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ 0 & \cdots & 0 & \alpha_{S_T} \end{bmatrix} [I_{T-p} \otimes \beta] \begin{bmatrix} Y_p \\ \vdots \\ Y_{T-2} \\ Y_{T-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{p+1} \\ \vdots \\ \varepsilon_{T-1} \\ \varepsilon_T \end{bmatrix} \qquad (2)$$

The next step is to retain those equations of the system that convey information about the missing values. Assume that the sample contains a missing or outlying value in period t. Then we retain the equations corresponding to the observations from $t-p$ to $t+p$, which yields the reduced equation system:

$$0 = \begin{bmatrix} \Phi_{S_t} & -I & 0 & \cdots & \cdots \\ 0_{N\times N} & \Phi_{S_{t+1}} & -I & 0 & \cdots \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ \cdots & \cdots & 0 & \Phi_{S_{t+p}} & -I \end{bmatrix} \begin{bmatrix} y_{t-p} \\ \vdots \\ \tilde{y}_t \\ \bar{y}_{t+1} \\ \vdots \\ y_{t+p} \end{bmatrix} + \begin{bmatrix} \nu_{S_t} \\ \vdots \\ \nu_{S_{t+p}} \end{bmatrix} +$$

$$\begin{bmatrix} \alpha_{S_t} & 0 & \cdots \\ 0 & \ddots & \vdots \\ \cdots & 0 & \alpha_{S_{t+p}} \end{bmatrix} [I_p \otimes \beta] \begin{bmatrix} Y_{t-1} \\ \tilde{Y}_t \\ \vdots \\ Y_{t+p-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \vdots \\ \varepsilon_{t+p} \end{bmatrix}. \qquad (3)$$

If the missing values in the lagged levels of the variables enter the cointegration relationships, we relate the missing error term to the last observed value of the corresponding error term:

$$\alpha_{S_{t+1}}\beta\tilde{Y}_t = \alpha_{S_{t+1}}\beta\left(Y_{t-1} + \tilde{y}_t\right). \tag{4}$$

Substituting for $\tilde{Y}_t$ in (3) we obtain:

$$0 = \begin{bmatrix} \Phi_{S_t} & -I & 0 & \cdots & \cdots \\ 0 & \Phi^a_{S_{t+1}} & -I & 0 & \cdots \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ \cdots & \cdots & 0 & \Phi_{S_{t+p}} & -I \end{bmatrix} \begin{bmatrix} y_{t-p} \\ \vdots \\ \tilde{y}_t \\ \bar{y}_{t+1} \\ \vdots \\ y_{t+p} \end{bmatrix} + \begin{bmatrix} \nu_{S_t} \\ \vdots \\ \nu_{S_{t+p}} \end{bmatrix} +$$

$$\begin{bmatrix} \alpha_{S_t} & 0 & \cdots \\ \alpha_{S_{t+1}} & 0 & \vdots \\ 0 & \ddots & 0 \\ \cdots & 0 & \alpha_{S_{t+p}} \end{bmatrix} \left[I_{p-1} \otimes \beta\right] \begin{bmatrix} Y_{t-1} \\ Y_{t+1} \\ \vdots \\ Y_{t+p-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t \\ \vdots \\ \varepsilon_{t+p} \end{bmatrix}. \tag{5}$$

where $\Phi^a_{S_{t+1}} = \Phi_{S_{t+1}} + \left[0_{N\times N(p-1)}\ \alpha_{S_{t+1}}\beta\right]$.

If the missing values are at the end of the sample, we now can go directly to (7) below and continue deriving the posterior distribution. However, if the missing values are within the sample, we have to substitute for $\bar{y}_{t+1}$. The estimated missing observation $\tilde{y}_t$ implies a value for $\tilde{Y}_t$. Together with the next observation Y_{t+1} this implies that $\bar{y}_{t+1} = Y_{t+1} - \tilde{Y}_t = Y_{t+1} - Y_{t-1} - \tilde{y}_t \equiv \Delta_2 Y_{t+1} - \tilde{y}_t$.

Substituting this in (5) and writing the rest more compactly yields:

$$0 = \begin{bmatrix} \Phi_{S_t} & -I & 0 & \cdots & \cdots \\ 0 & \Phi^b_{S_{t+1}} & -I & 0 & \cdots \\ \vdots & \ddots & \ddots & \ddots & \vdots \\ \cdots & \cdots & 0 & \Phi^b_{S_{t+p}} & -I \end{bmatrix} \begin{bmatrix} y_{t-p} \\ \vdots \\ \tilde{y}_t \\ \Delta_2 Y_{t+1} \\ \vdots \\ y_{t+p} \end{bmatrix} + \nu^* + a^*\mathrm{ec}^* + \varepsilon^*. \tag{6}$$

Define the $Np \times N$ matrix Φ^v containing the rows corresponding to $(\bar{y}_{t+1}, y_{t+2}, \ldots, y_{t+p})$ and to the columns corresponding to $\bar{y}_{t+1}$ in the matrix Φ of (5):

$$\Phi^v = \begin{bmatrix} -I \\ \Phi^{t+2,t+1}_{S_{t+2}} \\ \vdots \\ \Phi^{t+p,t+1}_{S_{t+p}} \end{bmatrix},$$

where $\Phi^{i,t+1}_{S_\cdot}$ denotes the parameter block of the data $\bar{y}_{t+1}$ in the equations relating to y_i in the matrix Φ of equation (5). Then, the matrix Φ in equation (6) is equal to Φ of equation (5) minus Φ^v in the rows corresponding to $(\Delta_2 Y_{t+1}, y_{t+2}, \ldots, y_{t+p})$ and the columns corresponding to $\tilde{y}_t$.

Express all in compact form:

$$0 = \Phi \begin{bmatrix} y^*_- \\ \tilde{y} \\ y^*_+ \end{bmatrix} + \nu^* + a^*\mathrm{ec}^* + \varepsilon^* \tag{7}$$

and partition $\Phi = \left[\Phi_{-}^{*}\ \tilde{\Phi}\ \Phi_{+}^{*}\right]$ such that $\tilde{\Phi}$ contains the columns corresponding to $\tilde{y}$ and $\Phi_{-}^{*},\ \Phi_{+}^{*}$ contain the columns relating to the past and future p observations, respectively. We obtain:

$$-\left[\Phi_{-}^{*}y_{-}^{*} + \Phi_{+}^{*}y_{+}^{*} + \nu^{*} + a^{*}\mathrm{ec}^{*}\right] = \tilde{\Phi}\tilde{y} + \varepsilon^{*}, \tag{8}$$

where ε^{*} is multivariate normal $N(0, \Sigma^{*})$.

Now, the elements of $\tilde{y}$ are permuted such that the missing values are ordered first. For example, if $N = 5$ and the observation of the third variable would be missing, the permutation would be $\rho = (3\ 1\ 2\ 4\ 5)$. The vector $\tilde{y}$ in (8) becomes $\tilde{y}_{\rho} = \tilde{y}(\rho)$. To keep the equation system unchanged, we have to permute the columns of $\tilde{\Phi}$ accordingly, $\tilde{\Phi}_{\rho} = \tilde{\Phi}(\cdot, \rho)$.

Assuming a normal prior for $\pi(\tilde{y}_{\rho}) = N(m_0, M_0)$, the posterior distribution is multivariate normal

$$\pi(\tilde{y}_{\rho}|y^{*}, \beta, S, \theta) = N(m, M) \tag{9}$$

with, respectively, variance and mean

$$\begin{aligned} M &= \left(\tilde{\Phi}_{\rho}'\Sigma^{*-1}\tilde{\Phi}_{\rho} + M_0^{-1}\right)^{-1} \\ m &= M\left(-\tilde{\Phi}_{\rho}'\Sigma^{*-1}\left[\Phi_{-}^{*}y_{-}^{*} + \Phi_{+}^{*}y_{+}^{*} + \nu^{*} + a^{*}\mathrm{ec}^{*}\right] + M_0^{-1}m_0\right) \end{aligned}$$

Given the multivariate joint posterior distribution of $\tilde{y}_{\rho}$, we can derive the conditional posterior of the missing elements $\tilde{y}_{\rho_1}$ given the observed values $\tilde{y}_{\rho_2}$. To this aim, we partition the moment vector $m = (m_1, m_2)$ into vectors corresponding to the missing (m_1) and the observed (m_2) elements of $\tilde{y}_{\rho}$. Partition the covariance matrix $M = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix}$ appropriately. Then the conditional posterior of $\tilde{y}_{\rho_1}$ is multivariate normal

$$\pi\left(\tilde{y}_{\rho_1}|\tilde{y}_{\rho_2}, y^{*}, \beta, S, \theta\right) \sim N\left(m_1 + M_{12}M_{22}^{-1}(\tilde{y}_{\rho_2} - m_2), M_{11} - M_{12}M_{22}^{-1}M_{21}\right) \tag{10}$$

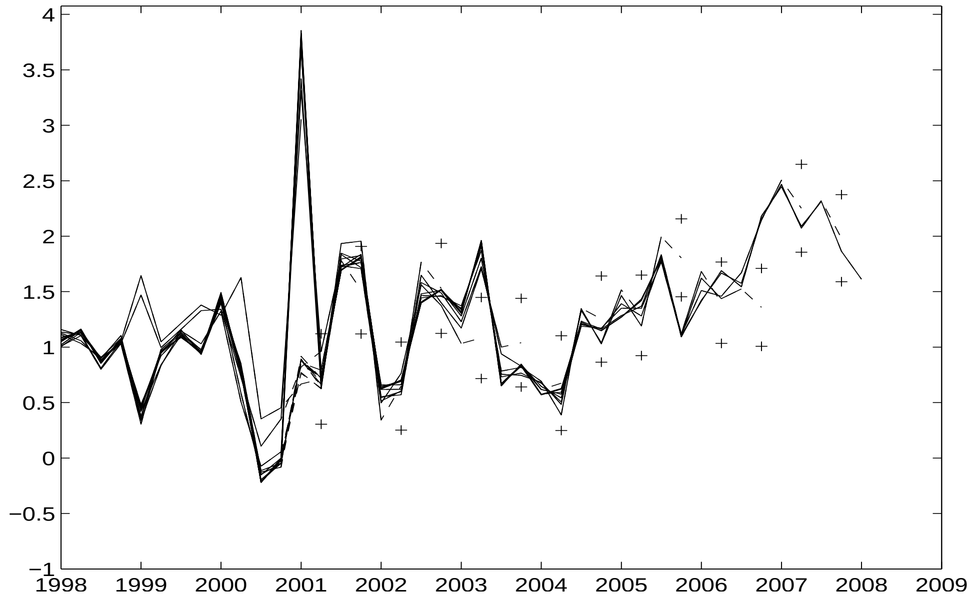
In the present paper, the hyperparameters of the prior for each element of $\tilde{y}_{\rho}$, $\pi(\tilde{y}_{\rho}) = N(m_0, M_0)$ are set to the median of the observed values of the corresponding variable (m_0) and the variance M_0 is set proportional to the interquartile range of the observed values, $M_0 = ((1/1.34) \cdot IQR)^2$.

3.2 Results

Figure 1 illustrates the replacement of missing values and the outlying value in the first quarter of 2001. In each year from 2001 onwards, we work with the data vintage available as of 1st May and as of 1st November. We choose these releases to compare the conditional forecasts we produce in section 4 to the Eurosystem Staff projections published in the Monthly Bulletin of the ECB at a semi-annual frequency in June and December from 2001 up to June 2004, and since then at a quarterly frequency. To produce these forecasts, Eurosystem Staff usually includes information available up to mid-May and mid-November, respectively. Thus, by choosing the releases of 1st May and 1st November we do not incorporate more information than was available to Eurosystem Staff.

In each vintage that we use, it is the case that not only GDP, but also M3 and HICP are missing for the current quarter. For instance, as of November 1st, a first release of the current year's second quarter GDP is available, and a first release of September's

Figure 1: Real money growth. Replacement of outlying and missing values. +/- One standard deviation confidence interval denoted by the crosses.



value for M3 and HICP are available. Conditional on the model structure and actual data for interest rates, we thus substitute the missing quarterly values with estimates. In figure 1, the dashed line connects the release of the second-last quarter with the mean estimate of the current (last) quarter real M3 growth rate. The crosses define the interval of +/- one standard deviation around the mean estimate. Most of the time, with the exception of three out of the fourteen cases, subsequently released observations lie within the interval. The exceptions are May 2003, November 2005 and November 2006, meaning the second quarter's observation in 2003 and the last quarter's observations in 2005 and 2006, respectively.

Beginning with November 2005, we interpret the significant positive deviation of model-implied real M3 growth rate from data releases as indicative of inflationary pressures building up due to monetary conditions. On the other hand, in November 2006 model-implied real M3 growth lies significantly below released data. Apparently, at that time monetary conditions were not indicative of inflationary pressures. We will back up these interpretations with additional evidence from the forecasting exercises in section 4 and from the evaluation of different monetary conditions in section 5. The same reasoning as for November 2006 applies to May 2003.

A marginal case is the situation as of November 2001. The first release of the fourth quarter's observation lied marginally above the +/- one standard deviation interval. Subsequent releases remained at the upper bound of the estimated interval. The forecasting and evaluation exercises will show that the assessment of monetary conditions for inflation pressures were more ambiguous in this situation.

4 Forecasting

4.1 Producing the forecast

Given that missing values are replaced by model-based estimates, the uncertainty in the inflation forecast will also incorporate the uncertainty about the missing values. The forecast we produce is conditional, meaning that we keep the short-term interest rate at its actual level. Given the posterior distribution, we obtain draws from the joint forecasting density (where the conditioning on β is dropped for notational convenience)

$$\pi\left(y_{T+1},\ldots,y_{T+H}|y_{\setminus\tilde{y}}\right)=\int\pi\left(y_{T+1},\ldots,y_{T+H}|y_{\setminus\tilde{y}},\tilde{y},S_T,\theta\right)\pi\left(\tilde{y},S_T,\theta|y_{\setminus\tilde{y}}\right)d\tilde{y}dS_Td\theta$$

by recursively simulating dynamic forecasts:

$$y_{T+h}^{(m)}=\nu_{S_{T+h}^{(m)}}^{(m)}+\sum_{j=1}^{3}A_{j,S_{T+h}^{(m)}}^{(m)}y_{T+h-j}^{(m)}+\alpha_{S_{T+h}^{(m)}}^{(m)}\beta Y_{T+h-1}^{(m)}+\varepsilon_{T+h}^{(m)},\qquad \begin{array}{l}h=1,\ldots,H,\\ m=1,\ldots,M\end{array} \tag{11}$$

where H is the forecast horizon and (m) denotes the mth draw of the MCMC sampler. If $T+h-j\leq T$, lagged values are replaced with actual observations, $y_{T+h-j}^{(m)}=y_{T+h-j}$, and past missing elements are replaced by their mth estimated value, $\tilde{y}_{T+h-j}=\tilde{y}_{T+h-j}^{(m)}$. The same rule applies to the level variables, $Y_{T+h}^{(m)}=y_{T+h}^{(m)}+Y_{T+h-1}^{(m)}$ with $Y_T^{(m)}=Y_T$ and/or $\tilde{Y}_T=\tilde{Y}_T^{(m)}$. Future values of the error term are independent of past values, therefore $\varepsilon_{T+h}^{(m)}$ is a draw from the multivariate normal $N(0,\Sigma^{(m)})$. Conditional on $S_{T+h-1}^{(m)}=k$, future values for the state indicator, $S_{T+h}^{(m)}$, are sampled from $\xi_{k\cdot}^{(m)}=(\xi_{k1}^{(m)},\xi_{k2}^{(m)})$. For $h=1$, $S_T^{(m)}$ corresponds to the mth sampled value of S_T. Thus, the forecasts take into account uncertainty about the parameters and the state indicator, and also uncertainty about missing values.

In order to compare the forecasts to the Eurosystem staff projections published in the Monthly Bulletin of the ECB, we condition the forecasts on the actual interest rate level, which is achieved by feeding in the shock combination that leaves the interest rate unchanged over the forecast horizon. Given that the ECB's focus lies on average yearly HICP inflation, the conditional inflation forecasts are cumulated to obtain the future path of the (log) price index $Y_{C,T+h}^{(m)}=Y_{C,T+h-1}^{(m)}+Y_{T+h}^{(m)}$. Average yearly inflation for the year Y, Y_{Y} is obtained by averaging over all M values:

$$Y_{\mathrm{Y}}=M^{-1}\sum_{m=1}^{M}\frac{1}{4}\sum_{t=T-H}^{T+H}\Delta_4Y_{Ct}^{(m)}I_{t\in\mathrm{Y}}, \tag{12}$$

where $\Delta_4Y_{Ct}=Y_{Ct}-Y_{C,t-4}$ and $I_{t\in\mathrm{Y}}$ is the indicator function, i.e. is one if quarter t falls into year Y and is zero otherwise. The summation begins at $T-H$ to take into account already observed values for the current year's HICP.

4.2 Comparison to Eurosystem staff projections

The model-based estimates of real M3 growth (see section 3.2) suggested three periods which may be worth discussing in more details. Two of them coincide with periods where the ECB's internal assessment of monetary conditions proved to be relevant for determining their effect on future inflation prospects (Fischer et al., 2007). Therefore, in the following we will focus in particular on the forecast situation at the turn of 2001/2002, 2005/2006 and also at the most recent one of 2007/2008.

The first two lines in each panel of the tables 1 to 3 reproduce the ECB's interval projections for the current and the next year, where the mean of the projection range is added for expositional convenience. The next two lines report the mean and the interquartile range of the MS-VECM conditional forecasts. The last three columns in the tables reproduce the dates and the extent of changes in the ECB's policy rate. The Monthly Bulletin of June usually reports projections for the current and the subsequent year, while the December issue contains a very precise estimate of current-year inflation and the projections for the following two years. The reported range is symmetric around the mean projected value. The size of the range corresponds to twice the average absolute differences between actual outcomes and past projected values (European Central Bank, 2001). Given the conditional nature of both the Eurosystem staff projections and the MS-VECM forecast, we will not compare them by formal statistical criteria like the root mean squared error. Rather, we will compare the forecasts first in a qualitative way with respect to their indication of future inflation prospects. A more formal assessment follows below.

In general, the ECB's published projections are based on an assessment of economic conditions for future inflation. We view the forecasts based on the MS-VECM as providing additional information about future inflation prospects determined by monetary developments. From June 2001 to June 2005 (see table 1), Eurosystem staff projected decreasing inflation rates at each forecast horizon, which, together with the ECB's internal assessment of liquidity conditions for future inflation prospects (Fischer et al., 2007, p.25ff), justified the two rounds of interest rate decreases in 2001 and at the end of 2002 through June 2003. We observe that in November 2001, the MS-VECM projects inflation rates well above 2%, although not at an accelerating rate. This may reflect the liquidity effect of decreasing policy rates, given that half a year later, the inflationary pressure from the monetary side decreased. In May 2002 the MS-VECM projects inflation rates remaining around 2%, which lies in the range of Eurosystem Staff projections. Cross-checking with figure 1 we observe that real M3 growth by that time had dropped to a quarterly rate of 0.6%. At first sight, the conclusion we may draw from the MS-VECM projections in November 2001 is thus ambiguous. However, as shown in section 5, taking into consideration expected interest rate developments would yield conditional forecasts with reduced inflation pressures (see table 6 below). Conditional forecasts including actual money development in the fourth quarter of 2001 would not necessitate a significant upward revision. This additional evaluation is consistent with the cited ECB's internal assessment of liquidity conditions and would lead us to conclude that upside inflation risks by that time would not originate from monetary developments.

Table 2 contains the projections at the turn of 2005/2006. In November 2005, the MS-VECM indicates strong inflationary pressures, given that the conditional inflation forecast increases above 4% at the two-year horizon. This is consistent with the ECB's assessment of upside inflation risks coming from monetary developments (Fischer et al., 2007, p.32). The rising inflation risks initiated a gradual increase in policy rates, the first move occurring on 6 December, followed by another five up to December 2006, raising the policy rate gradually by 125 basis points. We will see that a significantly low actual value nominal M3 growth in December transitorily brought down inflation pressures stemming from the monetary side.

Table 3 summarizes the conditional forecasts for the recent turn 2007/2008. We see that the MS-VECM continuously projects rising inflation rates. Incorporating information up to March 2008 the projected inflation rates for 2008 and 2009 are revised upwards from, respectively, 2.3% and 2.6% to 3%. Nevertheless, inflation rates are not projected to accelerate as it was at the end of 2005. As we by now know, although inflation risks were considerable, the ECB decided to stay put given that the financial crisis was expected to spread out to Europe and was beginning to put the interbank market under heavy stress. We may interpret that monetary developments were putting inflation at risk, but not so strongly for inflation to be expected to increase at an accelerating rate. This provided some leeway for the ECB to stay put.

So far, we illustrated with selected projection periods how MS-VECM conditional forecasts may be cross-checked with Eurosystem Staff projections. Given that both forecasts are conditional, a formal comparison by statistical criteria like the root mean squared error is problematic. Evaluating them like unconditional forecasts implies the assumptions that the conditioning path (the frozen EURIBOR rate in the MS-VECM case) is not too far away from the unconditional prediction and that policy feedbacks (the impact of future policy rate changes) would not be too large. Faust and Wright (2008) propose a method to evaluate the efficiency of conditional forecasts. However, we do not pursue their approach because on one side the Eurosystem Staff projections are mainly based on an evaluation of the economic stance and on the other side the MS-VECM is a very simple system including mainly monetary variables. Both can thus not be efficient in the sense of (Faust and Wright, 2008).

Nevertheless, in table 4 we compare the forecasts under a long-horizon and a short-horizon perspective. Panel (a) contains what we call the long-horizon perspective. The panel displays the deviation in percentage points of the first release of projected two-years ahead inflation versus the final release of observed inflation. Given that the ECB began publishing its projections in 2001, the first year we can evaluate is 2003. The first projected values for 2008 (available at the end of 2006) are compared to the published projections in the March 2008 Monthly Bulletin. So far, the Eurosystem Staff projection of two-years ahead inflation on average has been biased downwards. The bias is significant, given the standard deviation of 0.13%. On the other hand the deviations of the MS-VECM, although lower on average and not significantly biased, are more volatile. We see in particular that at the end of 2005, the MS-VECM indicates strong inflation pressures for 2007, with the first released projection lying 2.2 percentage points higher than the final release of observed inflation.

In panel (b), we present the short-term perspective. The reported differences relate to the June release of the projected actual year's inflation rate versus the final release of observed inflation. The Eurosystem Staff projections clearly outperform the MS-VECM projections. The current's year inflation rate is nearly exactly predicted using information available up to mid-May. The MS-VECM, although not significantly, usually underpredicts inflation. This obviously is due to the fact that the MS-VECM contains no information on short-term real and price developments like the labor market situation, wages and production prices.

5 When is money growth relevant?

In this section we illustrate how the MS-VECM and the method of substituting missing values by model-based estimates can be used to assess the impact of different monetary scenarios on inflation projections. We work with the same selection of periods as in section 4.2 to show that keeping track of monetary developments is crucial in particular when they indicate strong inflation pressures.

In the May and November vintages used to produce what we call the baseline projections, usually the last observations, i.e. the second-quarter and the last-quarter observations of the respective year, for M3 and for HICP are missing, and observed interest rates do neither incorporate eventual policy moves taking place in June or December, respectively, nor do they incorporate other influences coming from the real side. We may compare the baseline projections with projections obtained under different monetary scenario. One possibility is to include policy rate changes and their effect on the term spread. Another possibility is to include, in addition to the interest rate changes, an expected value for nominal M3 growth, which may reflect one of all potential monetary policy effects. To design and evaluate the different monetary scenarios at the turn of 2001/2002, 2005/2006 and 2007/2008, we use the data vintages available on 1 January of, respectively, 2002, 2006 and 2008. In these vintages, real GDP is the only variable still missing at the end of the sample. In a first scenario, to assess the impact of interest rates, we estimate the model including observed values for the interest rates and treating M3 growth and inflation as missing. Based on the estimate, we then form the projections. The second scenario additionally includes the observation on M3 growth in the last quarter of the year and treats inflation as missing. Based on this model we also form projections.

An example of the data structure under the different scenarios is depicted in table 5. In the baseline scenario using the vintage available on 1st November, M3 growth and inflation, in addition to GDP, are missing in the fourth quarter. In the vintage of 1st January 2006, the policy action of December 2006 is observable. The fourth-quarter short-term interest rate average increases by 14 basis points and the average long-term rate by 10 basis points, narrowing the spread by 4 basis points.

Beginning again with the period at the turn of 2005/2006, in table **??** we see that inflation projections based on observed interest rate increases in the fourth quarter and handling the other three variables as missing[3] still indicate strong inflation pressures, although they are lower than in the baseline scenario. Projected inflation for 2006 and 2007 decreases by 10 basis points to 3.7% and 4.2%, respectively. In table 7, in the column labelled 2005, we see that in this scenario estimated nominal M3 and real M3 growth are higher than the long-term average.[4] Conditioning the forecast on observed M3 growth in the fourth quarter amounting to 1.26%, which is significantly lower than the observed long-term average, curbs inflation pressures. Inflation for 2006 is projected to be 3.1% and 2.9% in 2006 and 2007, respectively. This amounts to a reduction of 70 basis points and 140 basis points relative to the baseline scenario, respectively. Thus, high inflation pressures also contained in monetary developments gave justification for a policy action in December 2005. However, it is the case that monetary developments appear to have

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[3] Note that any interest rate scenario could be fed into the model.

[4] The stars indicate significant departure from the long-term average. For nominal M3 growth, given that the variable is non-stationary, we have to interpret this as purely descriptive.

been crucial for alleviating inflationary pressures. This low nominal M3 growth rate lead to an estimated significantly lower real M3 growth rate of 0.5%. The first release of the observed fourth quarter value reaches 0.75%, which is lower, but not significantly so than the long-term average.

The discrepancies between the forecasting scenarios are not that striking at the turn of 2001/2002. In all scenarios, inflation is projected to decrease to 2.3% or 2.4% in 2002 and then to pick up again in 2003 to 2.5% if we include interest rate moves and to 2.9% if we include observed M3 growth in the last quarter of 2001. Overall, the inflation projections are not too divergent in this period. In table 7, we see that the first release of observed nominal M3 growth was not significantly higher than the long-term average. Although real money growth is estimated to be significantly above-average in each scenario, we see that nominal M3 growth is estimated to be roughly on average in the baseline scenario and to fall significantly below-average when interest rate developments are included.

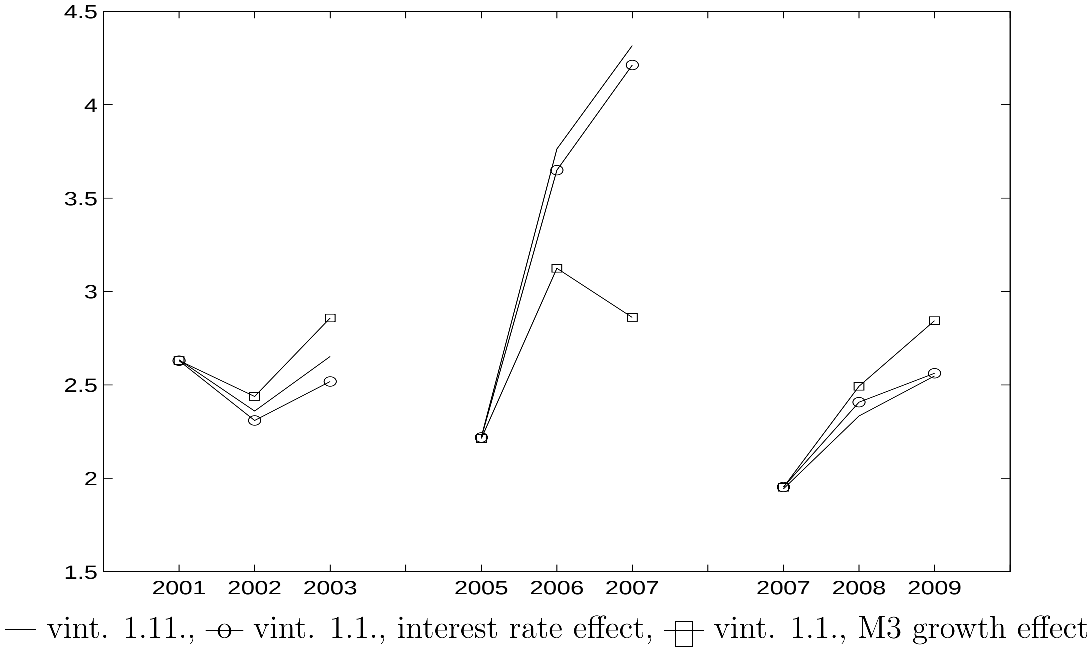
The inflation projections discussed so far are consistent with the ECB's internal assessments of monetary conditions for future inflation. In 2001, M3 growth developments were not viewed as containing momentum for inflationary pressures. The situation was different in 2005, where monetary developments were assessed to be crucial for future inflation risks. The columns for 2001 and 2005 in table 7 show that the small MS-VECM is able to reproduce these assessments. At the turn of 2001/2002, although all estimates of real M3 growth were significantly above-average, observed and estimated nominal M3 growth rates all were insignificantly departing from or were significantly below long-term average. At the turn of 2005/2006 the monetary situation is different. All estimated nominal and real M3 growth rates are significantly higher than the long-term average. It is only the very contained observed growth in nominal M3 which reduces projected inflation pressures at the two-year horizon.

At the recent turn of 2007/2008, nominal and real M3 are growing considerably above-average. Nevertheless, compared with the turn of 2005/2006, inflation pressures are contained given that the baseline scenario projects inflation to raise to 2.3% and 2.6% in 2008 and 2009, respectively. Taking into consideration monetary developments, inflation is expected to increase to 2.8% in 2009. The projections based on the different scenarios are indicative of monetary developments containing upward inflationary risks, but not to accelerating rates as it had been at the turn of 2005/2006. This interpretation is corroborated by the inflation projections we made with data available up to March 2008 (see table 3). Given that the effects of the financial crisis were beginning to spill over to Europe, the ECB, despite that inflation was obviously at risk, did not increase interest rates further. In March 2008, the MS-VECM projects inflation rates to increase to 3.0% for 2008 and to stay there throughout 2009. We may interpret that monetary conditions did not seem to have accelerating effects on inflation.

6 Conclusion

In the present paper we produce real-time conditional euro area inflation forecasts based on a Markov switching vector error correction model (MS-VECM). The system includes M3 growth, HICP inflation, the 3-month EURIBOR, the 10-year government bond yield and real GDP. Missing and outlying values in the data vintages are estimated conditional on the model estimate and all observed data. We confront the conditional forecasts

Figure 2: Inflation forecasts under different monetary scenarios.



to the inflation projections published in the June and December issue of the Monthly Bulletin of the European Central Bank (ECB) and to the history of the Council's decisions on interest rate changes. We find that they are consistent with the European Central Bank's assessment of liquidity conditions for future inflation prospects. A more formal comparison, although this is more problematic due to the conditional nature of both forecasts, shows that so far, the ECB's first release of two-years ahead projected inflation rate has been biased downwards. The long-term conditional MS-VECM forecast, although being more volatile, display so far no significant bias. On the other hand, the ECB's current year inflation projections published in the June Bulletin, clearly outperform the MS-VECM conditional forecasts and deliver a very precise estimate of actual inflation.

The method of substituting missing end-of-sample values with model-based estimates can be used to evaluate different monetary scenarios. We show that in particular at the turn of 2005/2006 actual nominal M3 growth in the fourth quarter of 2005 turned out to be crucial to curb inflation pressures indicated by the data observed up to the third quarter. On the other hand, monetary developments at the turn of 2001/2002 and at the recent turn of 2007/2008 do not seem to indicate inflation pressures to accelerating rates.

We interpret the evidence obtained in favour of the two-pillar approach of the ECB's monetary policy strategy. Moreover, the results also yield evidence in favour of using the conditional forecasts produced with the MS-VECM as indicators of periods when monetary developments have to be followed closely. As such, they may be used as one cross-check with inflation projections mainly based on the economic stance.

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Table 1: Eurosystem staff and MS-VECM inflation projections. Period 2001/2002. The bold-faced values are the finally released inflation figures.

Monthly Bulletin	Information available up to	Projection year			ECB interest rates		
		2001	2002	2003	With effect from	Bid rate	Change in bp
June 2001	17.5.2001	2.5[*]	1.8				
		(2.3 2.7)	(1.2 2.4)				
	1.5.2001	2.2	1.5				
		(2.1 2.4)[+]	(0.7 2.3)		11 May	4.5	-25
Dec. 2001	15.11.2001	2.7	1.6	1.5	31 Aug.	4.25	-25
		(2.6 2.8)	(1.1 2.1)	(0.9 2.1)	18 Sep.	3.75	-50
	1.11.2001	2.6	2.4	2.7			
		(2.60 2.67)	(1.9 2.8)	(1.6 3.6)	9 Nov.	3.25	-50
June 2002	15.5.2002	**2.5**	2.3	1.9			
			(2.1 2.5)	(1.3 2.5)			
	1.5.2002		2.2	2.1			
			(2.1 2.4)	(1.4 2.9)			
			2.3	**2.1**			

[*] The mean point of the ECB inflation projection range is added for expositional convenience.

[+] The interval is the interquartile range of the projection distribution.

Table 2: Eurosystem staff and MS-VECM inflation projections. Period 2005/2006. The bold-faced values are the finally released inflation figures.

Monthly Bulletin	Information available up to	Projection year 2005	2006	2007	ECB interest rates With effect from	Bid rate	Change in bp
June 2005	20.5.2005	2.0[*]	1.5				
		(1.8 2.2)	(0.9 2.1)				
	1.5.2005	1.4	1.2				
		(1.2 1.6)[+]	(0.4 1.9)				
Dec. 2005	21.11.2005	2.2	2.1	2.0			
		(2.1 2.3)	(1.6 2.6)	(1.4 2.6)			
	1.11.2005	2.2	3.8	4.3			
		(2.19 2.25)	(3.3 4.2)	(3.3 5.3)	6 Dec.	2.25	+25
June 2006	19.5.2006	**2.2**	2.3	2.2			
			(2.1 2.5)	(1.6 2.8)	8 Mar.	2.5	+25
	1.5.2006		1.9	2.0			
			(1.7 2.1)	(1.1 2.89)	15 Jun.	2.75	+25
			2.2	**2.1**			

[*] The mean point of the ECB inflation projection range is added for expositional convenience.

[+] The interval is the interquartile range of the projection distribution.

Table 3: Eurosystem staff and MS-VECM inflation projections. Period 2007/2008. The bold-faced values are the finally released inflation figures.

Monthly Bulletin	Information available up to	Projection year 2007	2008	2009	ECB interest rates With effect from	Bid rate	Change in bp
June 2007	11.5.2007	2.0[*]	2.0				
		(1.8 2.2)	(1.4 2.6)		14 Mar.	3.75	+25
	1.5.2007	2.0	2.9				
		(1.8 2.2)[+]	(2.1 3.6)		13 Jun.	4	+25
Dec. 2007	14.11.2007	2.1	2.5	1.8			
		(2.0 2.2)	(2.0 3.0)	(1.2 2.4)			
	1.11.2007	2.0	2.3	2.6			
		(1.91 1.98)	(1.9 2.8)	(1.6 3.5)			
March 2008	14.2.2008	**2.1**	2.9	2.1			
			(2.6 3.2)	(1.5 2.7)			
	1.3.2008		3.0	3.0			
			(2.7 3.2)	(2.2 3.8)			

[*] The mean point of the ECB inflation projection range is added for expositional convenience.

[+] The interval is the interquartile range of the projection distribution.

Table 4: Comparison of conditional forecasts

(a) First versus final release in pp

Forecast	2003	2004	2005	2006	2007	2008	Average	St. Deviation
MB	-0.6	-0.5	-0.6	-0.6	-0.1	-1.0*	-0.57	0.13
MS-VECM	+0.6	-0.2	-0.3	+0.5	+2.2	-0.8*	+0.33	0.47

(b) June versus final release in pp

Forecast	2001	2002	2003	2004	2005	2006	2007	Average	St. Deviation
MB	0	0	-0.1	0	-0.2	+0.1	-0.1	-0.04	0.04
MS-VECM	-0.3	-0.1	+0.3	-0.5	-0.8	-0.3	-0.1	-0.26	0.14

* compared to MB/March 2008, see table 3

Table 5: Data structure under different scenarios at the turn of 2005/2006.

Scenarios	Vintage 1.11.2005 baseline		Vintage 1.1.2006 int.rates included		Vintage 1.1.2006 M3 growth included	
Data level as of	Q3	Q4	Q3	Q4	Q3	Q4
R	3.27	3.32	3.27	3.42	3.27	3.42
r	2.13	2.2	2.13	2.34	2.13	2.34
Δm	2.80	*	2.79	*	2.79	1.26
Δp	0.80	*	0.76	*	0.76	*
$yr^{(a)}$	*	*	1.44	*	1.44	*

$^{(a)}$ in logs

Table 6: Inflation forecasts under different scenarios.

Forecasted year	Vintage 1.11. baseline	Vintage 1.1. interest rates included	Vintage 1.1. M3 growth included	Finally released
2001	2.6			2.5
2002	2.4	2.3	2.4	2.3
2003	2.7	2.5	2.9	2.1
2005	2.2			2.2
2006	3.8	3.7	3.1	2.2
2007	4.3	4.2	2.9	2.1
2007	2.0			2.1
2008	2.3	2.4	2.5	3.4-3.6*
2009	2.6	2.6	2.8	2.3-2.9*

* ECB Monthly Bulletin, September 2008

Table 7: Relevance of quarterly M3 growth and real M3 growth under different forecasting scenarios.

Scenarios and variables	2001	2005	2007
Vintage 1.11., data up to Q3			
M3 growth, mean[a]	2.07	2.00	2.02
(stand.dev.)	(0.07)	(0.07)	(0.07)
Real M3 growth, mean	0.77	0.81	0.87
(stand.dev.)	(0.06)	(0.06)	(0.06)
Vintage 1.1., Q4 data			
M3 growth	2.18	1.26	2.81
(t-value)	(1.86)	(-10.82)*	(12.15)*
Real M3 growth	1.94	0.75	1.80
(t-value)	(19.71)*	(-1.08)	(16.10)*
Vintage 1.11., baseline			
M3 growth Q4, estimated	1.95	2.61	2.53
(t-value)	(-1.51)	(8.97)*	(7.85)*
Real M3 growth Q4, estimated	1.51	1.80	1.98
(t-value)	(12.19)*	(17.63)*	(19.27)*
Vintage 1.1., including interest rates			
M3 growth Q4, estimated	1.88	2.62	2.52
(t-value)	(-2.13)*	(9.12)*	(7.69)*
Real M3 growth Q4, estimated	1.45	1.83	1.94
(t-value)	(11.61)*	(18.11)*	(18.61)*
Vintage 1.1., including M3 growth			
Real M3 growth Q4, estimated	1.76	0.50	2.24
(t-value)	(16.61)*	(-5.55)*	(23.68)*

[a] Given that M3 growth is non-stationary, the mean and the standard deviation do not exist. The moments thus are to be interpreted as purely descriptive.