Capturing the Link between M3 Growth and Inflation in the Euro Area – An Econometric Model to Produce Conditional Inflation Forecasts

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In this paper, we capture the link between M3 growth and inflation with a vector error correction model. The analysis also includes the 10-year government bond yield, the three-month EURIBOR interest rate and GDP. The long-run link between M3 growth and inflation is observable in the raw data. Over the years 1980–2006, we find that M3 growth and inflation are cointegrated, which means that deviations from long-term average real money growth lead to mean-reverting adjustment processes to restore the average level of real money growth. The full effect of an unexpected monetary shock thus materializes over time in the level of inflation, after a transitory period during which GDP and interest rates have been affected as well. Out-of-sample yearly conditional inflation forecasts are produced from 2001 to 2006 which are compared to Eurosystem staff projections. Qualitatively, the monetary model predicts future inflation rates which are consistent with the ECB's assessment of future inflation prospects.

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1 Introduction

Over the past seven years, two questions have repeatedly been addressed in debates on the relevance of monetary analysis for the conduct of monetary policy in the euro area. The first question concerns the relationship between money growth and inflation. After the first four years of policy implementation in the euro area, the Governing Council, in May 2003, confirmed and clarified the two-pillar approach of the ECB's monetary policy strategy (ECB, 2004). The Governing Council stated that monetary analysis, which constitutes the second pillar of the approach, is relevant for assessing the medium- to long-term liquidity perspectives for the euro area, as it exploits the long-run link between money and prices. Although the reference value for M3 growth was never intended to be interpreted as a target rate, the fact that yearly M3 growth rates have exceeded this reference value (4.5%) since 1999 (chart 1) has fueled the debate on the two-pillar approach. Unusually high growth rates between 7% and 8% were observed from 2001 to 2003. However, the ECB's internal assessment of underlying trend growth rates and corrections for estimates of non-resident holdings of marketable instruments issued by financial institutions and for temporary portfolio shifts did not indicate inflationary pressures for the medium- to long-term horizon (Fischer et al., 2007, p. 29). In 2005 and 2006, M3 growth surged again to 7% and 9%, respectively. In contrast to the previous period, however, considerable inflationary pressures built up this time, given that monetary expansion was accompanied by increasing loan growth rates (8% and 10%, respectively) and that economic recovery was gaining momentum (Fischer et al., 2007, p. 32).

The second question which has been repeatedly raised in recent years concerns the stability of the money demand function, which traditionally

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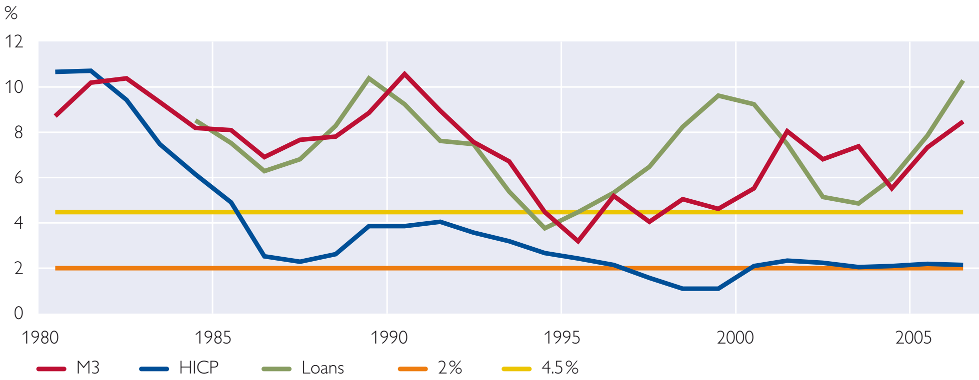
Chart 1

Annual Growth Rates of M3, HICP and Loans



Source: Author's calculations.

has been regarded as a prerequisite for monetary analysis to be meaningful in the policy implementation process. The increase in M3 growth rates occurred unexpectedly, rising from a quarterly rate of 0.7% in the fourth quarter of 2000 to 4% in the first quarter of 2001. This shift in the level of M3 had the consequence that no stable relationship between nominal money, prices and income could be estimated anymore with time series extending beyond 2001. Excess liquidity measured by the difference between M3 and the usual determinants of money demand, which are income and opportunity costs, remains substantial and persistent since 2001. Carstensen (2006) and Greiber and Lemke (2005) explain excess liquidity with changes in liquidity preferences since 2001, which are due to increased uncertainty and decreased confidence of economic agents. Including measures of stock market returns and volatility, and indicators of overall uncertainty, these authors can restore a stable money demand function. Including inflation beside the nominal interest rate as an additional opportunity cost of holding real balances, Dreger and Wolters (2006) also document that money demand is stable for observation samples extending beyond 2001.

In the present paper, we do not address this issue. If the rise in M3 growth is temporary, which means that it shifts the level of M3 once without affecting the trending rate, M3 growth will exceed the long-term average growth level once and then return back to its long-term average, which means that the inflation rate will not increase to a permanently higher level in the future. In this sense the discussion of the long-run relationship between money growth and inflation is independent from the issue of money demand stability.[1] For an analysis of the latter issue see Kaufmann and Kugler (2006).

Several studies have discussed the information content of money growth

[1] *Note that occasional shifts in the money demand function do not invalidate the relationship between money and the price level. Moreover, as long as the frequency of shifts remains low and as long as shifts are detectable to be taken into account within a short period of time, monetary analysis yields relevant results that may complement the first pillar of the ECB's monetary policy strategy.*

for inflation. Among others, the studies by Neumann and Greiber (2004), Bruggeman et al. (2005), Assenmacher-Wesche and Gerlach (2006) document the relevance of "trend" or core money growth for "trend" or core inflation by estimating the trend components with the Hodrick-Prescott filter (HP filter), with an exponentially weighted moving average filter or with a low-frequency band filter. Kugler and Kaufmann (2005) show that a stable relationship between nominal money growth and inflation is observable also in the raw data. Hofmann (2006) presents a comprehensive study which evaluates whether the inclusion of monetary variables (and also many other real variables) can improve naive or simple autoregressive forecasts of inflation. Generally, he finds that M3 growth and trend M3 growth can improve forecasts at a two-year horizon, whether they are computed directly or dynamically. Carstensen (2007) reaches the conclusion that various measures of core money growth contain valuable information for future inflation. The forecasting performance of single-indicator inflation models and of semi-structural models is improved when core money growth measures are included. The latter study also documents the stable forecasting performance of the semi-structural inflation models.

These results are not inconsistent with those derived from structural models, which traditionally assign no direct role to money. As Woodford (2006) shows, the results of the empirical literature are perfectly compatible with predictions derived by means of a standard New Keynesian dynamic stochastic general equilibrium model. The model can be complemented by a money demand function without affecting the main behavioral equations describing the dynamics of inflation and production and the monetary policy reaction function, irrespective of the parameterization of the money demand function and irrespective of whether money demand is stable or not. Woodford shows that, given the empirical fact that core money growth impacts on core inflation, core money growth may enter the Phillips curve as a proxy for core or "target" inflation in monetary policymaking. Beck and Wieland (2007) show that the inclusion of an assessment of monetary developments in the monetary policy reaction function may be useful. If measures of real unobservable variables like the output gap or the equilibrium real interest rate are subject to systematic errors, stabilization benefits may be obtained by taking into account developments in long-term money growth.

In the present paper, we use the same empirical model as Kugler and Kaufmann (2005) to estimate the relationship between money growth and inflation observable in the raw data. We also include the ten-year government bond yield, the three-month EURIBOR interest rate and GDP in the analysis to account for the effects on inflation coming from the real and the financial market side of the economy. Section 2 offers an economic interpretation of the empirical model that is used to analyze the relationship between the variables. After describing the data and analyzing their statistical properties, the model is estimated. The results yield evidence for a stable long-run relationship between money growth and inflation. Mean reverting dynamics drive money growth and inflation on a balanced growth path, which means that real money growth in the long run equates real GPD growth and changes in the income velocity of money. Impulse response functions and the forecast error variance decomposition document the relevance of shocks in nominal money growth for inflation. A shock in nominal money growth leads to a permanent increase in inflation in the long run and explains more than 40% of the inflation forecast error variance after six years.

Section 3 uses the model to produce out-of-sample yearly conditional inflation forecasts for the period from 2001 to 2006 and compares them to Eurosystem staff projections published in the December issues of the ECB's Monthly Bulletin of the respective years. The forecasts at the end of 2001 and 2002 are qualitatively in line with Eurosystem staff projections. The model predicts no rising inflationary pressures at a two-years horizon despite a persistent level of inflation. By contrast, the forecasts made at the end of 2005 and 2006 suggest rising inflationary pressures stemming from the monetary side of the economy. These forecasts are in line with the qualitative assessment of two-year-ahead monetary developments provided by the ECB. Therefore, we conclude in section 4 that conditional inflation forecasts obtained from the vector error correction model provide one alternative of cross-checking inflation projections based on the economic assessment of Eurosystem staff.

2 An Econometric Model for Money Growth and Inflation

2.1 Economic Intuition

The starting point of money demand analysis is the relationship between real money balances ($m-p$, assuming unitary price elasticity), real income (y) and a measure for the opportunity costs of holding money ($R-r$):

$$m-p=\beta_0+\beta_y y-\beta_r(R-r)-\upsilon \quad (1)$$

where υ represents the deviation from equilibrium. The spread between the long-term (R) and the short-term (r) interest rate is used here as a measure for opportunity costs. Alternatively, one could include "own M3 opportunity costs" using the spread between the return on assets not included in M3 and those included in M3 (as in Coenen and Vega, 2001) or using the inflation rate (as in Dreger and Wolters, 2006).

Expressed in terms of growth rates, the equation becomes

$$\Delta m-\Delta p=\beta_y\Delta y-\Delta\upsilon \quad (2)$$

which relates real money growth to real income growth. If we interpret the equation as a long-run or equilibrium relationship, a change in the inflation rate will not affect the spread, although it affects the level of nominal interest rates (Fisher effect). Therefore, we neglect changes in the spread. Under this assumption, the last term $\Delta\upsilon$ obtains the interpretation of velocity change. The equilibrium relationship also implies that, as long as real money growth equates real income growth and velocity changes, no change in the inflation rate will be observed. A monetarist interpretation would be that a one-time increase in the nominal money growth rate would lead to an equal increase in the inflation rate in the long run, where real money growth would again equate real income growth and velocity changes. During the transition to higher growth levels, the effects on real in-

Table 1

Data Labels and Frequency

r	Three-month EURIBOR FM.M.U2.EUR.4F.MM.EURIBOR3MD_.LST	monthly
R	Ten-year government bond yield FM.M.U2.EUR.4F.BB.U2_10Y.YLD	monthly
y	Real GDP (euro area fixed composition) ESA.Q.I2.S.0000.B1QG00.1000.TTTT.Q.U.A	quarterly, SA
m	M3 historical time series index (euro area-11 + GR until December 2000, euro area-12 from 2001 onward)	monthly, NSA
p	HICP overall index ICP.M.U2.N.000000.4.INX	monthly, NSA

Source: ECB statistical website and Area-Wide Model Data.
Note: SA: seasonally adjusted; NSA: not seasonally adjusted.

come, inflation, interest rates and velocity will ultimately depend on the transmission mechanism (see also Friedman, 1971, pp. 55–61). A reduced-form empirical estimation of the relationship between the variables would capture these effects by allowing general dynamics in the model.

2.2 Data and Statistical Properties

The relationship between money growth and inflation is investigated using quarterly data covering the years from 1980 to 2006. The data are taken from the ECB's statistics website and are combined with the data from the Area-Wide Model (AWM) for the euro area to obtain series dating back to 1980. The ten-year government bond yield (R) and the three-month EURIBOR interest rate (r) are simply linked. Real GDP (y) and HICP (p) are chained by growth rates. M3 (m) corresponds to the historical index series published by the ECB.[2] Table 1 contains data sources, frequency and seasonal adjustments. Quarterly data are obtained by calculating the average of monthly data. Seasonal adjustment is performed in EViews using the Census X12-procedure.

A first look at the data reveals that over the sample period real money grew at an average quarterly rate of 0.87%, which equals an annual rate of nearly 3.6%. The fact that real GDP growth averaged at a quarterly rate of 0.52% (annual rate: 2%) implies that velocity decreased at 1.6% on average. In table 2 we investigate the unit root (augmented Dickey-Fuller – ADF) and the stationarity (Kwiatkowski-Phillips-Schmidt-Shin – KPSS) properties of the data. The null of a unit autoregressive root cannot be rejected for the level of both interest rates, M3 growth, inflation and GDP. The null of stationarity is rejected for all these variables. The statistics obtained with the first difference of the variables reject the unit root hypothesis and do not reject the null of stationarity. For real money growth the results indicate stationarity and for the spread they indicate marginal stationarity. Thus, nominal M3 growth (Δm) and inflation (Δp)

[2] *We use the index series which from October 1997 onward is adjusted for reclassifications, revaluations and exchange rate variations.*

Table 2

Unit Root and Stationarity Tests

		ADF[1]		KPSS[2]
Series	Trend included	Statistic	p-value	Statistic
R	no	−1.01	0.75	0.82**
	yes	−2.55	0.31	0.29**
ΔR	no	−5.84**	0.00	0.25
r	no	−1.53	0.52	0.82**
Δr	no	−7.00**	0.00	0.10
Δm	no	−1.90	0.33	0.62*
	yes	−1.73	0.73	0.21*
$\Delta\Delta m$	no	−14.49**	0.00	0.12
Δp	no	−2.29	0.18	0.85*
	yes	−1.65	0.76	0.21*
$\Delta\Delta p$	no	−3.74**	0.00	0.22
y	no	0.16	0.97	1.44**
	yes	−1.74	0.73	0.14
Δy	no	−3.70**	0.01	0.31
Δm–Δp	no	−3.07*	0.03	0.41
R–r	no	−2.85	0.05	0.20

Source: Author's calculations.

[1] *Augmented Dickey-Fuller-test: The number of lags is selected according to the modified SIC criterion (Ng and Perron, 2002).*

[2] *Kwiatowski-Phillips-Schmidt-Shin-test: Newey-West bandwidth selection (Kwiatkowski et al., 1992); ** and * denote significance at the 1% and the 5% level, respectively.*

each follow a non-stationary process, while their linear combination, real money growth (Δm–Δp), follows a stationary process,[3] i.e. Δm and Δp are cointegrated.

In this empirical setting, cointegration between nominal money growth and inflation is an important issue for monetary policy. Given non-stationary inflation, the best forecast for future inflation would be the current level of inflation with a forecast confidence interval which increases over time. Theoretically, inflation could reach any level in the future as all shocks permanently feed into the level of inflation. Non-stationarity without cointegration would thus imply that inflation (and ultimately the price level) could not be controlled by monetary policy actors. The link to nominal money growth is therefore crucial. The assumption that policy actions which use interest rates as an instrument endogenously affect money holdings and money growth restores controllability. For given stationary velocity changes and real GDP growth, changes in nominal money growth will be reflected in inflation changes.

2.3 Vector Error Correction Model

Given the cointegration properties of the data, we proceed and analyze the dynamic relationships setting up a vector error correction model (VECM). In the vector

[3] *A nonstationary autoregressive process contains a unit root, which means that the best forecast of future growth rates (in the absence of a drift and of shocks) is today's growth rate. If uncertainty about future shocks is taken into account, the variance of the forecast increases with the forecast horizon. Econometrically, if Δx_t represents the growth rate of a variable, this may be expressed as $\Delta x_t = \Delta x_{t-1} + \varepsilon_t = \sum_{i=0}^{t} \varepsilon_{t-i}$ with $\varepsilon_t \sim N(0,\sigma^2)$. Assuming zero future shocks, the best univariate forecast is then $E(\Delta x_{t+h}) = \Delta x_t$ with variance $Var(\Delta x_{t+h}) = h\sigma^2$. Thus, the growth rate does not converge to a constant value, but may drift to any rate given that it equals the sum of all past shocks. A stationary process has an autoregressive root less than unity and returns to a constant value. If $\Delta x_t = c + \rho \Delta x_{t-1} + \varepsilon_t = \sum_{i=0}^{\infty} \rho^i (c + \varepsilon_{t-i})$ with $\rho < 1$, then with increasing horizon, the forecast will converge to a growth rate of $c/(1-\rho)$ with a variance of $\sigma^2/(1-\rho^2)$.*

$X_t = (R, r, \Delta m, \Delta p, y)$ we collect the long- and short-term interest rate, money growth, inflation and (logarithmic) real GDP. We then estimate the model in first differences:

$$\Delta X_t = C + A_1 \Delta X_{t-1} + ... + A_p \Delta X_{t-p} + \alpha\beta X_{t-1} + \varepsilon_t \qquad (3)$$

with $\varepsilon_t \sim iid\ N(0, \Sigma)$. The vector C captures drifts in the level variables; the matrices $A_1, \ldots A_p$ capture the dynamics between the data. The cointegrating relationships detected in the data are contained in the vector $\beta = \begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -1 & 0 \end{bmatrix}$.
Deviations from the long-run relationships ($\beta X_{t-1} \gtrless 0$) initiate adjustments in the variables to restore the long-run equilibrium. The adjustment coefficients are found in α. In this setup, nominal money growth obtains a role for future inflation dynamics, not only through past changes in nominal money growth by themselves, but also through adjustments to deviations from long-run average real money growth, i.e. nominal money growth relative to inflation.

System (3) is estimated by maximum likelihood (Johansen, 1995), which makes it possible to estimate all parameters simultaneously. Two lags ($p = 2$) of the variables suffice to remove autocorrelation in the residuals. We find evidence for two cointegration relationships, one including the term spread and the other real money growth. Table 3 shows the estimated cointegration relationships and table 4 the adjustment coefficients. The restrictions on the cointegrating vectors and the zero restrictions on the adjustment coefficients are jointly tested and not rejected. The χ^2-statistic with 9 degrees of freedom is 15.39 with a p-value of 0.08. Using this approach, we observe that real GDP enters the cointegration space with the spread. For the observation sample, this may reflect the relationship between expected investment returns and growth prospects affecting GDP level.[4] The zero restrictions on the adjustment coefficients (table 4) are based on statistical insignificance. The remaining estimated coefficients have the right sign. Deviations from long-term real money growth lead to significant adjustments of nearly equal extent in both inflation and money growth. The lagged adjustment of inflation to excess real money growth may be explained by short-term price rigidities. Lagged adjustment in nominal money growth implies that nominal money growth is not weakly exogenous. This may on the one hand reflect policy reactions, such as a monetary policy tightening (or easing) if the real money growth rate exceeds (or falls short of) the long-term average. On the other hand, in a rational expectations model with fully flexible prices, expectations about future nominal money growth are already incorporated in today's inflation. Therefore, the impression may arise that money lags inflation. In the last line of table 4 we find the adjusted R^2. The quoted figures are considerably high for the equations of the quarterly change in money growth and quarterly inflation acceleration. In these cases, the sys-

[4] *Given that the spread is marginally stationary according to the univariate unit root test, on statistical grounds it is also sensible that a non-stationary variable enters the cointegration space in the multivariate approach.*

Table 3

Cointegrating Vectors

	R	r	Δm	Δp	y
β_1	1	−1	0	0	−0.03 (0.01)
β_2	0	0	1	−1	0
X_9^2	15.39 (p-Wert: 0.08)				

Source: Author's calculations.
Note: Standard error of freely estimated parameters in brackets.

Table 4

Error Correction Coefficients

Error term	Adjustment in				
	ΔR	Δr	$\Delta\Delta m$	$\Delta\Delta p$	Δy
$R – r – \beta_1 y$	−0.07 (0.04)	0.04 (0.05)	0 (–)	0 (–)	0.12 (0.05)
$\Delta m – \Delta p$	0 (–)	0 (–)	−0.19 (0.09)	0.14 (0.05)	0.18 (0.11)
adjusted R^2	0.29	0.3	0.25	0.38	0.19

Source: Author's calculations.
Note: Standard errors in brackets.

tem explains 25% and 38%, respectively, of the variation in the variables.

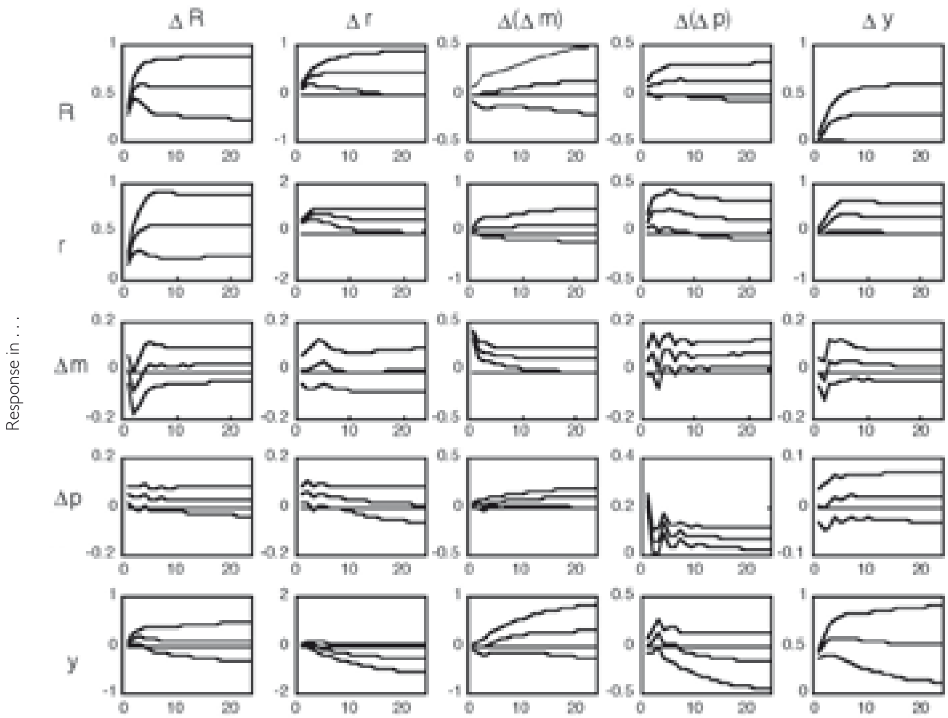
The estimated adjustment coefficients suggest that a substantial share of 15% to 20% of excess real money growth materializes in inflation changes and money growth within one quarter. To give an example: If real money growth unexpectedly increased by 1 percentage point, next to other dynamic adjustments, error correction in the following quarter would lead to an increase in inflation by 0.14 percentage point and to a decrease in money growth by 0.19 percentage point. Thus, real money growth in the following period would still exceed average growth by 0.67 percentage point. Conditional on the assumption that no further shocks occur, the rest of the adjustment process to the new levels of nominal money growth and inflation also takes into account the dynamic relationship between the variables, which runs through the matrices A_1, A_2. These dynamic adjustments are depicted in chart 2, which contains the impulse responses along with the 95 percentile interval.[5]

Table 5 presents test results for the model estimated respectively up to the end of 2001 to 2006 to assess the validity of the restrictions in the models used to produce conditional inflation forecasts in section 3. Based on the p-values in brackets, the trace test, which indicates at most two cointegrating vectors for the model estimated up to the end of 2006, does not reject cointegration for the other samples. Moreover, assuming two cointegration vectors for each sample

[5] *To build the interval, we draw 1,000 times from the joint coefficient and error covariance distribution, compute generalized impulse responses for each draw and take the 2.5th and the 97.5th percentiles of the responses at each point in time.*

Chart 2

Generalized Impulse Response Functions



Source: Author's calculations.

Note: Mean reaction with 95 percentile interval.

Table 5

Johansen Cointegration Trace Test: Stability of Test Results

	Estimation Up To											
Number of cointegrating vectors	Q4 01		Q4 02		Q4 03		Q4 04		Q4 05		Q4 06	
0	78.69*	(0.01)	71.47*	(0.04)	73.87*	(0.02)	79.02*	(0.01)	82.77*	(0.00)	80.33*	(0.01)
≤ 1	43.79	(0.11)	45.37	(0.08)	47.55*	(0.05)	50.93*	(0.03)	54.06*	(0.01)	50.82*	(0.03)
≤ 2	25.56	(0.14)	26.08	(0.13)	27.34	(0.09)	29.97*	(0.05)	32.85*	(0.02)	29.50*	(0.05)
X^2_9	12.49	(0.19)	11.19	(0.26)	12.40	(0.19)	13.81	(0.13)	12.54	(0.18)	15.39	(0.08)

Source: Author's calculations.
*Note: p-value in brackets; * denotes significance at the 5% level.*

period, the joint restrictions on the cointegration space as in table 3 and the zero restrictions on the adjustment coefficients as in table 4 are not rejected. The χ^2-statistics, except for the estimation sample ending in 2006, all have p-values well above 10%. Therefore, we will work with the restricted model in the following.

2.4 Impulse Responses and Variance Decomposition

To use the econometric model to produce conditional inflation forecasts, it is sensible to assess whether unexpected movements, so-called shocks, in the variables determine inflation dynamics and if so, which one are most influential. For forecasting, the relevance of variables does not de-

Table 6

Generalized Forecast Error Variance Decomposition

(a) Forecast error variance in Δm

	Attributable to				
Horizon	ΔR	Δr	$\Delta\Delta m$	$\Delta\Delta p$	Δy
1	0.05	0.01	0.89	0.05	0.02
4	0.06	0.03	0.82	0.08	0.04
8	0.06	0.04	0.80	0.11	0.05
12	0.06	0.04	0.78	0.13	0.05
16	0.06	0.05	0.77	0.14	0.05
20	0.07	0.05	0.75	0.16	0.05
24	0.07	0.05	0.74	0.18	0.05

(b) Forecast error variance in Δp

	Attributable to				
Horizon	ΔR	Δr	$\Delta\Delta m$	$\Delta\Delta p$	Δy
1	0.09	0.13	0.06	0.90	0.01
4	0.12	0.16	0.13	0.82	0.03
8	0.12	0.15	0.23	0.72	0.04
12	0.11	0.14	0.31	0.65	0.05
16	0.11	0.13	0.37	0.59	0.05
20	0.10	0.12	0.41	0.55	0.05
24	0.10	0.11	0.44	0.52	0.05

Source: Author's calculations.

pend on whether the driving forces originate from monetary policy actions or from economic developments, however. Therefore, we do not identify a model in which we could interpret the shocks structurally as monetary policy (supply) or demand shocks. Rather, we clean each shock, the impulse in each variable, from the contemporaneous influence from shocks in other variables. This means, for example, that a shock in money growth can then be interpreted as a shock in money growth, irrespective of whether it originates from a money supply of money demand shock. The advantage of this approach, based on a generalized decomposition of the error covariance matrix, is that the impulse responses and the variance decomposition are independent of the variable ordering (Pesaran and Shin, 1998).

The responses depicted in chart 2 are consistent with economic intuition; in general it takes about one and a half years for each shock to fully materialize at the new long-term level of all variables. Our interest focuses on the relationship between inflation and money growth. A shock to money growth (chart 2, third column) leads to a significant permanent increase in inflation (fourth line). Temporarily, inflation also reacts positively to interest rate shocks, which is consistent with cost channel effects in monetary policy transmission (Ravenna and Walsh, 2006; Chowdhury et al., 2006; Kaufmann and Scharler, 2006). Money growth reacts positively to shocks in inflation, but only marginally significantly. We observe a transitory short-term negative reaction to shocks in the long-term interest rate, a reaction which is consistent with portfolio allocation considerations. Interest rates react positively to shocks in GDP and to shocks in the inflation rate. Finally, GDP has a hump-shaped reaction to shocks in the short-term interest rate and decreases permanently in the long-run. Though not significant, the reaction to shocks in money growth is positive, that to inflation shocks negative.

The importance of money growth for inflation developments is assessed with the forecast error variance decomposition, which is also based on a generalized decomposition of the error covariance matrix. Table 6 presents the decomposition for money growth and inflation at various time horizons.[6] For nominal money growth, the major share of the forecast error variance at all horizons is explained by own shocks. This share decreases from 89% at the one-quarter-ahead horizon to 74% at the six-year-ahead horizon. The share of inflation shocks increases to approximately 20% as the time horizon increases. For inflation, we observe that, as in the case of nominal money growth, the share explained by own shocks is larger than the share explained by money growth shocks. Over time, up to the six-year-horizon, it decreases to 52%. Money growth shocks, however, explain an increasing share of the forecast error variance in inflation over time, amounting to 44% in the long run.

These results are consistent with those obtained from the frequency-filtered data in Assenmacher-Wesche and Gerlach (2006). The latter find that low-frequency components of money growth (core money growth) influence low-frequency components of inflation (core inflation). This is reflected here in the fact that money growth and inflation are cointegrated, i.e. that they contain the same stochastic, or long-term, component. Permanent shocks which disequilibrate balanced growth between the variables lead to a first, partial error correction adjustment in the following period. The full adjustment to the new long-term growth level implied by the initial shock occurs gradually over time through the dynamics linking the variables of the system. Permanent shocks thus do not feed through immediately into inflation but fully materialize only over time. This pattern is confirmed in the forecast error variance decomposition.

3 Conditional Inflation Forecasts

We now use the model to produce out-of-sample conditional inflation forecasts up to a two-year horizon based on estimated samples for the period from 2001 to 2006. We compare the forecasts to published Eurosystem staff projections. Given the conditional nature of the forecasts and the projections, an evaluation of the forecasts with usual formal statistical criteria like the root mean squared error is not sensible. Therefore, we qualitatively compare the inflation forecasts with respect to their indication for future inflation prospects to evaluate the usefulness of the inflation forecast obtained by the VECM in cross-checking the inflation projections based on the Eurosystem staff economic assessment.

3.1 Forecast Setting

From June 2001 to June 2004, the ECB published semiannually inflation projections based on Eurosystem staff macroeconomic projections. Since June 2004, inflation projections have been published quarterly. In the pres-

[6] *We omit the variance decomposition of both interest rates and GDP to save space and because, for all variables, the main share of the forecast error variance is explained by own shocks.*

ent study we concentrate on the projections published in the December issues of the ECB's Monthly Bulletin, which report a precise estimate of current-year inflation and the projections for the following two years based on information obtained up to mid-November. The ECB reports a projection range, the range being 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 (ECB, 2001). In the following, we compare inflation forecasts derived from the VECM presented in section 2 with the projections published in the Monthly Bulletin of the ECB. To create an information level similar to that reflected in the Eurosystem staff projections, we condition the forecasts on data up to the third quarter in each year. Of course, as we are using finally published data series, we still have an information advantage, in particular with respect to GDP. The comparison of projections using real-time data vintages is addressed in Kaufmann and Kugler (2007).

We make conditional dynamic inflation forecasts by keeping the short-term interest rate at its actual level over the forecast horizon h:

$$\Delta X_{T+h|T} = C + A_1 \Delta X_{T+h-1|T} + \ldots + A_p \Delta X_{T+h-p|T} + \alpha\beta X_{T+h-1|t} + \varepsilon_{T+h}$$

For $T+h-j<T$, $j=1,\ldots,p$, observed values are substituted for $\Delta X_{T+h-j|T}$, $\Delta X_{T+h-j|T} = \Delta X_{T+h-j}$; otherwise the forecasted values are inserted. The future level of the variables $X_{T+h-1|T}$ is obtained by cumulating the forecasted changes in the variables $X_{T+h-1|T} = X_{T+h-2|T} + \Delta X_{T+h-1|T}$. The short-term interest rate is kept constant over the entire forecasting horizon, i.e. the second element in $\Delta X_{T+h-j|T}$ equals zero in each period $T+h-j>T$. This is achieved by feeding in the shock combination ε_{T+h} necessary to obtain a projected zero change in the short-term interest rate, taking into account the dynamics $A_1, \ldots, A_p$, the error adjustment α and the covariance structure Σ.

We produce out-of-sample forecasts, which means that we estimate the model up to the third quarter of each year, starting in 2001 up to 2006. Forecasts of yearly inflation Y are obtained by summing up the quarterly dynamic inflation forecasts of a specific year y (e.g. 2001):

$$Y_y = \sum_{t=T-2}^{T+H} X_{t|T} I_{t\in y}$$

where $I_{t\in y}$ is the indicator function, which means that it equals 1 if quarter t falls into year y and is zero otherwise. The summation begins in $T-2$ to take into account that we already have observed values for the current year's inflation rate. The forecast horizon extends to two years ahead, which means that $H=9$.

3.2 Comparing Results against Eurosystem Staff Projections

Table 7 contains the conditional forecasts. The first two lines reproduce the inflation projections published in the Monthly Bulletin. The mean of the projection range is added for expositional convenience. The next two lines present the conditional forecasts obtained from the VECM model. We observe that at the end of 2001 and of 2002, the VECM model forecasted persistent inflation in contrast to the Eurosystem staff projections for the

Table 7

Eurosystem Staff Projections and Conditional VECM Inflation Projections

Monthly Bulletin	Information available up to	Projection year							
		2001	2002	2003	2004	2005	2006	2007	2008
Dec. 01	15. 11. 2001 Q3 01	2.7[1] (2.6–2.8) 2.1 (2.0–2.3)[2]	1.6 (1.1–2.1) 2.5 (2.0–3.0)	1.5 (0.9–2.1) 2.2 (1.5–3.0)					
Dec. 02	15. 11. 2002 Q3 02	**2.5**	2.2 (2.1–2.3) 2.2 (2.1–2.4)	1.8 (1.3–2.3) 2.1 (1.6–2.6)	1.6 (1.0–2.2) 2 (1.3–2.8)				
Dec. 03	15. 11. 2003 Q3 03		**2.3**	2.1 (2–2.2) 2 (1.8–2.1)	1.8 (1.3–2.3) 1.7 (1.1–2.2)	1.6 (1.0–2.2) 1.6 (0.9–2.4)			
Dec. 04	20. 11. 2004 Q3 04			**2.1**	2.2 (2.1–2.3) 2.1 (2.0–2.3)	2 (1.5–2.5) 2 (1.5–2.5)	1.6 (1.0–2.2) 1.9 (1.1–2.6)		
Dec. 05	21. 11. 2005 Q3 05				**2.1**	2.2 (2.1–2.3) 2.1 (2.0–2.3)	2.1 (1.6–2.6) 2.8 (2.3–3.3)	2 (1.4–2.6) 2.9 (2.2–3.7)	
Dec. 06	14. 11. 2006 Q3 06					**2.2**	2.2 (2.1–2.3) 1.9 (1.8–2.1)	2 (1.5–2.8) 2.6 (2.1–3.1)	2.2 (1.6–2.8) 2.7 (1.9–3.4)

Source: Eurosystem staff macroeconomic projections for the euro area and author's calculations.

Note: For each year, the first two lines reproduce the mean projection and the projection range published by the ECB; the next two lines display the mean projection and the projection interquartile range of the VECM. The bold-faced values are the finally released inflation figures.

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

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

years 2002–2003 and 2003–2004. In both years the conditional inflation forecast remained at 2% or some decimal percentage points higher, while decreasing inflation rates were projected based on Eurosystem staff assessments. The VECM conditional inflation forecasts and Eurosystem staff projections are comparable both in level and direction at end-2003 and end-2004. Recently, at the end of 2005 and 2006, the VECM indicates stronger inflationary pressures at the two-year horizon than Eurosystem staff projections. Qualitatively, the conditional forecasts reflect the ECB's assessment of current monetary developments with respect to inflation prospects. The ECB viewed increasing money growth rates driven by credit expansions and good economic prospects as indicating upside risks for future inflation.

For the year 2006, the finally released inflation rate is 2.2%. The VECM forecasted 1.9% based on data up to the third quarter of 2006. The discrepancy vis-à-vis the Eurosystem staff projections may be explained by the fact that the ECB's focus lies on yearly inflation measured as average year-on-year inflation. The conditional forecasts computed here, on the other hand, measure yearly inflation as the sum of quarterly inflation rates, i.e. the year's average inflation.

In years during which the inflation rate increases or decreases the two measures differ slightly.

Of course, the conditional forecasts of the VECM are based on a restricted information set and contain crude information on inflationary prospects stemming from the monetary side of the economy. The model does not include expectations about developments in other real or price variables like the unemployment rate, unit labor costs or producer prices, which may affect future inflation. Nevertheless, given the stable relationship between money growth and inflation over the past, conditional forecasts may provide an indicator that can be used in cross-checking the forecasts obtained from structural modeling. As Beck and Wieland (2007) show, the inclusion of information from monetary developments may improve inflation forecasts and policy reactions in situations where the uncertainty about real unobservable variables like the output gap and the real interest rate is high.

4 Conclusions

We use the empirical model presented in Kugler and Kaufmann (2005) to analyze quarterly data covering the period from 1980 to 2006. The model is estimated for data on nominal M3, HICP, the government bond yield, the three-month interest rate and real GPD. We then produce yearly out-of-sample conditional inflation forecasts for the period from 2001 to 2006 and compare them to Eurosystem staff projections published in the Monthly Bulletin of the ECB.

For the sample period, we find that nominal M3 growth and inflation are non-stationary but cointegrated. This means that real money growth, which in the period under review averages 3.6% annually, is stationary. This also means that deviations from this long-term average lead to dynamic adjustments in inflation and money growth to restore the level of 3.6% in the long run. The full effect of an unexpected monetary shock thus materializes over time in the level of inflation, after a transitory period during which GDP and interest rates have been affected as well. The impulse responses show that a shock in nominal money growth affects inflation permanently and that the dynamic adjustment to the new long-term level takes about one and a half years. At the same time horizon, nominal money growth shocks explain about 30% of the inflation forecast error variance. The share increases to 44% at the six-year horizon. Shocks to inflation also have a permanent effect on nominal money growth, though marginally significant. Their share in explaining nominal money growth forecast error variance is low, amounting to 12% at the one-and-a-half-year and to 18% at the six-year horizon.

To obtain conditional inflation forecasts, we keep the short-term interest rate at the current level over the entire forecasting horizon. At the end of 2001 and 2002, the model does not forecast rising inflation rates, although the latter are predicted to remain at slightly above 2% over the forecasting period. At the end of 2005 and 2006, the model predicts inflation rates to rise above 2.5%, a value which exceeds that predicted by Eurosystem staff projections. Qualitatively, however, these results are consistent with the ECB's assessment of future inflation prospects. Monetary expansion driven by rising credit growth against the background of favorable economic prospects is viewed as a critical upside risk to inflation.

Of course, the inflation forecasts presented in this study are based on restricted information and do not use additional information contained in real or price variables other than GDP and interest rates. They may prove useful in cross-checking inflation forecasts based on structural models, however, as they provide information on inflation prospects stemming from the monetary side of the economy.

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