Is there a role for monetary aggregates in the conduct of monetary policy for the euro area?

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Abstract: The conduct of monetary policy rules is typically analyzed in the New Keynesian framework, where inflation depends on expected future inflation rates and the output gap. In this paper, the approach is contrasted with the pstar model, which uses a broader measure for inflationary pressures, as the price gap measures the disequilibria on the goods market and on the money market. A monetary policy rule, which includes the price gap, as an alternative to the Taylor rule is proposed. To get some impression on the robustness of results the performance of the rules is compared in empirically estimated small scale macro models.

The views expressed in this paper are those of the author and do not necessarily reflect those of the Deutsche Bundesbank. The author is grateful to I. Brüggemann, G. Lombardo, J.-R. Kim, K.-H. Tödter and the participants at the ECB workshop. The standard disclaimer applies.

1 Introduction

The European Central Bank conducts a "two pillar" strategy, in which the monitoring of monetary aggregates has a prominent role. Nevertheless, in the analysis of monetary policy and monetary strategy in the context of small structural models this emphasis is not adequately reflected.

Models are typically specified in a "New Keynesian" style. Aggregate demand depends on expected future demand and the real interest rate. Inflation depends on the output gap and expected future inflation. These models are simulated by including some variant of a Taylor rule, i.e. the central bank adjusts the nominal interest rate in response to deviations of actual output from its potential level and deviations of the inflation rate from its desired target value. In empirical work the lagged interest rate is often included to account for "inertia". These models - with some exceptions - do not include any reference to monetary aggregates.

In the literature, there are a few attempts to incorporate money in a small structural model of the economy. One possibility is by assuming a nonseparable utility function in consumption and money. Nelson (2000) includes money directly in the IS function. Ireland (2000) argues that money has to be included in both the IS function and the Phillips curve, but finds only a small and insignificant coefficient. McCallum (2001) finds that it does not make a difference whether monetary aggregates are included in a "small prototype model" or not.

Another strand of the literature tries to find a role for money as an information variable. Coenen, Levin and Wieland (2001) use money to reduce the uncertainty about current output which is subject to major revisions for some quarters after its first publication. Dotsey and Hornstein (2000) do find only a limited role for the US. In all these approaches money does not play a causal role in influencing output and inflation.

The small empirical model for the euro area developed in this paper includes an aggregate demand function where the output gap depends on the short-term real interest rate and the change in real money. The foreign component (real effective exchange rate) appears to be of minor relevance. The model further includes an equation explaining long-run money demand which is used to construct the equilibrium price level (pstar) and the price gap and an equation for the term structure of interest rates which specifies the relationship between the short-term interest rate (policy instrument) and the long-term rate (opportunity cost measure in the money demand equation). Inflation depends on the output gap, the price gap and the change in pstar. Empirical estimates for the euro area have shown, that the price gap has a significant influence on inflation (e.g., Gerlach and Svensson (2001)).

In this paper it is analyzed, whether the pstar approach can be regarded as a useful alternative in incorporating money and whether a monetary policy rule taking the price gap into account gives better results to inflation variability than a simple Taylor rule. Compared with the Taylor rule a pstar rule incorporates a broader measure of future inflationary pressures than just the output gap. By deriving the equilibrium price as the long-run attractor of the price level it is implicitly forward looking.

Several models are estimated and analyzed as to get some impression of the robustness of the results. As there are indications of the rather limited role of forward-looking components purely backward-looking versions of the model equations are also estimated.

2 Macro models

At the moment the New-Keynesian model is the workhorse for the analysis of monetary policy rules. With respect to the Phillips curve, which includes the output gap, it can be regarded as a special case of the pstar approach, i.e. the velocity gap, derived from a long-run money demand equation, is not taken into account.

2.1 New Keynesian model

The basic New Keynesian model consists of two equations: an aggregate demand equation and a Phillips curve (Clarida, Gali and Gertler (1999), Woodford (1999), McCallum and Nelson (1999)). The equations are derived from optimal decision rules of economic agents. Output is explained as a function of expected future output and the ex-ante real interest rate (expectational IS curve). Inflation is a function of expected future inflation and the output gap. Expected future inflation enters due to price rigidity (Calvo (1983), Rotemberg (1982)). The output gap acts as a proxy for labour market conditions that affect wages and therefore, marginal costs. Marginal cost conditions are reflected by prices, due to monopolistic competition. Both equations are strictly forward looking. Persistence in this basic model is introduced by serial correlation of the error terms of the equations.

Alternatively, persistence can be introduced by taking lagged variables of output and inflation into account. In the backward/ forward-looking (hybrid) version the IS function is

$$\tilde{y}_t = \delta y_{t-1} + (1-\delta)\, E_t \tilde{y}_{t+1} + \sigma\,(r_t - E_t \pi_{t+1}) + e_t \tag{1}$$

and the Phillips curve is

$$\pi_t = \alpha \pi_{t-1} + (1-\alpha)\, E_t \pi_{t+1} + \kappa\, \tilde{y}_t + w_t \tag{2}$$

where $\tilde{y}_t$ is the output gap, π_t the inflation rate and r_t the short-term interest rate (policy instrument).[1] E_t is the expectations operator. It is assumed that the shocks are independent and serially uncorrelated with variances equal to σ_e^2 and σ_w^2.

[1] All variables - with the exception of interest rates - are expressed in logs.

The relevance of lagged output may be explained by habit persistence (Fuhrer (2000)). The importance of real wages for economic agents (Fuhrer and Moore (1995)) or the existence of polynomial adjustment costs (Brayton, Levin, Tryon and Williams (1997)) may rationalize the inclusion of lagged inflation in the Phillips curve. An alternative explanation is the existence of two types of economic agents. One type of firms is optimizing subject to constraints in the frequency of adjustment (a la Calvo), the other uses a rule of thumb (Roberts (1997), Gali and Gertler (1999)). The parameter α measures the portion of backward-looking economic agents. The "pure" New-Keynesian version is a special case of (2) with $\alpha = 0$. If $\alpha = 1$, equation (2) represents the traditional backward-looking Phillips curve. Roberts (1997) shows, that the Fuhrer and Moore (1995) model with two-period-contracts implies $\alpha = 0.5$.

The inclusion of lagged values of inflation and output in the respective equations is justified by estimation and simulation results in the literature. E.g., Fuhrer (1997) and Rudebusch (2000) find that lagged inflation is more important than the forward looking variable.[2] Judd and Whelan (2001) show that high coefficients for the forward-looking variables might be generated when applying the GMM as estimation procedure.

2.2 Pstar approach

The pstar approach offers a broader measure of inflationary pressures as the output gap used in (2). The starting point of the pstar approach, originally developed by Hallman, Porter and Small (1991), is the quantity equation

$$m + v = p + y \tag{3}$$

where m is the money stock, v is velocity, p is the actual price level and y is real output. The equilibrium price level p^* is defined as that price level that would prevail at the actual money stock, if production and velocity were in equilibrium, i.e. y^* and v^*, respectively.

$$p^* = m + v^* - y^* \tag{4}$$

Combining (3) and (4), the price gap, $(p^* - p)$, i.e. the difference between the equilibrium and the actual price level, is defined as the sum of the output gap $(y - y^*)$ and the velocity gap $(v^* - v)$.

$$p^* - p = (y - y^*) + (v^* - v) \tag{5}$$

The velocity gap is measured by introducing a long-run money demand function

$$m - p = \beta_0 + \beta_1 y + \beta_2 i + u \tag{6}$$

[2] For an overview of empirical results and sensitivity analysis for the estimation of a forward-looking Phillips curve see Jondeau and Le Bihan (2001).

where i is an opportunity cost measure and u is a residual term. This yields the following decomposition of the velocity gap

$$v^* - v = (\beta_1 - 1)(y - y^*) - \beta_2 (i^* - i) + u \tag{7}$$

where $(i^* - i)$ is the interest rate gap, i.e. the difference between the equilibrium level of the interest rate, i^*, and the actual interest rate, i. The equilibrium level i^* is determined by the equilibrium real interest rate and the inflation target.

Pstar is one possibility of including money in a macro model. It implies that money plays a causal role in determining inflation. The approach has been analyzed and applied by Coenen (1998), Gottschalk and Broeck (2000), Gottschalk and Stolz (2001), Trecroci and Vega (2000), Gerlach and Svensson (2001) and Scheide and Trabandt (2000).

3 Empirical estimates for Euro area

The sample period runs from the first quarter of 1980 to the fourth quarter of 2000 at a quarterly frequency. The data are seasonally adjusted. The series for M3, real GDP, potential output, GDP-deflator, short-term and long-term interest rates (three-month money market rate and 10 year rate) are drawn from the database of the ECB's area-wide model (Fagan, Henry and Mestre (2001)).

3.1 IS function

The IS function is estimated in various empirical studies (e.g. Rudebusch and Svensson (1999)) based on a backward looking equation

$$\tilde{y}_t = \delta_0 + \delta_1 \tilde{y}_{t-1} + \delta_2 \tilde{y}_{t-2} + \delta_3 r_{t-1} \tag{8}$$

where $\tilde{y}$ is the output gap and r the real interest rate which is defined as

$$r_t = \sum_{j=0}^{3} i_{t-j}/4 - (p_t - p_{t-4})$$

The lagged real interest rate allows for a transmission lag of monetary policy. Most studies use the short-term real interest rate, Coenen and Wieland (2000) use the respective long-term rate.

As interest rates for the euro area show a decreasing trend over time, it might be necessary to include a time trend in equation (8). OLS estimation of the aggregate demand equation gives an insignificant interest elasticity and an insignificant trend variable. The results improve, if the German interest rate is used as a proxy as was suggested by Peersman and Smets (1999). These results are similar to Gerlach and Smets (1999) who use an unobserved components approach for EMU-5/10. The estimated elasticities differ from Orphanides and Wieland (2000) who use annual data. For quarterly data, the coefficient of the real interest rate is about -0.10.

The estimation of a backward-looking IS function[3] by OLS gives

$$\tilde{y}_t = \underset{(20.00)}{0.90}\,\tilde{y}_{t-1} - \underset{(3.04)}{0.09}\,r_{t-1}$$

$$\bar{R}^2 = 0.86, \quad LM(1) = \underset{(0.55)}{0.36}, \quad LM(4) = \underset{(0.77)}{0.45}, \quad JB = \underset{(0.49)}{1.43}, \quad \sigma_u = 0.0036$$

In parenthesis the t-value of the estimated coefficients are given. $LM(1)$ and $LM(4)$ are Lagrange multiplier tests of autocorrelation of order one and four respectively. JB is the Jarque Bera test of normality. In parenthesis the p-values of the test statistics are given. The test statistics give no indication for autocorrelation or non-normality of the residuals.

The coefficient of the real interest rate has the expected negative sign. It is significant in the case of the German interest rate as a proxy, but is insignificant in the case of a euro area rate, when the real interest rate is measured as in Rudebusch and Svensson (1999). The coefficient does not change, if r_t is used instead of r_{t-1}. Higher order lags of y_t are not significant. Nelson (2000) argues for including the change in real balances.

$$\tilde{y}_t = \underset{(14.06)}{0.83}\,\tilde{y}_{t-1} - \underset{(2.94)}{0.08}\,r_{t-1} + \underset{(2.16)}{0.06}\,\Delta_4 mr_{t-2}$$

$$\bar{R}^2 = 0.83, \quad LM(1) = \underset{(0.89)}{0.02}, \quad LM(4) = \underset{(0.97)}{0.13}, \quad JB = \underset{(0.37)}{1.99}, \quad \sigma_u = 0.0035$$

The lagged annual change in real money balances, $\Delta_4 mr$, has a marginally significant effect on the output gap. If one takes additionally the real effective exchange rate, er_t, into account the result is

$$\tilde{y}_t = \underset{(18.72)}{0.89}\,\tilde{y}_{t-1} - \underset{(4.33)}{0.12}\,r_{t-1} + \underset{(2.39)}{0.04}\,\Delta_4 mr_{t-2} - \underset{(2.53)}{0.01}\,er_{t-1}$$

$$\bar{R}^2 = 0.87, \quad LM(1) = \underset{(0.95)}{0.003}, \quad LM(4) = \underset{(0.95)}{0.18}, \quad JB = \underset{(0.61)}{0.99}, \quad \sigma_u = 0.0034$$

The estimation of a backward/forward-looking equation by GMM using four lags of each variable and the quadratic kernel gives

$$\tilde{y}_t = \underset{(9.58)}{0.71}\,\tilde{y}_{t-1} + 0.29\,E_t\tilde{y}_{t+1} - \underset{(2.01)}{0.05}\,(r_t - E_t\pi_{t+1})$$

$$\bar{R}^2 = 0.83, \quad J = 7.20, \quad \sigma_u = 0.0040$$

[3]Potential output in the area-wide model is estimated by using a Cobb-Douglas production function.

The estimation of a purely forward looking IS curve, i.e. $\delta_1 = 0$, does not yield a sensible coefficient for the real interest rate. Taking the other explanatory variables into account gives

$$\tilde{y}_t = \underset{(22.08)}{0.63}\,\tilde{y}_{t-1} + 0.37 E_t \tilde{y}_{t+1} - \underset{(5.03)}{0.07}\,(r_t - E_t \pi_{t+1}) - \underset{(1.75)}{0.001} er_t + \underset{(3.02)}{0.02}\,\Delta mr_{t-2}$$

$$\bar{R}^2 = 0.84, \quad J = 8.00, \quad \sigma_u = 0.0038$$

3.2 Price gap

The equilibrium price level - for the GDP-deflator[4] - is calculated using the parameters of a long-run money demand equation (Tödter and Reimers (1994), Gerlach and Svensson (2001)).

$$p_t^* = m_t - \hat{\beta}_0 - \hat{\beta}_1 y_t^* - \hat{\beta}_2 i_t^*$$

Alternatively, in the literature the price gap is calculated as the sum of its components: output gap and liquidity gap. For each component the equilibrium level is estimated by applying the HP-filter (Scheide and Trabandt (2000), Fase (2001)) or the Kalman filter (Groeneveld (1998)). Here, the approach via the money demand equation is prefered, as it incorporates more structural economic information in explaining the time series characteristics of velocity.

The long-run money demand equation is estimated by FMOLS using the Bartlett kernel and a truncation parameter of four. The equation for M3 is specified in real terms, $(m_t - p_t)$. The price level, p_t, is measured by the GDP-deflator, the scale variable, y_t, by real GDP and the opportunity cost variable, i_t, by the difference between the yield on long-term government bonds, rl_t, and the own rate of M3, $rm3_t$. The own rate is a weighted average of the returns of the various components of M3.[5]

The income elasticity ($\hat{\beta}_1$) is estimated as 1.36, the semi-interest elasticity ($\hat{\beta}_2$) as -0.53. Similar results are obtained by the application of the Johansen procedure. The estimated coefficients are in the range typically obtained in the literature (e.g., Brand and Cassola (2000), Coenen and Vega (1999)). The approach applied here differs in the measurement of the opportunity cost variable that is traditionally approximated by the long-term interest rate or the difference between the long-term and short-term interest rates. Coenen and Vega (1999) also include the inflation rate in the long-run equation. Since some components of M3 are interest bearing, the difference between the long-term rate and the own rate of M3 is preferable. Inflation or inflation expectations are already incorporated in the long-term interest rate, so this variable is not included in the specification chosen above.

[4] As it is consistent with the analysis of money demand.
[5] This series was supplied by Dedola, Gaiotti and Silipo (2001).

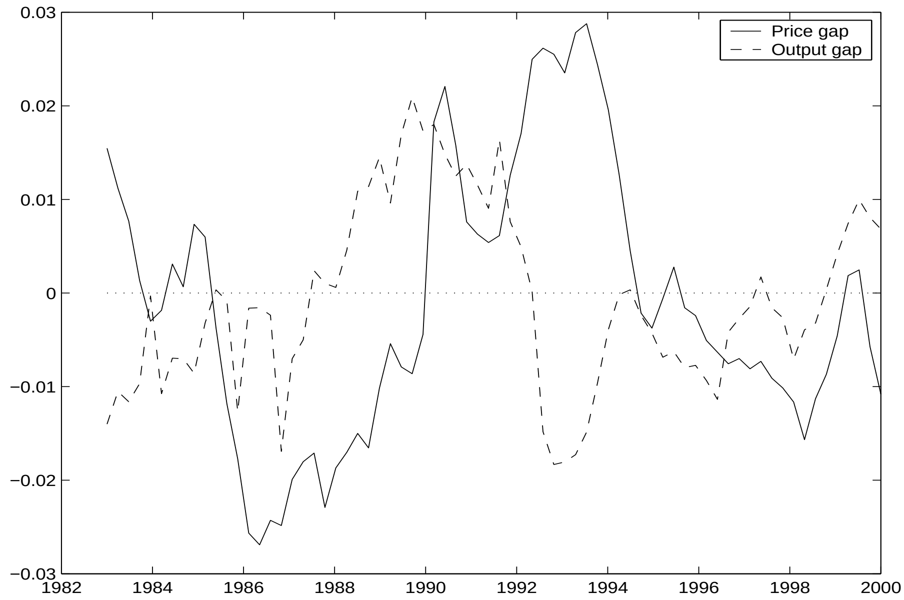

Figure 1: Price gap and output gap for the euro area

Since the interest rates for the euro area have a decreasing trend in the sample period, it is difficult to calculate the equilibrium level of the interest rate, i^*. Therefore, the equilibrium interest rate differential is calculated by using the HP-filter ($\lambda = 1600$). The results do not change significantly, if another smoothing parameter ($\lambda = 15000$) is chosen.

If there is a long-run relationship between the actual and the equilibrium price level, p_t and p_t^* should be cointegrated, i.e. the price gap should be stationary. Applying traditional unit root tests (Augmented Dickey-Fuller and Phillips-Perron), it is not possible to reject the null hypothesis of a unit root in the price gap. By construction, the price gap should be stationary, as it is the sum of the output gap, the interest rate gap and the residual of the long-run money demand equation. Applying the Johansen methodology, the trace test indicates cointegration between p_t and p_t^*, i.e. the hypothesis of one cointegrating relationship cannot be rejected at the 5% level, although the estimated relationship is statistically different from $\begin{pmatrix} 1 & -1 \end{pmatrix}$, which is implied by the theory. The specific assumptions about weak exogeneity cannot be rejected.

3.3 Inflation equation

The (annualized) quarterly inflation rate, π_t - measured as the change in (log) GDP-deflator against the previous quarter - clearly has a decreasing trend over the sample period. As in Gerlach and Svensson (2001) this is accounted for by using the difference between the inflation rate and the inflation target as the endogeneous variable. They model the euro area implicit inflation objective $\hat{\pi}_t$ as gradually converging to the Bundesbank's "inflation target", $\hat{\pi}_t^B$, according to

$$\hat{\pi}_{t+1} - \hat{\pi}_{t+1}^B = \gamma \left(\hat{\pi}_t - \hat{\pi}_{t+1}^B \right) \tag{9}$$

where γ determines the speed of convergence ($\gamma = 0.92$).

OLS estimation of the inflation equation including the price gap gives

$$(\pi_t - \hat{\pi}_t) = \underset{(4.03)}{0.45} \, (\pi_{t-1} - \hat{\pi}_{t-1}) + \underset{(4.52)}{0.12} \, \Delta p_t^* + \underset{(2.20)}{0.20} \left(p_{t-1}^* - p_{t-1} \right) - \underset{(2.71)}{0.04} \, \Delta pim_t \tag{10}$$

$$\bar{R} = 0.79, \quad LM(1) = \underset{(0.25)}{1.33}, \quad LM(4) = \underset{(0.32)}{1.19}, \quad JB = \underset{(0.97)}{0.66}, \quad \sigma_\varepsilon = 0.0084$$

where Δpim_t is the (annualized) quarterly change in (log) import prices. If the equilibrium price level is calculated by applying the HP-filter ($\lambda = 15000$) to the opportunity cost measure, $rlrm3_t$, the coefficient of the lagged price gap does not change: 0.20 (2.15). Changes in import prices have a significant negative effect on inflation. It is implicitly assumed in this framework, that these effects are only temporary. The negative effect is due to the definition of the GDP-deflator. Similar results can be obtained by using oil prices. Trecroci and Vega (2000) and Gerlach and Svensson (2001) estimate the coefficient of the price gap as 0.16 respectively 0.28.[6] Scheide and Trabandt (2000) get 0.18 for quarterly inflation rates. Compared with the other results, this coefficient is relatively high. In their specification Δp_t^* is not included. The effect of a change in p_t^* in equation (10) is increased by the effect via Δp_t^*, i.e. price disequilibria are removed relatively fast. After 10 quarters half of the adjustment has occurred.

OLS estimation including the lagged output gap gives

$$(\pi_t - \hat{\pi}_t) = \underset{(8.03)}{0.63} \, (\pi_{t-1} - \hat{\pi}_{t-1}) + \underset{(2.05)}{0.24} \, \tilde{y}_{t-1} - \underset{(0.78)}{0.01} \, \Delta pim_t$$

$$\bar{R} = 0.77, \quad LM(1) = \underset{(0.04)}{4.28}, \quad LM(4) = \underset{(0.19)}{1.57}, \quad JB = \underset{(0.49)}{1.41}, \quad \sigma_\varepsilon = 0.0094$$

The coefficient of the lagged output gap is about the same as that of the price gap.

The estimation of a hybrid Phillips curve including the price gap gives

$$(\pi_t - \hat{\pi}_t) = \underset{(6.96)}{0.37} \, (\pi_{t-1} - \hat{\pi}_{t-1}) + 0.63 E_t \, (\pi_{t+1} - \hat{\pi}_{t+1}) + \underset{(2.53)}{0.04} \, (p_t^* - p_t)$$

[6] Fase (2001) analyzes a pstar model for M1. Therefore his results are not directly comparable. He uses the first difference of the fourth differences, $\Delta\Delta_4 p_t$, as the endogenous variable, where Δ_4 removes the seasonality and Δ the "trend" from the data.

$$\bar{R} = 0.76, \quad J = 7.20, \quad \sigma_e = 0.0080$$

Using the lagged output gap gives similar coefficients. Using both variables gives

$$(\pi_t - \hat{\pi}_t) = \underset{(10.04)}{0.40} (\pi_{t-1} - \hat{\pi}_{t-1}) + 0.60 E_t (\pi_{t+1} - \hat{\pi}_{t+1}) + \underset{(2.58)}{0.07} \tilde{y}_t + \underset{(4.37)}{0.05} (p_t^* - p_t)$$

$$\bar{R} = 0.76, \quad J = 12.00, \quad \sigma_e = 0.0080$$

i.e. both variables are significant. The coefficients of the output gap and the price gap are relatively low. Ehrmann and Smets (2001) get 0.18 for the output gap using annual data. Given the theoretical foundations of the hybrid Phillips curve, the coefficient for annual data has to be at least 16-times higher than that for quarterly data (Roberts (2001)).

The coefficient of the forward-looking component is relatively high (0.60) and larger than that of the backward-looking component. This cannot be regarded as evidence against the backward-looking specification of the Phillips curve (Rudd and Whelan (2001)). Due to the two-stage least squares characterization of GMM in linear models, there is a bias in the estimated coefficients, if the driving variable ($\tilde{y}_t$ and/or $(p_t^* - p_t)$) and omitted variables are relatively persistent. In this case, the influence of lagged inflation and of the driving variable is to some extent already captured by $\hat{\pi}_{t+1}$. Even a purely backward-looking data generating process might results in a hybrid specification with a large weight on the forward-looking component when applying GMM. An alternative might be the application of full information methods. For the euro area this approach is problematic as it requires the specification of a monetary policy rule for closing the model. Before 1999 no single monetary policy rule existed.[7]

3.4 Long-term interest rate

In the model the opportunity cost of holding money is measured by the long-term interest rate (minus the own rate). The long-term interest rate, rl_t, is related to the short-term interest rate (policy instrument), rk_t, by an estimated term structure equation (error correction form) based on the expectations hypothesis. OLS estimation gives

$$\Delta rl_t = \Delta rk_t + \underset{(1.71)}{0.001} + \underset{(2.83)}{0.31} \Delta (rl - rk)_{t-1} - \underset{(3.38)}{0.14} (rl - rk)_{t-1}$$

$$\bar{R}^2 = 0.14, \quad LM(1) = \underset{(0.45)}{0.58}, \quad LM(4) = \underset{(0.23)}{1.43}, \quad JB = \underset{(0.87)}{0.29}, \quad \sigma_r = 0.0042$$

[7] Jondeau and Le Bihan (2001) get a large weight for the backward-looking component for the euro area using the ML approach. Their results favor the use of the output gap relative to the marginal cost model.

An alternative is to use the theoretical relationship

$$rl_t = \frac{1}{D}\sum_{i=0}^{D} E_t rk_{t+i} \qquad (11)$$

where D is the duration of the respective bonds. Equation (11) can be rewritten as

$$rl_t = \frac{1}{D+1} rk_t + \frac{D}{D+1} E_t rl_{t+1}$$

3.5 Monetary policy rule

3.5.1 Taylor rule

Monetary policy rules of the Taylor type typically include a measure of the output gap, the deviation of inflation rate from its target and, accounting for observed inertia, the lagged interest rate.

$$i_t = \rho i_{t-1} + (1-\rho)\, i_t^* + \varepsilon_t \qquad (12)$$

where the interest rate i_t depends on the interest rate in the previous period i_{t-1} and the target interest rate i_t^*. ε_t is an iid error term with mean zero. The target interest rate is determined by

$$i_t^* = \alpha + \beta\pi_t + \gamma\, \tilde{y}_t \qquad (13)$$

This approach can be regarded as a simple empirical representation of the behavior of the central bank. As there is no single monetary policy before 1999 the coefficients of the Taylor rule are not estimated, but set to values that are typical for various countries.

3.5.2 Price gap rule

In this case the price gap is included in addition to the inflation rate.

$$i_t^* = \alpha + \beta\pi_t + \gamma(p^* - p)_t \qquad (14)$$

This type of approach implies price-level targeting. Several studies have shown the superior performance of price-level versus inflation targeting. Price-level targeting reduces uncertainty about future price developments more than inflation targeting (Duguay (1994)). Woodford (2000) shows the importance of the stationarity of the price level under inflation targeting under commitment. Vestin (2000) shows the important role of forward looking elements of the model for the superiority of price level targeting under discretion.

4 Simulation results

The applications of the pstar approach to the euro area are rather limited. Fase (2001) compares the performance of two monetary policy rules in a pstar model (seasonally unadjusted, quarterly data, 1972Q1 - 1998Q4) for the euro area: money growth rule and Taylor rule. The pstar inflation equation is estimated for M1, assuming an income elasticity of 1.0 in the long-run money demand equation. His simulations show that "interest rate targeting seems to be superior to monetary targeting". Gottschalk and Stolz (2001) perform an impulse response analysis in a small macro model consisting of a pstar-type inflation equation (taken from Gerlach and Svensson (2001)), the money demand equation of Coenen and Vega (1999) and a Taylor rule.

As there is uncertainty about the structure of the economy, the following analysis is some type of robustness test, as different models - with respect to the specification of expectations and the inflation equation - are simulated for both rules mentioned above. In the backward-looking mode, a pstar economy and a model containing a traditional Phillips curve are explored. In the "hybrid" context, a mixture of both is used, as it was not possible to get significant coefficients in the separated versions.

For these empirical models two types of monetary policy rules are compared under a simple rule and under discretionary monetary policy. The traditional Taylor rule and a rule that includes the price gap.

4.1 Models

The backward-looking model consists of the following equations:

$$\tilde{y}_t = 0.90\,\tilde{y}_{t-1} - 0.09\,(\,rk_{t-1} - \pi_{t-1}) + e_t$$

$$\pi_t = 0.45\,\pi_{t-1} + 0.12\,\Delta p_t^* + 0.20\,\left(p_{t-1}^* - p_{t-1}\right) + w_t$$

$$p_t^* - p_t = 1.36 y_t - 0.53 rl_t + u_t$$

$$\Delta rl_t = \Delta rk_t + 0.31\,\Delta\,(rl - rk)_{t-1} - 0.14\,(rl - rk)_{t-1} + z_t$$

$$rk_t = 0.80 rk_{t-1} + 0.20\,(1.50\,\pi_{t-1} + 0.50\,\tilde{y}_{t-1})$$

with $\sigma_e = 0.36$, $\sigma_w = 0.84$, $\sigma_u = 2.00$ and $\sigma_z = 0.42$. In the case of the traditional Phillips curve, the price gap is substituted by the output gap.

The hybrid model can be described by

$$\tilde{y}_t = 0.71\,\tilde{y}_{t-1} + 0.29 E_t\tilde{y}_{t+1} - 0.05\,(rk_t - E_t\pi_{t+1}) + e_t$$

$$\pi_t = 0.40\,\pi_{t-1} + 0.60\,E_t\pi_{t+1} + 0.07\,\tilde{y}_t + 0.05\,(p_t^* - p_t) + w_t$$

$$p_t^* - p_t = 1.36\,\tilde{y}_t - 0.53 rl_t + u_t$$

$$rl_t = \frac{1}{1+D} rk_t + \frac{D}{1+D} E_t rl_{t+1}$$

with $\sigma_\varepsilon = 0.40$, $\sigma_w = 0.80$ and $\sigma_u = 2.0$.

In general the model can be represented in the form

$$\begin{bmatrix} x_{1t+1} \\ E_t x_{2t+1} \end{bmatrix} = A \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} + Br_t + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}$$

where x_{1t} is a vector of predetermined variables and x_{2t} a vector of forward-looking variables. In the case of a backward-looking system, x_{2t} contains no elements. r_t is the policy instrument and ε_t a vector of shocks. In the case of a simple rule

$$r_t = -F \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix}$$

the system can be rewritten as

$$\begin{bmatrix} x_{1t+1} \\ E_t x_{2t+1} \end{bmatrix} = (A - BF) \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t+1} \\ 0 \end{bmatrix}$$

The system of difference equation is decoupled by applying the Schur decomposition. In the case of a discretionary monetary policy the loss function of the central bank is given by

$$L_t = E_0 \sum_{t=0}^{\infty} \beta^t \left(x_t' Q x_t + 2 x_t' U r_t + r_t' R r_t \right)$$

which has to be minimized. The solution is generated by the algorithm of Söderlind (1999).

4.2 Impulse Responses

To get some impression of the reaction of the system under the two monetary policy rules, Figure 2 and 3 show the responses of the output gap, the inflation rate, the price gap and the short-term interest rate in the "pstar model" for monetary policy using a simple rule.

The reaction of the short-term interest rate is stronger in the case of the monetary policy rule including the price gap.

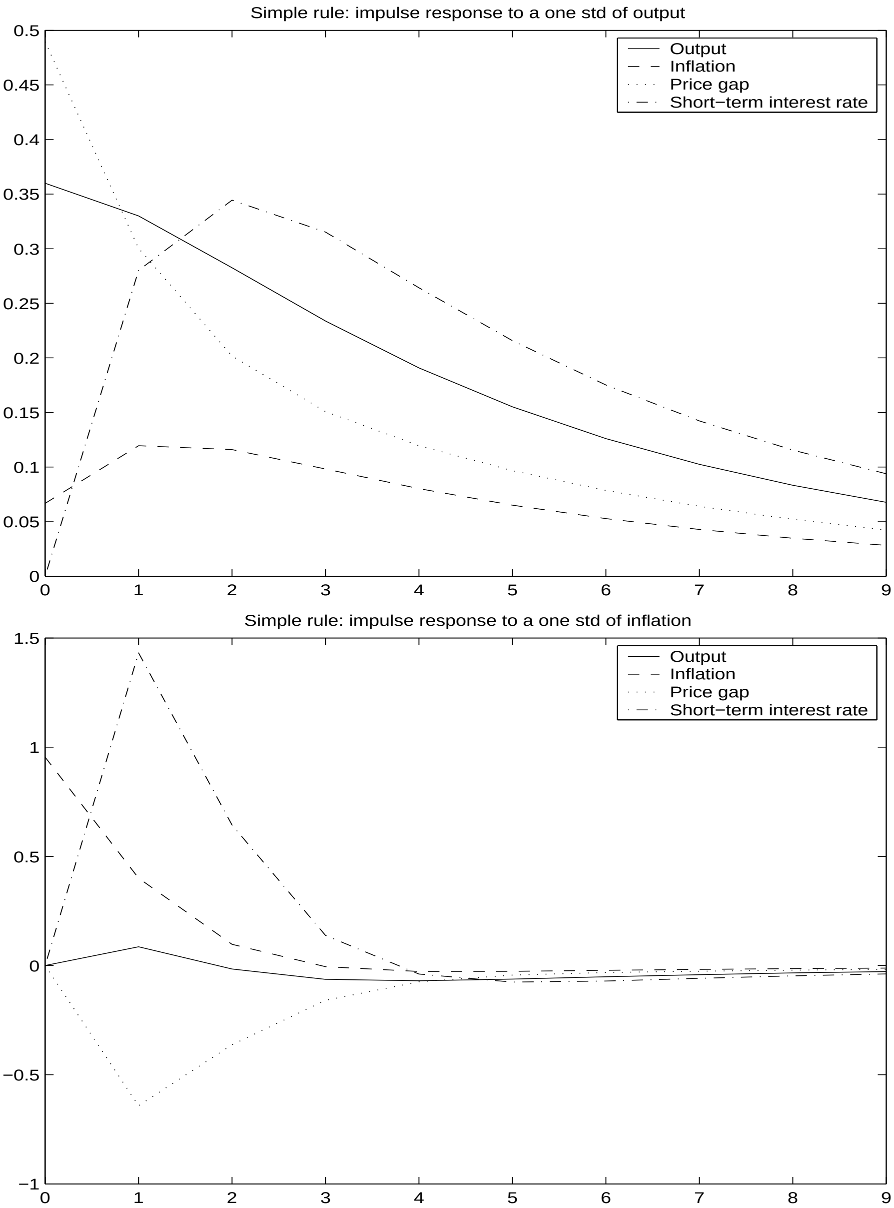

Figure 2: "Pstar model" with Taylor rule

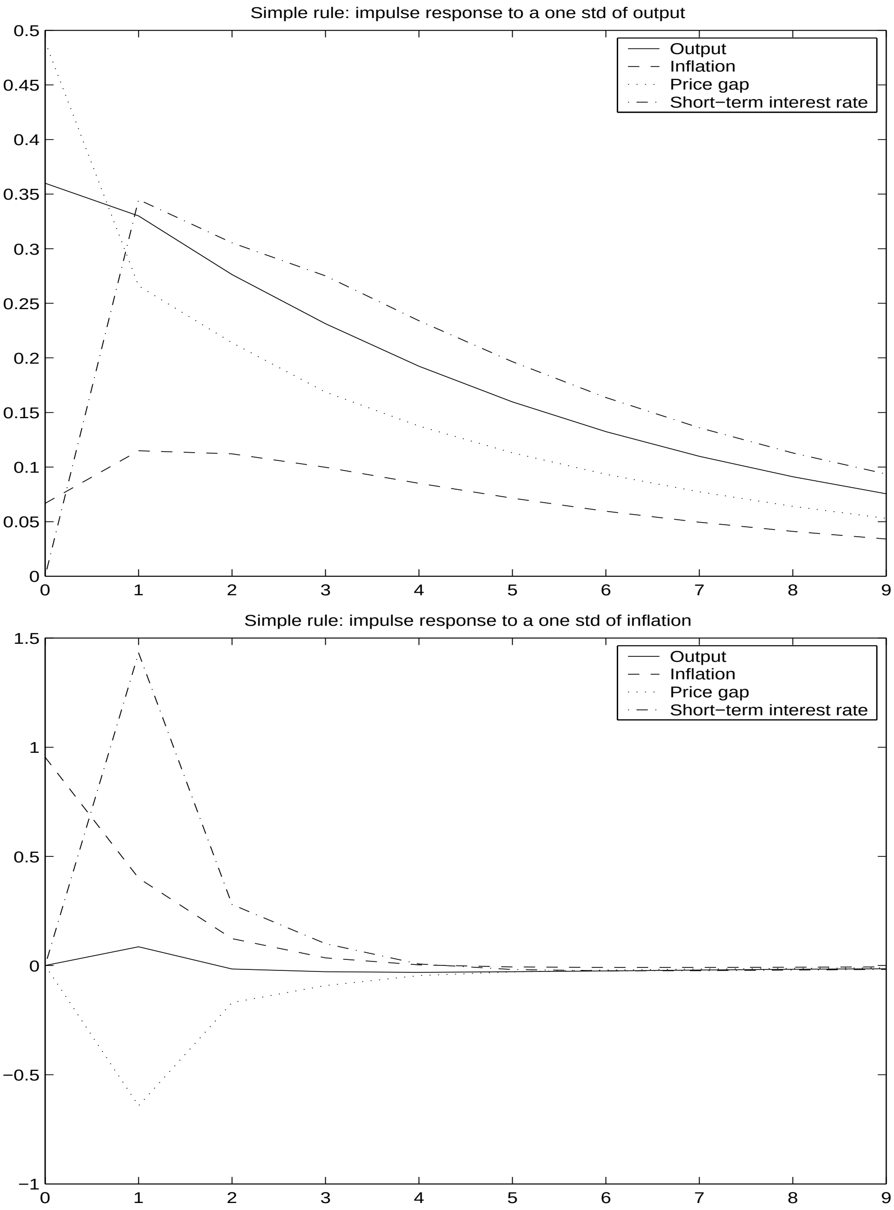

Figure 3: "Pstar model" with rule including price gap

4.3 Variances

Table 1 shows the standard deviations of output, inflation and the short-term interest rate for the models considered and for the specifications of the monetary policy rule.

Table 1: Standard deviations of output, inflation and short-term interest rate (simple rule)

Modell	Rule	$sd(y_t)$	$sd(\pi_t)$	$sd\,(rk_t)$
Pstar	$(p^* - p)_{t-1}$, π_{t-1}, rk_{t-1}			
	0.5, 1.5	0.72	1.12	2.16
	0.5, 1.5, 0.8	0.80	1.25	1.18
	$\tilde{y}_{t-1}$, π_{t-1}, rk_{t-1}			
	0.5, 1.5	0.70	1.16	1.86
	0.5, 1.5, 0.8	0.82	1.26	1.14
trad.	$(p^* - p)_{t-1}$, π_{t-1}, rk_{t-1}			
	0.5, 1.5	0.71	1.27	2.07
	0.5, 1.5, 0.8	0.82	1.31	1.31
	$\tilde{y}_{t-1}$, π_{t-1}, rk_{t-1}			
	0.5, 1.5	0.72	1.27	2.02
	0.5, 1.5, 0.8	0.84	1.32	1.41
"Hybrid"	$(p^* - p)_t$, π_t, rk_{t-1}			
	0.5, 1.5	0.97	2.32	3.97
	0.5, 1.5, 0.8	1.58	2.80	3.08
	$\tilde{y}_t$, π_t, rk_{t-1}			
	0.5, 1.5	0.97	2.34	3.85
	0.5, 1.5, 0.8	1.63	2.93	3.15

In the model with a traditional Phillips curve the variability in output and inflation is very similar for both rules. In the model including the price gap rule the standard deviations of the inflation rate are lower for the price gap rule, but with a higher interest rate variability. For the hybrid model the price gap rule results in a lower output and inflation variability compared to the Taylor rule.

The standard deviations of output and inflation are slightly lower in the hybrid model, if the price gap is used instead of the output gap as a target variable. This lower inflation variability is connected with (costs of) higher interest variability.

Table 2: Standard deviations of output, inflation and short-term interest rate (discretion)

Model	Target variables	$sd\,(\tilde{y}_t)$	$sd\,(\pi_t)$	$sd\,(rk_t)$
"Hybrid"	$(p^* - p)_t,\ rk_t$	0.74	3.09	4.12
	$(p^* - p)_t,\ \pi_t,\ rk_t$	0.65	2.19	3.44
	$\tilde{y}_t,\ \pi_t,\ rk_t$	0.66	2.20	3.42

5 Conclusion

The estimation of a backward-looking inflation equation including the lagged price gap and the change in pstar shows that the pstar approach might be a reasonable alternative to the traditional approach of including the output gap, as a proxy of real marginal costs. In the hybrid version of the model (combination of backward and forward looking) the estimation of the Phillips curve also gives a significant coefficient of the price gap, i.e. the price gap incorporates relevant information about the future development of the inflation rate which is not already included in the output gap. Using the price gap in the monetary policy rule results in a reduced inflation variability.

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