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Interest Rate Setting, Money and the Role of the Output Gap[2]

The paper shows that a robust and successful monetary policy implies an interest rate response to deviations of the inflation rate from target, to the change in the output gap, to a money gap and to the lagged interest rate. These elements of the reaction function are also the necessary consequence of assigning money a prominent role in the monetary policy strategy. As a drawback, this orientation introduces reactions to money demand shocks. On the other hand, such an inertial policy rule is robust to the use of real-time or ex post data, a point which is especially important for transition countries like Belarus. In a second step, we compare this rule with others under a welfare-theoretic perspective. We find that interest rate rules which include a response to money growth outperform both Taylor-type rules and speed limit policies once real-time output gap uncertainty is accounted for. One reason is that targeting money growth introduces history dependence into the policy rule which is desirable when private agents are forward-looking. The second reason is that money growth contains information on the "true" growth rate of output which can only be measured imperfectly.

1. Introduction

Gerberding et al. (2004, 2005) have shown that the use of real-time data for Germany considerably changes the assessment of the Bundesbank's monetary policy reaction function. According to that analysis, the Bundesbank did not respond to the level of the output gap as suggested by the Taylor (1993) rule, but rather to the change in the output gap as well as to deviations of (expected) inflation and money growth from their respective target values. Furthermore, the results suggest that the monetary policy of the Bundesbank was characterised by a high degree of interest rate inertia. This is interesting for other central banks, too, as the Bundesbank is usually judged to have been one of the most successful central banks.

Interestingly, targeting the rate of change rather than the level of the output gap has recently been advocated by a number of authors, such as Orphanides (2003a) and Walsh (2003, 2004). One argument in favour of such an approach is that estimates of the level of the output gap are subject to much greater uncertainty than estimates of its change. Another advantage is that targeting the change in the output gap makes monetary policy more history-dependent, which is an important element of an optimal commitment policy in forward-looking models.

Real-time data uncertainty is an international phenomenon (see Gerberding et al. (2005) for Germany, Gerdesmeier and Roffia (2005) for the Euro Area, Kamada (2004) for Japan, Nelson and Nikolov (2001) for the UK and Orphanides (2001) for the USA) and is especially important and severe for transition countries like Belarus (see also figure 1 for Germany). One common characteristic of the real-time data sets which exist is that the measurement errors regarding the change in the output gap were much smaller and much less persistent than the measurement errors regarding the *level* of the output gap. For the purpose of practical monetary policy, it seems essential to base interest rate setting on variables which are exposed to measurement error only to a comparatively small extent.

The purpose of the present paper is to derive such interest rate feedback rules and to answer the question what role money plays in such a rule.

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[2] This paper draws on joint work together with C. Gerberding, M. Scharnagl and A. Worms from the Deutsche Bundesbank. Nevertheless, the views expressed in the paper should not be interpreted as those of the Deutsche Bundesbank.

A robust monetary policy rule

With forward-looking price setting and a short-run output inflation trade-off, there are gains for monetary policy makers from commitment to a policy rule. Under commitment, the central bank takes the effects of its own actions on private sector expectations into account. As a consequence, optimal policy is not purely forward-looking, but history-dependent in the sense that it implies systematic responses to lagged variables of interest. Choosing the commitment solution that is optimal from a timeless perspective, the interest rate rule takes the form

$$i_t = (1-\rho_1)i^* + \rho_1 i_{t-1} + \rho_2 \Delta i_{t-1} + \phi_p(\Delta p_t - \Delta p_t^T) + \phi_{\Delta y}(\Delta y_t - \Delta y_t^*)\,, \qquad (1)$$

where i is a short term interest rate, i^* is its long-run equilibrium level (which is equal to the sum of the long-run equilibrium real rate of interest plus the trend rate of inflation). The parameters ρ, ϕ_p and $\phi_{\Delta y}$ capture the degree of interest rate smoothing and the strength of the interest rate response to the inflation gap (Δp-Δp^T) and the change in the output gap (Δy-Δy^*), respectively. Δ is the difference operator and "T" is a target value. All decisions have to be based on information available at time t.

Gerberding et al. (2007) have shown that using money as an indicator variable results in a feedback rule of the form

$$i_t = (1-\rho)\cdot\left(i_t^* + \phi_p\cdot\left(\Delta p_t - \Delta p_t^T\right) + \lambda_1\cdot\gamma_1\cdot\left(\Delta y_t - \Delta y_t^{*,est}\right) + \lambda_2\cdot\Delta\varepsilon_t - \lambda_1\cdot\eta_t\right) + \rho\cdot i_{t-1} + v_t\,, \qquad (2)$$

with $\lambda_1 > \lambda_2 \geq 0$ and where $\Delta\varepsilon_t$ captures short-run dynamics as well as fluctuations of money demand and η_t stands for measurement errors in money growth[1] (v is an error term). A positive value of λ_2 would either indicate that the staff made systematic mistakes in estimating the long-run relationships or that, despite the medium-term orientation of their approach, policymakers still showed some response to short-run fluctuations in money demand (even if these were correctly identified). Thus, the optimal time-invariant policy rule (1) under commitment shares many features with the interest rate representation of, as we call it, flexible monetary targeting (2).

The difference between (1) and (2) is that

a) money introduces measurement errors in money growth, ηt, into the policy rule and
b) money implies a policy response to Δεt.

The latter is usually seen as the principal drawback of a monetary orientation. However, a central bank should be aware of this problem and try to identify and filter out "special factors" which only influence money demand in the short run but do not have any repercussions on the long-run relationships, especially on trend inflation and on inflation expectations (see in the case of the Bundesbank Baltensperger, 1998; Deutsche Bundesbank, 1998, 36f.). In terms of Eq. (2), this practice of filtering actual money growth figures implies that the coefficient on $\Delta\varepsilon$ (λ_2) should be smaller than λ_1 or may even be zero.

At first sight, Eq. (2) also looks rather similar to the well-known forward-looking Taylor-type rule in that it includes the rate of inflation, the output gap and the lagged interest rate as feedback variables. However, a closer inspection reveals some important differences:

[1] In the case of Germany or the euro area the latter are practically non-existent.

(a) Using money as an indicator implies a policy response to the difference between the *growth rate* of actual output and the (estimated) growth rate of potential output growth (i. e. the change in the output gap) whereas the Taylor rule includes a response to the estimated *level* of the output gap. Hence, money introduces history dependence into the policy rule which is an important component of an optimal commitment policy when agents have forward-looking expectations

(b) Monetary orientation implies a response to the "true" values of Δp and Δy (which determine money demand) while at the same time introducing measurement errors in money growth, η_t, into the policy rule. By contrast, interest rate rules with a direct feedback from prices and output - such as Taylor-type rules or nominal income targeting - are vulnerable to measurement errors in these variables, but do not suffer from measurement errors in money growth. The relative performance of these rules compared to monetary targeting therefore crucially depends on the magnitude of the respective measurement errors.

(c) Money introduces additional inertia into the policy rule even if there is no interest rate smoothing motive a priori as $\rho > 0$ as long as the interest rate response to the money growth gap and the interest elasticity of money demand differ from zero.

(d) According to (2), a monetary pillar implies a response to the contemporaneous rate of inflation whereas the forward-looking variant of the Taylor rule allows for values of n greater than zero.

(e) Eq. (2) implies a policy response to $\Delta\varepsilon_t$.

(f) Eq. (2) also shows that simply amending a Taylor rule by a money (growth) gap in order to check whether monetary policy actually reacted to monetary aggregates (see, e.g., Clarida et al., 1998) does not do justice to the medium-term nature of monetary targeting. One potential advantage of money growth targeting over other monetary policy strategies is that money growth may contain useful information on the unobserved "true" value of current output (growth) whereas central banks which target output (growth) directly have to rely on noisy estimates of this variable. Of course, this advantage hinges critically on the relative magnitude of the measurement errors in money and output data as well as on the central bank's ability to identify money demand shocks in real time and to separate short-run from long-run influences on money demand (see Coenen et al., 2005).

3. Estimation and interpretation

Which monetary policy strategy a central bank really follows can obviously only be tested empirically by estimating a reaction function which contains all potentially relevant arguments, especially the level and the change in the output gap as well as a money gap. More generally, nesting the ingredients of the forward-looking Taylor rule and the feedback variables implied by Eq. (2) into one model leads to the following interest-rate rule (3). By allowing the horizon of the inflation gap, n, to vary from zero to six, the two variables measuring current and future price pressure can be subsumed into one error term μ.

$$\begin{aligned} i_t = {} & (1-\rho')\Big(\alpha + \Delta p^T_{t+n} + \phi_p \cdot E((\Delta p_{t+n} - \Delta p^T_{t+n})|\Omega_t) + \phi_y \cdot E((y_t - y^*_t)|\Omega_t) \\ & + \phi_{\Delta y} \cdot E((\Delta y_t - \Delta y^*_t)|\Omega_t) + \phi_m \cdot E((\Delta m_t - \Delta m^*_t)|\Omega_t)\Big) + \rho' i_{t-1} + \mu_t \end{aligned}, \qquad (3)$$

where the measurement error in money growth, η_t, has been set equal to zero. Furthermore, i_t*has been replaced by the sum of a constant and the price target, Δp^T_{t+n} . Ω_t is the information set available in t and E is the expectation operator. An important issue is the method used to generate the forecasts. Since we do not know policymakers' "true" forecasts of inflation, the output gap and the change in the output gap, we follow the standard practice of using the realized values as proxies. Therefore, the error term μ_t is a linear combination of the forecast errors of inflation and output and the exogenous disturbance term v_t. In order to avoid simultaneity problems, the RHS-variables are instrumented by a vector of variables I_t which belong to the central bank's information set at the time it sets interest rates and which are orthogonal to μ_t. As we use end-of-quarter values of the dependent variable, we include the contemporary values of those RHS variables which were known to policymakers at the end of quarter t (that is, inflation, the price assumption, the money growth target) as well as two lags of each RHS variable in the instrument set (see the notes to table 1 for more details).

Table 1 summarizes the results of estimating (3) on ex post and real-time German data for different forecast horizons n. Several observations are in order. First, in all cases, the J-statistic confirms the validity of the over-identifying restrictions. Second, the coefficient of the inflation gap, ϕ_p, is significantly positive for all values of n. Third, the coefficient of the level of the output gap, ϕ_y, is significantly positive only for $n=0$ in the ex-post setup, suggesting that in this case, the output gap acts as an indicator of future inflation rather than as an independent feedback variable. Fourth, the coefficients of the output growth gap, $\phi_{\Delta y}$, and of the money growth gap, ϕ_m, are significantly positive for all values of n. Fifth, with estimated values of ρ between 0.80 and 0.92, the rule exhibits a high degree of interest rate smoothing. However, what is perhaps most surprising is that the results based on real-time data differ only slightly from the results in the ex-post setting. An obvious explanation for this congruence is that (in contrast to other central banks) policymakers at the Bundesbank focussed their attention on indicator variables which were exposed to measurement error only to a comparatively small extent. Figure 1 illustrates that this was indeed the case. First of all, the measurement errors regarding the *change* in the output gap were much smaller and much less persistent than the measurement errors regarding the *level* of the output gap. Moreover, revisions in consumer prices and in money growth were even smaller in size throughout the sample period, with money growth figures being hardly ever revised at all. While this may not be true for other countries over different sample periods, Coenen et al. (2005) reach very similar conclusions with respect to euro-area data since 1999.

These results prove to be quite robust to changes in the forecast horizon n ($1 \leq n \leq 6$), the exact timing of the inflation and output variables, the concrete specification of the money gap (annual growth rates, annualised 6-month growth rates, level specifications), and to the choice of alternative proxies for the unobserved forecasts of inflation (consumer prices, output deflator, consensus forecasts).

Obviously, the Bundesbank did not follow a Taylor rule since the level of the output gap turns out to be insignificant in almost all regressions. Instead, the significant and sizable response to both, inflation and the output growth gap as well as the high degree of interest rate smoothing suggest that the Bundesbank took its money growth targets seriously. However, there are also two aspects in which the results deviate from the money based interest rate rule derived in Section 2. First, by responding to expected future inflation rather than to current inflation, policymakers at the Bundesbank seem to have been more forward-looking than implied by the interest rate rule (2). Second, beyond the feedback from the variables implied by monetary targeting, there seems to have been an additional, independent response to money growth.

Taken literally, our model of monetary targeting implies an interest rate response to deviations of current inflation from target. And in fact, for $n=0$, our estimates of the feedback coefficients correspond well with the predictions of the theoretical model, particularly in the real-time setup. However, increasing the forecast horizon of the inflation gap lowers the standard error of the regression even further until it reaches its minimum at a forecast horizon of three quarters. In order to better understand this result, recall that the Bundesbank tried to identify and filter out short-run fluctuations in money demand which did not have any repercussions on the long-run relationships, especially on trend inflation and on inflation expectations. Such fluctuations might not only be caused by shocks to real money demand (as captured by the variable $\Delta\varepsilon_t$), but also by the effects of price shocks on nominal money demand. Viewed from this perspective, increasing the time horizon of the inflation variable may improve the fit of the model because expected future inflation is a better proxy for medium-term price developments than the current rate of inflation which is driven by temporary price shocks as well as longer-term trends.

Finally, we still have to explain the role of the explicit money growth gap in the Bundesbank's reaction function. First of all, note that increasing the horizon of the inflation gap from zero to three quarters (in the case of $\phi_y = 0$, see tables 1b and 2b in Gerberding et al., 2007) lowers the coefficient of the money growth gap from 0.98 to 0.29 in the ex post setup and from 1.05 to 0.30 in the real-time setup just to increase again for $n > 3$. As regards the estimates based on real-time data, the remaining response to the money growth gap at $n=3$ might be explained by its role as an indicator of the "true" growth rate of real output. More generally, the significant reaction to money growth in both scenarios may reflect an insurance scheme to policymakers against measurement errors in output growth of unknown size at the time decisions were made. Apart from that, ϕ_m may capture a remaining influence of short-run dynamics and money demand shocks on the Bundesbank's interest rate decisions. This may simply reflect mistakes, possibly due to difficulties in identifying shocks in real time. But it may also indicate a conscious decision by policymakers to show some response to obvious deviations of money growth from target, even if they were believed to be caused by shocks and therefore not to feed into prices in the medium to long run (e.g. for credibility reasons).[1]

Normative Aspects

From a normative perspective, it is interesting to know whether adding money to an interest rate rule that already includes a response to both inflation and the output (growth) gap yields any extra benefits. On the one hand, augmenting a standard Taylor rule with a money growth target may be advantageous because it introduces inertia and history-dependence into the policy rule. On the other hand, this can also be achieved by including the lagged interest rate and output growth directly among the feedback variables (as in Stracca, 2007). However, even in this case, an additional response to money growth may be beneficial because money growth may contain information about the "true" rate of output growth which can only be measured imperfectly.

To gauge the relevance of these arguments for the euro area, we extend the set of simple rules analysed by Stracca (2007) to include variants of the Taylor rule and the speed limit rule which feature an additional response to money growth. We then go on to calculate the optimal feedback coefficients and to compare the performance of the optimised simple rules in a small estimated model of the euro-area. The setup that we use is a version of the canonical New Keynesian model which has been proposed by Rudebusch (2002) and estimated on euro-area data by Stracca (2007). To capture the implications of output gap uncertainty, we assume that policymakers observe only noisy measures of the output gap and of the change in the output gap. Moreover, we assume that the observed uncertain variables enter the policy rule directly. The model is described in detail in Scharnagl et al. (2007).

[1] Additional reasons why it might be helpful for policymakers to look at money are discussed in Gerberding et al. (2004), section 5.

As noted, our analysis takes place in a simple rules framework and focuses on the relative performance of several variants of the basic Taylor rule, taking into account that policymakers observe only a noisy measure of the output gap. These rules are simple because they model the interest rate as a function of a limited set of state variables while the fully optimal rule would involve all state variables of the model. Given the constraint on the number of feedback variables, the feedback coefficients are chosen so as to minimise policymakers' expected loss. A potential advantage of simple rules is that they are easier to understand and monitor for the public than the (complex) optimal commitment solution. Furthermore, simple rules may be more robust to model uncertainty.

The first simple rule that we consider is a Taylor rule with interest rate smoothing:

$$\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2 \cdot (\pi_{t|t} - \pi_t^*) + \phi_3 \cdot x_{t|t}, \tag{TR}$$

where x is the output gap, π is the inflation rate, $\hat{i}_t$ is the deviation of the nominal interest rate from its steady state value and the subscript $t|t$ indicates the information on the contemporaneous value of a specific variable available at time t. The second rule is a simple growth rate targeting or speed limit rule of the kind advocated by Orphanides (2003b) and Walsh (2003) which involves a response to the change rather than to the level of the output gap:

$$\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2 (\pi_{t|t} - \pi_t^*) + \phi_4 \cdot (x_{t|t} - x_{t-1|t}), \tag{SPL}$$

However, central banks need not be limited to a discrete choice among these two simple rules. Especially with output gap uncertainty, it may be advantageous to respond to the level as well as to the change in the output gap (see Rudebusch, 2002). Hence, we also consider a "hybrid" rule which nests both cases:

$$\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2 \cdot (\pi_{t|t} - \pi_t^*) + \phi_3 \cdot x_{t|t} + \phi_4 \cdot (x_{t|t} - x_{t-1|t}), \tag{TRSPL}$$

Finally, we consider a variant of the Taylor rule and a variant of the speed limit rule with an additional response to money growth:

$$\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2 \cdot (\pi_{t|t} - \pi_t^*) + \phi_3 \cdot x_{t|t} + \phi_5 \cdot (\Delta m_{t|t} - \Delta m_t^*), \tag{TRM}$$

$$\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2 (\pi_{t|t} - \pi_t^*) + \phi_4 \cdot (x_{t|t} - x_{t-1|t}) + \phi_5 \cdot (\Delta m_{t|t} - \Delta m_t^*), \tag{SPLM}$$

Table 2 gives an overview of the whole model. Deriving the optimal feedback coefficients requires an objective function, and we use a fairly standard one in which the central bank is assumed to minimize the variation in inflation around its target (which is normalized to zero), in the output gap, and in the change in the interest rate:[1]

$$L_0 = E_0 \sum_{t=0}^{\infty} \beta^t \left[w_\pi (\pi_t - \pi_t^*)^2 + w_x x_t^2 + w_{\Delta i} (i_t - i_{t-1})^2 \right], \tag{4}$$

where the parameters ω_π, ω_x and $\omega_{\Delta i}$ are the relative weights on the three elements of the loss function L.

[1] The target for output is assumed to be equal to the natural rate, so the target for the output gap is also zero.

As a first step, we use the model summarized in Table 2 to compare the relative performance of the five rules defined above under different degrees of output gap uncertainty (no uncertainty, low uncertainty, baseline uncertainty, high uncertainty). We assume that the central bank minimises Equation (4) subject to the rule in question and the model, while taking into account that its estimate of the output gap is imperfect. Furthermore, we assume that the policy rule is perfectly credible, so agents know the rule and assume (correctly) that it will be followed.

In order to gain a better understanding of the role of output gap uncertainty, we first consider the hypothetical case of perfectly observable output gaps. Here, our results regarding the Taylor rule (TR) and the speed limit rule (SPL) closely resemble the ones presented by Stracca (2007) despite the fact that we use a slightly different objective function. In particular, the optimal Taylor rule is found to have a very low degree of inertia, while the optimal speed limit rule is found to be very persistent (in fact, it is identical to a first difference rule). Stracca argues that the difference between the values of ϕ_1 is likely to reflect the fact that the Taylor rule feeds back strongly from the highly persistent level of the output gap, while the SPL rule reacts (again strongly) to the less persistent change in the output gap. Another interesting result is that the reaction to the output variable is much stronger than the response to current inflation, especially as regards the SPL rule. Again, this makes sense, since in an environment characterised by transmission lags and a low degree of inflation inertia, demand shocks which affect current output are much more relevant for future inflation than cost-push shocks which matter only for current inflation. Allowing for an additional response to money growth somewhat changes the optimal coefficients of the Taylor rule, but the associated reduction in the overall loss is fairly limited. Augmenting the speed limit rule by a response to the output gap (TRSPL) or to money growth (SPLM) has even less impact on the optimal coefficients and on the overall losses.

Allowing for measurement error in the output gap drastically changes these results in several directions. First of all, output gap uncertainty attenuates the optimal response to the output gap and to the output growth gap across all policy rules. The intuition for this result is straightforward: as the reliability of an indicator is reduced, one should place less emphasis on the information it conveys. Second, the optimal reaction to inflation increases with the degree of output gap uncertainty. While this result is in line with the literature on the consequences of output gap uncertainty in an optimal targeting rules framework (see Swanson, 2004), Rudebusch (2001) and Smets (2002) find that higher output gap uncertainty moderates the reaction to the inflation rate in the optimal simple rules they consider. As pointed out by Leitemo and Lonning (2006), this apparent contradiction can be explained by the presence of two countervailing effects. On the one hand, in the case of a demand shock, a stronger policy reaction to the inflation rate can substitute for a reaction to an imprecisely measured output gap. Ceteris paribus, this effect will increase the optimal coefficient on inflation. On the other hand, in the presence of cost-push shocks, a stronger reaction to inflation will destabilize the output gap even further. Hence, with increasing output gap uncertainty, it will be optimal for the central bank to reduce its response to both the output gap and inflation. Apparently, in the model considered here, the first effect dominates.

A third important result is that output gap uncertainty generates a non-trivial role for *money* growth as a feedback variable. Allowing for output gap uncertainty significantly increases the optimal coefficient on money growth, ϕ_5, in both the money-augmented Taylor rule and the money-augmented speed limit rule. At baseline (high) levels of uncertainty, ϕ_5 reaches a value of 1.42 (1.56) in the TRM rule and of 1.08 (1.20) in the SPLM rule. More importantly, even at a low degree of uncertainty, the additional response to money growth reduces the loss by 4.6% relative to the standard Taylor rule and by 3.9% relative to the standard speed limit rule (without money). Under baseline (worst case) assumptions about output gap uncertainty, the welfare gain increases to 6.4% (8.0%) for the Taylor rule and to 6.2% (6.4%) for the speed limit rule. One explanation for the welfare gain compared to the standard rules is that responding to money growth allows the central bank to reduce its response to inflation in both the TRM and the SPLM rule, thus enabling it to avoid inefficient reactions to cost push shocks. By contrast, augmenting the speed limit rule with a response to the output gap (TRSPL) reduces the loss relative to the standard SPL rule only marginally.

We now carry out some sensitivity analysis. In particular, we try to find out whether the superior performance of the money-augmented speed limit rule is robust to changes in the parameters of the central bank loss function and to variations in key coefficients of the underlying model. We find that

- the results (ranking of the policy rules) are independent of whether the increased uncertainty stems from higher persistence or higher shock variability,
- the money-augmented speed limit rule leads to lower variability in both the output gap and inflation for any choice of the relative weights in the objective function,
- increasing the standard error of the money demand shock reduces the coefficient of the money growth gap,
- it is better to overestimate the level of uncertainty (to choose the coefficients optimized for a higher degree of uncertainty),
- the ranking of the policy rules is robust to the choice of the relative weight on output gap versus inflation,
- the ranking of the policy rules is robust to changes in the model coefficients (degree of backward-lookingness of the Phillips curve / IS curve, interest rate elasticity, output-gap elasticity, standard deviation of the cost-push shock, of the IS-shock),
- the ranking of the policy rules is robust to misperceptions about the degree of inflation inertia and misperceptions about the true level of output-gap uncertainty

Summary, conclusions

In the present paper, we have shown that a monetary pillar taken seriously implies an interest rate response to deviations of inflation from target, to the *change* in the output gap, to the lagged interest rate and to deviations of money demand from long-run equilibrium. The latter is usually seen as the principal drawback of monetary indicators. However, we have argued that a central bank with a focus on money will be aware of this problem and, depending on the staff's success in identifying shocks to money demand, the interest rate response to such shocks will be muted or even non-existent.

With their implied response to the lagged interest rate and to the change in the output gap, money growth targets introduce inertia and history-dependence into monetary policy. As shown by Giannoni and Woodford (2003), both features are important components of optimal monetary policy in standard New-Keynesian models with forward-looking expectations. In addition, responding to the change in the output gap rather than to its level may be advantageous when the latter is subject to large and persistent measurement errors as has historically been the case. Furthermore, as pointed out by Nelson (2003), beyond the stabilisation concerns captured by short-run models, central banks have to be concerned with pinning down the steady-state rate of inflation, and this should be the main motivation behind a central bank's commitment to a monetary indicator approach.

Hence, the available empirical evidence suggests that the lessons from German data, together with the insights from recent research on optimal monetary policy under commitment and welfare-theoretical considerations, are more relevant for the euro area than the lessons from US data presented by Rudebusch and Svensson (2002). Having said this and against the background of the increased uncertainty monetary policy makers in EMU are confronted with, the Eurosystem's prominent role for money seems to be a sensible approach. Taken seriously, this orientation introduces the necessary ingredients of a robust and inertial monetary policy rule. This should be the more true for the even higher uncertainty case in transition countries.

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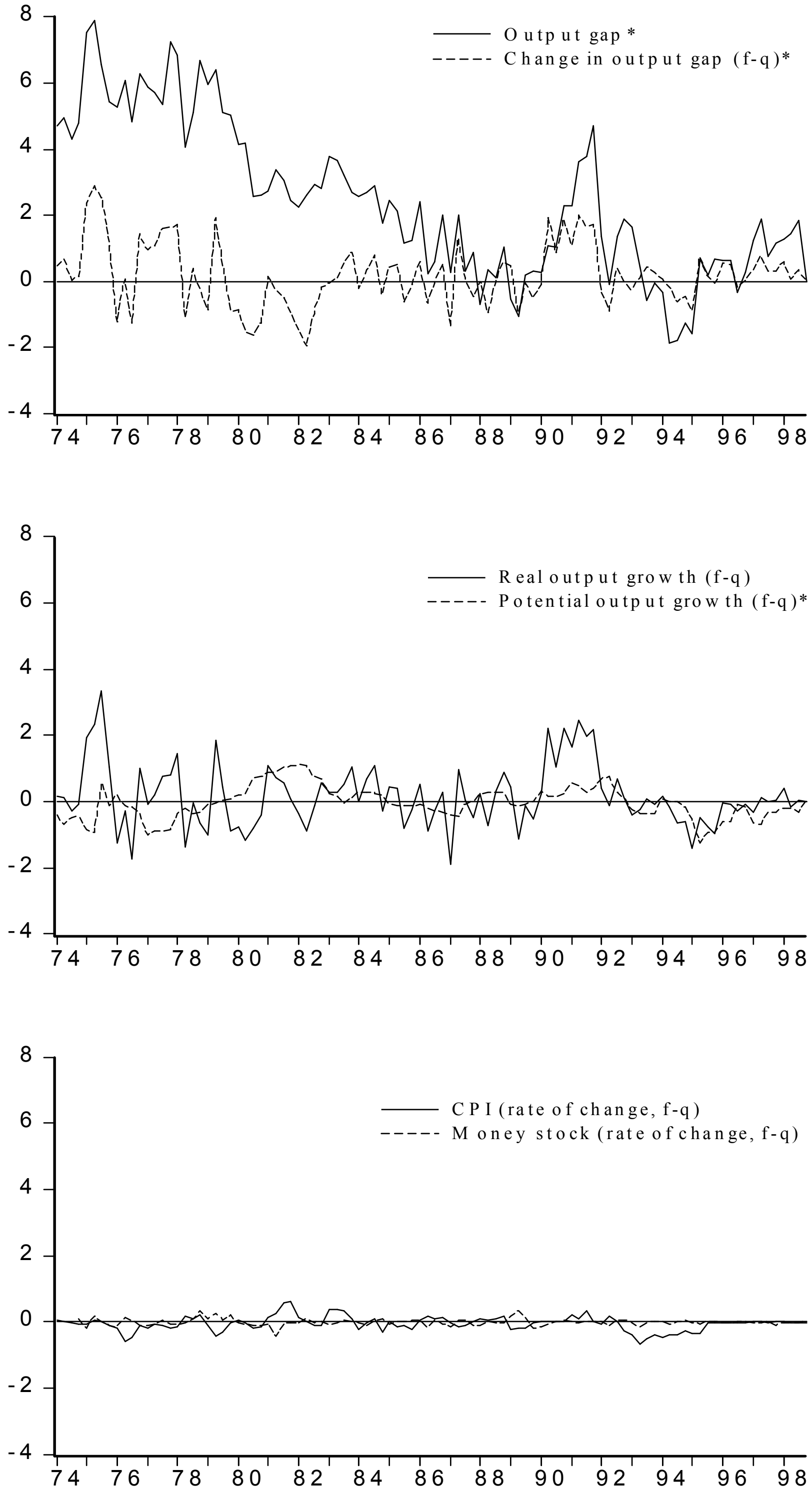
Figure 1: Measurement errors in key monetary policy indicators, 1975-1998[1]



* The calculation is based on Bundesbank estimates of potential output.

[1] The measurement errors are defined as the differences between the ex post figures (March 1999 vintages) and the initial figures.

Table 1: Ex-post and real-time estimates of (3)

	n=0	n=1	n=2	n=3	n=4	n=5	n=6
ex-post							
ϕ_p	1.03**	1.43***	1.71***	2.92***	**2.37****	**2.41****	**2.99****
	(0.41)	(0.42)	(0.60)	(0.77)	**(1.02)**	**(1.17)**	**(1.39)**
ϕ_y	0.55**	0.30	0.24	-0.14	**0.19**	**0.41**	**0.44**
	(0.23)	(0.18)	(0.30)	(0.27)	**(0.38)**	**(0.44)**	**(0.46)**
$\phi_{\Delta y}$	1.25**	1.04**	1.34**	1.33***	**1.74****	**2.08****	**2.33****
	(0.53)	(0.40)	(0.54)	(0.41)	**(0.68)**	**(0.92)**	**(1.06)**
ϕ_m	0.54***	0.46***	0.49**	0.25*	**0.40****	**0.52****	**0.61****
	(0.19)	(0.16)	(0.20)	(0.15)	**(0.18)**	**(0.23)**	**(0.27)**
$\hat{\rho}$	0.83***	0.80***	0.84***	0.85***	**0.88*****	**0.90*****	**0.91*****
	(0.04)	(0.05)	(0.05)	(0.03)	**(0.03)**	**(0.03)**	**(0.03)**
R^2	0.94	0.95	0.95	0.96	0.95	0.95	0.95
SEE	0.61	0.60	0.57	0.53	0.57	0.57	0.56
JB	0.00	0.01	0.28	0.32	0.87	0.39	0.09
J-stat	0.51	0.61	0.56	0.65	0.72	0.59	0.53
real-time							
ϕ_p	2.17***	2.19***	2.43***	3.05***	**2.64*****	**2.73*****	**3.56*****
	(0.48)	(0.36)	(0.33)	(0.45)	**(0.71)**	**(0.81)**	**(1.07)**
ϕ_y	0.06	0.01	-0.09	-0.31**	**0.00**	**0.04**	**-0.16**
	(0.18)	(0.14)	(0.11)	(0.15)	**(0.23)**	**(0.25)**	**(0.31)**
$\phi_{\Delta y}$	2.41***	1.79***	1.53***	1.72***	**2.57*****	**3.01*****	**3.57*****
	(0.77)	(0.53)	(0.43)	(0.48)	**(0.87)**	**(1.11)**	**(1.19)**
ϕ_m	0.98***	0.61***	0.39**	0.17	**0.60****	**0.80*****	**0.91*****
	(0.31)	(0.21)	(0.16)	(0.15)	**(0.23)**	**(0.30)**	**(0.34)**
$\hat{\rho}$	0.84***	0.82***	0.82***	0.85***	**0.89*****	**0.91*****	**0.92*****
	(0.04)	(0.04)	(0.04)	(0.03)	**(0.02)**	**(0.02)**	**(0.02)**
R^2	0.90	0.93	0.95	0.96	0.95	0.95	0.94
SEE	0.82	0.66	0.56	0.53	0.57	0.60	0.61
JB	0.00	0.14	0.67	0.45	0.91	0.58	0.04
J-stat	0.68	0.67	0.68	0.74	0.49	0.48	0.44

****(**/*) denotes significance at the 1% (5%/10%) level. Estimation period: 1979Q1 to 1998Q4,: estimation method: GMM; HAC-robust standard errors in parentheses; for further notes see table 1. Ex-post series as of March 1999.*

Variables: left-hand-side variable: 3-month money market rate (end-of-quarter); right -hand-side variables: inflation gap according to cpi; level and change in the output gap with Bundesbank's own estimates of production potential. For further details on the data see Gerberding et al (2004).

The instrument set includes the contemporary values of inflation and the price assumption (which were known to policy makers at the end of each quarter) as well as two lags of each explanatory variable. Pretesting suggests that this instrument structure is sufficient.

R^2: adjusted coefficient of determination; SEE: standard error of the regression; J-stat: p-value of the J-statistic on the validity of overidentifying restrictions ; JB: p-value of the Jarque Bera test of the normality of residuals.

Table 2: Overview of the model

(1) Aggregate demand	$x_t = \alpha_1 x_{t-1} + \alpha_2 x_{t-2} - \sigma(i_{t-1} - E_{t-1}\bar{\pi}_{t+3} - \bar{r}_{t-1}) + \varepsilon_t^x$ benchmark values: α_1=1.47; α_2=-0.53 σ=0.17; σ_x^2=0.20
(2) Aggregate supply	$\pi_t = \gamma\pi_{t-1} + (1-\gamma)E_{t-1}\bar{\pi}_{t+3} + kx_{t-1} + \varepsilon_t^\pi$ benchmark values: γ=0.20; k=0.31; σ_π^2=0.94
(3) Money demand	$\Delta m_t^r = -\kappa_m(m_{t-1}^r - \kappa_q q_{t-1} + \kappa_i i_{t-1}) + \kappa_1 \Delta m_{t-1}^r + \kappa_{\Delta q}\Delta q_t + \varepsilon_t^m$ benchmark values: κ_m=0.15; κ_q=1.20; κ_i=0.80; κ_1=0.40; $\kappa_{\Delta q}$=0.10; σ_m^2=0.20
(4) Output gap and potential output	$x_t = q_t - q_t^*$ $q_t^* = \rho_q q_{t-1}^* + \varepsilon_t^q$ benchmark values: ρ=0.95; $\sigma_{q^*}^2$=0.13
(5) Policy rules	$\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2 \cdot (\pi_{t\|t} - \pi_t^*) + \phi_3 \cdot x_{t\|t}$ (TR) $\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2(\pi_{t\|t} - \pi_t^*) + \phi_4 \cdot (x_{t\|t} - x_{t-1\|t})$ (SPL) $\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2 \cdot (\pi_{t\|t} - \pi_t^*) + \phi_3 \cdot x_{t\|t} + \phi_4 \cdot (x_{t\|t} - x_{t-1\|t})$ (TRSPL) $\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2 \cdot (\pi_{t\|t} - \pi_t^*) + \phi_3 \cdot x_{t\|t} + \phi_5 \cdot (\Delta m_{t\|t} - \Delta m_t^*)$ (TRM) $\hat{i} = \phi_1 \cdot \hat{i}_{t-1} + \phi_2(\pi_{t\|t} - \pi_t^*) + \phi_4 \cdot (x_{t\|t} - x_{t-1\|t}) + \phi_5 \cdot (\Delta m_{t\|t} - \Delta m_t^*)$ (SPLM)
(6) Output gap uncertainty	$\tilde{x}_t = x_t - \eta_t$; $\Delta\tilde{x}_t = \Delta x_t - \Delta\eta_t$ $\eta_t = \rho_\eta \eta_{t-1} + \varepsilon_t^\eta$ benchmark values: ρ_η=0.89; σ_η^2=0.98