GSfinal.tex

Money and Inflation in the Euro Area: A Case for Monetary Indicators?*

Stefan Gerlach† and Lars E.O. Svensson‡

First draft: July 1999
Final draft: May 2003

Abstract

This paper examines inflation indicators for the euro area by studying the relationship between inflation, output, money and interest rates, using data spanning 1980–2001. The central finding is that both the output gap and the real money gap (the difference between the real money stock and the long-run equilibrium real money stock) contain considerable information regarding future inflation. In contrast, the Eurosystem's money-growth indicator (the difference between nominal money growth and a reference value), the prominent "first pillar" in its monetary strategy, contains little information about future inflation, and no information beyond that contained in the output and real money gaps.

The predictive performance of the output gap has improved compared to that in a previous version of this paper, most likely because of better estimation methods.

JEL Classification Numbers: E42, E52, E58
Keywords: ECB, Eurosystem, Pstar

*We grateful to an anonymous referee whose comments considerably improved the empirical work; Juan-Luis Vega for data; Jeffery Amato, Andreas Fischer, Petra Gerlach, Roberto Golinelli, Reiner König, Stefan Palmqvist, Glenn Rudebusch, Pierre Sicsic and participants in seminars at the Money, Macro and Finance Research Group at LSE, the University of Basel, the University of Bern and the ECB for useful discussions; Gert Schnabel for research assistance; and Annika Andreasson for secretarial and editorial assistance. The views expressed are our own and not necessarily those of the HKMA or the HKIMR.

†Hong Kong Monetary Authority, Hong Kong Institute for Monetary Research, University of Basel and CEPR. Email: Stefan_Gerlach@hkma.gov.hk. Homepage: www.unibas.ch/wwz/wifor/english/staff_sg.htm.

‡Princeton University, Stockholm University, CEPR and NBER. Email: svensson@princeton.edu. Homepage: www.princeton.edu/~svensson.

1. Introduction

This paper focuses on what role the ECB should attach to broad money in its conduct of policy, using data spanning 1980–2001 on prices, output, money and interest rates in the countries constituting the euro area. It is motivated by two observations. First, the Eurosystem has adopted a monetary policy framework which emphasizes the role of monetary aggregates (see ECB, 1999b). While it has made clear that monetary targeting would not be appropriate under current conditions (Issing, 1998), the Eurosystem's announcements suggest that broad money growth is a major information variable used when setting policy. Second, it is sometimes claimed that the Bundesbank's and the Swiss National Bank's (SNB's) outstanding record of inflation control stemmed from their use of monetary targeting. However, a number of scholars of German monetary policy have argued that the Bundesbank's "pragmatic" monetary targeting was best viewed as monetary targeting in words only, but inflation targeting in deeds.[1] Similarly, many observers have interpreted the SNB's policy decisions as suggesting that the deviation of the monetary base from target was by no means the sole factor influencing policy.[2] Furthermore, in December 1999, the SNB (1999) officially abandoned monetary targeting, announced a definition of price stability similar to the Eurosystem's, and declared that "[m]onetary policy decisions will be based mainly on an inflation forecast, which will take all relevant indicators into account."

The Eurosystem has announced that it relies heavily on two "pillars" in determining the appropriate level of interest rates. The first of these is a money-growth indicator, defined as the deviation of M3 growth from a reference value, which under normal circumstances is supposed to signal "risks to price stability" (ECB, 1999b). The second pillar is essentially an

[1] This literature includes Neumann (1997), von Hagen (1995), Bernanke and Mihov (1997), Clarida and Gertler (1997), Clarida, Gali and Gertler (1998) (note a crucial typo: the coefficient for money supply in Table 1 should be 0.07 instead of 0.7), Laubach and Posen (1997), and Bernanke, Laubach, Mishkin and Posen (1998).

[2] Rich (1997) contains an excellent discussion of Swiss monetary policy since the early 1970s.

inflation forecast, referred to as a "broadly-based assessment of the outlook for future price developments." The prominence given to the money-growth indicator has been criticized by many observers, for instance Svensson (1999b), on the grounds that it may be a poor predictor of the future path of prices and that instead the second pillar, the inflation forecast, is likely to be considerably more useful in assessing risks to price stability.

Against this background, the paper examines the role of monetary aggregates as indicators of future inflation. We are particularly concerned by the question of what forms of monetary indicators are useful, if money does indeed play an important role in influencing inflation a year or two ahead. For instance, does the Eurosystem's money-growth indicator provide information about the future course of inflation? If so, is it more informative than a "price gap" or a "real money gap"?[3] We also investigate whether monetary indicators dominate output gaps as information variables for future inflation.

We note from the outset that an unavoidable problem in studying monetary relationships in the euro area is the fact that there is little data from the period after the introduction of the euro on January 1, 1999. One possible reaction to this is to conclude that empirical work had better wait until more data is available. Alternatively, one can construct measures of aggregate money, prices, output and interest rates in the countries forming the euro area for the period before the introduction of the euro, and use these to study the information content of money.[4] Of course, in doing so one must hope that the dynamic relationships between the data have remained broadly stable even after the introduction of the euro, in defiance of the Lucas critique. In this paper

[3]The role of indicators in monetary policy is discussed in a classic papers by Kareken, Muench and Wallace (1973) and Friedman (1975). A recent more general discussion is in Svensson (2001, Section 3.3). Svensson and Woodford (forthcoming a) provide a rigorous analysis of the role of indicators for optimal policy in a model with partial information and forward-looking variables.

[4]Wesche (1997) takes this approach and estimates P^* models on aggregated data for various European groupings of countries.

we take the second route, fully recognizing the problems that are inherent in the strategy.[5]

To preview our results, we find that the so-called P^* model has empirical support. Thus, the "price gap", or equivalently and in our view preferably, the "real money gap" (defined as the gap between the current real money stock and long-run equilibrium real money stock) contains considerable information about the future path of inflation.[6] However, the results indicate that the output gap is at least as informative about about the future path of inflation. Estimating a model that incorporates both the real money gap and output gap as determinants of inflation, we find that each is an important determinant of future price changes. (The reason these results differ somewhat from those in a previous version of this paper, in that the relative performance of the output gap is stronger, is most likely due to better estimation methods and a better estimate of the real money gap.) By contrast, the Eurosystem's money-growth indicator (the gap between current M3 growth and the Eurosystem's reference value) has little predictive power for future inflation, and no marginal predictive power beyond that of the output gap and the real money gap. Overall, our results thus suggest that while it is possible to extract useful information for future inflation from monetary aggregates, the money-growth indicator proposed by the Eurosystem is of little value.[7]

The rest of the paper is structured as follows. Section 2 discusses inflation, output, money

[5] A third route is to use U.S. data, on the ground that the Euro area is a closed economy of similar size as the U.S., and that therefore results about U.S. relations between inflation, interest rates, output and money should be of some relevance for the Euro area. This route is followed in Rudebusch and Svensson (2002).

[6] In our view, the "real money gap" is preferable to the "price gap" because it (1) refers directly to monetary aggregates (which is advantageous in a discussion of the predictive power of monetary aggregates), (2) is consistent with the insight that demand for money is demand for real money, (3) gives a precise meaning to the (often somewhat imprecise) notion of "monetary overhang," and (4) lends itself to comparison with the output gap.

[7] The issue of the existence of a direct real-money effect on output, discussed by Meltzer (2001) and Nelson (2000), is not examined in this paper.

and interest rates in theory. Section 3 examines the corresponding empirical relations between these variables in euro-area data, including the empirical properties of monetary indicators, especially the Eurosystem's money-growth indicator. Section 4 presents some conclusions.

2. Inflation and money in theory

In this section we set out a minimum model of the determination of prices. The model emphasizes the role of monetary factors and consists of an inflation equation and a money-demand equation. In what follows, all variables (except interest rates and time) are in natural logarithms. Logs and interest rates are scaled by one hundred and, hence, measured in percent. Time is measured in quarters.

2.1. Inflation determination

Let us start by writing a Phillips curve of the form

$$\pi_{t+1} = \pi^e_{t+1,t} + \alpha_y(y_t - y^*_t) + \alpha_z z_{t+1} + \varepsilon_{t+1}, \tag{2.1}$$

where $\pi_t \equiv 4\Delta p_t \equiv 4(p_t - p_{t-1})$ is the annualized inflation rate in quarter t, p_t is the price level, $\pi^e_{t+1,t}$ is the expectation in quarter t of inflation in quarter $t+1$ (which we specify further below), y_t is output, y^*_t is potential output, $y_t - y^*_t$ is the output gap, z_t is any exogenous variable or shift factor (for instance, a supply shock) (we discuss the dating of the exogenous variable further below), ε_t an iid "cost-push" shock, and $\alpha_y > 0$. In a Phillips curve of the form (2.1), the output gap is a crucial variable that indicates demand pressure and generates inflation.

Alternatively, as in Svensson (2000), we can consider a Phillips curve of the form

$$\pi_{t+1} = \pi^e_{t+1,t} + \alpha_m(\tilde{m}_t - \tilde{m}^*_t) + \alpha_z z_{t+1} + \varepsilon_{t+1}, \tag{2.2}$$

where $\tilde{m}_t - \tilde{m}_t^*$, the real money gap, is defined as the difference between the real money stock, $\tilde{m}_t \equiv m_t - p_t$, where m_t is the (nominal) money stock (for instance, M2 or M3), and the long-run equilibrium (LRE) real money stock, $\tilde{m}_t^*$. The LRE real money stock is in turn defined as

$$\tilde{m}_t^* \equiv y_t^* - v_t^*, \tag{2.3}$$

where $v_t \equiv p_t + y_t - m_t$ is velocity, and v_t^* is the LRE velocity (which we specify further below). Thus, the LRE real money stock is the level of the real money stock resulting with output at its potential level and velocity at its LRE level. In a Phillips curve of the form (2.2), the real money gap is the crucial gap variable that indicates demand pressure and generates inflation. We can interpret the real money gap as a measure of real "money overhang."

As noted in Svensson (2000), the real money gap is identical to the negative of the "price gap," $p_t - p_t^*$, in P^* models (Hallman, Porter and Small, 1991 and Tödter and Reimers, 1994).[8] Here, the LRE price level p_t^* is the price level that would make the real value of the current money stock equal to the LRE real money stock, provided output is at potential and velocity at its LRE level. Thus, p_t^* is defined as

$$p_t^* \equiv m_t - \tilde{m}_t^*. \tag{2.4}$$

By (2.3) and (2.4), it directly follows that

$$p_t - p_t^* \equiv -(\tilde{m}_t - \tilde{m}_t^*). \tag{2.5}$$

Therefore, a Phillips curve on the form (2.2) is equivalent to the P^* model.

While the microfoundations of the P^* model are not clear (to us, at least), the model has been used to account for the behavior of prices in a number of countries, and is typically seen among proponents for monetary targeting as providing a theoretical rationale for focusing policy

[8] Some of the literature has defined the price gap with the opposite sign, as $p_t^* - p_t$.

deliberations on the behavior of monetary aggregates.[9] For these reasons, we use the P^* set-up here, although, as noted in footnote 6, we prefer to formulate the P^* model in terms of the real money gap as in (2.2).[10]

The P^* model consequently assigns a crucial role to the real money gap as a predictor of future inflation, analogous to the role of the output gap in traditional Phillips curves. One immediate consequence of this is that, to the extent the P^* model accounts for the behavior of inflation, the real money gap, rather than nominal money growth, is the natural monetary indicator of future inflation. We show in the empirical part of the paper that this is the case in the euro-area data we consider.

2.1.1. Inflation expectations

To make the inflation equation operational, we need to specify how expectations are formed. For a forward-looking Phillips curve, the rational-expectations hypothesis is typically invoked.[11] For

[9] The P^* model is used to discuss Bundesbank monetary targeting in Jahnke and Reimers (1995), Neumann (1997), Tödter and Reimers (1994), Tödter and Ziebarth (1997) and von Hagen (1995). This may give the impression that the P^* model provides some rationale for money-growth targeting, especially since the P^* model seems to be part of the Bundesbank's view of the transmission mechanism of monetary policy, see Jahnke and Reimers (1995). Svensson (2000) shows that, although the P^* model gives a prominent role to monetary aggregates, in particular the "real money gap," it does not provide a rationale for money-growth targeting.

Hallman, Porter and Small (1991) and Christiano (1989) discuss the performance of the P^* model for the U.S.

[10] See Meltzer (2001), Nelson (2000), Rudebusch and Svensson (2002), Svensson (1999a) and Woodford (1999) for recent discussions of the role of money in monetary policy and the transmission mechanism.

[11] See Roberts (1995) for discussion of alternative Phillips curves. Bernanke and Woodford (1997), Clarida, Gali and Gertler (1999) and Svensson and Woodford (forthcoming b) discuss forward-looking Phillips curves, the latter with inflation predetermined by one period and given by

$$\pi_{t+1} = \delta \mathrm{E}_t \pi_{t+2} + \alpha_y \mathrm{E}_t (y_{t+1} - y^*_{t+1}) + \varepsilon_{t+1},$$

where δ $(0 < \delta \leq 1)$ is a discount factor.

a simple backward-looking Phillips curve, inflation expectations, $\pi^e_{t+1,t}$, are normally modelled as being adaptive and determined by current and lagged inflation.[12] However, in addition to past inflation rates, monetary-policy makers' views regarding the acceptable or desirable rate of inflation should influence inflation expectations to some extent. To model this relationship, we let the expected rate of inflation also depend on the euro-area central banks' average implicit "inflation objective" for inflation in period t, $\hat{\pi}_t$, which we specify further below. This objective, which may be time-varying, can be interpreted as the inflation rate policy makers would find appropriate in the near future, but it need not necessarily be interpreted as a formal target. In our econometric work, we assume that inflation expectations evolve over time according to

$$\pi^e_{t+1,t} = \hat{\pi}_{t+1} + \alpha_\pi(\pi_t - \hat{\pi}_t), \tag{2.6}$$

where $0 \leq \alpha_\pi \leq 1$. In this formulation, we may interpret $1 - \alpha_\pi$ as an indicator of the degree of credibility of the inflation objective. The closer to unity this indicator is, the more credible is the inflation objective, in the sense of inflation expectations being more influenced by the objective and less influenced by the current inflation deviation from the objective.

Before proceeding, it is useful to consider the behavior of inflation in LRE, which we define as a situation in which $y_t \equiv y^*_t$, $\tilde{m}_t \equiv \tilde{m}^*_t$, $v_t \equiv v^*_t$, $z_{t+1} \equiv 0$, $\varepsilon_{t+1} \equiv 0$ and $\pi^e_{t+1,t} = \hat{\pi}_{t+1}$. From (2.6), in a LRE we then have

$$\pi_{t+1} \equiv \hat{\pi}_{t+1}, \tag{2.7}$$

and the LRE inflation rate is given by the central banks' (possibly time-varying) inflation objective.

[12] Fuhrer (1995 and 1997), comparing forward- and backward-looking Phillipcs curves for the U.S., finds that a backward-looking Phillips curve cannot be rejected. Rudebusch and Svensson (1999), Gerlach and Smets (1999), Peersman and Smets (1999) and Taylor (1999) have recently estimated such backward-looking Phillips curves for U.S. and European data.

2.2. The demand for the real money stock

To operationalize the concept of the real money gap, we must specify the demand for the real money stock. Following the large econometric literature on the demand for money, we assume the following simple, but reasonably flexible and realistic, error-correction specification,

$$\Delta\tilde{m}_{t+1} = \kappa_0 - \kappa_m[\tilde{m}_t - \kappa_y y_t - \kappa_\tau t + \kappa_i(i_t^l - i_t)] - \kappa_\pi(\pi_{t+1} - \hat{\pi}_{t+1}) + \kappa_1\Delta\tilde{m}_t + \kappa_2\Delta\tilde{m}_{t-1} + \xi_{t+1}, \quad (2.8)$$

where i_t^l is the yield to maturity on long bonds, i_t is a short interest rate, $\kappa_\tau t$ is a time trend, ξ_t is an iid money-demand shock, and $\kappa_m, \kappa_y, \kappa_i > 0$. The time trend is included to capture gradual changes in money demand that are not due to rising income and/or changes in interest-rate spreads. Such changes may be due to, for instance, developments in the financial system or increases in wealth. Needless to say, empirically it is possible that there is no time trend, so that $\kappa_\tau = 0$. Since we use a broad monetary aggregate, M3, in the econometric analysis below, it is unrealistic to assume that money is not interest bearing. Thus, we consider the spread between the long and the short interest rate, $i_t^l - i_t$, as measuring the opportunity cost of holding money. This is consistent with the short interest rate being a proxy for the own return on money, and long bond yields capturing the return on the main non-monetary assets.[13] With the dating of variables in (2.8) and the assumption in (2.2) that inflation is predetermined one quarter, it follows that money demand is also predetermined one quarter.[14]

Several aspects of this demand function are notable. First, the inclusion of the term $-\kappa_\pi\pi_{t+1}$

[13] In most economies, time deposits constitute an large part of M3 and act as a buffer stock when funds are shifted in to, and out of, M3. Since time deposits are typically remunerated at rates close to interbank rates, short rates are a good proxy for the own return on broad monetary aggregates.

[14] See Browne, Fagan and Henry (1997) for a survey of European money-demand equations. A similar money-demand equation for M2, although with the short interest rate being the opportunity cost of holding money and without the inflation term on the right hand side, is estimated on U.S. data and used to discuss monetary targeting in Rudebusch and Svensson (2002).

on the right side of (2.8) allows the adjustment towards a long-run money demand to be in terms of the change in the *real* money stock ($\kappa_\pi = 0$) or the *nominal* money stock ($\kappa_\pi = 1$), or intermediate cases between the two ($0 < \kappa_\pi < 1$). Thus, the equation does not impose short-run homogeneity of money demand with respect to prices; long-run homogeneity is imposed, though. Second, the term inside the bracket can be interpreted as long-run money demand equal to

$$\tilde{m}_t = \kappa_y y_t + \kappa_\tau t - \kappa_i (i_t^l - i_t), \tag{2.9}$$

where we assume that real money stock and the time trend are normalized so that there is no constant in (2.9). Third, in the LRE defined above, shocks are zero, output equals potential output ($y_t \equiv y_t^*$), inflation by (2.7) equals the inflation objective ($\pi_{t+1} \equiv \hat{\pi}_{t+1}$, which requires the inclusion of $\kappa_\pi \hat{\pi}_{t+1}$ on the right side of (2.8) to eliminate the effect of π_{t+1} in LRE), and velocity equals LRE velocity ($v_t \equiv v_t^*$), which corresponds to the interest-rate spread equaling its LRE value. On the basis of figure 2 and an ADF test reported below (see footnote 22), we assume that the interest rate spread is stationary and that the LRE spread is constant. Thus, the LRE real money stock fulfills

$$\tilde{m}_t^* = \kappa_y y_t^* + \kappa_\tau t + \kappa^*, \tag{2.10}$$

where κ^* is a constant, equal to the negative of κ_i times the LRE spread.[15] By (2.3), it follows

[15] This is consistent with defining the short and long LRE nominal interest rates, i_t^* and i_t^{l*}, as $i_t^* \equiv r^* + \hat{\pi}_{t+1}$ and $i_t^{l*} \equiv r^{l*} + \hat{\pi}_{t+1}$, where r^* and r^{l*} are constant short and long LRE real interest rates, and both short- and long-run inflation expectations equal the current inflation objective. Then,

$$\kappa^* = -\kappa_i (i_t^{l*} - i_t^*) = -\kappa_i (r^{l*} - r^*).$$

Furthermore, in a LRE, it follows that $\Delta \tilde{m}_t^* = \kappa_y \Delta y_t^* + \kappa_\tau$. Assuming that Δy_t^*, the trend growth of potential output, is constant and equal to Δy^*, substituting this and $\pi_{t+1} = \hat{\pi}_{t+1}$ into (2.8), it follows that the parameter κ_0 is constant and fulfills

$$\kappa_0 = (1 - \kappa_1 - \kappa_2)(\kappa_y \Delta y^* + \kappa_\tau).$$

that the LRE velocity is defined by

$$v_t^* \equiv (1 - \kappa_y) y_t^* - \kappa_\tau t - \kappa^*. \tag{2.11}$$

3. Inflation and money in euro-area data

Having reviewed our model, we next discuss the data, our estimation strategy, and the results.

3.1. The data

As noted above, since the euro was launched at the beginning of 1999, there is little actual euro-area data available. In order to carry out the empirical analysis, we therefore use aggregate data for the euro area before the introduction of the euro. The data on output, money and short and long interest rates stem from Coenen and Vega (1999), and were updated using the ECB's *Monthly Bulletin*. Moreover, we construct measures of euro-area wide consumer prices and of the energy component in the consumer price index, and a measure of the output gap.[16] Potential output is computed using the Hodrick-Prescott filter with a smoothing parameter of 1600. While the data set starts in 80:1 and ends in 01:1, estimation typically starts in 81:2 to compute growth rates and to allow for sufficient lags in the regression equations.

To explore the relationship between the variables, figure 1 plots inflation and nominal money growth measured over four quarters, $\Delta_4 p_t$ and $\Delta_4 m_t$.[17] The figure shows that the inflation rate fell sharply from close to 11 percent per annum in the early 1980s to around 2 percent in 1986, then rose to about 5 percent in early 1992, after which it gradually declined and fell to .8 percent

[16] After 95:1, the official HICP and the energy component thereof are used. For the earlier period we constructed euro-area wide consumer and energy price indices by weighting the growth rates of national price indices, using as weights nominal GDP expressed in common currency. In addition, oil prices were converted into euro (for use as instruments in the Hausman test) using a synthetic exchange rate.

[17] We let $\Delta_4 x_t \equiv x_t - x_{t-4}$ for any variable x.

in the end of 1998 before rising above 2 percent in 2000. The rate of money growth fell from 12 percent in late 1982 to 3.6 percent in 1997, before accelerating to almost 6 percent in the beginning of 2000. While there is a gradual decline in both variables over the sample period, the bivariate relationship between the two variables does not appear very tight.[18] Of course, this is not necessarily surprising, since the figure disregards changes in real income growth, which would tend to obscure the relationship between money growth and inflation.[19] In figure 2 we show the behavior of the short and long interest rates; these also fall gradually over time. All in all, the behavior of the nominal variables illustrate the gradual disinflation achieved in the euro area.

To get a clearer view of the role of money in the inflation process, we next turn to the estimation of the empirical model.

— Figures 1 and 2 about here —

3.2. Inflation and the inflation objective

As a preliminary step, it is useful to consider the overall behavior of inflation. There is little doubt that the decline of inflation in the period under consideration has largely been due to

[18] ECB (1999a) presents a variant of graph 1 which gives the impression of a somewhat tighter correlation between money growth and inflation. In that variant, money growth is led by 6 quarters and 4-quarter money growth and inflation are smoothed by 8-quarter moving averages. To our knowledge, this was the only empirical evidence the Eurosystem had provided in favor of its money-growth indicator by the time the first version of this paper was distributed.

[19] Note that, as discussed in Rudebusch and Svensson (2002), the relation between inflation and nominal money growth can be illuminated by the identity

$$\Delta_4 p_t \equiv \Delta_4 m_t - \Delta_4 \tilde{m}_t,$$

where $\Delta_4 \tilde{m}_t$ is 4-quarter real money growth. With an empirical money-demand equation like (2.8), real money growth will vary over time. This will reduce the correlation between inflation and nominal money-growth.

the growing commitment on the part of monetary policy makers in the euro area to achieve and maintain low inflation. The gradual decline in inflation can therefore be interpreted as corresponding to a fall in the average (implicit) inflation objective, $\hat{\pi}_t$, of the central banks in the euro area.

Since, as assumed in (2.6), the implicit inflation objective influences inflation by affecting inflation expectations, we need to model the evolution over time of the inflation objective. To do so, we start from the observation that a main purpose of the European Monetary System, which was founded in 1979, was to facilitate reduction in members' inflation to levels similar to those in Germany. While the Bundesbank never adopted a formal inflation target, an implicit inflation target (referred to by the Bundesbank as "unavoidable inflation", a "price norm" or a "medium-term price assumption") played an integral part in the computation of its monetary target. Below we refer to this for simplicity as Bundesbank's inflation objective. The line of long dashes in figure 3 below shows the Bundesbank's inflation objective.[20]

Moreover, we assume that the long-run inflation objective of the central banks in the euro area was to reduce inflation to the level given by the Bundesbank's inflation objective. Of course, with the average inflation rate in the euro area about 8 percentage points above the Bundesbank's inflation objective in the early 1980s, it was clear that the disinflation had to be gradual. In line with this, we assume that the euro-area inflation objective, $\hat{\pi}_t$, evolved over time according to

$$\hat{\pi}_{t+1} - \hat{\pi}^b_{t+1} = \gamma(\hat{\pi}_t - \hat{\pi}^b_t), \tag{3.1}$$

where $\hat{\pi}^b_t$ denotes the Bundesbank's inflation objective and γ, the rate of convergence of the inflation objective towards the Bundesbank's inflation objective, fulfills $0 \leq \gamma \leq 1$. By iterating

[20] The source of Bundesbank's implicit inflation target through 98:4 is Bofinger (2000), except for 1985 for which we use 2.5% (see von Hagen, 1995). We assume that the inflation target equals 1.5% per year from 99:1.

backwards in time to an initial period $t_0 \leq t$, the time the process of inflation convergence started (which we will choose to be 81:1), we have

$$\hat{\pi}_{t+1} - \hat{\pi}^b_{t+1} = \gamma^{t+1-t_0}(\hat{\pi}_{t_0} - \hat{\pi}^b_{t_0}), \tag{3.2}$$

which relates the current value of the inflation objective to the initial divergence between the two inflation objectives, $\hat{\pi}_{t_0} - \hat{\pi}^b_{t_0}$.

— Figure 3 about here —

3.3. Estimating the model

Fitting the model entails estimating the parameters of the inflation equation, (2.2); the weight α_π on the inflation objective in the expectations equation, (2.6); the parameters of the long-run money-demand equation, (2.9); the additional parameters of the money-demand equation, (2.8); and the convergence parameter γ and the initial divergence between the initial inflation objective and Bundesbank's inflation target $\hat{\pi}_{t_0} - \hat{\pi}^b_{t_0}$ in the equation for the inflation objective, (3.2). Since we use data starting in the early 1980s, but are interested in the determination of inflation in the period after establishment of the euro in January 1999, we find it natural to perform the estimation on data ending in 1998:4, and use the data 99:1–01:1 to study the model's out-of-sample performance and to test for structural breaks.

3.3.1. Estimating long-run money demand

In order to estimate $\tilde{m}^*_t$ in (2.10), we need to know the long-run income elasticity of money demand, κ_y, and, if applicable, the deterministic trend, κ_τ. Since the real money stock and income are non-stationary, and the interest rates at least borderline non-stationary, the long-run income elasticity can be thought of as a cointegration parameter.

To proceed with estimation, it is useful to note that we have in fact a system of *two* cointegrating vectors.[21] The first cointegration relationship can, by (2.9) be expressed as $\tilde{m}_t - \kappa_y y_t - \kappa_\tau t + \kappa_i(i_t^l - i_t) = u_t^m$, where u_t^m is I(0). This cointegrating vector hence corresponds to the long-run money demand function. The second cointegrating relationship can be expressed as $i_t^l - i_t = u_t^i$ where u_t^i is I(0).[22]

The fact that we are estimating one cointegrating relationship in a system of two has important implications for our choice of estimation strategy. Following the suggestions in Hamilton (1994), we estimate the parameters in the long-run money demand equation in two ways. First, we estimate κ_y, κ_i and κ_τ by fitting (disregarding the constant)

$$\tilde{m}_t = \kappa_y y_t + \kappa_\tau t - \kappa_i(i_t^l - i_t) + \sum_{s=-r}^{r} \left(\kappa_y^s \Delta y_{t+s} + \kappa_i^s(\Delta i_{t+s}^l - \Delta i_{t+s})\right) + \eta_t \qquad (3.3)$$

with OLS. We denote the estimated standard error of the residuals, η_t, by $\hat{\sigma}_\eta$. While the estimated values of the parameters κ_y, κ_i and κ_τ are consistent, in order to conduct inference we need to adjust the standard t-statistics. Hamilton suggests doing so by fitting a low-order AR process on the residuals from (3.3), say $(1 - \phi_1 L - ... - \phi_k L^k)\hat{\eta}_t = \theta_t$, and adjusting the t-statistics by multiplying them with $\hat{\sigma}_\eta/[\hat{\sigma}_\theta/(1 - \hat{\phi}_1 - ... - \hat{\phi}_k)]$ (where ˆ denotes estimates). Second, we follow Hamilton's suggestion to employ the more efficient method proposed by Stock and Watson (1993). This entails estimating (3.3) with OLS, forming a consistent estimate of the autocorrelation of the residuals η_t, and reestimating the equation using generalized least squares. Below we use both approaches, referring to them as the methods H and SW, respectively.

Using data spanning 81:1–98:4, we obtain the following results for the parameters of interest, that is, κ_y, κ_τ and κ_i (t-statistics for test of the hypothesis that the parameter is zero in

[21] We are grateful to an anonymous referee who pointed out an error in the way we estimated the cointegrating parameters in a previous version of this paper.

[22] An ADF test with one lag and no time trend over the sample 81:3–01:1 yields −3.17, which is greater (in absolute value) than the 5% critical value of −2.90.

brackets):[23]

— Table 1 about here —

Several aspects of these results are of interest. First, the efficiency gain of the SW method seems important, as indicated by the fact that the t-statistics are about twice as large when this approach is used. Second, the income elasticity of money demand is estimated to be almost exactly unity. Third, the time trend is significant and implies that velocity is shifting by $4 \cdot .313 = 1.25$ percent per annum. In calculating $\tilde{m}_t^*$ below, we treat .98 as the true value of κ_y, .31 as the true value of κ_τ, and .85 as the true value of κ_i.

3.3.2. Inflation

By combining (3.2), (2.2) and (2.6), we derive an estimable inflation equation of the form

$$\begin{aligned}\pi_{t+1} - \hat{\pi}_{t+1}^b \quad &= \quad \gamma^{t+1-t_0}(\hat{\pi}_{t_0} - \hat{\pi}_{t_0}^b) + \alpha_\pi[\pi_t - \hat{\pi}_t^b - \gamma^{t-t_0}(\hat{\pi}_{t_0} - \hat{\pi}_{t_0}^b)] \\ &\quad + \alpha_m(\tilde{m}_t - \tilde{m}_t^*) + \alpha_y(y_t - y_t^*) + \sum_{s=0}^{3} \alpha_{qs}\Delta q_{t+1-s} + \varepsilon_{t+1}, \qquad (3.4)\end{aligned}$$

where we have added the output gap among the explanatory variables, in order to compare the information content of the real money gap and the output gap. Furthermore, we have also added the current and three lags of energy-price inflation, Δq_{t+1}, among the regressors. Hence, they correspond to the exogenous variable z_{t+1} in (2.2). There are several reasons for doing so. Energy-price movements typically account for a large fraction of the short-term variability of CPI inflation. Excluding them from the regression would thus lead to a potentially important omitted variables bias. Moreover, doing so would also worsen the fit of the equation and thus result in larger standard errors for the estimated parameters. Finally and most importantly, the

[23] In doing so we set $r = 3$ and $k = 2$. In constructing the GLS estimates we assume that the errors follow an AR(2) model. See Greene (1993) for details.

greater variance of the residuals will lead to wider confidence bands for out-of-sample forecasts, which makes it more difficult to reject the hypothesis of parameter constancy. Controlling for energy-price movements by including the current and lagged energy-price inflation among the regressors is therefore desirable.

Next, we turn to the results. Before reviewing these in detail, we focus on the importance of the real money gap and the output gap for inflation. In table 2, column 1, we report NLS estimates of the inflation equation without the output gap, using data spanning 81:2–98:4. The coefficient on the real money gap, α_m, is highly significant, as are the parameters characterizing the implicit inflation objective, γ and $\hat{\pi}_{t_0} - \hat{\pi}^b_{t_0}$, where $t_0 = 81{:}1$. In column 2, we report estimates of the same equation with the output gap instead of the real money gap. It is notable that the coefficient on the output gap, α_y, is also highly significant and that the other parameter estimates are similar to those in column 1. The fact that the real money and output gaps are significant in regressions incorporating only one of them raises the question of their relative importance in explaining movements in inflation. To assess this issue, the model in column 3 includes both variables in the regression. Perhaps somewhat surprisingly, both variables are significant. In light of this, we incorporate both the real money gap and the output gap in the empirical inflation models below.

Turning to the estimates of the other parameters in column 3, we note that the coefficient α_π is about a fourth and significant at a 5% level. Thus, the indicator of the credibility of the inflation objective, $1 - \alpha_\pi$, is about three fourths. The coefficient on the real money gap, α_m, is substantial and highly significant. Thus, the real money gap does feed into the inflation process. As noted above, the coefficient on the output gap, α_y, is also highly significant. The changes of energy prices are highly significant, implying that movements in energy prices play an important role in the inflation process, as suggested above. However, since the contemporaneous change in energy prices is significant, it may be argued that the estimates may be subject to simultaneity bias of unknown magnitude. To guard against this possibility, we conduct a Hausman (1978) test for specification error, and obtain a p-value of .972.[24] This suggests that the equations can be estimated without worrying about simultaneity. Moreover, the diagnostic tests for 4-th order serial correlation of the residuals, normality, 4-th order ARCH effects, and White tests for heteroscedasticity all suggest that the model is well specified.

Next, we consider the estimates of the parameters characterizing the inflation objective, that is, γ and $\hat{\pi}_{t_0} - \hat{\pi}^b_{t_0}$. With $t_0 = 81{:}1$, that is, the observation immediately before the beginning of the estimate period, we estimate γ to .954. Given the estimate of γ, we can then calculate a "half life" of the deviation between the inflation objective and Bundesbank's inflation target of about 14.7 quarters, that is, about 3.7 years.[25] The point estimate of $\hat{\pi}_{81:1} - \hat{\pi}^b_{81:1}$, the difference between the average inflation objective in the countries that came to form the Euro area and the Bundesbank's objective in 81:1, is about 6 percentage points, which seems plausible to us.

To better understand what these estimates imply for the implicit inflation objective, figure 3 contains plots of CPI inflation over four quarters (thus, not the quarterly inflation rate at an annualized rate, which we used in the estimation), together with the estimated inflation objective and the Bundesbank's objective. The figure shows that, in the early 1980s, actual inflation was somewhat above the inflation objective, and that both were declining rapidly. By 1986, inflation had fallen to the level of the objective. Following the collapse in oil prices in that year, however, it undershot the objective, but rose sharply towards the end of the 1980s. By the early 1990s, inflation was clearly above the objective, but following the introduction of tighter

[24] The R-squared in the first-step regression is 0.776 and the p-value for a test of the hypothesis that all regressors are zero is rejected at the one percent level. As instruments we used the other regressors in (3.4) and the current and four lagged values of the log of US dollar oil prices.

[25] The half life h solves the equation $\gamma^h = 1/2$, and hence fulfills $h = -\ln 2/\ln \gamma$.

monetary and fiscal policy, inflation started to decline and fell below the objective by the time of the introduction of EMU in 1999.[26]

— Table 2 about here —

In column 4 in table 2, we reestimate the inflation equation together with the short-run money demand equation, (2.8), using Seemingly Unrelated Regression techniques (SUR). Since the results are very similar to those in column 3 (although the standard errors are somewhat smaller), we do not refer to them further.[27]

3.3.3. Money demand

Next, we turn to the estimates of the short run money-demand equation, (2.8). The OLS results for 81:2–98:4, shown in table 3, column 1, indicate that the coefficient on the error-correction term, κ_m, is highly significant, as is the coefficient on the difference between inflation and the inflation objective, κ_π. Overall, the OLS estimates of the money-demand function seems quite good and the diagnostic tests do not reveal any misspecification.[28] Since the current inflation rate by definition enters in $\tilde{m}_{t+1}$ and in $(\pi_{t+1} - \hat{\pi}_{t+1})$, there is a risk that the equation is affected by simultaneity bias. However, a Hausman test yields a p-value of .807.[29] Column 2 shows that the parameter estimates are virtually unaffected (except that κ_π is somewhat smaller), when

[26] Recall that we assume that the Bundesbank's inflation objective, to which the inflation objective is viewed as converging, is 1.5% after 1999, that is, after the introduction of the EMU.

[27] The correlation coefficient for the error terms in the inflation and money-demand equations is −.211.

[28] The exception is that the White test suggests some heteroscedasticity. However, reestimating the equation with robust standard errors leads to results very similar to those reported in the table. In the interest of brevity, they are omitted here.

[29] The R-squared in the first-step regression is .614 and the p-value for a test of the hypothesis that all regressors are zero is rejected at the one percent level. As instruments for $(\pi_{t+1} - \hat{\pi}_{t+1})$ we used the other independent variables in (2.8), and additional lags of $\widetilde{m}_t$, $\widetilde{m}_t^*$, π_t and $\hat{\pi}_t$.

the equation is reestimated together with the inflation equation using SUR.

— Table 3 about here —

3.4. Out-of-sample predictions

We have estimated our model for the sample period 81:2–98:4. To explore whether it is stable following the introduction of the euro in January 1999, we construct one-quarter-ahead out-of-sample forecasts for quarterly inflation, $\pi_t \equiv 4\Delta p_t$, and real money growth, $4\Delta\tilde{m}_t$, (hence both measured at an annual rate) for the period 99:1–01:1. To do so, we use the single-equation estimates of the two equations, column 3 in table 2 and column 1 in table 3, and actual values of the explanatory variables. The results are displayed in figures 4 and 5. We interpret the result as suggesting that our models for inflation and real money growth are both stable out-of-sample. It is notable that the predictions arising from the inflation equation are quite good even in late 1999, when inflation increased sharply. However, the decline in inflation in 01:1 was sharper than predicted. To more formally assess the stability of the two equations, we also perform Chow forecast tests for a break at 99:1, obtaining a p-value of .542 for the inflation equation and .236 for the money demand function.[30] Thus, these tests also support the hypothesis that the equations are stable.

Finally, we reestimate the equations using the full sample ending in 01:1. The parameter estimates in table 2, columns 5 and 6, and table 3, column 3 and 4 are very similar to those for the sample ending 98:4, supporting the notion that the estimates are stable.

— Figures 4 and 5 about here —

[30] For the money demand equation, which entails a small number of parameters, it is also possible to calculate a standard Chow test for a structural break in 1999:1. The p-value is in this case .394.

3.5. The information content of money

The finding that the real money gap is significant and thus has predictive power for future inflation in the euro-area data considered raises the question, whether the real money gap is more or less informative about future inflation than the output gap and the Eurosystem's money-growth indicator. To address this question, we specify the money-growth indicator as $\Delta_4 m_t - \Delta_4 m_t^*$, the four-quarter growth of nominal M3, $\Delta_4 m_t$, less a reference value for four-quarter money growth, $\Delta_4 m_t^*$. The Eurosystem, following the Bundesbank, specifies the reference value as the sum of an inflation target and a forecast of potential output growth, less a forecast of the velocity trend (see ECB, 1998 and 1999b). Thus, we can interpret

$$\Delta_4 m_{t+4,t}^* \equiv \Delta_4 \hat{p}_{t+4} + \Delta_4 y_{t+4,t}^* - \Delta v_{t+4,t}^*$$

as a reference value for nominal money growth for the next four quarters, involving the four-quarter inflation objective, $\Delta_4 \hat{p}_{t+4}$, and four-quarter forecasts of potential output, $\Delta_4 y_{t+4,t}^*$, and LRE velocity, $\Delta v_{t+4,t}^*$.[31] In the empirical work below, we define the reference value as

$$\Delta_4 m_t^* \equiv \Delta_4 \hat{p}_t + \Delta_4 y_t^* - \Delta_4 v_t^*,$$

involving the realized (estimated) values of potential output and LRE velocity.

As a first step, figure 6 displays the real money gap, $\tilde{m}_t - \tilde{m}_t^*$, the output gap, $y_t - y_t^*$, and a four-quarter average inflation gap, $\Delta_4 p_t - \Delta_4 \hat{p}_t \equiv \sum_{j=0}^{3} (\pi_{t-j} - \hat{\pi}_{t-1})/4$ of the quarterly inflation gap, $\pi_t - \hat{\pi}_t$, between inflation and the inflation objective (recall that quarterly inflation and the inflation objective are measured in percent per annum). The figure shows that the real money gap, the output gap and the four-quarter inflation gap evolve in much the same way over time. Moreover, and perhaps more interestingly, the real money gap appears to move somewhat before

[31] We let $\hat{p}_t \equiv \hat{p}_0 + \sum_{j=1}^{t} \hat{\pi}_{t+j}/4$ denote the price level associated with the inflation objective, so $\Delta_4 \hat{p}_t \equiv \hat{p}_t - \hat{p}_{t-4} \equiv \sum_{j=0}^{3} \hat{\pi}_{t-j}/4$ denotes a four-quarter moving average of the inflation objective.

the inflation gap, suggesting that it may be useful for predicting future inflation. Furthermore, the output gap seems to move even earlier, suggesting that it might be useful for predicting inflation at a longer horizon.

— Figure 6 about here —

Table 4 reports contemporaneous correlation coefficients between the three gaps in figure 6 (thus with the four-quarter inflation gap), with the addition of the Eurosystem's money-growth indicator. We see that the real money gap has the highest contemporaneous correlation with the inflation gap. Notably, the money-growth indicator has a negative contemporaneous correlation with the inflation gap, indicating that it is rather loosely related to the inflation gap.

— Table 4 about here —

To more formally assess the information content of the different variables, we next calculate the cross correlations between, on the one hand, the real money gap, $\tilde{m}_t - \tilde{m}_t^*$, the output gap, $y_t - y_t^*$, and the money-growth indicator, $\Delta_4 m_t - \Delta_4 m_t^*$, with past and future values of the four-quarter inflation gap, $\Delta_4 p_{t+j} - \Delta_4 \hat{p}_{t+j}$, for the lead j ranging between -16 to $+16$ quarters.

The correlation coefficients are plotted as a function of the lead j in figure 7, together with an approximate 95 percent confidence interval around zero.[32] The figure shows that for $j = 0$ (corresponding to table 4), the real money gap is most strongly correlated with the inflation gap, with the output gap slightly less correlated with the inflation gap. The money-growth indicator, in contrast, is negatively correlated with the inflation gap. As the lead of the inflation gap, j, rises the correlation coefficients increase, and that for the real money gap reaches a peak at $j = 4$ quarters, at which lead the output gap is equally correlated with the inflation gap. The

[32] The approximate 95 percent confidence interval is given by $\pm 2\sigma$, where $\sigma = 1/\sqrt{T}$, where T is the number of observations.

correlation coefficient for the output gap, however, continues to rise with j until $j = 7$, before starting to decline. In contrast, the correlation coefficient for the money-growth indicator rises only gradually and is lower for that of the real money gap for $0 \leq j < 10$, and smaller than those for the output gap for $0 \leq j < 14$. These results suggest that the output gap is a more important indicator of future inflation than the real money gap except for short horizons. Moreover, they indicate that the money-growth indicator is the least important indicator of future inflation for horizons relevant for monetary policy.

— Figure 7 about here —

As a final step, we regress the four-quarter inflation gap four and eight quarters ahead on the current four-quarter inflation gap, the real money gap, the output gap and the money-growth indicator, using GMM and allowing for third- and seventh-order moving-average errors. That is, we estimate (disregarding the constant)

$$\Delta_4 p_{t+j} - \Delta_4 \hat{p}_{t+j} = \beta_\pi(\Delta_4 p_t - \Delta_4 \hat{p}_t) + \beta_m(\tilde{m}_t - \tilde{m}_t^*) + \beta_y(y_t - y_t^*) + \beta_m(\Delta_4 m_t - \Delta_4 m_t^*) + \theta_{t+j} \quad (3.5)$$

for $j = 4$ and 8. While this regression has no direct structural interpretation, it does capture the correlations between the future path of inflation (measured relative to the inflation objective) and the current levels of the information variables, and thus provides a simple summary measure of the extent to which these are useful in assessing inflation pressures.

In table 5, panel (a), column 1 shows the estimates of this equation for $j = 4$, with only the real money gap in addition to the current inflation gap. (Since the latter is included solely to control for the information content of the current inflation rate, we do note comment on it below). The real money gap is highly significant, whereas the current inflation gap is not. In column 2, we replace the real money gap with the output gap in the estimation. The output gap is also highly significant, as is the current inflation gap. Furthermore, the adjusted R-squared is in this case much higher. Column 3 shows the corresponding estimate for the money-growth indicator. We see that it is not significant, although the current inflation gap is, and the adjusted R-squared is higher than for the real-money gap (but substantially lower than that for the output gap). In column 4 we include all three gaps in the equation. The money-growth indicator is not significant, the output gap is highly significant, and the real money gap is somewhat less significant. The adjusted R-squared is the highest of the equations. In column 5, we eliminate the money-growth indicator, in which case all remaining gaps (including the current inflation gap) are highly significant, and the adjusted R-squared is virtually unchanged. Overall, the results suggest that while the output gap and the real money gap are important indicators of future inflation, the output gap may be more important. By contrast, the Eurosystem's money-growth indicator appears to contain no information at all beyond that contained in the other gaps.

Panel (b) reports results for the longer forecast horizon of eight quarters, $j = 8$. These results reinforce the impression for the four-quarter horizon. The output gap is even more dominating as the single most important indicator, whereas the real money gap now is somewhat less significant. Column 4 indicates that the money-growth indicator contains no information about inflation 8 quarters ahead beyond that contained in the other gaps. Finally, column 5 shows that the best forecasts are obtained by combining the information in the real money gap with that in the output gap.

— Table 5 about here —

The results in table 5 warrant several comments. First, and most notably, the money-growth indicator appears to contain no or very little information about future inflation. While this result hinges on the exact way in which we have constructed this indicator (and in particular on our estimates of the inflation objective), it does cast considerable doubt on its usefulness for policy purposes. Second, although the money growth indicator appears of little value, the fact that the real money gap is highly significant suggests that monetary factors have played an important role for inflation in the period we study. Thus, some monetary aggregates (other than the Eurosystem's money-growth indicator) are clearly informative for future inflation. Third, the output gap appears to be an important indicator of inflation pressures, and perhaps even more important than the real money gap for horizons beyond four quarters (as suggested by figure 3.7). However, the best forecasts are obtained by using the information contained in both the output gap and the real money gap.

4. Conclusions

This paper provides a preliminary study of the determination of inflation and the role of monetary indicators in the euro area, using reconstructed data for the period 1980–2001. A main finding is that the P^* model, which we prefer, as in Svensson (2000), to express in terms of the real money gap (the difference between the actual and the long-run equilibrium real money stock), has empirical support. Thus, we find that the real money gap has considerable predictive power for future inflation. However, the results indicate that the output gap is at least as informative about about the future path of inflation, which suggests that it is appropriate to consider both the real money gap and output gap when judging price pressures. Perhaps surprisingly, the Eurosystem's money-growth indicator does not seem to have any predictive power for future inflation. Overall, these results do not provide support for the prominent role the Eurosystem has attached to its money-growth indicator.

Moreover, as argued theoretically in Svensson (1999a, 1999b and 2000) and demonstrated empirically in Rudebusch and Svensson (2002), but counter to much conventional wisdom, the lack of predictive power of the money-growth indicator does *not* depend on the existence of stable short- or long-run money-demand functions. In the present paper, the inferior performance of the money- growth indicator occurs in spite of well-behaved estimated short-run and long-run money-demand functions.

In interpreting these results, several caveats need to be kept in mind. First, like all empirical results, our results may be sensitive to the exact choice of data, sample period and estimation strategy, and the findings reported above should be interpreted accordingly.[33] Second, the output gap, the real money gap, and the money-growth indicator all depend on estimates of potential output, which are notoriously difficult to estimate and uncertain. Thus, other estimates of the output gap may lead to different conclusions. Third, the real money gap and the money-growth indicator also depend on the assumed stability of the long-run income elasticity of money demand, which may have shifted after the introduction of the euro, which would further deteriorate the performance of the monetary indicators relative to the output gap. Indeed, the P^* model breaks down without such stability (see Orphanides and Porter, 1998, and Rudebusch and Svensson, 2002). Of course, the introduction of the euro (especially the introduction of euro coins and notes in January 2002) might have been associated with a shift in the long-run demand for euro which would make the P^* model unreliable, possibly increasing the relative advantage of the output gap as an indicator for future inflation.

Thus, the first two caveats above apply in equal measure to all three indicators studied and do not provide any compelling reason to modify the conclusion that the information content of the output gap and the real money gap are superior to that of the money-growth indicator. The third caveat does not apply to the output gap and may hence further strengthen its indicator performance relative to the monetary indicators.

[33] In particular, the way the synthetic euro-area data has been constructed may matter.

References

Bernanke, Ben S., Thomas Laubach, Frederic S. Mishkin, and Adam S. Posen, 1998. Inflation Targeting: Lessons from the International Experience (Princeton University Press, Princeton, NJ).

Bernanke, Ben S., and Ilian Mihov, 1997. What Does the Bundesbank Target? European Economic Review 41, 1025–1054.

Bernanke, Ben S. and Michael Woodford, 1997. Inflation Forecasts and Monetary Policy, Journal of Money, Credit, and Banking 29, 653–684.

Browne, Frank X., Gabriel Fagan and Jerome Henry, 1997. Money Demand in EU Countries: A Survey, Staff Paper No. 7, European Monetary Institute.

Bofinger, Peter, 2000. Inflation Targeting: Much Ado About Nothing New, Working Paper, University of Würzburg.

Christiano, Lawrence C., 1989. P^* Is Not the Inflation Forecaster's Holy Grail, Federal Reserve Bank of Minneapolis Quarterly Review 13, Fall, 3–18.

Clarida, Richard, Jordi Gali and Mark Gertler, 1998. Monetary Policy Rules in Practice: Some International Evidence, European Economic Review 42, 1033–1067.

Clarida, Richard, Jordi Gali and Mark Gertler, 1999. The Science of Monetary Policy, Journal of Economic Literature 37, 1661–1707.

Clarida, Richard, and Mark Gertler, 1997. How the Bundesbank Conducts Monetary Policy, in: Romer, Christina, and David Romer, eds., Reducing Inflation: Motivation and Strategy (Chicago University Press, Chicago, IL).

Coenen, Günter and Juan-Luis Vega, 2001. The Demand for M3 in the Euro Area, Journal of Applied Econometrics 16, 6, 727-748..

European Central Bank, 1998. The Quantitative Reference Value for Monetary Growth, Press Release, December 1.

European Central Bank, 1999a. Euro Area Money Aggregates and Their Role in the Eurosystem, Monetary Policy Strategy, ECB Monthly Bulletin, February, 29–46.

European Central Bank, 1999b. The Stability-Oriented Monetary Policy Strategy of the Eurosystem, ECB Monthly Bulletin, January, 39–50.

Friedman, Benjamin M., 1975. Targets, Instruments, and Indicators of Monetary Policy, Journal of Monetary Economics 1, 443–473.

Fuhrer, Jeffrey C., 1995. The Phillips Curve Is Alive and Well, New England Economic Review, March/April, 41–56.

Fuhrer, Jeffrey C., 1997. The (Un)Importance of Forward-Looking Behavior in Price Specifications, Journal of Money, Credit, and Banking 29, 338–350.

Gerlach, Stefan and Frank Smets, 1999. Output Gaps and Monetary Policy in the EMU area, European Economic Review 43, 801–812.

Greene, William H., 1993. Econometric Analysis, Second edition (Prentice-Hall, Englewood Cliffs, NJ).

Hallman, Jeffrey J., Richard D. Porter, and David H. Small, 1991. Is the Price Level Tied to the M2 Monetary Aggregate in the Long Run? American Economic Review 81, 841–858.

Hamilton, James D., 1994. Time Series Analysis (Princeton University Press, Princeton, NJ).

Hausman, Jerry A., 1978. Specification Tests in Econometrics, Econometrica 46, 1251-1271.

Issing, Otmar, 1998. The European Central Bank at the Eve of EMU, speech in London, November 26.

Jahnke, Wilfried, and Hans-Eggert Reimers, 1995. The Transmission of Monetary Policy in the Econometric Model of the Deutsche Bundesbank for the German Economy, in: Financial

Structure and the Monetary Policy Transmission Mechanism, Bank for International Settlements, Basle, Switzerland.

Kareken, John H., Thomas Muench, and Neil Wallace, 1973. Optimal Open Market Strategy: The Use of Information Variables, American Economic Review 63, 156–172.

Laubach, Thomas, and Adam S. Posen, 1997. Disciplined Discretion: Monetary Targeting in Germany and Switzerland, Essays in International Finance, No. 206, Princeton University.

Meltzer, Allan H., 2001. The Transmission Process, in: Deutsche Bundesbank, The Monetary Transmission Process: Recent Developments and Lessons for Europe (MacMillan, London).

Nelson, Edward, 2000. Direct Effects of Base Money on Aggregate Demand: Theory and Evidence, Working Paper, Bank of England.

Neumann, Manfred, 1997. Monetary Targeting in Germany, in: Kuroda, Iwai, ed. Towards More Effective Monetary Policy (MacMillan, London).

Orphanides, Athanasios, and Richard Porter, 1998. P^* Revisited: Money-Based Inflation Forecasts with a Changing Equilibrium Velocity, Journal of Economics and Business 52, 87–100.

Peersman, Gert, and Frank Smets, 1999. The Taylor Rule: A Useful Monetary Policy Benchmark for the Euro Area?, International Finance 2:1, 85-116.

Rich, Georg, 1997. Monetary Targets as a Policy Rule: Lessons from the Swiss Experience, Journal of Monetary Economics 39, 113–141.

Roberts, John M., 1995. New Keynesian Economics and the Phillips Curve, Journal of Money, Credit and Banking 27, 975–984.

Rudebusch, Glenn D., and Lars E.O. Svensson, 1999. Policy Rules for Inflation Targeting, in: John B. Taylor, ed., Monetary Policy Rules (University of Chicago Press, Chicago, IL).

Rudebusch, Glenn D., and Lars E.O. Svensson, 2002. Eurosystem Monetary Targeting: Lessons from U.S. Data, European Economic Review 46, 417–442.

Stock, James H., and Mark W. Watson, 1993. A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems, Econometrica 61, 783–820.

Svensson, Lars E.O., 1999a. Inflation Targeting as a Monetary Policy Rule, Journal of Monetary Economics 43, 607–654.

Svensson, Lars E.O., 1999b. Monetary Policy Issues for the Eurosystem, Carnegie-Rochester Series on Public Policy 51-1, 79–136.

Svensson, Lars E.O., 2000. Does the P^* Model Provide Any Rationale for Monetary Targeting? German Economic Review 1, 69–81.

Svensson, Lars E.O., 2001. Price Stability as a Target for Monetary Policy: Defining and Maintaining Price Stability, in: Deutsche Bundesbank, The Monetary Transmission Process: Recent Developments and Lessons for Europe (MacMillan, London).

Svensson, Lars E.O., and Michael Woodford, forthcoming a. Indicator Variables for Optimal Policy, Journal of Monetary Economics.

Svensson, Lars E.O. and Michael Woodford, forthcoming b. Implementing Optimal Policy through Inflation-Forecast Targeting, in: Bernanke, Ben S. and Michael Woodford, eds., Inflation Targeting (University of Chicago Press, Chicago, IL).

Swiss National Bank, 1999. Monetary Policy Decisions of the Swiss National Bank for 2000, Press Release, December 10.

Taylor, John B., 1999. The Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank, Journal of Monetary Economics 43, 655–679.

Tödter, Karl-Heinz, and Hans-Eggert Reimers, 1994. P-Star as a Link between Money and Prices in Germany, Weltwirtschaftliches Archiv 130, 273–289.

Tödter, Karl-Heinz, and Gerhard Ziebarth, 1997. Price Stability vs. Low Inflation in Germany:

An Analysis of Costs and Benefits, NBER Working Paper No. 6150.

von Hagen, Jürgen, 1995. Inflation and Monetary Targeting in Germany, in: Leiderman, Leonardo, and Lars E.O. Svensson, eds., Inflation Targets (Centre of Economic Policy Research, London).

Wesche, Katrin, 1997. Die Geldnachfrage in Europa: Aggregationsprobleme und Empirie (Physica-Verlag, Heidelberg).

Woodford, Michael, 1999. Price-Level Determination under Interest-Rate Rules, chapter 2 in: Interest and Prices, book manuscript.

Table 1. Estimates of the long-run money-demand function, (3.3)

Method	H	SW
κ_y	1.060	.982
	[3.017]	[5.665]
κ_τ	.285	.313
	[1.367]	[3.116]
κ_i	1.005	.852
	[1.341]	[2.500]

Note: t-statistics in brackets. The constant is not reported.

Table 2. Estimates of the inflation equation, (3.4)

Sample	81:2–98:4				81:2–01:1	
Equation	(1)	(2)	(3)	(4)	(5)	(6)
Estimation	NLS	NLS	NLS	SUR	NLS	SUR
α_π	.340**	.364**	.244*	.276**	.245*	.267**
	(.099)	(.102)	(.100)	(.092)	(.095)	(.089)
γ	.964**	.962**	.954**	.955**	.951**	.952**
	(.013)	(.013)	(.010)	(.010)	(.010)	(.009)
$\hat{\pi}_{81:1} - \hat{\pi}^b_{81:1}$	5.363**	5.641**	5.956**	5.962**	5.827**	5.847**
	(.532)	(.619)	(.540)	(.511)	(.531)	(.508)
α_m	.280**	-	.241**	.232**	.192**	.188**
	(.073)		(.070)	(.065)	(.061)	(.057)
α_y	-	.194**	.155**	.156**	.177**	.179**
		(.060)	(.056)	(.051)	(.054)	(.050)
α_{q_0}	.247**	.286**	.242**	.244**	.232**	.231**
	(.054)	(.054)	(.051)	(.047)	(.045)	(.042)
α_{q_1}	−.044	−.033	−.030	−.035	−.031	−.035
	(.061)	(.063)	(.059)	(.054)	(.054)	(.050)
α_{q_2}	−.137*	−.132*	−.138**	−.141**	−.092*	−.095*
	(.054)	(.056)	(.052)	(.047)	(.047)	(.044)
α_{q_3}	.225**	.203**	.202**	.193**	.186**	.180**
	(.049)	(.052)	(.048)	(.044)	(.044)	(.041)
$\bar{R}^2$	.943	.939	.948	.948	.947	.947
SEE	.619	.637	.588	.589	.584	.584
DW	2.030	2.079	2.101	2.150	2.080	2.117
Diagnostics tests	*p*-values					
Q-statistic, 4th-order	.906	.868	.444	.421	.355	.338
Normality	.797	.000	.137	.119	.031	.028
ARCH, 4th-order	.683	.934	.601	.546	.747	.685
White	.126	.836	.271	NA	.199	NA

Note: Standard errors in parentheses. */** denotes significance at the 5%/1% level. The constant is not reported.

Table 3. Estimates of the money demand function, (2.8)

Sample	81:2–98:4		81:2–01:1	
Equation	(1)	(2)	(3)	(4)
Estimation	OLS	SUR	OLS	SUR
κ_m	.105**	.107**	.098**	.099**
	(.028)	(.026)	(.026)	(.025)
κ_π	.098**	.080**	.112**	.098**
	(.031)	(.030)	(.031)	(.030)
κ_1	.297**	.317**	.323**	.336**
	(.096)	(.091)	(.093)	(.089)
κ_2	.332**	.321**	.289**	.285**
	(.094)	(.090)	(.091)	(.088)
$\bar{R}^2$	.575	.573	.545	.544
SEE	.306	.307	.312	.312
DW	1.836	1.921	1.851	1.903
Diagnostic tests	p-values			
Q-statistic, 4th-order	.791	.811	.942	.947
Normality	.511	.582	.557	.600
ARCH, 4th-order	.176	.218	.306	.364
White	.025	NA	.317	NA

Note: Standard errors in parentheses. */** denotes significance at the 5%/1% level.

Table 4. Contemporaneous correlations

1981:1–2000:4

	$\Delta_4 p_t - \Delta_4 \hat{p}_t$	$\tilde{m}_t - \tilde{m}_t^*$	$y_t - y_t^*$	$\Delta_4 m_t - \Delta_4 m_t^*$
$\Delta_4 p_t - \Delta_4 \hat{p}_t$	1.00	.56	.42	−.29
$\tilde{m}_t - \tilde{m}_t^*$		1.00	.41	.22
$y_t - y_t^*$			1.00	.14

Table 5. Estimates of the four-quarter inflation gap 4 and 8 quarters ahead, (3.5)

Equation	(1)	(2)	(3)	(4)	(5)
(a) Four quarters ahead ($j = 4$, sample 81:2–01:1)					
$\Delta_4 p_t - \Delta_4 \hat{p}_t$	.228	.372**	.570**	.211	.280**
	(.115)	(.093)	(.095)	(.124)	(.087)
$\tilde{m}_t - \tilde{m}_t^*$	.707**	-	-	.280*	.217**
	(.113)			(.108)	(.069)
$y_t - y_t^*$	-	.250**	-	.269**	.261**
		(.039)		(.052)	(.047)
$\Delta_4 m_t - \Delta_4 m_t^*$	-	-	.122	−.062	-
			(.067)	(.083)	
$\bar{R}^2$	.339	.605	.464	.735	.733
(b) Eight quarters ahead ($j = 8$, sample 81:2-99:1)					
$\Delta_4 p_t - \Delta_4 \hat{p}_t$	−.224	−.135	.110	−.207	−.242
	(.243)	(.122)	(.124)	(.152)	(.151)
$\tilde{m}_t - \tilde{m}_t^*$	.263*	-	-	.246*	.293**
	(.125)			(.098)	(.081)
$y_t - y_t^*$	-	.308**	-	.396**	.401**
		(.056)		(.063)	(.065)
$\Delta_4 m_t - \Delta_4 m_t^*$	-	-	.144	.065	-
			(.084)	(.088)	
$\bar{R}^2$	.088	.309	.129	.685	.683

Note: Estimates of equation (3.5) for $j = 4$ and 8 with moving-average errors of order $j - 1$. Standard errors in parentheses. */** denotes significance at the 5%/1% level.

Figure 1: Inflation and money growth (four-quarter averages)

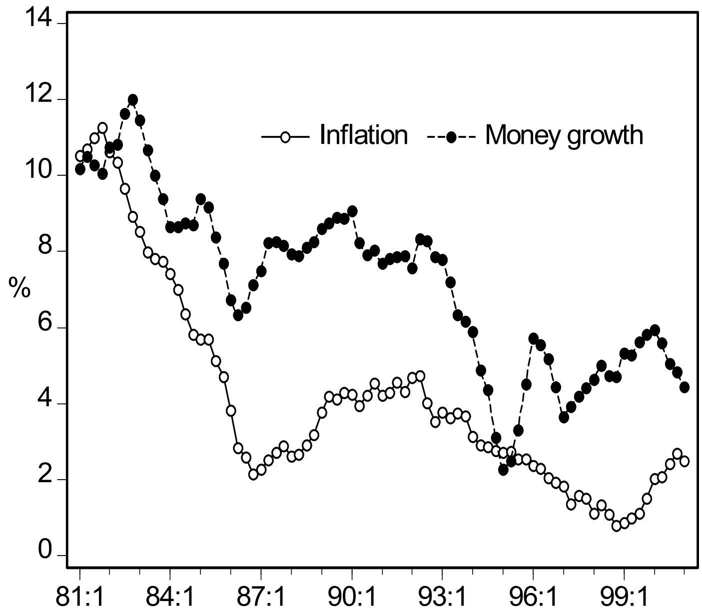

Figure 2: Short and long interest rates

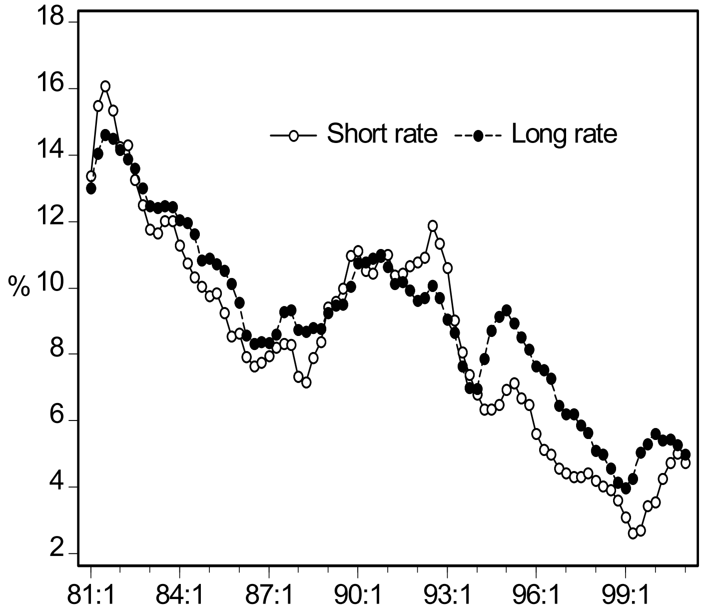

Figure 3: Inflation (four-quarter), Bundesbank's inflation objective,

and the estimated inflation objective

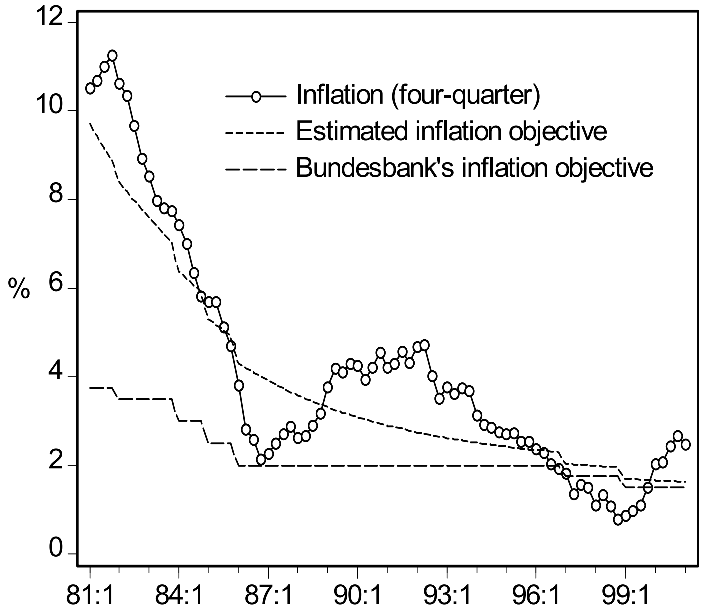

Figure 4: Actual and predicted one-quarter-ahead inflation (out-of-sample 91:1–01:1)

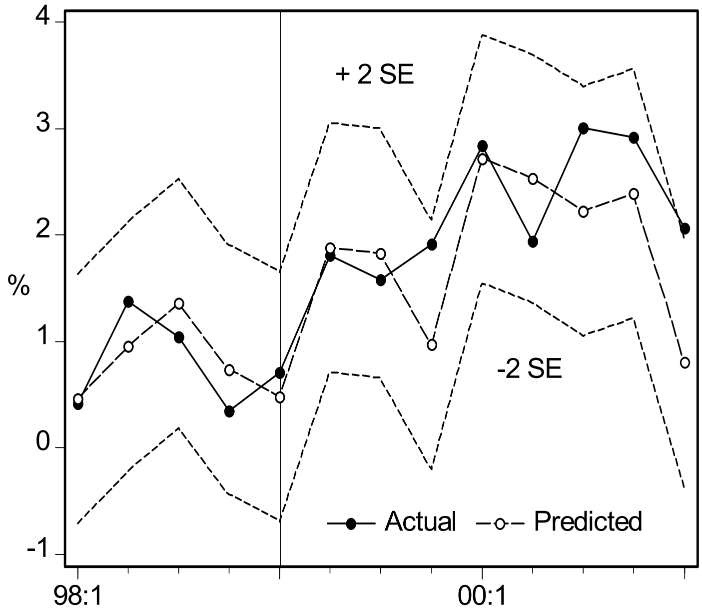

Figure 5: Actual and predicted one-quarter-ahead money demand (out-of-sample 91:1–01:1)

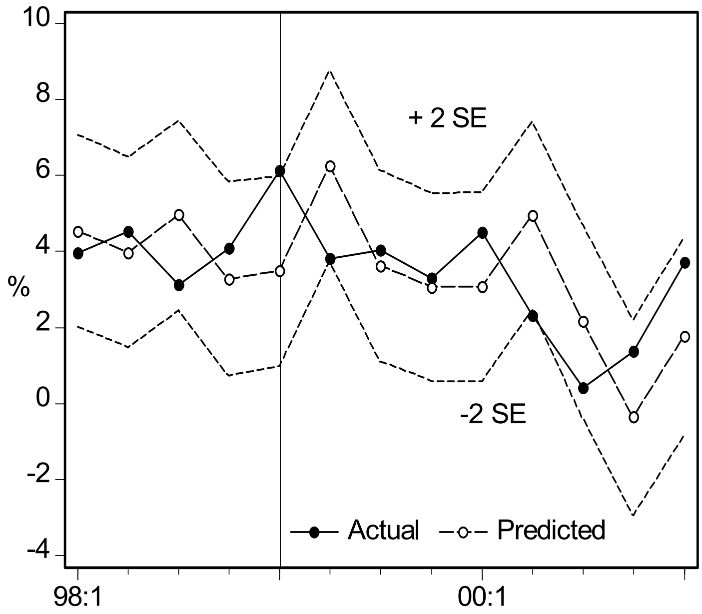

Figure 6: The real money gap, the four-quarter inflation gap and the output gap

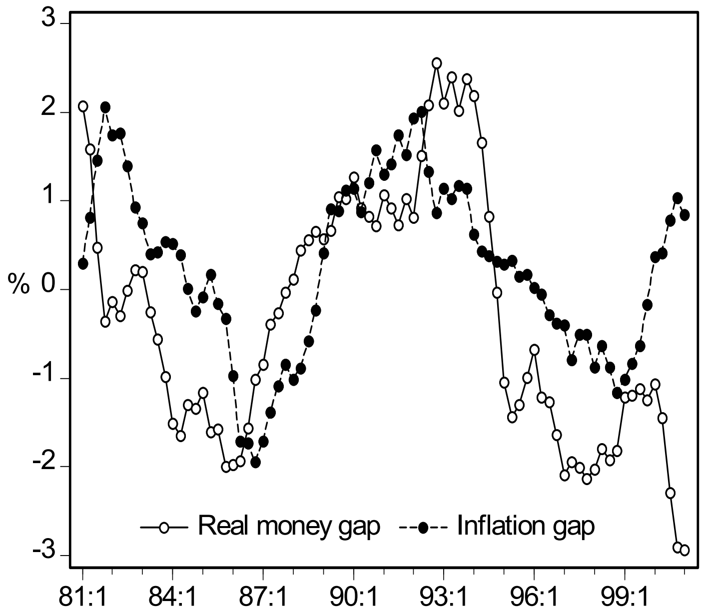

Figure 7: Correlations of the four-quarter inflation gap j quarters ahead with the current real money gap, output gap and money-growth indicator, as a function of j