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**The Link of the Monetary Indicator to  
Future Inflation in the Euro Area  
– A Simulation Experiment**

by

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# **The Link of the Monetary Indicator to Future Inflation in the Euro Area – A Simulation Experiment**

Abstract:

We examine the indicator property of the monetary indicator for inflation. Using a P\*-model, Svensson shows theoretically in a recent paper that the relationship between these two variables is rather tenuous. The present study employs empirical evidence on the relations in his model to quantify its dynamics for the euro area. Moreover, we extend Svensson's analysis by considering different shocks and monetary regimes. It becomes apparent that the system exhibits complicated dynamics and that for most shocks and policy regimes the monetary indicator is not a leading indicator of dangers to price stability in the medium term.

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JEL classification: E 51, E 52

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## I. Introduction

The primary objective of the single monetary policy conducted by the European Central Bank (ECB) is the maintenance of price stability. Acknowledging the existence of short-term volatility of prices which cannot be controlled by monetary policy, the ECB is committed to maintaining price stability over the medium-term. This requires monetary policy to have a forward-looking, medium-term orientation.<sup>1</sup> The Eurosystem's monetary policy strategy to achieve this objective is comprised of two pillars: the announcement of a reference value for the growth rate of broad money, and a broadly based assessment of the outlook and risks to price stability. This strategy assigns an important role to the deviation of money growth from its target, denoted in the remainder of this paper as monetary indicator, as an indicator for dangers to future price stability. The rationale for this role is twofold. First, since inflation is deemed to be ultimately a monetary phenomenon, the pursuit of a money growth target compatible with long-run price stability is meant to demonstrate the commitment of the ECB to its goal of maintaining price stability. Second, the monetary indicator aims to enhance the transparency of monetary policy, thereby making it more difficult for policy makers to deviate from the path of a stability-oriented policy. If monetary policy embarks on an expansionary course which ultimately leads to higher inflation than that compatible with price stability, the monetary indicator is expected to show the build-up of inflationary pressures early on. In this sense the monetary indicator acts as a leading indicator of 'threats to price stability'.<sup>2</sup>

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<sup>1</sup> See ECB (1998).

<sup>2</sup> ECB (1999).

The preceding discussion suggests that maintaining price stability over the medium-term is equivalent to money growth targeting. However, Svensson (1997) has shown that this is only the case if future inflation is best predicted by just the growth rate of money, that is, money growth is a sufficient statistic for future inflation. Using the  $P^*$ -model to capture the dynamics of inflation, a model which assigns money growth a central role in the monetary transmission mechanism, Svensson (2000) shows theoretically that the monetary indicator of the ECB fails to be such a sufficient statistic for future inflation. This is a remarkable result, since the  $P^*$  approach to modeling inflation is based on the same monetary theory of inflation as the monetary indicator employed by the ECB. If there is only a weak relation of the monetary indicator to future inflation in a framework embodying the Monetarist view of inflation, this would imply that the relationship between the indicator and future inflation would likely be even more tenuous in other frameworks placing less emphasis on monetary aggregates in the transmission mechanism.

Since  $P^*$ -models are popular in applied business cycle research to forecast inflation, a number of such models have been estimated for the euro area. Examples include Gottschalk and Broeck (2000), Trecroci and Vega (2000), Gerlach and Svensson (2000) and Scheide and Trabandt (2000). Trecroci and Vega present in addition to a  $P^*$ -equation for the euro area inflation dynamics also estimates for a money demand relationship for M3. In the present study, we take their empirical model of money and inflation as a point of departure. For our purpose, we extend their model by introducing an additional 'IS' equation to model the link between the short-term interest rate, the policy instrument of the ECB, to output. Resorting to such a modeling strategy, we obtain a small empirical model of the transmission mechanism, linking the policy instrument of the ECB to output, broad money and inflation. This model may be of interest in its own right for researchers in the field of applied business cycle analysis and it is

available from the authors upon request. In the present study, we use this model to complement the theoretical analysis by Svensson (2000) with an empirical analysis of the link between the monetary indicator and future inflation.

Regarding inflation dynamics, there are four factors influencing inflation in our model. One of those factors is, of course, monetary policy. Besides monetary policy, shocks to money demand, and aggregate demand as well as cost-push shocks all affect inflation. Since the monetary indicator is an endogenous variable in our model, this allows us to simulate the effects of these three shocks on inflation and then investigate the leading indicator properties of the monetary indicator regarding future inflation. In this simulation experiment, we take into account that the response of inflation to these shocks is sensitive to the reaction function of monetary policy. To this end, we analyze the dynamics of inflation in response to shocks hitting the economy for three different monetary policy regimes. We consider a real interest rate targeting regime, an inflation targeting regime, and a monetary targeting regime. In the first regime, the central bank aims at keeping the real short-term interest rate constant. In the second (third) regime, following a shock to the economy the central bank has the objective to bring inflation (money growth) back on target within a given time horizon. By considering different shocks and policy regimes, we extend the analysis by Svensson (2000). These simulations show that the relationship between the monetary indicator and future inflation is far more complex than one would expect, given that this indicator is supposed to be employed in a straightforward manner as a leading indicator of ‘threats to price stability’. Our results confirm the finding by Svensson (2000) who also sheds doubt on the suitability of the monetary indicator as a leading indicator of inflation. Over and above, we show that the relationship of the monetary indicator to future inflation depends on the nature of shocks hitting the economy and on the response of monetary policy to

these shocks. This complicates the usage of this indicator as a predictor of future inflation even further.

The structure of the paper is as follows. In section II, we give a short outline of Svensson's paper and results. In section III, we present our empirical model and explore the corresponding transmission mechanism from the policy instrument to output, money and inflation. In section IV, we study the indicator property of the monetary indicator under different shocks and policy regimes. In section V, we summarize our conclusions.

## II. P\* and Svensson's theoretical model

In 1991, Hallman et al. proposed a new indicator of inflationary pressures, which they named the price gap. Their point of departure was the logarithmic version of the quantity equation

$$m + v = p + y, \quad (1)$$

where  $m$  is the logarithm of the money stock in circulation,  $v$  the logarithm of velocity of circulation,  $p$  the logarithm of the price level and  $y$  the logarithm of real output. The equilibrium price level is then defined as

$$p^* \equiv m - y^* + v^*, \quad (2)$$

where  $*$  indicates equilibrium values.

The basic idea of the P\*-model is that, in the long-run, an increase in the money stock raises the price level by the same amount, provided that output and velocity remain constant. The P\* literature, therefore, assumes the long-run neutrality of money. In the short-run however, an increase in the money stock can



lead to a deviation of output and velocity from their equilibrium values.<sup>3</sup> Combining (1) and (2) gives:

$$p^* - p = (y - y^*) + (v^* - v). \quad (3)$$

The price gap is therefore composed of the output gap  $(y - y^*)$  and the velocity gap  $(v^* - v)$ . The output gap shows the effect of higher money balances on real activity, whereas the velocity gap shows the effect on money holdings. The velocity gap is sometimes also referred to as the liquidity gap because a positive velocity gap implies that agents hold more liquidity than they would do in equilibrium. A positive velocity gap therefore indicates a monetary overhang. Taken together, a positive price gap (high rate of capacity utilization and/or monetary overhang) signals inflationary pressures because the actual price level is below its equilibrium value and will, therefore, tend to move towards the higher equilibrium price level.

The effects of the price gap on inflation can be modeled with the help of the following error-correction model:

$$\mathbf{p}_t = (1 - \mathbf{a}_{\Delta p})\mathbf{p}_{t-1} + \mathbf{a}_{\Delta p}\Delta p_{t-1}^* + \mathbf{a}_p(p_{t-1}^* - p_{t-1}) + \mathbf{e}_t^p, \quad (4)$$

where  $\mathbf{p}_t = p_t - p_{t-1}$ ,  $0 \leq \mathbf{a}_{\Delta p} \leq 1$ ,  $\mathbf{a}_p > 0$ ,  $\mathbf{e}_t^p$  is an i.i.d. error term with zero mean,  $\Delta$  is the difference operator, and  $t$  is the time index.

This is the P\* specification used by Svensson, which encompasses the specification by Hallman et al. (1991) with  $\mathbf{a}_{\Delta p} = 0$  and an alternative specification used by Tödter and Reimers (1994), who assume  $\mathbf{a}_{\Delta p} = 1$ . According to

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<sup>3</sup> In the original Hallman et al. (1991) essay, velocity is assumed to be constant.

Svensson's specification of the  $P^*$ -model, inflation depends on lagged inflation, lagged  $P^*$  inflation and the lagged price gap. Given a positive (negative) price gap in the previous period, inflation accelerates (decelerates).

To summarize, in the  $P^*$ -model, inflation is entirely determined by the money growth rate. If money supply exceeds money demand for given values of equilibrium output  $y^*$  and equilibrium velocity  $v^*$ , this leads to a corresponding rise of the equilibrium price level  $p^*$  and hence to an increase of the inflation rate. In this regard it is noteworthy that the reference value for money growth published by the ECB corresponds exactly to the change in money demand due to rising potential output  $\Delta y^*$  and the change in equilibrium velocity  $\Delta v^*$  plus the target rate of inflation. This shows that the monetary indicator is derived from the same monetary theory of inflation as the  $P^*$ -model.

Given the importance of money growth in this framework for modeling inflation, it is necessary to take a stand on the question of what determines money growth. Most of the literature on  $P^*$ -models for the euro area uses broad money to model the price gap. The disadvantage of this monetary aggregate is that it cannot be directly controlled by the ECB, but it is chosen nevertheless because there is ample evidence for a stable money demand relationship linking M3 to output, prices and other potential determinants of money demand.<sup>4</sup> Without this stable money demand relationship equilibrium velocity cannot be determined, making it impossible to operationalize the  $P^*$  concept. Even though the ECB cannot control M3 directly, it has some control over the supply of broad money via its control over the non-borrowed monetary base. If the multiplier linking this narrow monetary aggregate to M3 is fairly stable, monetary policy

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<sup>4</sup> See for instance Coenen and Vega (1999).

can still exert a considerable influence on M3. This line of reasoning, which is implicitly underlying many applications of the  $P^*$ -model, suggests that M3 can be considered a monetary policy variable, even though the ECB controls this variable less than perfectly.

However, if a central bank uses the non-borrowed monetary base as an instrument to exercise control over M3, this yields potentially large fluctuations in the nominal short-term interest rate. With this policy, fluctuations in money demand cannot be accommodated by corresponding movements of money supply, so interest rate movements have to clear the money market. Most central banks find such interest rate fluctuations undesirable and conduct money market operations with the objective to keep the nominal short-term interest rate at its desired level. That is, the short-term interest rate is the central bank's policy instrument of choice. For this reason Svensson adopts the short-term rate as the policy instrument in his model. This specification is also in accordance with practically all modern macroeconomic models.<sup>5</sup> Regarding broad money, Svensson points out that, in practice, the central bank's control over broad money is exercised via its control over the short-term interest rate which then affects the demand for broad money. In his model, money is therefore an endoge-

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<sup>5</sup> McCallum (1999) surveys a number of models presented at recent conferences and notes that practically all of them specify the interest rate as the instrument variable. He writes: "The fact is that actual central banks in industrial countries conduct monetary policy in a manner that is much more accurately depicted by writing  $R_t$  [short-term interest rate] rather than  $m$  (even if interpreted as the monetary base) as the instrument or operating-target variable."

nous variable, determined by money demand.<sup>6</sup> In summary, the money demand

equation has two functions in his model: On the one hand, it models equilibrium velocity. On the other hand, money demand determines money balances in the economy.

The money demand function in the Svensson model is given in error-correction form

$$\Delta(m_t - p_t) = -\mathbf{k}_m[(m_{t-1} - p_{t-1}) - \mathbf{k}_y y_{t-1} + \mathbf{k}_s s_{t-1}] + \mathbf{k}_1 \Delta(m_{t-1} - p_{t-1}) + \mathbf{e}_t^m, \quad (5)$$

where  $\mathbf{k}_m, \mathbf{k}_y, \mathbf{k}_s > 0$ ,  $\mathbf{k}_1 \geq 0$ ,  $s_t$  is the nominal short-term interest rate and  $\mathbf{e}_t^m$  is an i.i.d. money demand shock with zero mean.

Equilibrium money demand is obtained by inserting equilibrium values into the long-run money demand function given by term in square brackets in (5):

$$m_t = p_t + \mathbf{k}_y y_t^* - \mathbf{k}_s s_t^*, \quad (6)$$

where  $y^*$  is the potential output and  $s^*$  is the equilibrium interest rate given by

$$s_t^* = r^* + \hat{p}. \quad (7)$$

Equilibrium velocity can be derived from the long-run money demand function as

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<sup>6</sup> Again, this view is in accordance with the literature on the controllability of broad money in the euro area. Cabrero et al. (1998) write in this context: ‘Under arrangements such as those for EMU, where the common monetary policy operational objective is a very short-term interest rate, modifying short-term financial conditions will be the main instrument the ECB could use to control the money stock.’ Other studies, including Vlaar and Schuberth (1998) and Coenen and Vega (1999), also model the influence of the ECB over broad money via its control over short interest rates and their effect on money demand.

$$v_t^* = (1 - \mathbf{k}_y) y_t^* + \mathbf{k}_s s_t^* . \quad (8)$$

Regarding the controllability of money, the short-term interest rate has a direct effect on real money balances via its role in the money demand function. Moreover, a change in the policy instrument is likely to affect output, which also enters the money demand function. As is apparent from (5), real balances only respond with a lag to a change in the policy instrument. In addition to these two direct effects, there is also an indirect channel. Once nominal money balances have started to increase, this leads to a price response with a lag of one period, via the effect of the money stock on the price gap. Higher prices increase the demand for nominal money balances further, leading to additional price increases, which consequently induce a self-reinforcing process of rising money demand. Finally, real balances are also subject to money demand shocks after the policy instrument has been set which implies that the central bank has only imperfect control over money.

With respect to controlling inflation, this model implies that the central bank faces two types of time lags: First, the interest rate does not affect demand for money until the next period (one-period control lag). Second, given the above inflation dynamics, the changes in the money stock do not affect the inflation rate until the next period (one-period inflation lag). The optimal policy under strict inflation targeting is therefore to set the interest rate such that the two-period-ahead inflation forecast conditional on information available today ( $\mathbf{p}_{t+2|t} = \hat{\mathbf{p}}$ ) equals the inflation target:

$$\mathbf{p}_{t+2|t} = \hat{\mathbf{p}} \quad (9)$$

This raises the question whether the Eurosystem money-growth indicator is a good indicator for deviations of future inflation from the inflation target. The

money-growth indicator is defined as the deviation of present money growth from its target:

$$\Delta m_t - \Delta \hat{m}_t, \tag{10}$$

where

$$\Delta \hat{m}_t = \hat{p} + \Delta y_t^* - \Delta v_t^* \tag{11}$$

is the money-growth target or, as the European Central Bank calls it, the reference value.

Svensson (2000) shows that the deviation of the two-period-ahead forecast of inflation from the inflation-target ( $\mathbf{p}_{t+2|t} - \hat{\mathbf{p}}$ ) is given by:

$$\begin{aligned}
\mathbf{p}_{t+2|t} - \hat{\mathbf{p}} &= \mathbf{p}_{t+1|t} - \hat{\mathbf{p}} - (\mathbf{a}_m + \mathbf{a}_{\Delta m})\Delta(m_{t+1|t} - p_{t+1|t}^*) - \mathbf{a}_m(m_t - p_t^*) \\
&+ (\mathbf{a}_m + \mathbf{a}_{\Delta m})\mathbf{k}_m(\mathbf{k}_y y_t - \mathbf{k}_s s_t) \\
&+ [\mathbf{a}_m - (\mathbf{a}_m + \mathbf{a}_{\Delta m})\mathbf{k}_m](m_{t-1} - p_{t-1}) \\
&- [\mathbf{a}_m + (\mathbf{a}_m + \mathbf{a}_{\Delta m})(\mathbf{k}_1 - \mathbf{k}_m)](\mathbf{p}_t - \Delta m_{t|t-1}^*) \\
&+ [\mathbf{a}_m + (\mathbf{a}_m + \mathbf{a}_{\Delta m})(\mathbf{k}_1 - \mathbf{k}_m)](\Delta m_t - \Delta m_{t|t-1}^*)
\end{aligned} \tag{12}$$

The last term represents the effect of the current money-growth indicator on the deviation of the two-period-ahead inflation forecast from the inflation target. Svensson concludes that the relation between the expected deviation of inflation from the target and the money-growth indicator is rather weak, since the money-growth indicator is only one of many factors affecting the two-period-ahead forecast of inflation.<sup>7</sup>

### III. The empirical model

#### 3.1 Modeling Inflation

Following Svensson (2000), we employ a P\*-model to model the inflation process in the euro area. For this purpose, we draw on the P\*-model estimated in Trecroci and Vega (2000). Their model builds on the money demand system in Coenen and Vega (1999) that contains equations for real money balances, inflation, output, and short-term as well as long-term interest rates. Coenen and Vega derive from this system a stable money demand function for M3 in the euro area.

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<sup>7</sup> At least the sign of this effect probably is positive since empirically  $0 < \mathbf{k}_m < \mathbf{k}_1$  has often been found.

In Trecroci and Vega (2000), this money demand system is extended to obtain a P\*-model for inflation. The fact that the empirical model proposed in the present paper also requires a money demand function allows us to extract equations for money demand and for inflation dynamics from the same empirical model of money demand. An alternative is the P\*-model of Gerlach and Svensson (2000), which also models money demand. The empirical model presented below has also been simulated using the results from Gerlach and Svensson, but to preserve space, these results are not reported in full detail. Instead, this second simulation serves to check the robustness of the results obtained from the model above.

The empirical work by Trecroci and Vega yields the following equation for inflation dynamics in the euro area:<sup>8</sup>

$$\begin{aligned} \mathbf{p}_t - \mathbf{p}_{t-1} = & -0.783(\mathbf{p}_{t-1} - \hat{\mathbf{p}}) + 0.196(p_{t-1}^* - p_{t-1}) \\ & + 0.262(y_{t-1} - y_{t-1}^*) + 0.249((s_{t-1} - \hat{\mathbf{p}}) - (s - \mathbf{p})^*) + \mathbf{e}_t^P \end{aligned} \quad (13)$$

with  $\mathbf{p}$  annualized inflation rate,

$\hat{\mathbf{p}}$  inflation target,

$(s - \mathbf{p})^*$  equilibrium real short-term interest rate, and

$\mathbf{e}^P$  inflation shock.

The comparison of equation (13) with equation (4) shows that the Trecroci and Vega P\*-model is augmented with a number of additional variables, relative to the ‘pure’ P\*-model used by Svensson. This is an important result which has implications for the feasibility of monetary targeting. As discussed in the introduction, inflation targeting and monetary targeting only coincide if the money

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<sup>8</sup> See Trecroci and Vega (2000), p. 15.



growth variable is a sufficient statistic for inflation. For the following discussion, it is useful to notice that the price gap can be decomposed as  $(p^* - p)_t = (p^* - p)_{t-1} + \Delta(m - \tilde{m})_t$ , as Trecroci and Vega show.<sup>9</sup> The term  $\Delta(m - \tilde{m})$  denotes the deviation of money growth from its reference value, that is,  $\Delta(m - \tilde{m})$  corresponds to the monetary indicator of the ECB. In the ‘pure’ P\*-model, the price gap is a sufficient statistic for inflation. The decomposition of the price gap by Trecroci and Vega shows that even if euro area inflation dynamics are modeled with a ‘pure’ P\*-model, the monetary indicator of the ECB would not be a sufficient statistic for inflation, because inflation depends also on the past price gap. Trecroci and Vega write:<sup>10</sup> “ ... when interpreting monetary developments in relation to the reference value, one needs necessarily to take into account the prevailing liquidity situation, since money growth above/below the reference value may well coexist with negative/positive real money gaps [price gaps in the notation of this paper].” Moreover, equation (13) shows that the price gap itself is *not* a sufficient statistic for inflation because, contrary to the predictions of the ‘pure’ P\*-model, the price gap is only one of several variables influencing inflation. Inflation targeting requires that all of these variables are taken into account. Hence, inflation targeting is not equivalent to monetary targeting.<sup>11</sup>

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<sup>9</sup> Following Gerlach and Svensson (2000), Trecroci and Vega denote the term  $(p^* - p)_t$  as real money gap and define  $(p - p^*)_t$  as price gap, whereas this paper defines  $(p^* - p)_t$  as the price gap.

<sup>10</sup> See Trecroci and Vega (2000), p. 13.

<sup>11</sup> The finding that the ‘pure’ P\*-model needs to be augmented with additional terms to account for inflation dynamics in the euro area is consistent with the analysis in Gerlach and Svensson who also employ additional variables.

The inflation target of the central bank plays an important role for the inflation dynamics modeled in equation (13). In fact, it serves as a nominal anchor. This is shown in Gerlach and Svensson, who use the same specification as Trecroci and Vega. In long-run equilibrium, which is defined here as a situation in which  $p_t \equiv p_{t-1}$ ,  $p_t \equiv p^*$ ,  $y_t \equiv y_t^*$ ,  $e_t^p \equiv 0$ , and  $s_t - \hat{p} \equiv (s - p)^*$ , one obtains  $p_t = \hat{p}$ . Thus, the long-run equilibrium rate of inflation is determined by the central bank's inflation target.<sup>12</sup> Deviations of inflation from this target are due to fluctuations of the price gap, the output gap, the real short-term interest rate and the inflation shock. Since the output gap already forms part of the price gap, the significance of the separate output gap variable shows that this variable has a higher weight in the inflation equation than suggested by the P\* framework.

In the remainder of this paper, the variables representing potential output, the equilibrium real short-term interest rate, and the inflation target of the central bank are treated as exogenous. Equation (13) models the path of the price variable  $p_t$ , which leaves the nominal interest rate, output and the equilibrium price level  $p^*$  to be modeled. Regarding  $p^*$ , this variable is defined as  $p_t^* \equiv m - y_t^* + v_t^*$ . The money demand function estimated in Coenen and Vega and presented below will determine money balances. Equilibrium velocity  $v^*$  is defined as  $v_t^* \equiv y_t^* - (m - p)_t^*$ , where  $(m - p)^*$  denotes equilibrium real money balances. These are determined by inserting equilibrium values for output, interest rates and inflation

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<sup>12</sup> This is derived from an expectations augmented P\*-model,  $p_t = p_{t,t-1}^e - a_p(p_t - p_t^*) + e_t$ , where  $p_{t,t-1}^e$  is expectations in quarter  $t-1$  of inflation in quarter  $t$ . Expected inflation is modeled according to  $p_{t,t-1}^e = \hat{p} + a_p(p_t - \hat{p})$ , where  $(1 - a_p)$  is an index of credibility of the inflation objective. The closer to unity this index is, the more credible is the inflation objective, so that expected inflation is more influenced by the inflation objective and less influenced by deviations of inflation from the objective. Inserting this expression for expected inflation into the expectations augmented P\*-model yields the formulation used in (13). See Gerlach and Svensson (2000), pp. 4.

into the long-run money demand function estimated in Coenen and Vega, yielding  $(m-p)_t^* \equiv 1.14y_t^* - 0.82(l-s)^* - 1.46\hat{p}$ .<sup>13</sup> The term  $(l-s)^*$  denotes the equilibrium spread between long- and short-term interest rates. This variable is assumed to be constant. Hence, once nominal money balances have been determined, the equilibrium price level can be computed.

### 3.2 Modeling Money Demand

Coenen and Vega propose the following empirical specification for money demand in the euro area:<sup>14</sup>

$$\begin{aligned} m_t = & \mathbf{p}_t + m_{t-1} - 0.739 + 0.075 \Delta(y_t - y_{t-1}) \\ & + 0.194(s_t - s_{t-2})/2 - 0.359(l_{t-1} - l_{t-2}) - 0.526(\mathbf{p}_t - \mathbf{p}_{t-2})/2 \\ & - 0.136[(m_{t-2} - p_{t-2}) - 1.14 y_{t-2} + 0.82(l_{t-2} - s_{t-2}) + 1.462\mathbf{p}_{t-2}] + \mathbf{e}_t^m \end{aligned} \quad (14)$$

with  $m$  nominal money balances,

$l$  long-term interest rate, and

$\mathbf{e}^m$  money demand shock.

Coenen and Vega specify their money demand function in terms of an error-correction model for real money balances, which has been reformulated here to

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<sup>13</sup> Trecroci and Vega employ a slightly different equation for equilibrium real money balances:  $(m-p)_t^* \equiv 1.158y_t^* + k^* - 1.278\hat{p}$ , where  $k^* = k_0 + k_i(l-s)^*$ . They estimate  $k^*$  as the average sample value, but do not report the resulting value. For this reason, the long-run money demand specification reported in Coenen and Vega (1999) is employed instead, which has also the advantage that it is consistent with the money demand function used in section 3.2.

<sup>14</sup> See Coenen and Vega (1999), p. 13. Their specification also includes a dummy variable for the year 1986, which has been omitted here, since it has no effect on the simulations conducted in the remainder of this paper.

yield nominal balances. The first two lines of (14) describe the short-run dynamics of money demand. Both output and short-term interest rates have positive impacts on money demand, whereas the long-term interest rate has a negative impact. The third line contains the error-correction term, which defines the long-run demand for money balances. As in Section 3.1, long-run money balances are given by

$$m = p + 1.14y - 0.82(l - s) - 1.46p . \quad (15)$$

If actual money balances deviate from the value implied by (15), this leads to an error-correction mechanism returning money balances to the value implied by (15). This mechanism is represented by the term in squared brackets in (14).

Like in the equations used to depict the short-run dynamics, output and short-term interest rates enter the long-run money demand function with a positive sign, whereas the other two variables enter with negative signs. Money demand theory suggests that an increase in output raises the demand for money balances for transaction purposes. The short-term interest rate represents the own rate of return of money, so that a higher short-term rate lowers the opportunity costs of holding money, which also leads to higher money demand. Higher long-term rates or inflation, on the other hand, raise the opportunity costs of holding money, thereby reducing money demand.

### 3.3 Modeling Aggregate Demand

Modeling inflation and money demand requires as input the path of actual output,  $y_t$ . For this purpose, this paper draws on the reduced form aggregate demand equation estimated in Gerlach and Smets (1999):<sup>15</sup>

$$(y_t - y_t^*) = 0.94(y_{t-1} - y_{t-1}^*) - 0.09(s_{t-1} - \bar{p}_{t-1}) + e_t^y, \quad (16)$$

with  $\bar{p}$  average inflation rate over the last four quarters,

$e^y$  aggregate demand shock.

As in the familiar IS curve framework, the output gap is here a function of its own lag and a lagged real short-term interest rate. To obtain the real interest rate, the nominal short rate is deflated with average inflation over the last four quarters, which can be interpreted as a measure of expected inflation. The coefficient for the real interest rate implies a rather modest response of the output gap to an increase in the interest rate: A one percentage point increase in the real short-term interest rate reduces the next quarter's output gap only by about 0.1 percentage points. However, the output gap response is very persistent. The coefficient of 0.94 for the AR(1) term implies a half-life of a disturbance of 12 quarters.

The aggregate demand shock corresponds to disturbances which shift the IS curve in the output / interest rate figure. This shock could represent, for example, a government spending shock. To distinguish this shock from monetary policy shocks, which also affect aggregate demand, the aggregate demand shock is denoted as a real demand shock in the remainder of this paper.

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<sup>15</sup> See Gerlach and Smets (1999), pp. 806.

A final building block of the model remains to be put into place: The short-term interest rate as the policy instrument of the ECB has been treated as an exogenous variable up to now. To endogeneize this variable, three different monetary policy regimes will be considered. However, before introducing these regimes, it is useful to simulate the effects of a given change in the short-term interest rate in order to explore the transmission mechanism of the model outlined so far.

### 3.4 The Effects of an Increase of the Short-term Interest Rate by 100 Basis Points

Before the results of numerical simulations of the setup can be presented, the initial conditions need to be spelled out. Before the model is subjected to a shock, it is assumed to be in equilibrium. Equilibrium is defined here as a situation in which  $\mathbf{p}_t \equiv \mathbf{p}_{t-1} \equiv \hat{\mathbf{p}}$ ,  $p^* - p_t \equiv 0$ ,  $y_t - y_t^* \equiv 0$ ,  $s_t - \hat{\mathbf{p}} \equiv (s - \mathbf{p})^*$ , and  $e_t^p = e_t^m = e_t^y \equiv 0$ . Moreover, it is assumed that for all variables  $x_t \equiv x_{t-1}$ . Regarding the exogenous variables,  $y_t^*$  is set equal to 100. The inflation target  $\hat{\mathbf{p}}$  is set to 0%.<sup>16</sup> With constant values for potential output and equilibrium velocity,  $p^*$  only depends on the money stock. Since empirical evidence suggests that the equilibrium real short-term interest rate in the euro area is approximately 3%, this value is chosen here for this variable.<sup>17</sup> Furthermore, this variable represents the neutral rate so that an real interest rate above 3% corresponds to a restrictive policy stance whereas an interest rate below 3% represents an expansionary policy. The neutral nominal short-term interest rate is also 3% since inflation is 0% in equilibrium. Another exogenous variable is the equilibrium spread between long- and short-term interest rates, which has been on average over the past twenty years approximately 0.80%, reflecting a risk premium for assets with long time periods to maturity. The link between the short- and long-term interest rates is provided by the expectations theory of the term structure, which states that the long rate is equal to the expected weighted average of future short rates plus a risk premium. With these assumptions, inflation is zero at the onset of the simulation, as are the price gap and the output gap. The short-term interest rate is at its neutral value of 3%.

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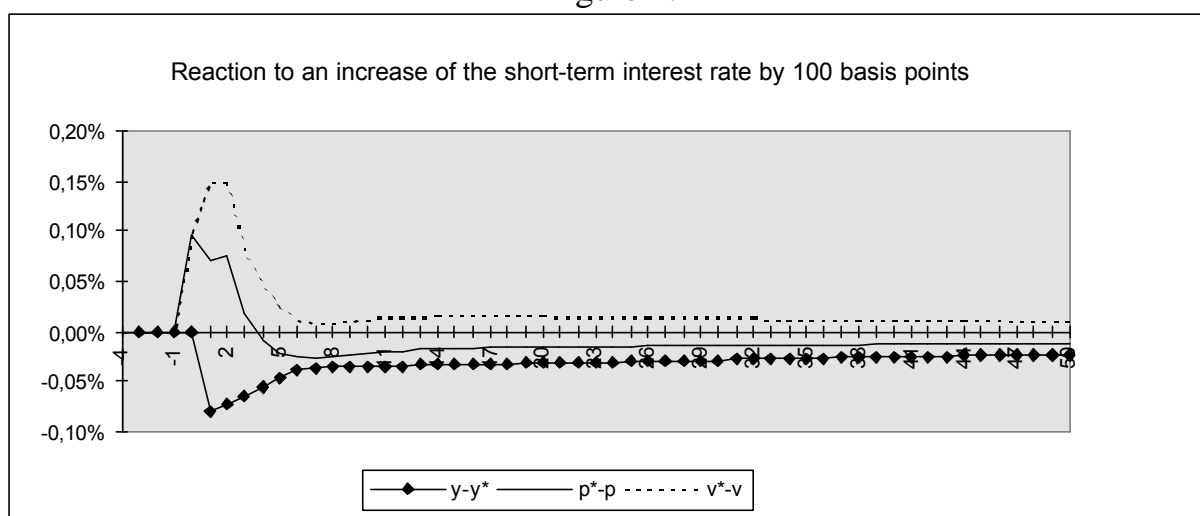
<sup>16</sup> We could have also chosen the likely ECB target of 1.5%, but setting it to zero simplifies the exposition by defining for all variables the zero-line as baseline.

<sup>17</sup> See Kamps and Scheide (2001) for a discussion.

To illustrate the transmission mechanism, we conduct the following experiment: Starting from equilibrium, the central bank raises the short-term interest rate by 100 basis points, but after one quarter, it lowers the interest rate again by the same amount, thereby returning the policy instrument to its neutral value of 3%. This experiment traces out the effects of an exogenous monetary policy shock, which is modeled here as a shock to the policy instrument. This shock can be interpreted as a discretionary policy action, leading to a one-period deviation of the policy instrument from the path implied by the interest rate rule the central bank otherwise follows.

Figure 1 shows the impact of the monetary policy shock on the price gap which can be decomposed into an output gap and a velocity gap. The output gap, represented as the line with the solid boxes, reacts with a lag of one period to the interest rate impulse. Since a higher nominal interest rate translates into a higher real interest rate, according to the IS relation, the output gap becomes negative following the tightening of the policy. After the interest rate impulse is reversed, the output gap returns to zero, but only very slowly, reflecting the high persistence of this variable.

Figure 1:





Whereas the output gap response is in accordance with conventional wisdom, the response of the velocity gap, represented by the dotted line, is more surprising. Following an interest rate hike, the velocity gap does not become negative, but positive. The positive response of the velocity gap is even strong enough to overcompensate the negative output gap so that the price gap, represented by the solid line, becomes positive. This result is clearly counter-intuitive. However, the ultimate source of this result lies in the specification of the money demand function, which turns out to be quite robust in the literature on money demand in the euro area.

To gain an understanding of the response of velocity to higher interest rates, a convenient starting point is the definition of velocity given by  $v = y + p - m$ . It is apparent here that lower output following a tighter monetary policy stance induces a decline of velocity. The velocity gap is defined as  $(v^* - v)$ , so that the output response to the interest rate shock, *ceteris paribus*, leads to a positive velocity gap. In fact, if prices and the money stock were not responding initially to the interest rate impulse, the upward movement of the velocity gap would initially exactly offset the negative output gap. The intuition behind this result is that in the  $P^*$  framework prices only move upwards when  $p^*$  has increased. With constant values for  $y^*$  and  $v^*$  this can only happen when the money stock rises. As long as the money stock does not respond to the interest rate impulse,  $p^*$  does not change and hence the price gap remains zero. This implies that the velocity gap has to exactly offset the movements of the output gap. However, in figure 1 we observe that the velocity gap rises in absolute terms more strongly than the output gap, so that one obtains a positive price gap. Thus, the money stock must have increased. The money demand function proposed by Coenen and Vega shows a strong positive contemporaneous response of money demand to an increase in the short-term interest rate, which accounts for this finding. In addition, two periods after the interest rate impulse, the error-correction term representing the long-run money demand relationship has an effect on money demand. An increase in the short-term interest rate reduces the term-spread,

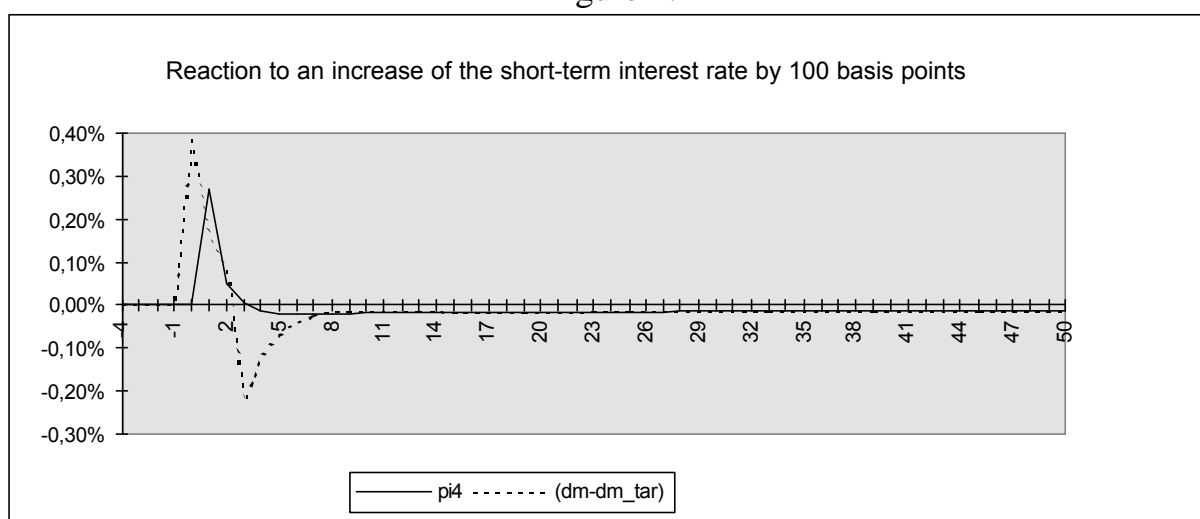
which stimulates long-run money demand. Lower output, on the other hand, reduces long-run money demand, but output responds only with a lag to the interest rate impulse, so that initially the positive interest rate effect on money demand dominates. Thus, the positive effect of higher short-term interest rates on money demand in the long-run relationship also contributes to the counter-intuitive result that the price gap is initially positive following a tightening of the policy stance.

Whereas the specification of the short-run dynamics of the money demand function is specific to each empirical model of money demand, most models agree on the long-run specification regarding the role of the short-term interest rate as the own rate of return of broad money. In particular, a positive coefficient for the short-term interest rate in the long-run money demand relationship is also reported in Gottschalk (1999), Hahn and Müller (2000) and Gerlach and Svensson (2000). To evaluate the robustness of the results reported here, we have investigated the same model using the money demand function and  $P^*$  equation as utilized in Gerlach and Svensson. The results are qualitatively similar to those reported here, which points to the robustness of this finding. An exception is the money demand system proposed by Brand and Cassola (2000), who exclude the short-term interest rate from the money demand long-run relationship on a priori grounds. Substituting their money demand function in the model investigated here yields a negative response of the price gap to the interest rate impulse. Even though this result is more intuitive, this specification of the money demand function remains the exception. In this regard, it is interesting to notice that it is the velocity gap which distinguishes the  $P^*$ -model from other models of inflation. These models usually explain inflation as a function of the output gap. Thus, the initially positive response of inflation to higher short-term interest rates is a feature specific to  $P^*$ -models since it is due to the strong response of velocity to an interest rate impulse.

In the model considered here, the velocity gap stays positive for some time although the interest rate has been returned to its neutral value already after one quarter. The persistence of the velocity gap is a reflection of the high persistence inherent in the money demand function. An important factor here is that the rise in prices leads to further increases in money demand. With nominal money balances rising, the velocity gap remains positive, indicating a monetary overhang. However, after about one year, the negative effect on money demand of the decline in output begins to dominate so that money demand and hence money balances begin to fall. This goes along with a fall of  $p^*$  so that the price gap becomes negative.

Figure 2 shows the response of the annualized rate of inflation to this policy experiment: It takes about six quarters for inflation to fall below its baseline. All in all, the one-period increase of the short-term interest rate by 100 basis points does not reduce the inflation rate by much, but the dampening effect lasts for a considerable time. The reason for this is that lower inflation translates for a given nominal interest rate into a higher real interest rate, which in turn slows down the closing of the output gap. With the output gap remaining negative,  $p^*$  continues to fall, keeping the inflation rate below its baseline.

Figure 2:



Regarding the relationship of the monetary indicator to future inflation, the turning point of the monetary indicator (also expressed as an annualized rate) leads the turning points of inflation by one quarter. However, there is no one-to-one relationship of the monetary indicator with future inflation: the monetary indicator initially overshoots by approximately 0.40%, while inflation is at its peak only by about 0.25% higher than it was at the beginning of the experiment. Also, when the dampening effect of the negative output gap begins to dominate and inflation declines, the monetary indicator undershoots by approximately 0.20%, whereas inflation falls at most by 0.02% below the baseline. Thus, the monetary indicator is in this simulation at most a leading indicator of the *direction* toward which inflation is moving, but it does not predict by how much inflation is going to change.

The lead of one quarter is also too short to employ the monetary indicator as a leading indicator of the movements of inflation over the medium term, which is of particular interest for the ECB. For instance, immediately after the central bank raises the short-term interest rate by 100 basis points, the monetary indicator signals that inflationary pressure is building up. If one interprets the monetary indicator as an indicator of threats to price stability over the medium term, one has to conclude that following this shift to a tighter monetary policy stance the central bank is likely to miss its target of price stability. However, interpreting the medium term as a two year horizon, inflation is at this horizon actually below its target and not above. Thus, in this instance the monetary indicator turns out to be highly misleading, due to the positive short-run response of money demand to an increase in the short-term interest rate.

To summarize, figure 2 suggests that the monetary indicator must be interpreted with care even when inflation is modeled within a P\* framework and fluctuations of inflation are due only to monetary policy actions.

### 3.5 Monetary regimes

To model the systematic response of monetary policy to disturbances, we consider three different policy regimes: real interest rate targeting, inflation targeting, and monetary targeting. With real interest rate targeting (RIT), the central bank is assumed to aim always at keeping the short-term real interest rate constant. In our simulation, we implement this regime by imposing the restriction that the short-term interest rate has to be set so that the sum of the squared deviations of the short-term real interest rate from its neutral value (3.00 %) is being minimized. Under inflation targeting (IT), the central bank is assumed to aim at bringing the inflation rate back to its target (0.00 %) within two-years after a shock has occurred. The two-year horizon is chosen to reflect the commitment of central banks to maintain price stability over the medium-term. This policy regime imposes the restriction on the path of the policy instrument to minimize the sum of squared deviations of the inflation rate from its objective in the time period beginning two years after the shock. For the monetary targeting regime (MT), we assume that monetary policy makers wish to bring money growth back to the reference value within one year after a shock has occurred. Here a shorter horizon than for inflation targeting is chosen because monetary targeting refers to an intermediate target. The reference value for the money growth target is given by equation (10). With the assumptions of constant potential output and equilibrium velocity, and with a zero inflation target, the reference value is set to zero in our model. Monetary targeting requires setting the policy instrument so as to minimize the sum of the squared deviations of money growth in the time period beginning one year after the shock.

For all policy regimes, an additional smoothing restriction is imposed. Since interest rate smoothing is an important part of monetary policy, we require the simulation to keep the variance of the change of the policy instrument below

a certain threshold value, which we derive from empirical data on interest rate setting behavior. All simulations cover a horizon of 25 years, which serves to tie down the long-run responses of the model. For the graphical presentation offered below, a 12 year horizon is sufficient.<sup>18</sup>

Before presenting the results, it needs to be stressed that the empirical model proposed here is not intended to generate exact predictions of the transmission mechanism in the euro area. Rather, this model is conditional on the assumption that the inflation process can be described by an extended P\*-model. This is a fairly strong assumption, because the P\*-model, as pointed out by Gerlach and Svensson, has no microeconomic foundation which sets it apart from most modern macroeconomic models. Nevertheless, the P\*-model is popular in applied business cycle research.<sup>19</sup> More generally, we believe our model captures with the P\* and IS relations two fundamental relationships which form the analytical basis of many business cycle reports. Moreover, the P\* framework is chosen on the grounds that if the ECB's monetary indicator works anywhere, it does so here. Regarding the parameter estimates used to quantify this model, these are, of course, open to debate. To account for this, we also experimented with the P\* equation and money demand function reported in Gerlach and Svensson. In addition we employed the money demand function estimated in Brand and Cassola (2000) in our model. The results reported below turned out to be robust with regard to these alternative specifications.<sup>20</sup>

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<sup>18</sup> The simulations have been computed in Excel, using the solver function to impose the restrictions on the model. The corresponding files with all results are available from the authors upon request.

<sup>19</sup> It is employed, for example, in the business cycle analysis of Goldman Sachs (Mayer and Deo (1999)) and of the Kiel Institute of World Economics (Kamps and Scheide (2001)).

<sup>20</sup> All these files are available to the reader upon request.

## IV. Shocks

Having gained a first impression of how the transmission works in this system, we explore now the response of the output gap, the price gap, inflation and the monetary indicator to the three exogenous shocks in our empirical model. We begin with the real demand shock because this shock played a prominent role in causing recent business cycle fluctuations in the euro area. Foreign demand shocks due to the Asian crisis, the Russian crisis and the boom and bust in the U.S.A. fall all into this category. This is followed by a discussion of the effects of an inflation shock. Such a shock can be interpreted as a cost-push shock, for example, due to rising import prices. Finally, we consider a money demand shock. The effects of this type of shock are interesting because it affects inflation only in the P\* framework, but not in a traditional Phillips curve framework. We analyze the effects of all three shocks for each of the three monetary policy regimes outlined above. The discussion of the effects of a real demand shock will be fairly comprehensive. Once the dynamics of the model have been outlined, the discussion of the remaining two shocks will be kept brief.

### 4.1 Real demand shock

To model the effects of a real demand shock, the shock variable  $e_t^y$  in the aggregate demand relation takes the value 0.01 in period 0, leading to an increase in output of 1% in this period. In the time period thereafter, the shock variable is set to zero again. If there is no policy response to this increase in aggregate demand, the output gap remains positive for a considerable period of time. Higher output leads to higher money demand because of increased demand for money to be used for transaction purposes. This leads to a higher money stock, which in turn leads to a positive price gap, triggering an increase in inflation. The resulting

lower real interest rates stimulate aggregate demand, thereby keeping the output gap positive. In the long-run, however, the system returns to its equilibrium. This is due to the presence of the nominal anchor, the inflation target, which appears in the inflation equation. Deviations of inflation from the inflation target lead to an error-correction mechanism, which ensures a gradual return of inflation to its target value. With the inflation rate returning to its target, the real short-term interest rate returns to its equilibrium value. Since the output gap is a stationary variable, the effects of the real demand shock on output also die out eventually, so that the system is back in equilibrium. However, in the empirical model considered here, it takes more than 25 years before all adjustment processes have been completed.

Figure 3:

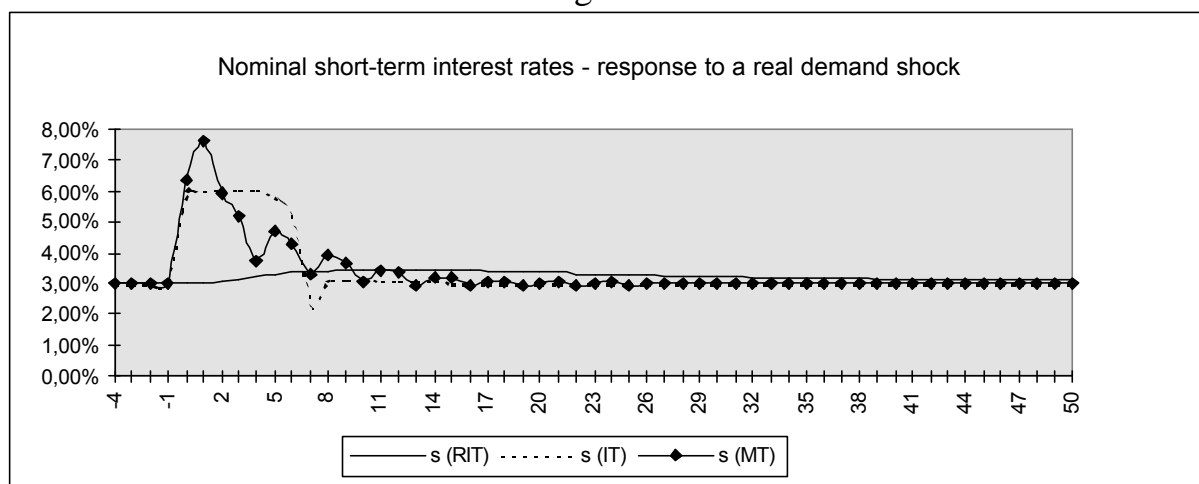


Figure 4:

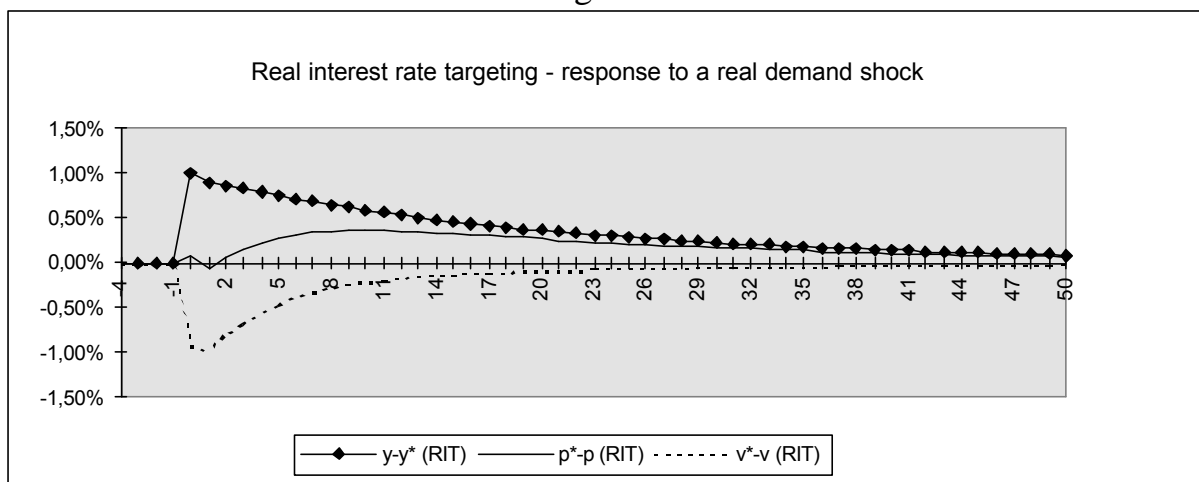
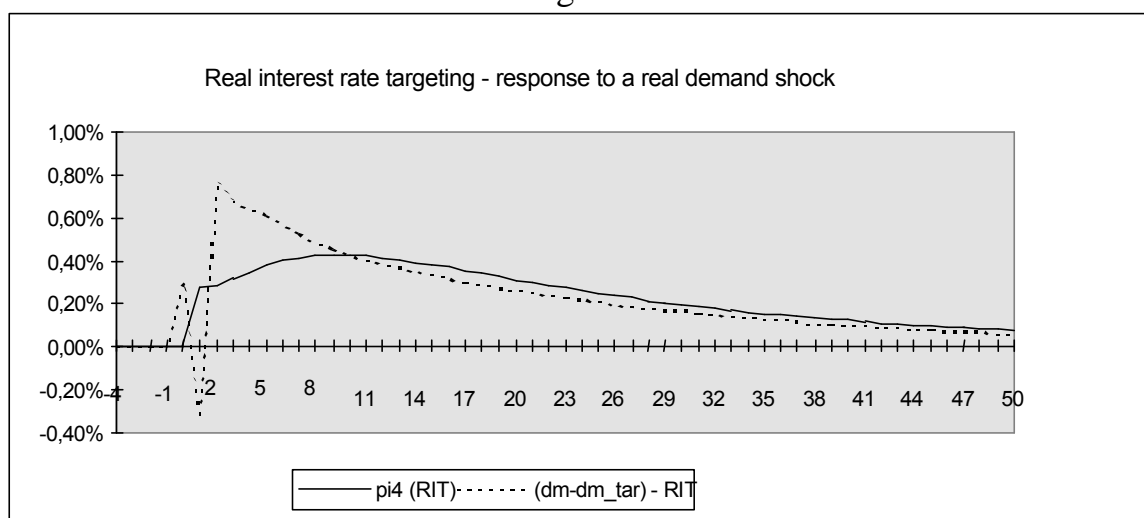




Figure 5:



The first monetary regime we consider is the real interest rate targeting regime. Given that the increase of inflation leads to a lower real interest rate, the central bank has to raise the nominal interest rate in order to hold real interest rates constant. The interest rate response is shown in Figure 3. It is apparent that to stabilize the real interest rate, it is sufficient to raise the nominal interest rate only slightly. Consequently, the output gap returns only very gradually to its baseline (Figure 4). This is a reflection of the high persistence of the output gap. As noted above, the half-life of a disturbance is 12 quarters. The positive output gap triggers a similarly persistent positive price gap. In addition, the output gap has a direct effect on inflation. Thus, inflation rises in response to the real demand shock, reaches its peak after about three years after the shock, and then returns slowly to its baseline. The relationship between the monetary indicator and inflation is shown in Figure 5. The monetary indicator reaches its peak about two years earlier than inflation. Thus, in this simulation the monetary indicator has a considerable lead before inflation. Once inflation has reached its peak, inflation and the monetary indicator coincide.<sup>21</sup> As with the case of the monetary

<sup>21</sup> The decrease of money growth in the immediate aftermath of the real demand shock results from the specification of the short-run dynamics of the money demand function and therefore is specific to the money demand model estimated in Coenen and Vega (1999).

policy shock, there is again no one-to-one relationship between the monetary indicator and inflation since the former overshoots by 0.8 % whereas inflation overshoots by only 0.4 %. In summary, in the case of the real interest targeting regime the monetary indicator correctly indicates dangers to medium term price stability, even though it over-predicts them somewhat.

The second regime we consider is that of inflation targeting. In striking contrast to real interest rate targeting, inflation targeting requires the central bank to raise short-term interest rates sharply to bring inflation back on target with-

Figure 6:

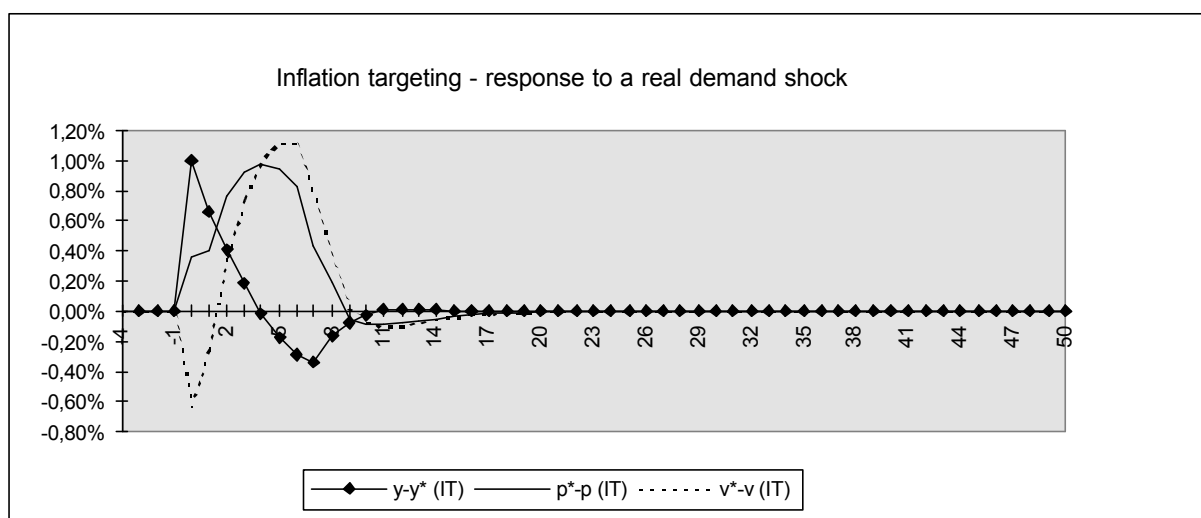
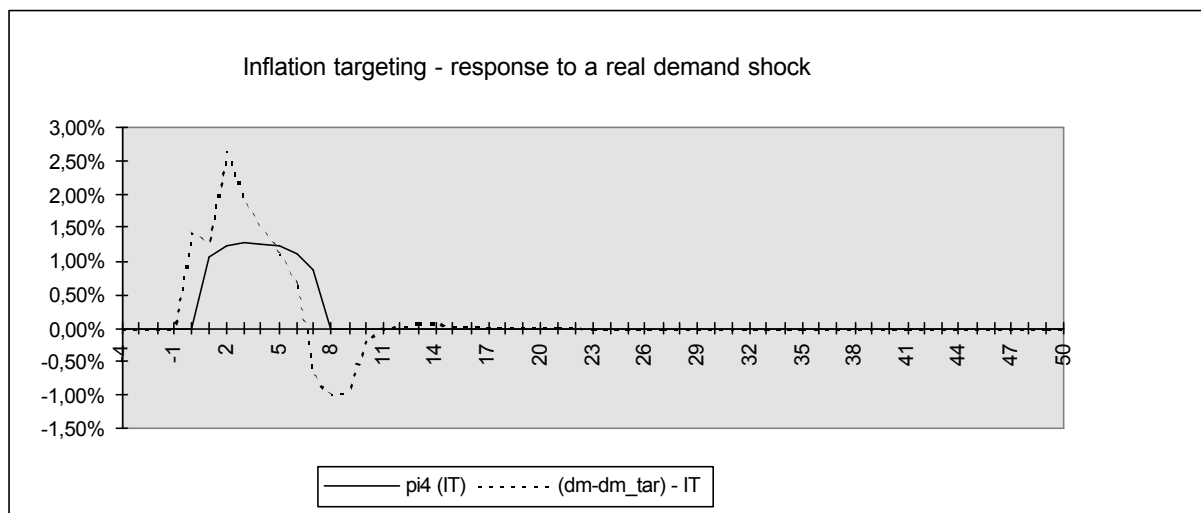


Figure 7:



in the desired two year horizon (Figure 3). The effects of this tight monetary policy stance are shown in Figure 6. High real short-term interest rates bring the output gap quickly back to zero. In the second year after the shock, the output gap even undershoots. But high short-term interest rates also induce a positive velocity gap, so that tight monetary policy initially leads to a larger positive price gap than would have been obtained with a less restrictive monetary policy. This initial positive effect of higher short-term interest rates on the price gap has been discussed already in Section 3.4. There it has also been shown that the dampening effect of high real interest rates on output eventually begins to dominate, closing the price gap again. It is apparent from figure 6 that with inflation targeting, the path of the policy instrument is chosen so that the output gap and the price gap are approximately zero two years after the shock, thereby completing the adjustment process of output, money and prices to the real demand shock within the envisioned two year horizon. Output returns to potential, whereas money and prices reach new, higher equilibrium values following the shock. Compared to the real interest rate targeting regime, this represents a considerable acceleration of the adjustment process. However, this acceleration also leads to higher inflation in the first two years after the shock, as a comparison of Figures 5 and 7 shows. Thereafter, inflation is exactly on target in the inflation targeting regime.

Regarding the relationship between the monetary indicator and inflation, the results are similar here to those reported for the effects of a monetary policy shock. This is not surprising because monetary policy essentially neutralizes the effects of the real demand shock by sharply raising interest rates. Since the monetary indicator is not much of a leading indicator when the economy is subjected to the higher interest rates due to a monetary policy shock, the monetary indicator's leading indicator qualities also suffer when the economy is subjected to higher interest rates caused by a strong systematic monetary policy response.

In Figure 7, it is apparent that the monetary indicator initially has a short lead of about one quarter before inflation. This lead is too short to employ this variable as a leading indicator of medium term risks to price stability. In fact, in the inflation targeting framework, there are, by construction, no medium term risks to price stability, so that the initial overshooting and the later undershooting of the monetary indicator give a wrong signal.

Figure 8:

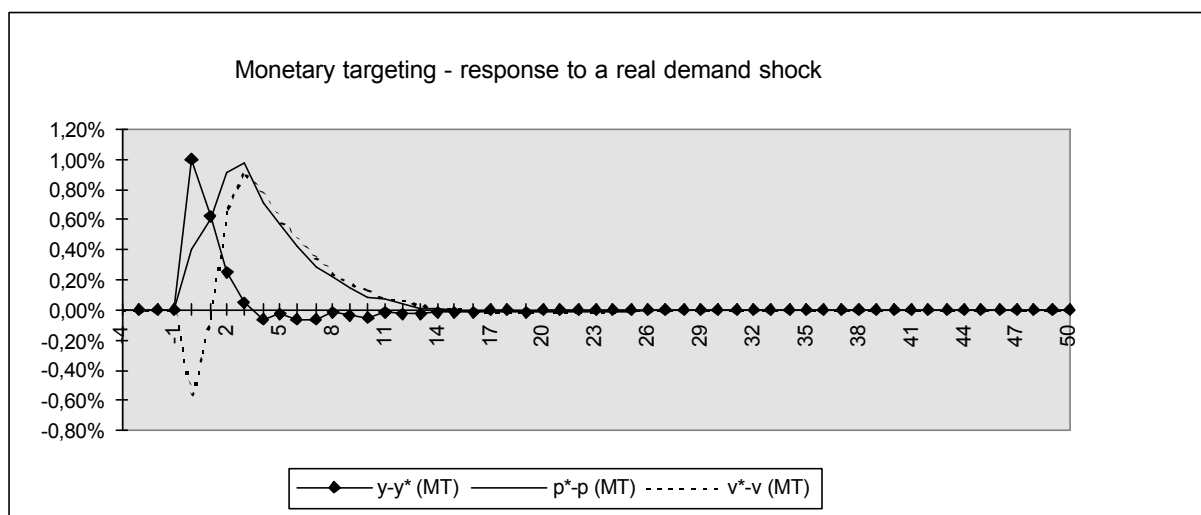
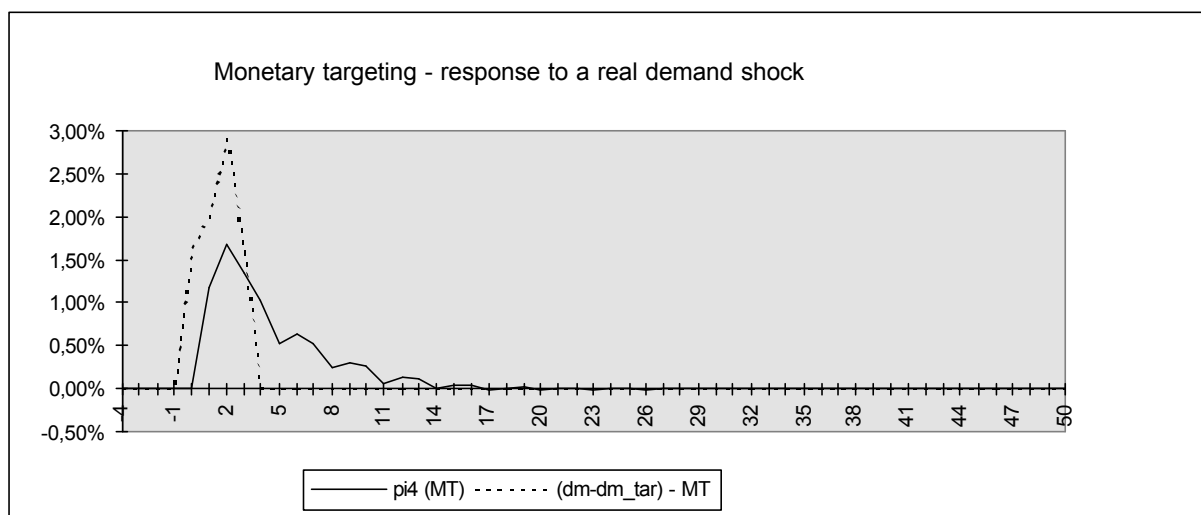


Figure 9:



The third monetary policy regime we consider is that of monetary targeting (Figure 8 and 9). As Figure 3 shows, the path of the interest rate under monetary targeting and inflation targeting are generally similar. The difference is that monetary targeting requires a stronger initial interest rate hike, but then the short-term interest rate more quickly returns to its neutral value. This stronger initial response of the central bank is necessary to complete the adjustment of the money stock to its new long-run equilibrium value within four quarters. Compared with inflation targeting, this policy closes the output gap faster, but the velocity gap and hence the price gap remain positive for a longer time period. From this it follows that inflation also takes longer to return to its target. Instead of two years, it takes about three years here whereas the money stock is on target already one year after the shock. The comparison of this result with Figure 7 shows that monetary and inflation targeting are not equivalent to each other, even in a  $P^*$  framework. Instead, there appears to be a trade-off: If one aims at bringing inflation back on target within the envisioned two year horizon, one has to accept fairly persistent deviations of money growth from the reference value. Vice versa, if money growth is to be back on target within one year, then inflation takes three instead of two years to return to target. This confirms a central result of Svensson (2000) who also shows that inflation targeting is not the same as monetary targeting within this framework.

Regarding the leading indicator qualities of the monetary indicator, both the monetary indicator and inflation reach their peak two quarters after the shock, so that both variables are coincident. However, the monetary indicator overshoots by 3%, whereas inflation is at its peak only 1.75% over target. Money growth returns to its target within the following two quarters, whereas this process for the inflation rate takes approximately an additional three years. As an indicator of threats to price stability over the medium term, the monetary indicator signals considerable risks, but this is (again) a false signal because inflation is at the two year horizon well on its way back to target.

## 4.2 Inflation shock

Figure 10:

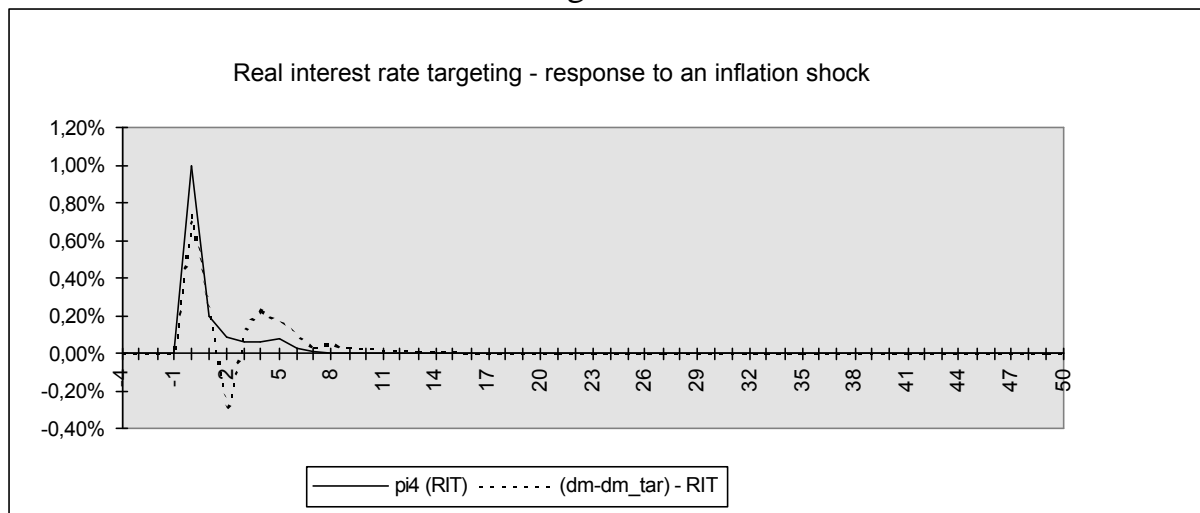


Figure 11:

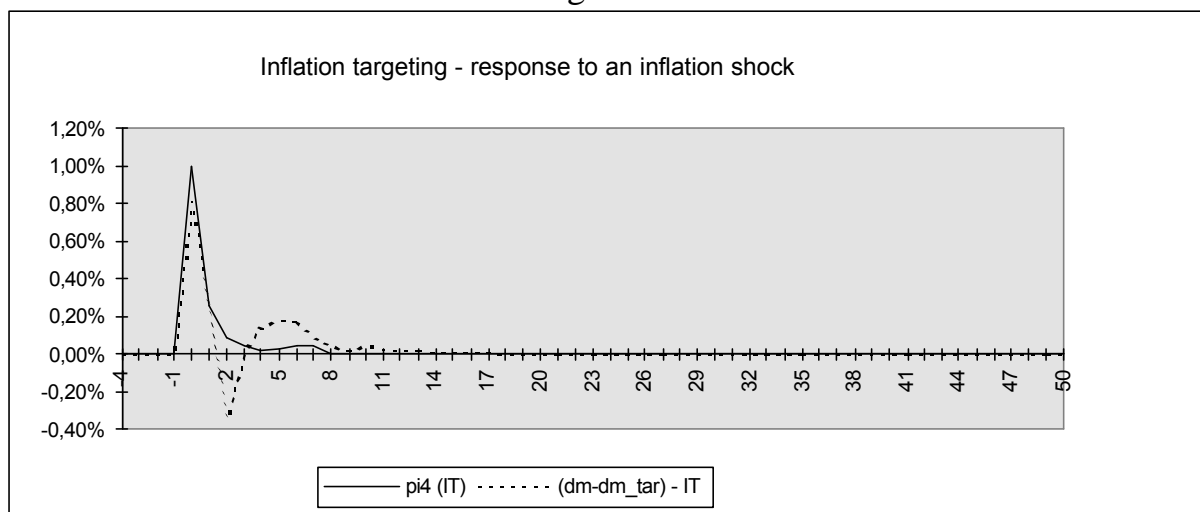
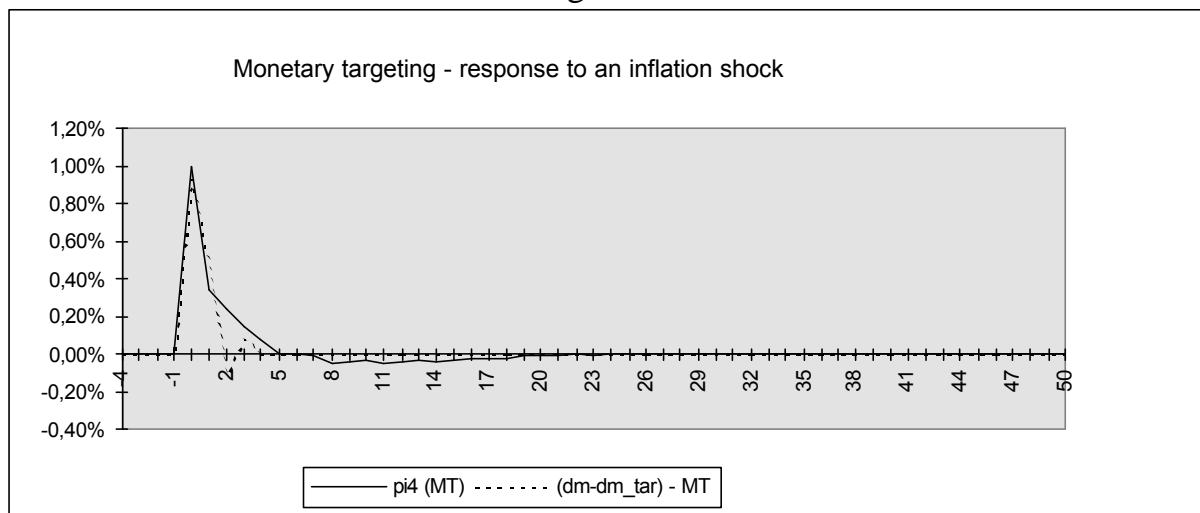


Figure 12:



In this section we consider the effects of an inflation shock. This shock leads to a rise of inflation by 1.00% in period 0. Before and thereafter, the inflation shock  $e^p$  is set to zero. Having discussed the transmission mechanism and the monetary policy in some detail already in the preceding section, we focus here on the relationship between the monetary indicator and inflation (Figures 10 to 12). Under all monetary regimes, the inflation shock initially drives up both inflation and money growth. The causality runs in this case from prices to money, because inflation leads to an increase of the price level, which in turn leads to higher demand for money for transaction purposes. The rise in inflation is merely temporary since inflation returns quickly to its target. Money growth, in contrast, first undershoots and then overshoots in all three monetary policy regimes before returning to the baseline. These dynamics are attributable to the negative effect of inflation on money demand (undershooting) and the positive effect of higher interest rates on money balances (overshooting). Taken together, the case for the monetary indicator as a leading indicator of inflation again does not appear to be very strong.

### 4.3 Money demand shock

Figure 13:

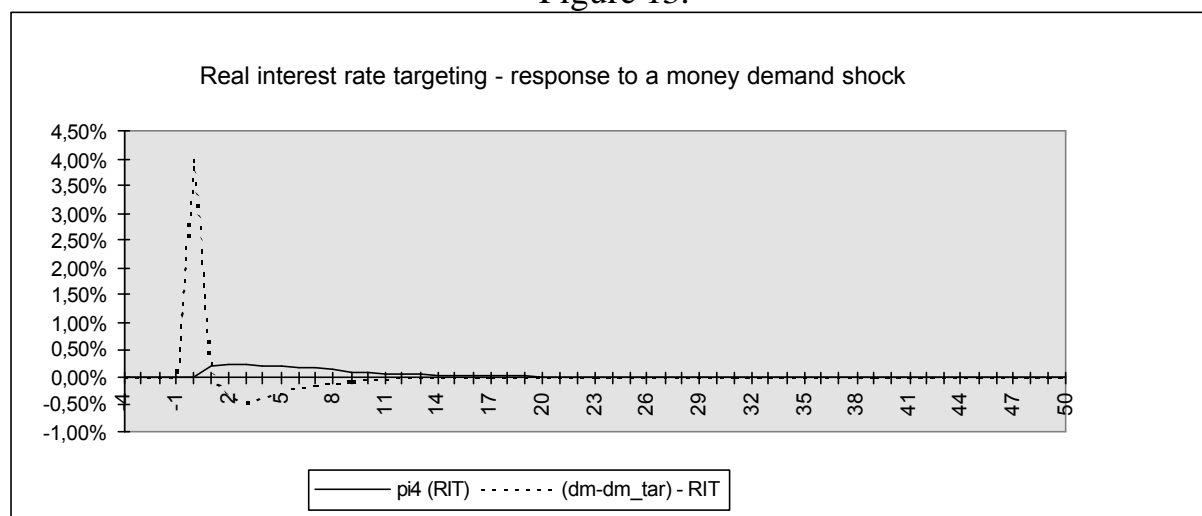


Figure 14:

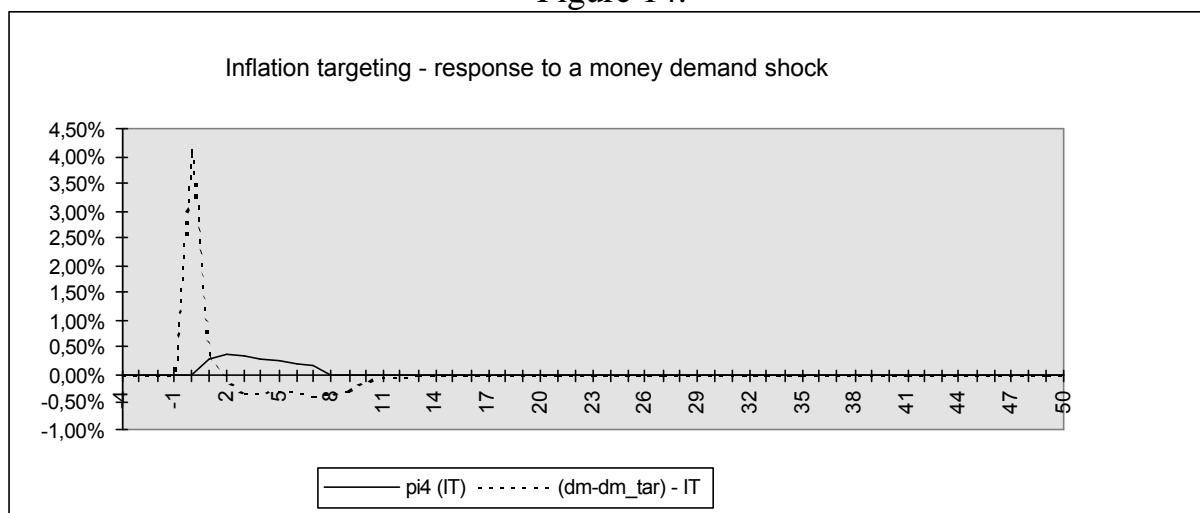
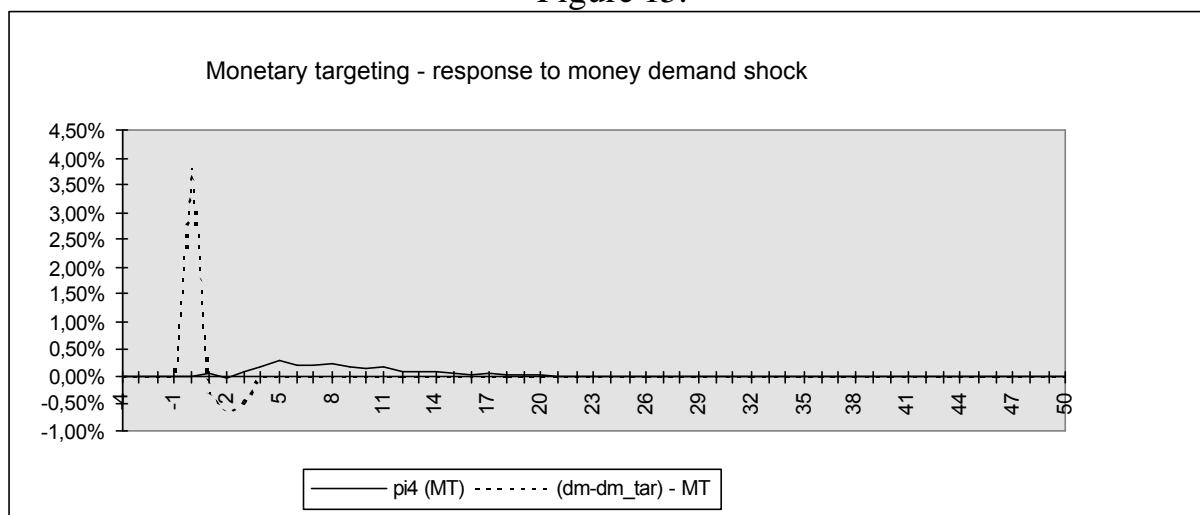


Figure 15:



The money demand shock  $e^m$  raises the demand for money balances by 1.00% in period 0. In all other periods, the money demand shock takes the value zero. The results for this simulation are shown in the Figures 13 to 15. Since the monetary indicator is expressed like the inflation rate as an annualized rate, the money demand shock leads on impact to an annualized growth rate of 4% in the money stock. Thereafter, money growth undershoots the target growth rate in all monetary regimes before returning to the target of the growth rate. Inflation does not respond very much to this temporary acceleration of money growth. In a conventional Phillips curve framework for modeling inflation, there would be no response of inflation to a money demand shock at all, whereas in the P\*



framework, higher money balances lead to a higher equilibrium price level. Therefore, in this example, causality runs from money to prices. The initial jump of the monetary indicator by 4% correctly indicates that inflation is going to rise. But there are hardly risks to medium term price stability. The subsequent undershooting of the monetary indicator gives a wrong signal since inflation does not undershoot at any time. Again, all in all, the information content of the monetary indicator as a leading indicator of inflation is limited.

## V. Conclusion

The empirical analysis in this paper confirms the theoretical results found by Svensson (2000): Even if one models inflation with a  $P^*$ -model, the relationship of the monetary indicator to future inflation is too weak to use the monetary indicator as a leading indicator of future inflation, let alone to consider it as a sufficient statistic for this variable. This result even holds if the world is characterized by only one shock and one monetary regime. This finding is mainly due to the following two reasons. First, with the money stock being endogenously determined, the causality does not run only from the money stock to prices (as is the case in the 'traditional'  $P^*$ -model where the money stock is assumed to always equal money supply, with latter being set by the central bank), but also runs from prices to money. This two-way relationship has an adverse effect on the leading indicator properties of the monetary indicator for future inflation. Second, all three equations in the model considered in the present paper display complicated dynamics. Since the relationship of the monetary indicator to future inflation involves all three equations as well as the monetary policy response, one cannot expect a simple linear relationship between these two variables. For instance, one reason why a given change in the monetary indicator does not imply that the inflation rate has to change eventually by a similar amount is that time is required for a higher growth rate of money to work its way through to higher inflation. Before this process is completed, the effects of tighter monetary

policy can reduce the money stock again, thus preventing the initial build-up of inflationary pressures to materialize. Consequently, there is no longer any simple relationship between the monetary indicator and inflation, or, for that matter, no simple relationship between the money stock and the price level.

If the actual world is characterized by many different shocks and possibly by changing monetary regimes, this implies that the relationship of the monetary indicator with inflation becomes even more tenuous than in a one shock / one policy regime. Regarding the source of shocks, the results presented here suggest that the leading indicator property of the monetary indicator is likely to suffer particularly if inflation and money demand shocks dominate.

Also, if an inflation model other than the  $P^*$  framework used above is chosen, the relationship between the ECB's monetary indicator and future inflation is likely to be even weaker because broad money balances usually do not play a major role in the transmission mechanism in those models. For example, McCallum (1999) writes that it is a typical feature of models presented at recent conferences not to include money demand equations or sectors. Instead, these models usually contain an expectations based IS equation, a price-adjustment relationship and a Taylor-style monetary policy rule. These three equations are fully sufficient to determine the time paths of the three endogenous variables of interest, namely real output, inflation and the interest rate. McCallum concludes that in such a model there is no need for a money demand function. Including a money demand function is not inconsistent with such a model, but would be irrelevant in determining the behavior of output, inflation and the policy instrument.<sup>22</sup> Thus, there is not much reason to expect money balances to perform better as an indicator of future inflation than in the type of model we employed in our empirical experiment.

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<sup>22</sup> See McCallum (1999), pp. 23.

Finally, the question arises how the results presented here can be reconciled with the empirical finding that broad money provides significant information for future inflation, especially at medium term horizons. Both Gottschalk et al. (1999) and Altimari (2001) find that for long forecast horizons (two years and beyond) broad monetary aggregates have leading indicator properties for future inflation.<sup>23</sup> The simulation experiment above shows that the monetary indicator is indeed a leading indicator of inflation at the two year horizon if real demand shocks dominate and monetary policy does not respond strongly to such shocks (real interest rate targeting regime). Since real demand shocks are arguably an important source of business cycle fluctuations and since the record of high inflation in many European countries prior to European Monetary Union suggests that those national European central banks did not always act vigorously to fend off dangers to price stability, this experiment is likely to capture a significant part of past conditions in the euro area. However, the monetary policy strategy of the ECB is probably better described as an inflation targeting or a monetary targeting regime than as a real interest targeting regime. In other words, the shift to a single monetary policy constitutes a regime shift away from a passive conduct of monetary policy towards a policy with a strong commitment to act decisively to maintain price stability, if necessary. Our simulation experiments with the inflation and monetary targeting regimes suggest that such a regime shift will have adverse consequences for the information content of broad monetary aggregates. In particular, due to the strong positive effect of the short-term interest rate on money demand it is to be expected that the ability of the monetary indicator to signal future inflation developments suffers if the ECB increases (or lowers) the short-term interest rate forcefully to keep inflation on target. That is, our results

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<sup>23</sup> However, for shorter horizons both studies find that the forecast performance of models based on nominal M3 is not particularly satisfactory.

point to the relevance of the familiar Lucas (1976) critique in the present context.<sup>24</sup>

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<sup>24</sup> See also Woodford (1994) for a discussion of this issue.

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