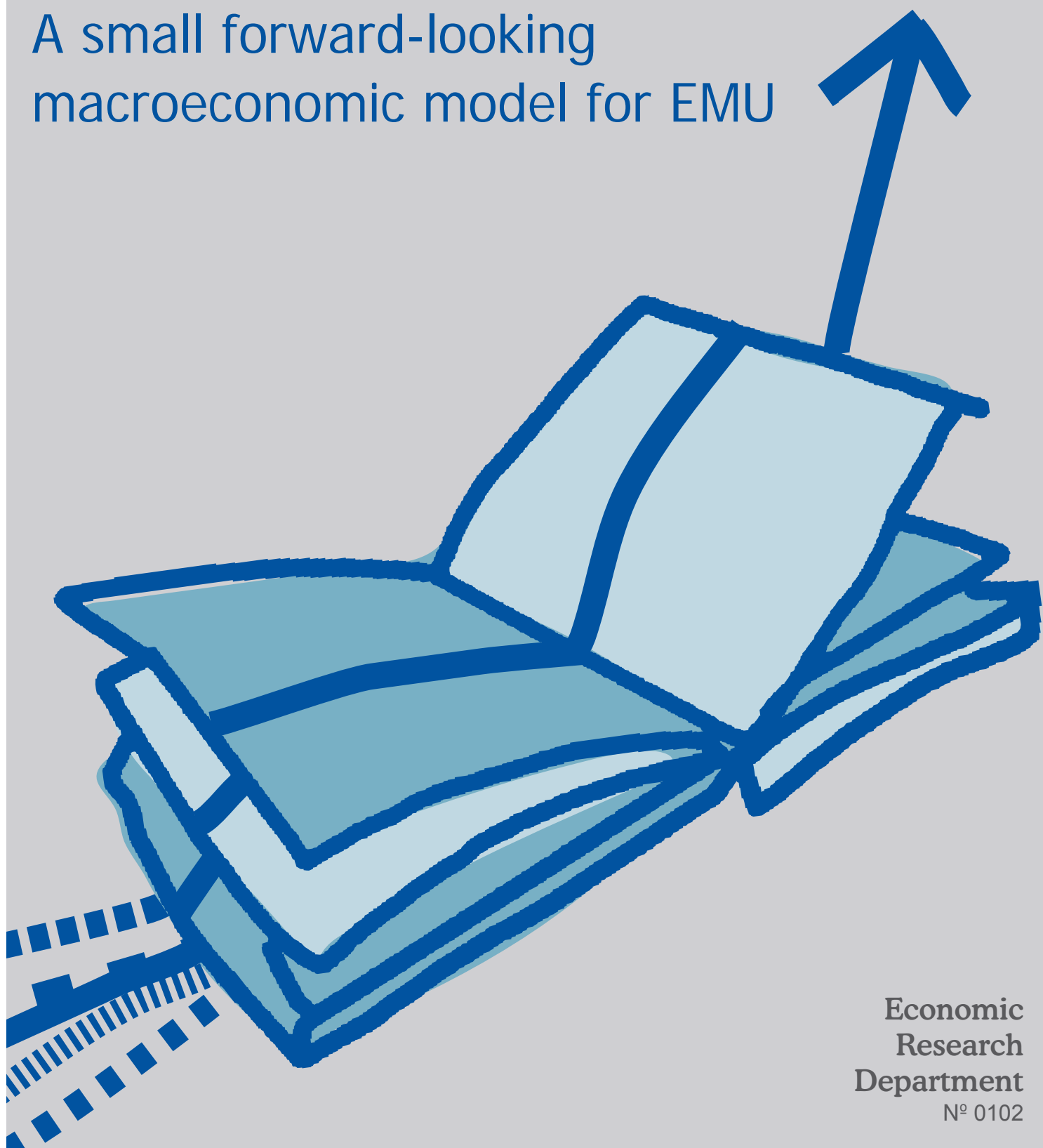


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A small forward-looking
macroeconomic model for EMU



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A Small Forward-Looking Macroeconomic Model for EMU*

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Abstract

In this paper we estimate a small forward-looking macroeconomic model for EMU which allows us to analyze the transmission mechanism of the monetary policy implemented by the European Central Bank through an interest rate rule that stabilizes inflation and output. The estimation of this model, which comprises forward-looking versions of the IS and the Phillips curves as well as the interest rate rule, is conducted by GMM using quarterly data from 1986 to 2000. We find that this simple model matches the dynamic properties of the output gap, inflation and the interest rate in EMU quite accurately. We also perform several exercises that show the response of output, inflation and interest rates to different kinds of shocks affecting the economy, under the assumption that the ECB implements the monetary policy described by the estimated interest rate rule. Comparisons with backward-looking models for the United States show that our forward-looking model produces less persistence of the endogenous variables in response to shocks of the same magnitude.

Keywords: IS curve, inflation, interest rate rule, monetary policy

JEL Classification: E31, E32, E52

1. Introduction

In this paper we estimate a small forward-looking macroeconomic model for EMU which allows us to analyze the transmission mechanism of the monetary policy implemented by the European Central Bank through an interest rate rule that stabilizes inflation and output. Although central banks use more information than inflation and output gaps to set their interest rates, the validity of such a rule has been emphasized by Clarida, Galí and Gertler (1998 and 2000), Judd and Rudebusch (1998), Gerlach and Schnabel (2000)

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or Doménech, Ledo and Taguas (2001). These papers found that diverse variants of the Taylor rule seem to track the short-term interest rates instrumented by the Fed, the ECB and other central banks, such as the Bundesbank or the central banks of Japan, United Kingdom, France or Italy, very closely.

The effects of the interest rate movements implied by this kind of monetary policy rule are less well known. However, as stressed by King (2000) and Clarida, Galí and Gertler (1999) among others, the development in recent years of optimizing small macroeconomic models which are similar to the traditional IS-LM models, but grounded in solid microfoundations that reflect the optimizing behaviour of economic agents, has led to a great interest in the design, analysis and evaluation of monetary policy. In most papers, the analysis of the transmission mechanism is based on calibrated versions of such a model, which usually include an IS curve, a Phillips curve and a monetary policy rule. Although there are some exceptions to this approach, the estimation of the parameters in these baseline models is somewhat rare in EMU.

In the case of the USA, Fuhrer and Moore (1995), Rotemberg and Woodford (1998), McCallum and Nelson (1999), Rudebusch and Svensson (1999), Rudebusch (2000), or Lansing (2000) offer estimates of diverse specifications (some of them backward-looking versions) of a baseline model. This evidence is complemented by estimates of the Phillips curve, as for example Fuhrer (1997) or Galí and Gertler (1999). For EMU, there is less empirical evidence for this kind of models. Thus, Peersman and Smets (1999) and Gerlach and Smets (1999) have estimated backward-looking versions of the IS and Phillips curves. Coenen and Wieland (2000) estimate a small macroeconomic model, with more emphasis on the specification of the aggregate supply, which is modeled using the nominal wage contracting model proposed by Taylor (1980) and variants of relative real wage contracting models. However, their IS curve simply follows a backward-looking specification and the coefficients in the interest rule are calibrated. The specifications of the aggregate demand and supply estimated by Smets (2000) are closer to ours, with expectations in both the IS and the Phillips curve, but he uses annual data over the period 1974 to 1998. More recent evidence has been offered by Galí, Gertler and López-Salido (2001), who focus only on the Phillips curve.

Our paper contributes to this growing literature with the GMM estimation of a small macroeconomic model, which comprises forward-looking versions of the IS and the Phillips curves as well as the interest rate rule, using quarterly data from 1986 to 2000. The sample period is dictated by the stability of the interest rate rule, as Doménech, Ledo and Taguas (2001) have pointed out, coinciding with the integration of some countries in the EMS and the commitment of previous members to avoiding realignments of the exchange rates. We find that this simple model matches the dynamic properties of the

output gap, inflation and the interest rate quite accurately. Our results suggest that monetary policy, instrumented by means of the short-term interest rate, has a stabilizing role in EMU. With this model we perform several exercises that show the response of output, inflation and interest rates to different kinds of shocks affecting the economy under the assumption that the ECB implements the monetary policy described by the estimated interest rate rule. The comparison with a backward-looking model for the United States estimated by Rudebusch and Svensson (1999),² which fits the data quite well, shows that our forward-looking model produces less persistence of the endogenous variables in response to shocks of the same magnitude.

The structure of this paper is as follows. In Section 2 we specify the main equations of our model which summarizes aggregate demand and supply. Section 3 describes the data, analyzes the empirical evidence in EMU and presents the results of the GMM estimation of forward-looking versions of the IS and Phillips curves, and the interest rate rule. In section 4 we simulate the impulse response function of output, inflation, nominal and real interest rate to output and inflation shocks, comparing the results with the simulations provided by Rudebusch and Svensson (1999) for the United States. Finally, section 5 concludes.

2. The Model

Our model is based on a forward-looking specification of a small macroeconomic framework which captures the key relationships between the output gap, inflation and interest rates, with microfoundations that were absent in earlier Keynesian models.³ This kind of model can be derived from dynamic general equilibrium models with money and nominal price rigidities in the short run (e.g., Walsh, 1998), and has been used to evaluate optimal monetary policy in the US (for example, Lansing and Trehan, 2001, McCallum and Nelson, 1999, and McCallum, 2001) and in EMU (Peersman and Smets, 1999, Smets, 2000, or Ehrmann and Smets, 2001). The equations that describe our small model are as follows.

The basic specification of the forward-looking IS equation is given by

$$y_t = \beta_y E_t y_{t+1} + (1 - \beta_y) y_{t-1} - \beta_r \hat{r}_{t-j} + v_{yt} \quad (1)$$

where y is the output gap, \hat{r} is the deviation of the real interest rate (r^r) from its equi-

² This model has also been used by Rudebusch (2000, 2001) to evaluate the optimality of the Fed policy rule.

³ See, e.g., Clarida, Gali and Gertler (1999) and the references therein.

librium level (\overline{rr}), and v_{yt} is a disturbance variable. Let r and π be the nominal interest rate and the inflation rate respectively. Then \widehat{rr} is defined as

$$\widehat{rr}_{t-j} \equiv rr_{t-j} - \overline{rr}_{t-j} \equiv r_{t-j} - E_{t-j}\pi_{t-j+1} - \overline{rr}_{t-j} \quad (2)$$

where E_{t-j} is the expectation operator conditional on the information available at $t-j$. As usual, we assume that agents have full knowledge about the structure of the economy so their expectations are rational. It is important to note that, contrary to Smets (2000), our IS equation allows for lags in the transmission mechanism, although monetary policy may have immediate effects upon output through expectations.

Equation (1) is interpreted as the IS curve, because it relates the current output gap with the real interest rate, and the lagged and expected output gaps. The standard optimizing consumption problem produces a similar specification relating current and expected output gaps. However, lagged output gaps can be introduced if we allow the existence of habits in consumption (see, e.g., Fuhrer, 2000), and since output displays empirically important persistence, the inclusion of y_{t-1} will improve significantly the fit of the basic forward-looking IS curve. In the steady state, when aggregate demand shocks are absent, the output gap is zero ($y_t = E_t y_{t+1} = y_{t-1} = 0$), so the deviation of rr_t from the equilibrium real interest rate is also zero.

The expectational Phillips curve relates current inflation to past and expected inflation, and also to the output gap

$$\pi_t = \mu_{\pi e} E_t \pi_{t+1} + (1 - \mu_{\pi e}) \pi_{t-1} + \mu_y y_{t-s} + v_{\pi t} \quad (3)$$

where $v_{\pi t}$ is a disturbance variable affecting the inflation rate and, for simplicity, we assume that the inflation rate is expressed as deviations from its long-run level. This Phillips curve is a generalization of what has been called the New Phillips curve, which relies on the Calvo (1983) pricing model, involving staggered nominal prices set by monopolistically competitive firms. After imposing the assumption that the real marginal cost is positively related to the output gap, this model leads to an equation relating current inflation to the expected future inflation rate and the output gap.

However, as in the case of the output gap, given the high persistence of the inflation rate (see, e.g., Fuhrer, 1997, and Fuhrer and Moore, 1995, in the case of the US economy) it is convenient to allow for an alternative specification in which the lagged inflation rate is included, giving rise to what Galí and Gertler (1999) called the hybrid model of the Phillips curve. According to this model, only a fraction of firms set prices as in the Calvo model, whereas the rest of firms use a simple backward-looking price rule. Finally, to obtain equation (3) another assumption is needed: the absence of a long-run trade-off between output and inflation, which implies a vertical long-run Phillips curve

(see King, 2000, and King and Wolman, 1999).

As for the central bank policy rule, our model considers a forward-looking interest rule

$$r_t = (1 - \rho)\gamma_\pi E_t \pi_{t+1} + (1 - \rho)\gamma_y E_t y_{t+1} + \rho r_{t-1} + v_{rt} \quad (4)$$

where v_{rt} is a disturbance variable. This kind of rule has been used as a benchmark to evaluate the stabilization policy of the Fed, the ECB and other central banks, such as the Bundesbank or the central banks of Japan, England, France or Italy (for example, Clarida, Galí and Gertler, 1998 and 2000, Judd and Rudebusch, 1998, Gerlach and Schnabel, 2000, or Doménech, Ledo and Taguas, 2001). One advantage of the specification proposed by equation (4) is that, despite its simplicity, such a rule seems to stabilize inflation and output in a way close to optimal policy rules in many macroeconomic models (see, e.g., Taylor, 1999, or Rudebusch and Svensson, 1999).

Equations (1), (3) and (4) form a linear rational expectation model which does not have a closed-form solution. In such circumstances, as we want to obtain a numerical solution of this model, we use the framework proposed by Sims (2000), who generalizes the method of Blanchard and Khan (1980). In order to write this system in expanded state vector form, we define

$$x_t \equiv \left[y_t \quad \pi_t \quad r_t \quad E_t y_{t+1} \quad E_t \pi_{t+1} \quad E_t r_{t+1} \right]'$$

$$\Psi = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \quad v_t = \begin{bmatrix} v_{yt} \\ v_{\pi t} \\ v_{rt} \end{bmatrix}, \quad \Pi = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \quad \eta_t = \begin{bmatrix} \eta_{yt} \\ \eta_{\pi t} \\ \eta_{rt} \end{bmatrix}$$

where $y_t = E_{t-1} y_t + \eta_{yt}$, $\pi_t = E_{t-1} \pi_t + \eta_{\pi t}$ and $r_t = E_{t-1} r_t + \eta_{rt}$. Thus, defining Γ_0 and Γ_1 conveniently, under the assumption that $\overline{rr}_{t-j} = 0$, we can write our forward-looking model in a compact state vector form

$$\Gamma_0 x_t = \Gamma_1 x_{t-1} + \Psi v_t + \Pi \eta_t \quad (5)$$

The solution of this linear rational expectation model is then given by

$$x_t = \Theta_1 x_{t-1} + \Theta_v v_t \quad (6)$$

In order to compute the elements of Θ_1 and Θ_v we need to know the values of the different parameters in equations (1), (3) and (4). This is precisely the objective of the

following section.

3. Empirical evidence

One of the problems when analyzing monetary policy in EMU is the fact that the ECB policy formally started in January 1999. Therefore, it can be argued that this was a structural change for European countries. Nonetheless, before this date the convergence process and the quasi-fixed exchange rate regime between these economies ensured a certain degree of homogeneity in monetary policy. This allows us to consider the economic performance of EMU from a longer perspective. In particular, in this empirical section, we use quarterly data for the period 1986(1)-2000(4), that is, for a period of fifteen years in which the monetary policy rule for the EMU does not seem to show any structural change, as shown in Doménech, Ledo and Taguas (2001).

In the small forward-looking macroeconomic model given by equations (1), (3) and (4), the cyclical behavior of the EMU economy plays a central role. However, the estimation of the output gap is a controversial issue and the uncertainty surrounding output gap measures can have important implications for monetary policy, as Smets (1999) has pointed out, since it could explain why central banks seem to react cautiously to changes in the cyclical position of their economies. Smets (2000) and Coenen and Wieland (2000) measure the output gap as the deviations from a linear trend, and Camba-Méndez and Palenzuela (2001), Fagan, Henry and Mestre (2001), and Mc Morrow and Roeger (2001) offer different estimations of the output gap in the euro-zone. After a comparison of the different methodologies for the measure of the output gap, we have chosen the Hodrick-Prescott filter, which is judgement free and seems to fit rather well with different phases in the European economic activity shown by other economic indicators. The same conclusion is reached by Mc Morrow and Roeger (2001).

As shown in Figure 1, after the second oil shock there was a recession, followed by several years of stagnation, until the end of 1988 when the EMU economy entered a period of growth ending in late 1992.⁴ With the collapse of the European Monetary System that followed German reunification, a new recession took place, ending in 1994. From then until the end of 1999, the EMU economy again went through a period with a negative output gap, which ended in the year 2000. The positive output gap in this year was smaller than previous expansions when the cyclical component of the GDP was close to 2 per cent.

⁴ We have applied the Hodrick-Prescott filter to quarterly EMU real GDP from 1970(1) to 2002(4) using the predictions provided by the BBVA-Aries BVAR model. More details about the aggregation of national GDPs and the other variables used in this paper (almost identical to those in Fagan, Henry and Mestre, 2000) can be found in Ballabriga and Castillo (2000).

Figure 2 approximates the definition used in the IS equation by the three month nominal interest rate minus the inflation rate one-quarter ahead, that is, in this figure we substitute $E_t\pi_{t+1}$ by π_{t+1} . As we can see, the real interest rate has fluctuated in a range between 3 to 8.5 per cent until 1993. From that year onwards, the nominal convergence process among the countries joining EMU accelerated, and at the beginning of 1999 the real interest rate was at the lowest level of the last two decades: 1.2 per cent. Since then, it increased to a level of 3 per cent at the end of 2000. Figure 2 also shows that the equilibrium real interest rate may have changed from the eighties to the second half of the nineties, as a consequence of the reduction in the risk premium for many countries that entered the euro. In Figure 2 we also show the deviation of the real interest rate from a trend, estimated using the Hodrick-Prescott filter, making more evident the transitory increase of the real interest rate after the ERM collapse in 1992.

The specification of the IS equation we have estimated is given by

$$y_t = \beta_{ye}E_t y_{t+1} + \sum_{i=1}^4 \beta_{yi} y_{t-i} - \alpha \beta_r (r_{t-2} - E_{t-2} \pi_{t-1} - \bar{r}_{t-2}) - (1 - \alpha) \beta_r (r_{t-3} - E_{t-3} \pi_{t-2} - \bar{r}_{t-3}) + v_{yt} \quad (7)$$

The Generalized Method of Moments produces efficient estimators of the IS coefficients in the class of instrumental variable estimators defined by the orthogonality conditions

$$E \{ \mathbf{z}_t v_{yt} \} = 0 \quad (8)$$

where \mathbf{z}_t is a vector of instruments included in the information set I_t . As the number of instruments usually exceeds the number of parameters to be estimated, the GMM estimation computes an optimal weighting matrix W of the instruments such that $u' \mathbf{z}' W \mathbf{z}' u$ is asymptotically distributed as χ^2 with degrees of freedom equal to the number of overidentifying restrictions. We use this test to evaluate the validity of our instrument set.

In a first estimation of equation (7), the interest rate elasticity (β_r) is 0.06, as shown in the first column of Table 1. As we can see in column (2), we cannot reject the hypothesis that the sum of lagged and lead output is equal to one: the p -value of a test of this hypothesis is 0.44. The estimated value of α indicates that the appropriate lag of the interest rate in the IS equation is two quarters. The coefficient for the forward-looking component of the IS-curve (β_{ye}) is close to 0.5. These results are similar to the ones obtained by Smets (2000), who uses annual data over the period 1974 to 1998 and estimates $\beta_{ye} = 0.56$ and $\beta_r = 0.06$. However, this interest rate elasticity seems to be low, in particular, when we compare it with estimations for the US or with the values used in calibrated models. For example, Lansing and Trehan (2001) use

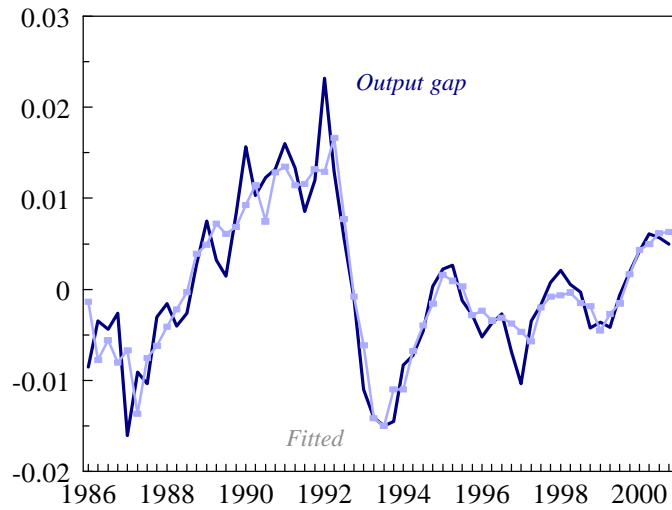


Figure 1: EMU output gap.

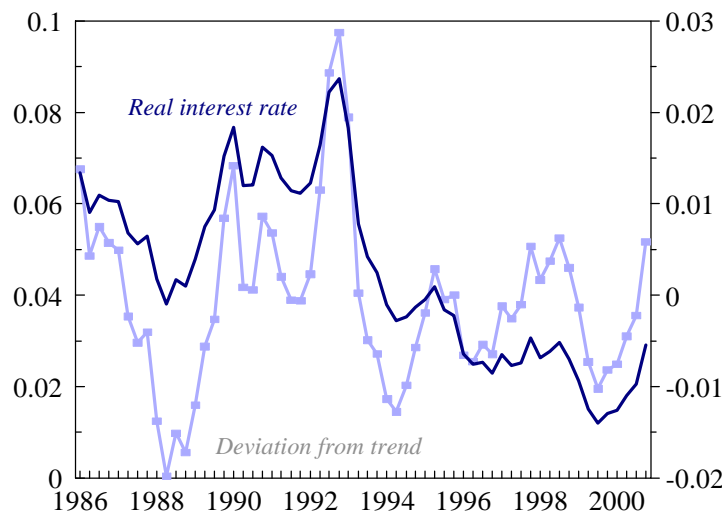


Figure 2: Real short-term interest rate in EMU and deviations from its trend (right scale).

Table 1

IS curve

$$y_t = \beta_{ye} E_t y_{t+1} + \sum_{i=1}^4 \beta_{yi} y_{t-i} + \alpha \beta_r \hat{r}_{t-2} + (1 - \alpha) \beta_r \hat{r}_{t-3} + v_{yt}$$

	(1)	(2)	(3)	(4)	(5)	(6)
β_{ye}	0.499 (22.1)	0.477 (25.7)	0.467 (29.9)	0.429 (10.2)	0.430 (13.7)	0.440 (10.1)
β_{y1}	0.448 (8.54)	*	*	*	*	*
β_{y2}	0.047 (0.93)	0.032 (0.76)				
β_{y3}	-0.109 (2.01)	-0.093 (1.98)				
β_{y4}	0.161 (3.47)	0.126 (4.10)	0.073 (3.35)	0.083 (1.62)		
α	0.909 (4.09)	0.965 (5.22)	1.00*	1.00*	1.00*	1.00*
β_r	-0.090 (3.89)	-0.081 (3.68)	-0.090 (5.49)	-0.115 (3.16)	-0.109 (3.11)	-0.108 (2.93)
\overline{R}^2	0.859	0.862	0.868	0.880	0.880	0.880
σ_{vy}	0.003	0.003	0.003	0.003	0.003	0.003
Sign. level	—	0.832	0.386	—	—	—

* stands for restricted coefficient.

a value of $\beta_r = 0.2$, which is equal to the estimation obtained by McCallum and Nelson (1999), and McCallum (2001) even chooses a higher value of β_r equal to 0.4.

Moreover, an interest rate elasticity of 0.06 does not capture the recession of 1993 immediately after the ERM crisis, when as we have shown in Figure 2, the real short-term interest rate increased by almost 3 per cent. The output gap was 2.3 per cent at the start of 1992 and, after a fast slowdown, bottomed out at -1.5 per cent in the middle of 1993, suggesting a higher interest rate elasticity than the one shown in this unrestricted estimation. Figures 1 and 2 shows that the negative relationship between the output gap and the real interest rate increases in the nineties. It is in the late eighties when this relationship seems to be less clear, perhaps as a consequence of the increase in other demand components not linked to the interest rate. In this case, demand shocks produce higher real interest rates if monetary policy tries to stabilize output, implying a positive correlation of the output gap with the real interest rate, which can bias downward the

interest rate elasticity in the IS equation. In other words, we can infer a more precise estimate of the coefficient β_r when we use the empirical evidence of a period in which interest rate movements were the main driving force behind the changes in the output gap as, for example, after the ERM crisis.

When we restrict further the model, excluding some lags of the output gap that are not significant and imposing $\alpha = 1.0$ (the p -value of a test of this joint hypothesis is now 0.25), the coefficient of the real interest rate increases in absolute value to -0.09 , as shown in column (3). In this estimation, the coefficient of the expected output gap decreases to 0.47 but it is still close to the value used by Lansing and Trehan (2001) in their calibration for the US, and higher than a value of 0.30 which, as Rudebusch (2000) has pointed out, is the appropriate value for the habit persistence model of Fuhrer (2000). With a higher degree of persistence of the output gap in response to shocks, the impact of interest rates changes on output is also higher. Using the results of this estimation, Figure 1 shows that the fitted value of the output gap obtained with the estimated IS curve, after substituting the expected values of the output gap with the VAR solution we obtain in the next section, tracks the actual data very well.

In columns (4), (5) and (6) we present the values of the coefficients of the IS equation, when it is jointly estimated with the Phillips curve and the interest rate rule. In column (4) we do not impose any restriction in our system of equations. In column (5) we impose that $\beta_{y4} = 0$ jointly with some specific values of the interest rate rule. Finally, in column (6) we add core inflation in the interest rate rule as an additional regressor. As we can see, the values of the main coefficients of the IS equation remain very stable, with β_{ye} and β_r close to 0.43 and -0.10 respectively.

As for the Phillips curve, disinflation was without any doubt one of the most important events during the nineties in EMU countries. The increasing credibility of monetary policy was an important factor behind this fact. After the disinflation of the second half of the eighties, having reached a level of about 5.0 per cent in March 1992, inflation fell again continuously to a minimum of 0.8 per cent at the end of 1998. In this period, we can clearly distinguish two different sub-periods as shown in Figure 3. The first one, lasting until the end of 1994, took place during the recessive phase of the cycle, whilst the second one, from 1995 to 1998, took place in a phase of stagnation, suggesting an important role for demand factors in the inflation performance.

The GMM estimation of the Phillips curve, given by equation (3), shows a forward-looking parameter $\mu_{\pi e}$ equal to 0.537 as shown in column (1) of Table 2. Column (2) shows that we cannot reject the hypothesis that the sum of lagged and lead inflation is equal to one (the p -value of this restriction is 0.784). This value of $\mu_{\pi e}$ is close to the one used by Lansing and Trehan (2001) in their calibrated model for the USA and

Table 2
Phillips curve

$$\pi_t = \mu_{\pi e} E_t \pi_{t+1} + \mu_{\pi 1} \pi_{t-1} + \mu_y y_{t-1} + v_{\pi t}$$

	(1)	(2)	(3)	(4)	(5)
$\mu_{\pi e}$	0.537 (21.9)	0.536 (23.7)	0.542 (16.5)	0.542 (16.5)	0.553 (19.0)
$\mu_{\pi 1}$	0.463 (20.4)	*	*	*	*
μ_y	0.063 (6.75)	0.062 (6.88)	0.062 (3.15)	0.061 (3.05)	0.057 (2.96)
\overline{R}^2	0.978	0.979	0.981	0.981	0.980
$\sigma_{v\pi}$	0.002	0.002	0.002	0.002	0.002
Sign.level	—	0.984	—	—	—

* stands for restricted coefficient.

consistent with the range from 0 to 0.6 provided by Rudebusch (2000). For EMU, Smets (2000) obtains a similar value of 0.52.

As expected, the slope of the Phillips curve is positive, that is, a negative output gap pushes the inflation rate downwards and conversely. We have tried different lags of the output gap, and the best results are obtained for y_{t-1} . The initial estimated value of the output gap elasticity, μ_y , is 0.062, slightly higher than the 0.03 used by McCallum (2001) and the 0.04 used by Lansing and Trehan (2001), in their calibrated models for the US economy. Contrary to the results by Galí, Gertler and López-Salido (2001), we find that our measure of the output gap performs better than real marginal costs. However, since it is lower than the value of 0.18 estimated by Smets (2000) for the EMU economy, we have included time dummies which correct some large residuals. The presence of these dummies does not alter the estimated value of $\mu_{\pi e}$ but increases the value of μ_y up to 0.10, suggesting a steeper Phillips curve in the euro area. We have also estimated the Phillips curve using quarterly inflation rates. Although more lags of the inflation rate (up to four) are statistically significant in this case, the estimated coefficients of the expected inflation ($\mu_{\pi e}$) and the output gap (μ_y) are close to the ones reported in Table 2. Figure 3 shows the actual and the fitted inflation rate given the results in column (2) of the estimated Phillips curve, after substituting $E_t \pi_{t+1}$ with the VAR solution obtained in the next section.

As for the IS equation, in columns (3), (4) and (5) we present the values of the coefficients of the Phillips curve, when it is jointly estimated with the IS equation and the interest rate rule. As we can see, the values of $\mu_{\pi e}$ and μ_y are very stable, around 0.54 and 0.06 respectively.

Table 3

Monetary policy rule

$$r_t = \gamma_0 + (1 - \rho)\gamma_\pi E_t \pi_{t+1} + (1 - \rho)\gamma_y E_t y_{t+1} \\ \rho r_{t-1} + \gamma_{\Delta r} \Delta r_{t-1} + v_{rt}$$

	(1)	(2)	(3)	(4)	(5)
γ_π	2.015 (19.7)	2.00*	2.079 (7.13)	2.00*	2.271 (31.1)
γ_y	1.002 (3.35)	1.00*	1.306 (2.24)	1.00*	0.883 (5.25)
ρ	0.834 (42.0)	0.75*	0.852 (22.6)	0.80*	0.573 (7.52)
$\gamma_{\Delta r}$	0.374 (11.6)	0.376 (12.5)	0.302 (3.81)	0.315 (2.68)	0.396 (4.43)
γ_c					0.303 (2.96)
\overline{R}^2	0.979	0.978	0.980	0.980	0.985
σ_{vr}	0.004	0.004	0.004	0.004	0.004
Sign. level	—	0.528	—	0.052	—

* stands for restricted coefficient.

Finally, in Table 3 we present the GMM estimation results of the forward-looking version of the monetary policy rule. We allow for interest rate smoothing, in order to fit the gradual adjustment of the interest rate to its target level, which captures the actual behavior of the main central banks. This behavior helps to reduce output and inflation variability as McCallum and Nelson (1999) have pointed out. In column (1) we obtain initial estimates of ρ , γ_π and γ_y equal to 0.83, 2.01 and 1.00, respectively. In column (2) we restrict the values of these coefficients (the p -value of this hypothesis is 0.53). The values of ρ , γ_π and γ_y are very close to the ones estimated by Clarida, Galí and Gertler (2000) for the United States during the Volcker and Greenspan mandates. This value of ρ is considered to be a realistic degree of smoothing by McCallum (2001). However, the estimated values for the coefficients of inflation and output gap expectations are higher to the original values proposed by Taylor (1993). We also include two dummy variables in this equation. The first one is for the ERM crisis, which implied a higher interest rate for reasons other than inflation and output expectations. The second dummy is for the ECB period, which supposed the reduction of a risk premium in real interest rates. Figure 4 shows that the estimated version of the monetary policy rule given by column (2) seems to track the short term interest rate behavior reasonably well for the period 1986(1)-2000(4).

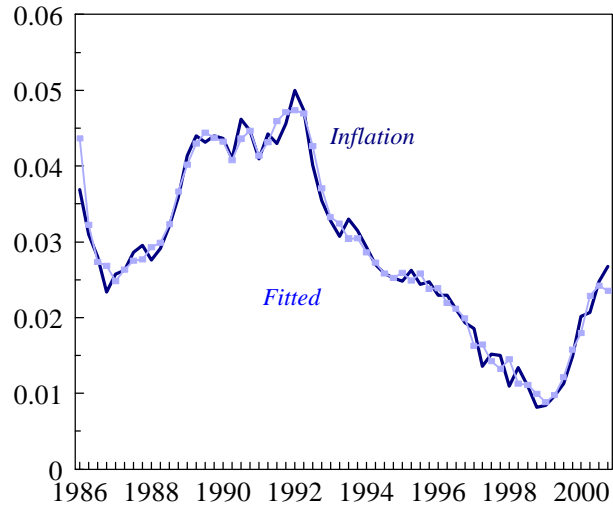


Figure 3: *Fitted and actual inflation in EMU, 1986(1)-2000(4).*

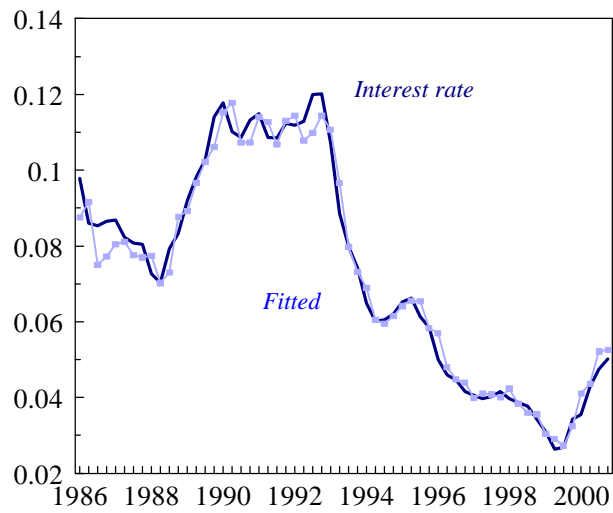


Figure 4: *Short term interest rates and monetary rule.*

In columns (3), (4) and (5) we present the values of the coefficients of the interest rate rule, when it is jointly estimated with the IS equation and the Phillips curve. When we do not impose any restriction in our system of equations, as in column (3), we obtain similar values of the coefficients to the ones estimated in column (1). Again, in column (4) we accept the same restrictions as in column (2). Finally, in column (5) we add a linear combination between core ($\bar{\pi}$) and headline inflation (π) in the interest rate rule, that is, we have approximated the expected inflation by the central bank as

$$\gamma_c \pi_t + (1 - \gamma_c) \bar{\pi}_t$$

This formulation is similar to the one proposed by Galí (2001) for the ECB. The estimated value of γ_c , close to 1/3, can be interpreted as if core inflation were twice more important for the central bank than headline inflation. As column (5) shows, the fit of the interest rate increases and, more importantly, the higher smoothing of inflation implies a lower coefficient of r_{t-1} , close to 0.60 and well below the value of 0.80 estimated with headline inflation alone.

4. Impulse response functions

Having estimated the main parameters of equations (1), (3) and (4), which are summarized in Table 4, we can compute the numerical solution of the linear rational expectations model given by equation (6). In Figures 5 and 6 we show the impulse response functions of the output gap, the inflation rates and the nominal and real interest rate in EMU to a transitory output shock v_y (e.g., an increase in demand) and to a transitory inflation shock v_π (e.g., an increase in oil prices), together with the estimated responses by Rudebusch and Svensson (1999) for the United States. Our choice of this model is based in two reasons. First, it is a simple linear model with the same endogenous variables as ours. Rudebusch and Svensson (1999, RS onwards) and Rudebusch (2001) choose their specification, among other things, by its empirical fit of the US economy, in order to evaluate the properties of different monetary rules. Second, the RS model is a backward-looking one and, therefore, we can obtain an additional insight of the monetary policy implications of our forward-looking model for EMU, comparing the impulse response functions of both models.

In Figure 5 we can see that an output shock has positive effects upon output and the inflation rate in EMU (solid line). The output shock affects inflation through the lagged output gap but also through expectations of future inflation. This latter effect explains why the shock has contemporaneous effects on inflation, something that is not present in the RS impulse response functions (dotted line). In others words, in a backward-looking model in which the output gap appears in the Phillips curve with

Table 4
Parameters of the baseline EMU model

β_{ye}	β_{yA}	β_r	α	$\mu_{\pi e}$	μ_y	ρ	γ_y	γ_π	$\gamma_{\Delta r}$
0.43	0.08	0.11	1.00	0.54	0.06	0.70	1.00	2.00	0.32

one or more lags, demand shocks do not have contemporaneous effects on the inflation rate, but in a forward-looking model, such as ours, contemporaneous effects are possible since inflation is not a predetermined variable. Another property of our model is that the effects on the inflation rate are far less persistent than in the RS model. Although the peak of these responses are similar for the output gap and for the inflation rate to the ones found by RS for the US, in the backward-looking model the persistence of the effects of an output shock is higher since, for example, after 15-20 quarters inflation is still half way between the maximum impact and its steady state level. As the monetary policy rule has stabilizing effects, both the nominal and the real interest rate also increase with the demand shock. The positive effects on output disappear after 6-7 quarters, and become negative since the absence of a long-run trade-off between inflation and output implies that the only way of reducing inflation to its target level is by means of a transitory recession. This is the reason why the real interest rate is still positive after 6-7 quarters. Finally, after 10 quarters the effects of such a demand shock have almost disappeared. In terms of the magnitude, the most important differences are observed in the case of the nominal and real interest rate. The reason is that in our forward-looking model monetary policy affects expectations and, therefore, a smaller increase in interest rates is needed to stabilize the economy since private agents anticipate these effects.

Figure 6 shows that the effects of an inflationary shock on inflation last approximately 6-7 quarters in EMU (solid line). Given the interest rate smoothing, which is responsible of the hump-shaped pattern of the nominal interest rate, the initial impact on the inflation shock on the real interest rate is negative, although small. However, the nominal interest rate increases until it reaches a maximum after 3 quarters. The increase of the nominal interest rate above inflation also produces an increase in the real interest rate, such that its negative effects on output, together with its effects on inflation expectations, cancel out the deviation of inflation from the central bank target. Again, comparing the shapes of our impulse response functions with those of the RS model after an inflation shock, which has similar maximum effects on the inflation rate and the output gap, we can see that the most substantial difference occurs in terms of the persistence of these effects, which are much lower in our model. Thus, after 15 quarters one third of the initial shock in the inflation rate is still present in the RS model, whereas the

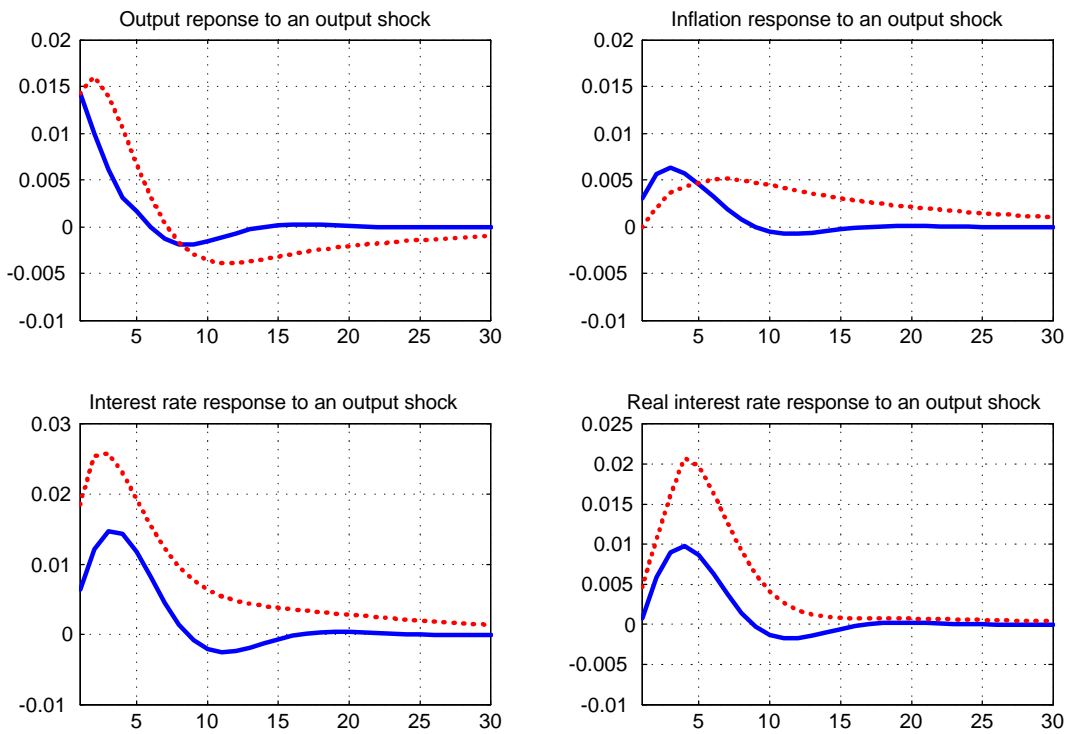


Figure 5: Impulse response to an output shock in EMU (solid line) and in the United States (dotted line).

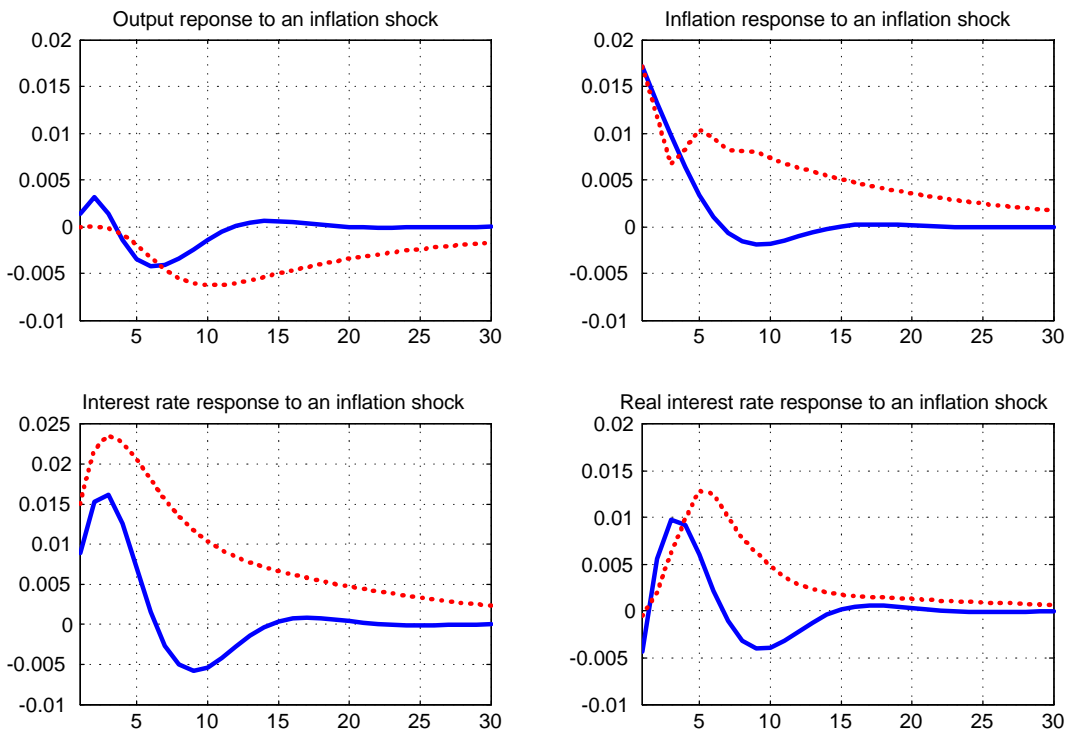


Figure 6: Impulse response to an inflation shock in EMU (solid line) and in the United States (dotted line).

maximum negative impact upon the output gap is reached after 10 quarters.

In summary, the results show that, although the inflation-output trade off faced by central banks are similar in EMU and in the United States, the persistence of the effects on the endogenous variables is much lower in a forward-looking model such as ours than in the backward-looking model estimated by Rudebusch and Svensson (1999).

Finally, we have also analyzed the robustness of these results to the small changes of the main parameters in equations (1), (3) and (4) that we observe in Tables 1 to 3. The effects on the shapes of the impulse response functions are very small and go in the expected directions. Thus, an increase of $\beta_{\pi e}$ or $\mu_{\pi e}$ (i.e., the IS and the Phillips curve become more forward-looking respectively) reduces the persistence of the endogenous variables to the shocks. On the contrary, a higher smoothing parameter for the nominal interest rate (ρ) reduces the variability of the interest rate but increases the persistence of the impulse response functions.

5. Conclusions

In this paper we have estimated a small forward-looking macroeconomic model for EMU which allows us to analyze the transmission mechanism of the monetary policy through an interest rate rule that stabilizes inflation and output. The model comprises a forward-looking version of the IS and the Phillips curves and also of the interest rate rule, and has been estimated by GMM, using quarterly data from 1986 to 2000. We have found that this simple model matches the dynamic properties of the output gap, inflation and the interest rate quite well. The IS and Phillips curves include expectations for the output gap and the inflation rate, to model the channels through which monetary policy affects these variables more realistically. In the estimated Phillips curve we cannot reject the hypothesis that the sum of lagged and lead inflation is equal to one and, therefore, that there is no long-run trade-off between output and inflation, a result that implies a vertical long-run Phillips curve. Finally, with this model we have performed several exercises that show the response of output, inflation and interest rates to different kinds of shocks affecting the economy under the assumption that the ECB implements the monetary policy described by the estimated interest rate rule.

Our results suggest that econometric models similar to the one estimated here can be very useful to understand the effects of the ECB monetary policy in the EMU economy. However, extensions in several directions are needed in order to obtain richer versions of this baseline model. Thus, the inclusion of financial wealth, as Bernanke and Gertler (1999) have pointed out, the specification of dynamic open-economy macroeconomic models, as in McCallum and Nelson (2001) and the incorporation of fiscal variables constitute useful extensions which deserve further attention.

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