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Comparing Monetary Policy Rules in a Small Open Economy Framework: An Empirical Analysis Using Bayesian Techniques

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Comparing Monetary Policy Rules in a Small Open Economy Framework: An Empirical Analysis Using Bayesian Techniques*

by

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Abstract

This paper examines the role of exchange rate changes in the monetary policy for the Euro Area. Moreover, it compares different Taylor-type policy rules with respect to the numerical results as well as the impulse responses to exogenous shocks and the fit of the different data model specifications when using the underlying data. Overall, a monetary policy rule which includes the expected inflation rate as well as the output gap performs best and supports a possible role of exchange rate changes in the Euro Area's monetary policy.

JEL - Classification: C11, E52, F41

Keywords: Bayesian Estimation, Small Open Economy, Monetary Policy, Taylor Rule

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1 Introduction

Looking at exchange rates in the last year always ends up with recognizing the very low US $ to a strong € which has consequences for im- and exports as well as for the whole Euro Area economy. So the question that arises immediately is shouldn't the European Central Bank take exchange rate changes into account when thinking about monetary policy. An additional question we try to answer is what Taylor-type policy rule performs best when comparing three different implemented policy targets. First, we assume that the central bank targets the actual inflation rate as well as the actual output deviation from the steady state. Second, we include the output gap instead of the output deviation from the steady state and finally, we replace the actual inflation rate by the expected inflation rate.

The Euro Area is modeled as a small open economy. We closely follow the model of Thomas Lubik and Frank Schorfheide in "Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation" [8], published 2007 in the Journal of Monetary Economics which is an improved version of the DSGE model developed by Galí and Monacelli [6]. Using a New Keynesian framework[1] the underlying model consists of a forward-looking IS-curve for the demand side of the economy as well as a forward-looking Phillips curve describing the supply side. Monetary policy is carried out by setting the interest rate according to a Taylor-type interest rate rule. Moreover, the exchange rate is indirectly introduced in the model by the definition of CPI inflation under the assumption that the relative purchasing power parity (PPP) holds. To implement the terms of trade into the model, we describe the law of motion for terms of trade changes as an exogenous AR(1) process. Due to the fact that we use a small open economy (SoE) framework, world output, world inflation, and technology are also exogenous AR(1) processes.

To estimate the model, we use Bayesian techniques[2,3] for the time period 1998-2007.[4] Computation is proceeded by using DYNARE.[5] After the estimation of the underlying

[1]See also Clarida, Galí and Gertler [3].

[2]The Bayesian estimation technique is based on Bayes' rule, see Bayes [2].

[3]Smets and Wouters [14] use Bayesian techniques to estimate a DSGE model for the Euro Area. See Lubik and Schorfheide [7] and [8] for the usage as well as the limitations and risks of Bayesian techniques in a small open economy framework.

[4]The chosen time period is due to the invention of the European Central Bank in 1998.

[5]See [4].

model, we compare the numerical results for the different model specifications as well as the impulse responses of the endogenous model variables to an exogenous shock.
The next section describes the model setup. In the third section, we first describe the data preparations prior to estimation and then compare the estimation results as well as the fit of the three model specifications. The fourth section shows the impulse response analysis and the last section concludes.

2 The Model

Following Lubik and Schorfheide [8], we assume that the Euro Area is a small open economy, i.e., trading with the rest of the world and small compared to the trading partners as a whole.
Based on Galí/Monacelli's [6] extended DSGE model, the underlying framework can be described as follows: The model consists of 4 equations. One equation characterizes the demand side of the model by a forward-looking IS equation, one the supply side by using a forward-looking Phillips-curve. To include the exogenous world in the model, consumption-based price-index (CPI) inflation for the home country as well as for the rest of the world is implemented assuming that the relative purchasing power parity holds.[6]
Monetary policy depends on one of the three considered different interest rate rules. In the following, we will describe the linearized equations which are used in computation.
Solving the maximization problem for the household sector the consumption Euler equation results in a forward-looking IS curve. Due to the fact that the model of Lubik and Schorfheide is based on the Galí/Monacelli model, derivation details can be found in [6].

$$\begin{aligned} y_t = {} & E_t y_{t+1} - \left[\tau + \alpha\left(2-\alpha\right)\left(1-\tau\right)\right]\left(i_t - E_t \pi_{t+1}\right) - \rho_z \tau z_t \\ & -\alpha\left[\tau + \alpha\left(2-\alpha\right)\left(1-\tau\right)\right] E_t \Delta q_{t+1} + \alpha\left(2-\alpha\right)\frac{1-\tau}{\tau} E_t \Delta y^*_{t+1}. \end{aligned} \tag{1}$$

y_t is the aggregate output of the home country[7] and π_t is the CPI inflation. With i_t we denote the nominal interest rate. All other variables are assumed to be exogenous. z_t is defined as the worldwide technology growth rate of the nonstationary technology process

[6] Relative purchasing power parity describes the relation between the inflation rate of two countries and the changes in the corresponding exchange rate.

[7] We assume that there exists a producer and a household sector consisting of many individual producers and households.

A_t. To ensure a stationary steady state, all real variables are included as deviations from A_t. The changes in the terms of trade, i.e., the difference of the relative price of exports in terms of imports in t and $t-1$ is denoted by Δq_t. We implement the Δ-term because only changes in relative prices affect inflation and not relative prices per se. y_t^* is the exogenous world output. In the underlying open economy framework $0 < \alpha < 1$ is the import share[8] whereas τ represents the intertemporal elasticity of substitution.

The price setting decision of domestic producers is described in a forward-looking open economy Phillips curve:

$$\pi_t = \beta E_t \pi_{t+1} + \alpha\beta E_t \Delta q_{t+1} - \alpha \Delta q_t + \frac{\kappa}{\tau + \alpha(2-\alpha)(1-\tau)}(y_t - \overline{y}_t) \tag{2}$$

where $\overline{y}_t = [-\alpha(2-\alpha)(1-\tau)/\tau]\, y_t^*$ is the potential output under the assumption that no nominal rigidities exist. The model parameter κ is a function of structural parameters depending on the model specification. We take κ as a structural parameter itself and do not use any further information included in the function variables which create κ.[9]

To introduce the nominal exchange rate changes Δe_t into the model, we implement the following definition of CPI inflation:[10]

$$\pi_t = \Delta e_t + (1-\alpha)\Delta q_t + \pi_t^*. \tag{3}$$

π_t^* denotes an unobservable world inflation shock to slacken the tight relations of the model due to data outliers.

Finally, the model is closed by describing monetary policy with an interest rate rule. We differ between three alternative rules. The first monetary policy rule pursues inflation and output deviation targeting whereas the second rule describes inflation and output gap targeting. In the third policy rule, the interest rate rule is modeled such that expected inflation influences the policy decision of the central bank.

$$i_t = \rho_i i_{t-1} + (1-\rho_i)[\psi_1 \pi_t + \psi_2 y_t + \psi_3 \Delta e_t] + \varepsilon_t^i \tag{4.1}$$

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\psi_1 \pi_t + \psi_2\left(y_t + \frac{\alpha(2-\alpha)(1-\tau)}{\tau} y_t^*\right) + \psi_3 \Delta e_t\right] + \varepsilon_t^i \tag{4.2}$$

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\psi_1 E_t \pi_{t+1} + \psi_2\left(y_t + \frac{\alpha(2-\alpha)(1-\tau)}{\tau} y_t^*\right) + \psi_3 \Delta e_t\right] + \varepsilon_t^i. \tag{4.3}$$

[8] We assume that the households of the small open economy consume at least one unit of a home produced good and import at least one unit of a good produced in the rest of the world.

[9] There exists only the restriction that κ is positive, i.e., in general we assume that $\kappa \in \mathbb{R}^+$ holds.

[10] We assume that the relative purchasing power parity holds.

Monetary policy in this framework depends on output, CPI inflation and exchange rate changes. The rule described in equation (4.1) is an output deviation rule where the goal value, i.e., the steady state value is assumed to be equal to zero.[11] Due to a possible persistence in the nominal interest rate we implement a smoothing term where $0 < \rho_i < 1$. ε_t^i denotes an exogenous interest rate shock which affects the monetary policy rule. Following Lubik and Schorfheide,[12] the output gap in the equations (4.2) and (4.3) is modeled as a combination of home output y and foreign output y^*.

The following four equations characterize the law of motion of the exogenous variables terms of trade, the worldwide technology growth rate, the world inflation, and the world output. All variables are modeled as AR(1) processes.

(a) Terms of trade shock:

$$\Delta q_t = \rho_q \Delta q_{t-1} + \varepsilon_t^q \tag{a}$$

(b) Shock in worldwide technology:

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \tag{b}$$

(c) Shock in world inflation:

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \varepsilon_t^{\pi^*} \tag{c}$$

(d) Shock in world output:

$$y_t^* = \rho_{y^*} y_{t-1}^* + \varepsilon_t^{y^*} \tag{d}$$

For the shock in the monetary policy rule the equation

$$E_t \varepsilon_{t+1}^i = 0 \tag{e}$$

holds. We will analyze the effects of the five shocks described above on the endogenous variables of the model in the impulse response analysis. The model is solved using MATLAB[13] and a solving algorithm based on Sims [13] as well as DYNARE.[14]

[11] This is due to the linear structure of the model.

[12] For details see the model description in the published Gauss program on the website of Prof. Schorfheide [12].

[13] See [9].

[14] See [4].

3 Estimation Results

In the current section, we first describe the data, the data preparation before the estimation of the model, and the choice of priors. In the second part, a comparison of the estimation results follows.

3.1 Data Preparation and Priors

Due to the model structure described above, we need data for the CPI inflation rate, the output growth,[15] the interest rate and changes in the exchange rate, i.e., the depreciation rate. Moreover, we use data for changes in the terms of trade. All data is obtained from the International Financial Statistics Database of the International Monetary Fund (IMF). The data time series start 1998:1 and end 2007:3 and are all given as quarterly and seasonally adjusted data. The output growth rates are computed as log differences of the real GDP data series obtained from the IMF server. The output growth rate data present a quarter-to-quarter series. Inflation rates are derived as log differences of the consumer price indices and are multiplied with 400 to get annualized percentage data. To approximate the series for the nominal interest rate we use the Interbank Rate for the Euro Area. Multiplying with four gives annualized nominal interest rates in percentages. The trade weighted nominal exchange rate indices (NEER) are taken as data for the exchange rate. To convert the indices into depreciation rates, we have to take log differences of the underlying data series. Furthermore, we include changes in the terms of trade by first deriving the terms of trade as the quotient of the unit value index of exports and the unit value index of imports with base year 2000. Finally, we take log differences to obtain the changes in the terms of trade. In equations (1)–(3) and (a) only changes in the terms of trade are included. Therefore, it is reasonable to create data series containing first differences and not absolute values. The data for this exogenous variable is needed to compute the priors of ρ_q. Before computation the described data is demeaned.

The discount factor $\beta = exp\left(-r/400\right)$ is included in the model by estimating the annualized r, the steady state real interest rate.

A first step is to load the data. Linking the converted data series described above to the

[15] We assume that the observed output growth data contains also the unobservable technology growth component z.

endogenous model variables y, π, i and Δe requires the following measurement equations:

$$\begin{aligned} Y_t^{GR} &= y_t - y_{t-1} + z_t \\ \Pi_t &= 4 \cdot \pi_t \\ I_t &= 4 \cdot i_t \\ \Delta E_t &= \Delta e_t \end{aligned}$$

where capital letters denote the data series for output growth, inflation rate, nominal interest rate and the depreciation rate. So the vector Y including all observable variables is:

$$Y_t = [4i_t, 4\pi_t, \Delta y_t + z_t, \Delta e_t, \Delta q_t]'.$$

In the underlying framework, we use primarily the priors described in the basis paper of Lubik and Schorfheide [8].[16] The priors for the parameters of inflation and output in the monetary policy rule are centered at the parameter values known from recent literature. So we choose as prior mean for ψ_1 1.5 with a prior standard deviation of 0.5 and for the mean of ψ_2 0.5 with a standard deviation of 0.125. The mean and the standard deviation for the exchange rate coefficient ψ_3 are assumed to be equal to the values of the output parameter. For the interest rate smoothing term ρ_i, we set the mean as 0.5 and the standard deviation as 0.2.

The import share α is tightly centered at 0.2. We restrict the intertemporal elasticity of substitution τ such that $0 < \tau < 1$ holds.[17] Therefore, we center the mean at 0.5 and allow to vary it with a standard deviation of 0.2. The mean of the structural model parameter κ is set as 0.5[18] with a standard deviation of 0.25. For the steady state real interest rate r, the prior mean is set to 2.5 and we allow a rather large variation.

Due to the dependence of the country specific data, we choose different priors for the exogenous shocks compared to the ones in the reference paper. Because for the Euro Area, there is no data available before 1998, we take priors we obtain for Germany as a part of the Euro Area from a pre sample analysis for the time periods 1965:1-1974:4. To

[16] See tables 1 and 2 in [8].

[17] Inserting $\tau = 1$ in the model described in section 2.1 forces a singularity of the model: in equation (1), the technology growth term as well as the foreign output shock disappears. Thus the y^*-shock would drop out of the whole model.

[18] This corresponds to the literature, see for example Galí and Gertler [5].

get a prior for ρ_z and ρ_q, we use AR(1) processes for the domestic output growth and for the changes in the terms of trade data for German data samples. Following the results of the pre sample analysis, we center the technology growth parameter at 0.695 and the terms of trade parameter at 0.321.

Following Lubik and Schorfheide [8], we estimate an AR(1) process for the ratio of the US GDP and the domestic GDP[19] to get a prior for ρ_{y^*}. For the prior mean, we obtain 0.956 and allow the foreign output to vary only very limited. We fit an AR(1) process to the US CPI inflation to get a prior for the foreign inflation parameter ρ_{π^*}. The mean is chosen as 0.819 with a standard deviation of 0.1.

The standard deviations of the exogenous shocks are additionally obtained from the AR(1) estimations above. Therefore, we center the standard deviation σ_{y^*} at 0.016 which is a remarkably small value. For the mean of σ_{π^*}, we choose 0.451. The prior mean of σ_z and σ_q is set to 1.802 and 3.492.

The benchmark priors are listed in the following tables[20] where the first table contains all policy parameters and the second table contains the remaining parameters of the model.

Parameter	Domain	PDF	Prior Mean	Prior Standard Deviation
ψ_1	$\mathbb{R}^+$	Gamma	1.500	0.500
ψ_2	$\mathbb{R}^+$	Gamma	0.250	0.125
ψ_3	$\mathbb{R}^+$	Gamma	0.250	0.125
ρ_i	[0,1)	Beta	0.500	0.200

Table 1: Prior Distributions for the Policy Parameters

In table 2, the a priori beliefs of α, the import share, τ, the intertemporal elasticity of substitution, κ, a function of structural parameters, r, the real interest rate as well as the parameters of world inflation, world output, terms of trade, and technological progress, i.e., the worldwide technology growth rate of the shock equations including the corresponding standard deviations are shown.

[19]The ratio is chosen to correct for the influence of the technology growth which is included in the observed data.

[20]In the first column all parameters are itemized. The second column shows the domains which are chosen due to a priori beliefs of possible values of the corresponding parameter. The third column includes the assumed probability density functions (PDF) whereas the last two columns itemize the prior means and standard deviations for each variable.

Parameter	Domain	PDF	Prior Mean	Prior Standard Deviation
α	[0,1)	Beta	0.200	0.050
τ	[0,1)	Beta	0.500	0.200
κ	$\mathbb{R}^+$	Gamma	0.500	0.250
r	$\mathbb{R}^+$	Gamma	2.500	1.000
ρ_{y^*}	[0,1)	Beta	0.956	0.050
ρ_{π^*}	[0,1)	Beta	0.819	0.100
ρ_q	[0,1)	Beta	0.321	0.200
ρ_z	[0,1)	Beta	0.695	0.050
σ_i	$\mathbb{R}^+$	InvGamma	0.500	4.000
σ_{y^*}	$\mathbb{R}^+$	InvGamma	0.016	4.000
σ_{π^*}	$\mathbb{R}^+$	InvGamma	0.451	4.000
σ_q	$\mathbb{R}^+$	InvGamma	3.492	4.000
σ_z	$\mathbb{R}^+$	InvGamma	1.802	4.000

Table 2: Prior Distributions for the Remaining Parameters

3.2 Estimation Results

In the following section, we analyze and compare the results of the Bayesian estimation. The results are shown in tables 4-6 in the appendix section.

First, we discuss the results when implementing an interest rate rule including the output deviation, i.e., equation (4.1) which are shown in table 4. Looking at the policy parameters, the coefficient for the inflation rate ($\psi_1 = 1.46$) is close to the expected value. But the coefficient for the output variable y is very small compared to recent literature. The coefficient ψ_3 of the exchange rate changes is with a value of 0.14 significantly larger than zero. The estimate for the interest rate smoothing term ($\rho_i = 0.85$) shows that there seems to be a high degree of persistence in the data which corresponds to the expectations. The import share α is estimated too small compared to the actual data of the worldbank.[21] Moreover, the intertemporal elasticity of substitution is with $\tau = 0.22$ estimated significantly smaller than expected. The estimate of the structural parameter κ is close to its prior. Finally, the coefficients of the exogenous AR(1) processes for foreign

[21]See [18].

output, foreign inflation, the terms of trade as well as the technology process show a high persistence in the data.

When we implement the output gap interest rate rule[22] we immediately see, that the estimates differ remarkably from the results discussed above: Especially the policy parameters ψ_1, ψ_2 and ψ_3 are estimated larger. The coefficient for the inflation rate is estimated very high ($\psi_1 = 4.24$), whereas the coefficient for the output gap is now estimated close to recent literature. The coefficient for the exchange rate changes is more than 2 times larger than the value for ψ_3 implementing the output deviation in the interest rate rule. ρ_i is estimated close to the one obtained before. The last significantly different estimated parameter is κ which differs with 0.89 from its prior. We see as before a high degree of persistence in the data.

The last model modification, i.e., the implementation of equation (4.3) in the model, shows mainly similar results as the second estimation. The coefficient for the interest rate smoothing is with 0.63 smaller than before such that the persistence found in the data seems to be smaller. The policy parameter ψ_3 is estimated even a bit higher as before, but ψ_1, ψ_2, α, and τ are estimated a bit smaller. The remaining parameter estimates are closely the same in all model modifications.

Finally, we compare the posterior odds ratios to see which model fits best. Additionally we try to clarify if there seems to be an influence of the exchange rate changes in the monetary policy process of the European Central Bank. To obtain the posterior odds ratios we have to estimate each model variation under the assumption that $\psi_3 = 0$, i.e., there does not exist any influence of exchange rate movements in the monetary policy process. The calculated posterior odds ratios are shown in the following table:

Decision Rule	Marginal Data Density		Posterior Odds Ratio
	$\psi_3 = 0$	$\psi_3 > 0$	
1	-417.37	-421.37	54.6
2	-336.16	-332.41	0.02
3	-341.12	-329.32	$7.5\text{x}10^{-6}$

Table 3: Posterior Odds Ratios

[22]We use equation (4.2) in the following discussion.

Using the first model specification,[23] the posterior odds ratio is significantly larger than zero. Therefore, the influence of the exchange rate changes in the monetary policy rule is clearly rejected. But assuming one of the remaining model specification[24] returns a posterior odds ratio close to zero, which confirms the role of exchange rate movements in the monetary policy process of the European Central Bank. Furthermore, due to the fact that the posterior odds ratio is largest for the model including an expected inflation output gap target for the central bank, the model specification using equation (4.3) performs best. Overall, the third model specification seems to fit best with the underlying data. Only the coefficient for the inflation rate is estimated very high in contrast to recent literature. The model supports a possible role of exchange rate movements in the monetary policy process for the Euro Area.

4 Impulse Response Analysis

In the following section, we discuss the impulse responses of the endogenous model variables output, inflation rate, interest rate, and depreciation rate in the occurrence of one of the five exogenous shocks described in section 2 in the equations (a)-(e). Due to the fact that the qualitative responses are the same for all model variations, we will directly also compare the strength of reaction across the models. In the following, model 1 denotes the model specification implementing equation (4.1), model 2 the model which includes equation (4.2), and model 3 the model implementing equation (4.3). All shocks are positive 1% shocks in the corresponding exogenous variable. The shock in the terms of trade, the technology process, the world inflation, and the world output affects directly the variables through the AR(1) processes. For the monetary policy shock, ε^i, the shock variable is implemented directly in the three interest rate rules.

The impulse response analysis proceeds in the following way: first we discuss a shock in the terms of trade and a shock in the technology process z.[25] Then, we examine the shocks in the exogenous variables world inflation and world output.[26] Finally, the description of

[23]We implement the monetary policy rule (4.1) in this case.

[24]We implement equation (4.2) in the first case and equation (4.3) in the second case.

[25]See figures 1 and 2.

[26]See figures 3 and 4.

a monetary policy shock follows.[27]

Looking at a positive shock in the terms of trade, the output declines for all models. The decline is weak for model two and three[28] and stronger for model 1. The output for all models reverts back to its steady state value[29] within 6 periods. The inflation rate as well as the depreciation rate decrease due to the shock. Model one reacts strongest whereas the other two models respond in a similar range of intensity. The inflation rate for each model almost reverts within the plotted periods. But the depreciation rate has a slow speed of reversion such that it does not reach the steady state value for all models within the presented time periods. The speed is highest for model one. Finally, the central bank sets the interest rate lower for all three models which corresponds to our expectation. The reaction is strongest assuming the second model and weakest for the third model.

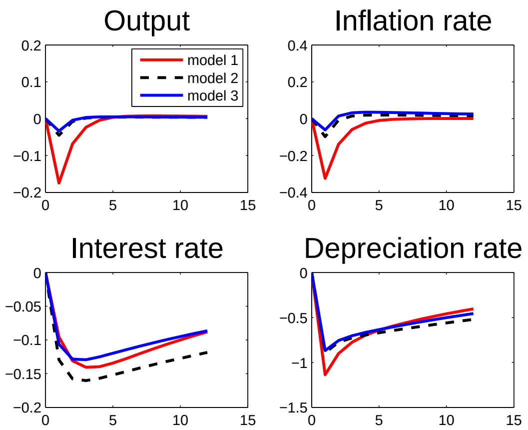

Figure 1: Terms of Trade Shock

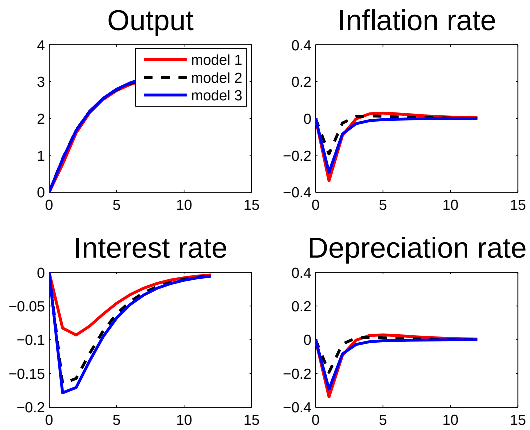

Figure 2: Technology Shock

A positive shock in the worldwide technology, i.e., a rise in the technology level, affects output permanently such that the output can be expanded. Therefore, the response of the output on a technology shock results in a permanent positive rise and the convergence to a higher steady state value. This reaction is closely the same for all model specifications. The inflation rate declines with almost the same intensity for all models. The currency appreciates which corresponds to a decline in the depreciation rate and is quantitatively closely the same for all models. The central bank loosens its policy and lowers the interest

[27]See figure 5.

[28]The intensity of reaction is closely the same for the two models. This holds also true for the response of the inflation rate and the depreciation rate in the occurrence of a terms of trade shock.

[29]The steady state value is equal to zero for all variables due to the linear structure of the model equations.

rate.[30] The reaction of the central bank is strongest for model two and three and weakest for model one. All endogenous variables almost revert to their old steady state values[31] within the plotted time periods.

In the occurrence of a shock in world inflation the output as well as the inflation rate rises. For the output, the reaction is strongest for model one. For model two and three, the responses look closely the same. Output reverts back to its steady state value within 10 periods for all model specifications. The inflation rate reacts weakest for model two whereas it reacts similar for model one and three. The speed of reversion is highest for model one such that the inflation rate almost returns to its steady state value within the plotted time periods. The inflation impulse responses for the other two models do not fully revert. Currency appreciates with closely the same intensity for all models. The speed of reversion is fastest for model one and slowest for model three.[32] When a shock in world inflation occurs, the central bank tightens its policy and therefore raises the interest rate. The response of the interest rate is strongest for model three and weakest for model one. Similar to the impulse response of exchange rate changes to a shock in worldwide inflation, the interest rate reverts fastest for model one and slowest for model three.

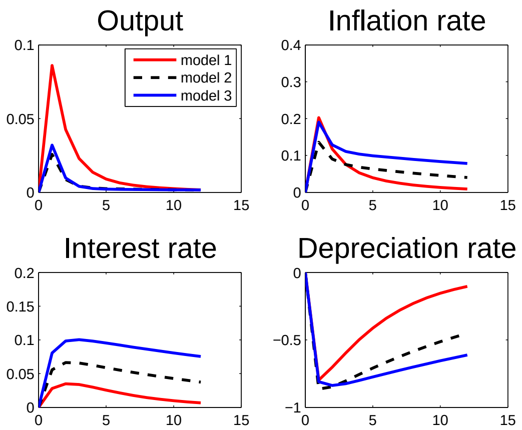

Figure 3: World Inflation Shock

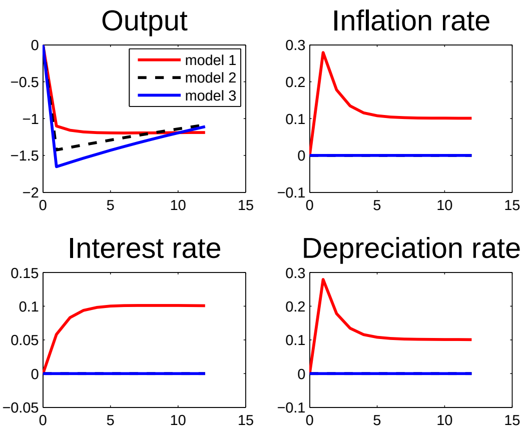

Figure 4: World Output Shock

Due to the fact, that domestic and foreign output are substitutes, a positive shock in world output lowers the domestic output. The output of model three reacts most, the output of model one least. The speed of reversion is slow for all models but slowest for model one such that only a slight tendency of reversion is identifiable. Compared to model one, the

[30]The expansionary policy has an additional positive effect on the output.
[31]This holds true except for the output which converges to a new, higher steady state.
[32]A tendency of reversion is clearly identifiable.

three remaining variables of the two other models react only with a very low intensity. The inflation rate for model one rises as well as the interest and depreciation rate. The speed of reversion is very slow such that all variables are far from their steady state values at the end of the plotted period. But the slope of the impulse response functions of the three variables are negative for all time periods after period 3 such that they indeed revert. Finally, we assume that an interest rate shock, i.e., a monetary policy shock occurs.[33] Due to the contractionary policy of the central bank, output declines. Also the inflation rate and the depreciation rate react negatively.[34] The response of all endogenous variables[35] is strongest for model one. All variables fully revert within the given time periods for all model specifications.

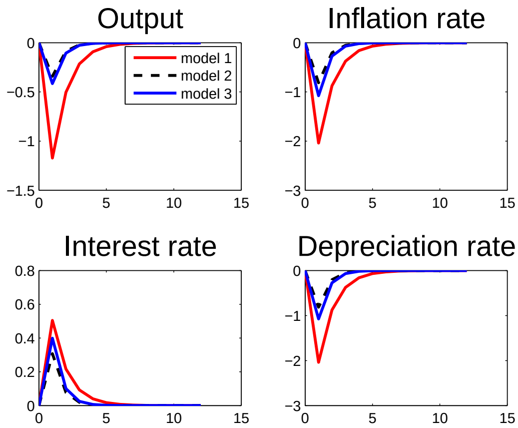

Figure 5: Monetary Policy Shock

Overall, the impulse responses of all variables to the underlying shocks are as expected. Only a shock in world output forces all variables to revert remarkably slow under the assumption that equation (4.1) is implemented in the model.

5 Conclusions

The underlying three small open economy model specifications for the Euro Area are estimated by Bayesian techniques. On one side, the modifications are compared, on the other side, the fit of the models with the used data is determined as well as the role of

[33] Due to the direct implementation of the interest rate shock in equations (4.1)-(4.3), the interest rate rises.

[34] The currency appreciates.

[35] This holds true also for the interest rate.

exchange rate changes in the monetary policy process of the European Central Bank.
Using a monetary policy rule which includes the output deviation gives acceptable estimation results. Only the estimate of the monetary coefficient for the output variable is estimated too small compared to recent literature. For the remaining two model specifications, the estimated coefficients are reasonable except of an unnatural high estimate for the inflation rate in the monetary policy rules.
The influence of exchange rate movements in the monetary policy rule of the Euro Area is confirmed for both model specifications including the output gap in the monetary policy rule. Furthermore, the model assuming that the central bank targets expected inflation and the output gap seems to fit best when we use the underlying data.
Finally, the impulse response analysis shows reasonable reactions of the endogenous model variables to one of the five exogenous shocks described in section 2. Only the responses of all endogenous variables to a positive world output shock in the first model specification seem to revert unexpected slowly.
Overall, the question why the coefficient for the inflation rate is estimated too high for the last two model specifications remains unanswered. Future research should try to check for the robustness of the results under a variation of the model which results in acceptable estimates of the parameter mentioned above.

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A Estimation results

In the following, we list the estimation results. The first table shows the results assuming that equation (4.1) is implemented in the model, whereas for the second table, equation (4.2) is used. Finally, the last table shows the results assuming an expected inflation, output gap target for the central bank, i.e., implementing equation (4.3).

For comparison purposes, the tables do not only consist of the point estimates for the mean but also of the prior moments (mean and standard deviation) as well as the confidence intervals.

Parameter	Prior Mean	Prior SE	Posterior Mean	Confidence Interval	
ψ_1	1.500	0.500	1.4565	1.4565	1.4565
ψ_2	0.250	0.125	0.0513	0.0490	0.0531
ψ_3	0.250	0.125	0.1404	0.1380	0.1438
ρ_i	0.500	0.200	0.8506	0.8480	0.8528
α	0.200	0.050	0.1876	0.1860	0.1889
τ	0.500	0.200	0.2203	0.2165	0.2250
κ	0.500	0.250	0.4842	0.4759	0.4904
r	2.500	1.000	2.4927	2.4868	2.4997
ρ_{y^*}	0.956	0.050	0.9989	0.9977	1.0000
ρ_{π^*}	0.819	0.100	0.8200	0.8172	0.8223
ρ_q	0.321	0.200	0.9389	0.9146	0.9621
ρ_z	0.695	0.050	0.6958	0.6953	0.6963
σ_i	0.500	4.000	0.8956	0.7911	1.0066
σ_{y^*}	0.016	4.000	0.0164	0.0062	0.0318
σ_{π^*}	0.451	4.000	0.5107	0.4673	0.5531
σ_q	3.492	4.000	3.3321	2.8837	3.6800
σ_z	1.802	4.000	1.6483	1.3032	1.9794

Table 4: Results including Equation (4.1)

Parameter	Prior Mean	Prior SE	Posterior Mean	Confidence Interval	
ψ_1	1.500	0.500	4.2408	2.8328	5.4239
ψ_2	0.250	0.125	0.2486	0.0786	0.4006
ψ_3	0.250	0.125	0.3203	0.1793	0.4461
ρ_i	0.500	0.200	0.8177	0.7495	0.8991
α	0.200	0.050	0.2046	0.1528	0.2613
τ	0.500	0.200	0.2049	0.0820	0.3074
κ	0.500	0.250	0.8904	0.4315	1.2587
r	2.500	1.000	2.5092	1.0634	3.9747
ρ_{y^*}	0.956	0.050	0.9755	0.9527	1.0000
ρ_{π^*}	0.819	0.100	0.9375	0.8870	0.9816
ρ_q	0.321	0.200	0.9651	0.9353	0.9940
ρ_z	0.695	0.050	0.7004	0.6257	0.7813
σ_i	0.500	4.000	0.7998	0.5735	1.1346
σ_{y^*}	0.016	4.000	0.0206	0.0039	0.0435
σ_{π^*}	0.451	4.000	0.4753	0.1506	0.7302
σ_q	3.492	4.000	2.8360	2.0231	3.5606
σ_z	1.802	4.000	1.9061	1.0728	2.6340

Table 5: Results including Equation (4.2)

Parameter	Prior Mean	Prior SE	Posterior Mean	Confidence Interval	
ψ_1	1.500	0.500	4.1021	2.7735	5.3288
ψ_2	0.250	0.125	0.2381	0.0656	0.4252
ψ_3	0.250	0.125	0.3907	0.1529	0.6613
ρ_i	0.500	0.200	0.6330	0.4386	0.8214
α	0.200	0.050	0.1930	0.1319	0.2558
τ	0.500	0.200	0.1742	0.0693	0.3009
κ	0.500	0.250	0.8976	0.3072	1.4049
r	2.500	1.000	2.5722	0.8322	4.2433
ρ_{y^*}	0.956	0.050	0.9644	0.9169	1.0000
ρ_{π^*}	0.819	0.100	0.9669	0.9314	0.9982
ρ_q	0.321	0.200	0.9543	0.9108	0.9947
ρ_z	0.695	0.050	0.7035	0.6298	0.7903
σ_i	0.500	4.000	0.6191	0.4540	0.7632
σ_{y^*}	0.016	4.000	0.0115	0.0037	0.0203
σ_{π^*}	0.451	4.000	0.4015	0.1388	0.7683
σ_q	3.492	4.000	2.4801	1.3833	3.3032
σ_z	1.802	4.000	2.4592	0.9615	3.9896

Table 6: Results including Equation (4.3)