

DEPARTMENT OF ECONOMICS

**Monetary policy in the New-Keynesian model:
An application to the Euro-Area**

Cindy Moons, Harry Garretsen, Bas van Aarle & Jorge Fornero

UNIVERSITY OF ANTWERP
Faculty of Applied Economics



Stadscampus
Prinsstraat 13, B.213
BE-2000 Antwerpen
Tel. +32 (0)3 220 40 32
Fax +32 (0)3 220 47 99
<http://www.ua.ac.be/tew>

FACULTY OF APPLIED ECONOMICS

DEPARTMENT OF ECONOMICS

Monetary policy in the New-Keynesian model:
An application to the Euro-Area

Cindy Moons, Harry Garretsen, Bas van Aarle & Jorge Fornero

RESEARCH PAPER 2007-014
JUNE 2007

University of Antwerp, City Campus, Prinsstraat 13, B-2000 Antwerp, Belgium
Research Administration – room B.213
phone: (32) 3 220 40 32
fax: (32) 3 220 47 99
e-mail: joeri.nys@ua.ac.be

The papers can be also found at our website:

www.ua.ac.be/tew

(research > working papers)

D/2007/1169/014

Monetary policy in the New-Keynesian model: An application to the Euro-Area*

Cindy Moons¹, Harry Garretsen², Bas van Aarle³ and Jorge Fornero¹

Abstract

This paper analyses monetary policy in a stylized new-Keynesian model. A number of issues are focused upon: (i) optimal monetary policy under commitment or discretion vs. ad-hoc monetary policy based on simple rules, (ii) the effects of fiscal policies and foreign variables on monetary policy, (iii) the effects of fiscal deficit and interest rate smoothing objectives and the amount of forward-looking in the model. The model is estimated for the Euro-Area. Using simulations of the estimated model, it is analyzed how these aspects might affect monetary policy of the ECB and macro-economic fluctuations in the Euro-Area.

Keywords: Fiscal Policy, Monetary Policy

JEL Code: F31, F41, G15

May 2007, Third version

¹ University of Antwerp, Department of Applied Economics, Prinsstraat 13, 2000 Antwerpen, Belgium.

² Utrecht School of Economics, Utrecht University, the Netherlands and CESifo, Munich, Germany.

³ Department of Economics, University of Maastricht, the Netherlands and CESifo, Munich, Germany.

Corresponding author: b.vanaarle@algec.unimaas.nl

* We would like to thank seminar participants at the University of Nijmegen, the University of Maastricht and at the CESifo conference “Macro, Money and International Finance 2006” held in Munich, February 24-25, 2006, and the editor and referees for pointing our attention to a number of possible improvements to the first version of our paper.

1. Introduction.

Since its start on January 1st 1999 the design, implementation and transmission of the common monetary policy of the European Central Bank (ECB) has been the subject of close scrutiny. An important question concerns the optimal monetary policy for the Euro-Area (EA). Among other things, this question also concerns the credibility of the ECB. Some observers have argued that the ECB practically inherited the reputation and commitment towards low inflation of the Bundesbank. Others have assumed that as a complete new institution, the ECB would lack initially such a possibility to commit its policies vis-à-vis the private sector and that it would need time to earn a reputation. In other words, starting from a regime with discretionary policymaking, it may only gradually establish a policy regime with commitment in its policies. From the academic side, e.g. adopting inflation targeting has been proposed for the ECB to foster credibility.

Optimal monetary policy under commitment and discretion has received ample interest in the recent New-Keynesian (NK) literature but most results relate to a closed economy setting and ignore the presence of fiscal policy. Clarida *et al.* (1999) and Woodford (2003) demonstrate that in the closed-economy NK model if expectations are entirely forward-looking the optimal monetary policy is history dependent under commitment and contemporaneous under discretion following a cost-push shock. The history dependency under commitment gives rise to an improved trade-off between output and inflation variability as it enables the monetary authorities to smooth out over time the adjustments resulting from the cost-push shock. Jensen (2002) shows that in a closed-economy setting without fiscal policy, with purely forward-looking output and inflation expectations and a monetary authority that has no interest rate smoothing objective, the distinction between commitment and discretion is essentially only relevant in the presence of cost-push shocks. There, stabilization of output and inflation is subject to such a trade-off between the variability of output and inflation. Demand and potential output shocks do not pose such dilemmas as monetary policy can then always be set –both under commitment and discretion- to perfectly offset demand shocks and to perfectly accommodate potential output shocks.

It has also been argued from various sides that there may be a need for using simple policy rules rather than an optimal but highly complicated strategy that is difficult to communicate to the public. The presence of initial institutional uncertainties, large uncertainties about the actual workings of the EA economy (model uncertainty), the lack of consistent EA data (data uncertainty) and the possibility of structural breaks (parameter uncertainty) due to establishment of the EA support this view. Following that logic, it has been argued that the ECB would better follow a simple policy rule that emphasizes predictability, transparency and accountability in conducting monetary policy. A large number of empirical studies have estimated Taylor rules for the EA and find that such simple rules are adequate to characterize actual policymaking.

In this paper we analyze the effects of alternative monetary policy regimes using a stylized NK model that is estimated and simulated using EA data. The analysis focuses on three aspects: (i) optimal monetary policy under commitment or discretion and compare with ad-hoc monetary policy based on simple rules, (ii) the effects of fiscal policies and foreign variables on monetary policy, (iii) the effects of fiscal deficit and interest rate smoothing objectives and the amount of forward-looking in the model.

The paper has been structured as follows: Section 2 proposes a stylized NK model. Section 3 discusses the design of monetary policy in this model. In Section 4, we report estimation results for the EA of the model using system Bayesian estimation. Section 5 discusses the simulation results for various shocks using the model of the EA estimated in Section 4. In Section 6 some sensitivity analysis of the outcomes w.r.t. two crucial model parameters is undertaken. The conclusion summarizes our main results.

2. A stylized NK model of the EA.

The NK research agenda aims at providing a stronger micro-economic underpinning of aggregate demand and aggregate supply analysis and the resulting policy prescriptions. Aggregate demand is driven by the optimizing behavior of households that maximize an intertemporal utility function. Aggregate supply is the result of firms that set the prices for their products so as to maximize profits in a monopolistic competition setting. Governments decide upon monetary and fiscal policies and the small open economy is connected to the rest of the world through a trade in goods and financial assets by a foreign sector and the exchange rate is determined. The setup of the NK model in this paper is rather standard and follows largely well-known expositions such as McCallum and Nelson (1999) and is similar e.g. to Giordani (2004), Muscatelli *et al.* (2004), Svensson (2000), Leitemo *et al.* (2002), Jensen (2002) and others. The Appendix derives the main relations and solves the policy optimization problem confronting the policymakers.

The basic blocs of the model are the aggregate demand and aggregate supply curves, the Uncovered Interest Parity (UIP) condition and the design of monetary and fiscal policies. Concerning the latter: we try to include in the model a number of aspects that are relevant for actual monetary and fiscal policies in the EA, in particular the distinction between monetary policy commitment versus discretion and restrictions on fiscal flexibility in the form of the Stability and Growth Pact (SGP).

The aggregate demand -IS curve-, of the EA economy¹ takes the following form:

$$y_t = \psi y_{t-1} + (1-\psi)E_t y_{t+1} - \alpha(i_t - E_t \Delta p_{t+1} - \bar{r}) + \eta g_t + \sigma y_t^* + \delta(e_t + p_t^* - p_t) + u_t^d \quad (1),$$

in which y denotes output, i the short-term nominal interest rate, (the policy instrument of the ECB), p the general price level, g the fiscal balance (a positive value of g denotes a fiscal deficit), e is the nominal euro exchange rate (a positive value implying a depreciation), \bar{r} is the equilibrium real interest rate². u^d is an aggregate demand shock. The subscript t denotes time and E_t is the rational expectations operator. All variables are given in logarithms and refer to deviations from an initial (non-stochastic) steady-state. Foreign variables are denoted by an asterisk.

In this reduced form, output depends on past output, expected future output, the real interest rate (expressed as a deviation from the equilibrium real interest rate), (net) government spending, (net) exports and a demand shock. The backward-looking component in the IS curve can be explained e.g. by “habit formation” in

¹ EA variables can be interpreted as weighted averages of individual country variables: thus, aggregate inflation, real output and fiscal deficit can be defined as a weighted average of individual countries.

² In practice, it may be quite complicated to determine the equilibrium real rate of interest, \bar{r} , as the study on real equilibrium interest rates in the EA by Giammarioli and Valla (2003) shows. Similar to estimating equilibrium output \bar{y} it would be crucial, however, for the monetary authority to get its estimation on this variable right.

consumption decisions³. The forward-looking part is produced by rational, intertemporally maximizing agents that apply the principles of optimal “consumption smoothing”. In case consumers are entirely forward looking ($\psi_i = 0$), (1) is also sometimes referred to as the “intertemporal IS”.

Exchange rates adjust in such a manner that uncovered interest rate parity holds throughout:

$$E_t e_{t+1} - e_t = i_t - i_t^* + u_{t+1}^e \quad (2),$$

where u_t^e represents random exchange rate shocks (risk premium shocks, expectation shocks or other shocks in international financial markets) that cause temporary deviations from UIP.⁴

Inflation dynamics are given by a hybrid Phillips-curve which contains elements of both forward and backward-looking price setting. In addition, demand-pull and cost-push factors affect inflation,

$$\Delta p_t = \omega \Delta p_{t-1} + (1 - \omega) E_t \Delta p_{t+1} + \gamma (y_t - \bar{y}_t) + \tau \Delta (p_t^* + e_t) + u_t^s \quad (3).$$

Inflation equals the first difference of the general price level and is assumed to be a function of past inflation, expected future inflation, the output gap, $y_t - \bar{y}_t$, -reflecting demand pull inflation- and inflation of import prices, $\Delta (p_t^* + e_t)$, which induces cost-push inflation.⁵ u_t^s , are domestic cost push shocks (or “mark-up” shocks) which will be interpreted as supply-shocks in the remainder of the analysis since (3) can also be considered as describing the short-run aggregate supply (AS) curve. In addition, the supply side of the economy can be hit by shocks to potential output viz. productivity shocks.

If $\omega = 1$, we obtain the backward-looking Phillips curve, if $\omega = 0$, on the other hand, we obtain the forward-looking NK Phillips curve⁶. In the first case, only past economic conditions matter for current inflation. In the presence of forward-looking expectations, current price setting depends on expectations about future economic conditions. The hybrid Phillips curve assumes that both backward and forward-looking price setting are present, it results if ω lies in between 0 and 1.⁷ The hybrid Phillips curve allows for both a forward-looking component and a backward-looking component, reflecting e.g. learning effects, staggered contracts or other institutional arrangements that affect pricing behavior.

The output gap proxies the effects of demand-pull factors on the general price level. Foreign inflation spillovers affect domestic prices via the price of imported raw materials, and intermediate and final goods used in

³ This IS curves nests several alternative formulations that can be found in the literature: the current output gap can be positively related to past output gaps only (Fuhrer and Moore (1995), Huh and Lansing (2000)), both past and expected future output gaps, Clarida *et al.*, (1999)), or expected future output gaps only (McCallum (2001), Woodford (2001)). Leith and Malley (2002), Batini *et al.* (2003) and McCallum and Nelson (1999) provide micro-foundations for the presence of habit formation in consumption. Empirical evidence is provided that the backward looking component in consumption is substantial.

⁴ For empirical studies on deviations of UIP see e.g. Jeanne and Rose (2002). McCallum and Nelson (1999) analyze the effects of deviations from UIP on the exchange rate and the current account in a framework that is related to ours.

⁵ See Gagnon and Ihrig (2004), Leitimo *et al.* (2002), Coenen and Wieland (2002) who use similar Phillips curves.

⁶ See e.g. Clarida *et al.* (1999) for a similar analytical framework and a detailed discussion on the generalised IS (1) and Phillips curves (3). They illustrate how ψ and ω jointly determine the endogenous inflation and output persistence. Leith and Malley (2002) derive (3) from the overlapping contracts model à la Calvo.

⁷ In empirical applications, more lags of output (in case of the IS curve) and output and inflation (Phillips curve) are often included to improve the empirical fit. Adding these lags will also induce a more persistent and therefore more realistic adjustment to shocks. In empirical studies and monetary policy analysis sometimes concepts of equilibrium and/or core inflation are added to (3), to distinguish short-run fluctuations of inflation from longer term, equilibrium inflation. In our analysis this issue is not dealt with and inflation (as all other variables) is defined in terms of deviations from (possibly non-

the domestic production process. The strength of the foreign inflation and depreciation spillovers, depends not only on the intensity with which foreign goods are absorbed but also on the amount of pass-through in import pricing. Recent empirical research suggests that pass-through is generally non-negligible.⁸ Inflation will be affected by changes in the exchange rate through the direct effect via import prices, implying cost-push inflation. Exchange rate changes can also affect inflation indirectly through aggregate demand, since they will affect the relative price between domestic and foreign goods, thereby influencing net exports and domestic output, which in turn will affect prices through demand-pull inflation.

Demand shocks (u^d), cost-push shocks (u^s), potential output (\bar{y}), equilibrium real interest rate (\bar{r}), fiscal shocks (u^f), exchange rate shocks (u^e) and foreign output (u^{f*}), price (u^{p*}) and interest rate (u^{i*}) shocks are all assumed to follow stationary AR(1) processes $u_t = \rho u_{t-1} + v_t$, with $0 \leq \rho < 1$ and v_t is white noise, $v \propto N(0, \sigma_v^2)$, all shocks are assumed to be contemporaneously uncorrelated, $E[v_i v_j] = 0, \forall i, j$.

Macroeconomic stabilization policies are another shock-absorber. The macroeconomic policy regime consists of the monetary and fiscal policy strategies that are implemented in the EA. The monetary and fiscal policy strategies are interacting and their joint implementation affects macroeconomic adjustments. In the model, macroeconomic shocks lead to fluctuations in output and prices. This will affect the interest rate and through (2) the exchange rate. External exchange rate adjustment in the form of changes of the euro exchange rate, therefore, remains a potentially important shock absorber in the EA, in particular in case the shocks are of foreign origin. In fact, whereas a monetary union precludes internal exchange rate adjustments by definition, external exchange rate adjustments may partly take over as a shock-absorber. In the context of the EA, one should in other words not only focus on the interest rate channel of its monetary policy but also the exchange rate channel is important in assessing the transmissions of monetary policy of the ECB.

Concerning fiscal policy we assume that net government spending is determined by a fiscal policy rule. Taylor (2000), developed a framework for simple fiscal policies that relate net government spending to the structural fiscal balance, \bar{g} , and the cyclical fiscal stance, as measured by the automatic stabilizers $-\chi y_t$, the elasticity of the deficit to cyclical output fluctuations times output. In addition, we allow for the possibility of deficit smoothing and the occurrence of stochastic deficit shocks, u^g :

$$g_t = \lambda_g g_{t-1} + (1 - \lambda_g) (\bar{g} - \chi_g y_t) + u_t^g \quad (4).$$

χ_g measures automatic stabilization of the business cycle fluctuations by fiscal policy, λ_g the degree of fiscal policy inertia/activism.

The fiscal policy rule (4) enables to represent in the model -albeit in a highly stylized way- the various budgetary rules and strategies one may observe in practice. Here, we would like also to relate the fiscal policy rules with the provisions in the Stability and Growth Pact. The budgetary target \bar{g} can be thought e.g. as being the “close-to balance or in surplus medium term objective”, reflecting a preference for long-run sustainability and

zero inflation) steady-state. See Vega and Wynne (2003) and references therein on core inflation in the EA.

⁸ See e.g. Gagnon and Ihrig (2004) and Anderton (2003). Apart from “pass-through” by importers of foreign price changes, including exchange rate changes, it is sometimes also argued that importers will consider domestic inflation when setting import prices as they seek to react to the pricing of domestic competitors. Such a “pricing to market” could be added to our

neutrality. In particular, the flexibility in the Stability Pact relates to the degree to which the automatic stabilizers are allowed to function in the short-run. Here, the amount of inertia in fiscal policy, summarized by λ_g , reflects the ability of fiscal policymakers to adjust fiscal policy in the short-run. If $\lambda_g = 0$ fiscal flexibility is the highest and the fiscal balance only driven by the automatic stabilizers. If λ_g increases, fiscal flexibility declines, implying more persistence in fiscal adjustments, more “smoothing” of deficits. In the limiting case where $\lambda_g = 1$, fiscal deficits do not adjust at all over time. Ignoring fiscal shocks, this would imply the absence of fiscal stabilization. This element of deficit smoothing seems therefore quite related to the recent discussion on the question if the SGP is not too rigid in some circumstances and should not be amended in any form to become more flexible and e.g. to let automatic stabilizers work freely in a recession.

3. Monetary Policy: Optimal policies vs. ad hoc rules

As noted in Section 1, it is of significant importance, whether the monetary authorities would be able or not to implement their policies under discretion or commitment. In our dynamic NK model, the difference between the commitment and discretionary case results from the forward-looking part of the model (the expectations of the private sector about output, inflation and exchange rates) and is essentially an extension to a dynamic setting of the time-inconsistency problem in the well-known static setting á la Barro-Gordon. It is important to realize here that the transmission of monetary policy also takes place through the private expectations about current and future monetary policy behavior, the s.c. expectations channel of monetary policy.

Commitment enables the policymaker to smooth the stabilization costs over time: if a macroeconomic shock hits the economy, the policymaker can announce a path of current and future policy actions and credibly implement this strategy. The private sector anticipates correctly the policies that the policymaker will undertake to stabilize the shocks and sets its expectations accordingly. Under discretion, such announcements of future policy contingent on commitment are not credible. As a result, under commitment adjustments of interest rates and inflation will typically display more inertial adjustment and less volatility than under discretion, given this ability to smooth out the adjustment costs over time. Under discretion, policies and inflation are excessively volatile in the short run compared to the commitment case and also welfare losses will be higher with discretionary policymaking due to the existence of a stabilization bias in the short-run⁹. The differences between commitment and discretion will vanish when output and inflation become increasingly backward-looking¹⁰, since in that case the private sector expectations are less and less affected by policy commitments, or stated differently, optimal policies will suffer less and less from time-inconsistency problems when there is less and less forward-looking. In

analysis as well by adding domestic inflation to the RHS of (3).

⁹ Discretionary policies will also induce an inflationary bias in case the policymaker chooses an output objective that exceeds potential output, reflecting e.g. the case of a dependent Central Bank that is steered by political objectives. In the remainder of this study we will, however, not deal with such cases. It would essentially further strengthen the benefits of commitment over discretion.

¹⁰ Note that in our analysis, we will assume that exchange rate expectations are always set in an entirely forward-looking manner.

a purely backward-looking model, the time-inconsistency problems of optimal monetary policy disappear by definition.

It is this basic optimal monetary policy problem that our analysis will focus. We extend this problem by adding a few elements (i) comparing optimal monetary policy under commitment or discretion with ad-hoc monetary policy based on simple rules, (ii) the effects of interest rate smoothing objectives and the degree of forward-looking of expectations, (iii) the effects of fiscal policies and foreign variables on monetary policy.

Concerning the design of monetary policy by the ECB, we will distinguish between two different settings: (i) a setting where the ECB implements an optimal policy, where we need to distinguish between discretion and commitment strategies. (ii) a setting where the ECB implements an ad-hoc policy rule. Following the terminology of Svensson (2000), the first case falls into the category of targeting rules and the second case into the category of instrument rules.

Targeting rules seek to determine optimal policy responses to economic conditions, given a set of objectives. In the context of the above model, we look at the policy strategies that minimize the following intertemporal quadratic loss function of the ECB:

$$L_t^E = E_t \sum_{\tau=0}^{\infty} \Gamma^{\tau} \left[\beta (\Delta p_{t+\tau})^2 + \xi (y_{t+\tau} - \bar{y}_{t+\tau})^2 + \nu (\Delta i_{t+\tau})^2 + \kappa (\Delta e_{t+\tau})^2 \right] \quad (5).$$

subject to the adjustment dynamics of the economy and under assumptions whether or not the ECB acts under commitment or discretion. Strict inflation targeting implies $\beta > 0$, $\xi = \nu = \kappa = 0$, strict output gap targeting $\beta = 0$, $\xi > 0$, $\nu = \kappa = 0$, strict interest targeting $\beta = \xi = 0$, $\nu > 0$, $\kappa = 0$ and strict exchange rate targeting $\beta = \xi = \nu = 0$, $\kappa > 0$. Note that in a setting of perfect capital mobility as expressed by the UIP condition (2), interest rate stability and stability of the exchange rate are intrinsically linked. Flexible inflation targeting implies that inflation targeting is an important objective of the CB but that it is also concerned about output and interest rate / exchange rate stability, $\beta > 0$, $\xi > 0$, $\nu > 0$, $\kappa > 0$.

From an institutional point of view, the advantage of simple rules is their transparency and their ease to in communicating and monitoring to/by the outside world. It is therefore interesting to confront the targeting rule in (5) with the alternative of a simple instrument rule like the Taylor rule:

$$i_t = \lambda_i i_{t-1} + (1 - \lambda_i) (\bar{i} + \phi_i (\Delta p_t - \Delta \bar{p}) + \chi_i (y_t - \bar{y}_t) + \mu_i \Delta e_t) + u_t^i \quad (6),$$

with $\bar{i} \equiv \bar{r} + \Delta \bar{p}$. Given the definition of variables as deviations from steady-state it is convenient in the remainder of the analysis to put inflation target $\Delta \bar{p}$ equal to 0. The feedback on the output gap and inflation are standard in arguments of the Taylor rule. A feedback on the exchange rate has been investigated in some open-economy Taylor rules, and we have followed Taylor (2001) in this specification¹¹. Monacelli (1999) shows that, under incomplete exchange rate pass-through, an exchange rate augmented Taylor rule performs better than the standard Taylor rule (be it based on CPI inflation or domestic inflation) in terms of inflation stabilization (but not in terms of output stabilization). The preference for instrument smoothing is measured by the value of λ_i , where $0 \leq \lambda_i \leq 1$

¹¹ In Taylor (2001) the real rather than the nominal exchange rate features in the policy rule. Like Clarida (2001) we adopt nominal exchange rate targeting here as it seems to be a more realistic and operational target in the monetary policy rule. Given price-stickiness in the model, it should be stressed that this difference may in fact have only minor implications and the

if λ_i goes to zero the original Taylor rule, which ignores instrument-smoothing objectives, is obtained. Interest rate shocks can be either the result of money demand shocks or of discretionary monetary policy impulses (in that last case monetary policy according to (6) contains both a “rules” and a “discretion” part).

It is useful to note in this context that the Taylor rule above can be seen as an example out of a broader class of simple policy rules. Along this line, Söderlind (1999) defines simple policy rules as optimal policies that result from the general optimal policy problem defined by (5) but augmented with restrictions on the coefficients and/or number of state variables to which the policymaker reacts. This definition of the simple rules case as a restricted optimal policy problem is shown by the equivalent structure of both solutions in terms of optimal policy. Depending on the amount of restrictions, the policy rule can be made more or less complicated and in the absence of restrictions the optimal policy under commitment results. In this interpretation the parameters $\{\lambda_i, \phi_i, \chi_i, \mu_i\}$ that the CB operates would be resulting from the solving an optimal monetary policy problem like in (5) but one with a set of additional restrictions.

4 Estimation of the EA model.

In this section we estimate the model presented in Section 2 for the EA. Quarterly data of EA output, prices, interest rates, fiscal deficit, and euro dollar exchange rate are taken from Eurostat from 1980:I to 2005:IV. For the period before 1999 when the EA did not exist yet, Eurostat compiles EA data using weighted averages of harmonized national data. Figure 1 displays the adjustment of the EA variables during this period. Foreign output, prices and interest rates are approximated by the respective U.S. variables taken from the IMF International Financial Statistics.

[Insert Figure 1 here]

The methodology used to estimate the EA model is the system Bayesian estimation, which has been widely used in recent papers that estimate related New-Keynesian models.

In order to obtain Bayesian estimates for the whole system independent prior densities for each of the 31 model parameters are formulated. Before estimation, variables have been de-trended to take out the effects of economic growth and trend inflation, and to make sure that variables can be interpreted in terms of deviation from steady-state as in the theoretical model. In order to compute the joint sample likelihood and get the estimators, we use the Kalman filter. The paper by Ratto *et al.* (2005a) discusses this method in detail. All our computations are performed using the DYNARE toolbox for Matlab (see Juillard (2005)).

The choice of these prior densities is mostly based on the empirical estimates on the EA in the literature surveyed in Table 1.

[Insert Table 1 here]

more so if the exchange rate feedback is small, of course.

These empirical studies suggest that the EA economy is characterized by a (i) substantial degree of backward looking in output and inflation, (ii) a substantial degree of deficit and interest rate smoothing in the policy rules. Note that the estimated monetary and fiscal rules of Table 1 can be regarded as relatively accurate representations of policies in the EA: empirical estimates of policy rules typically can explain monetary and fiscal policy with a high degree of accuracy.

We report in Table 2 estimation results of the model parameters and standard deviation of shocks.

[Insert Table 2 here]

In a few cases, the posterior densities seem sensitive to the assumed prior densities. This suggests that such coefficients are estimated with a limited degree of accuracy. This possibility is also warned for by Onatski and Williams (2003), Smets and Wouters (2002), Lubik and Schorfheide (2005) and Levin *et al.* (2005) who show that point estimates of the posterior means and corresponding standard errors and of standard deviations of the shocks are conditional on the estimation methodology, the sample (duration) and the values of calibrated (non-stochastic) parameters. In most cases, however, the parameters appear to be adequately estimated.

It turns out that the first guesses in Table 1 of the model parameters based on the estimates in other empirical studies in most cases were not wholly unfounded. According to the estimates, output is somewhat more backward-looking and inflation more forward-looking than the prior of 0.5. Our priors about monetary and fiscal policy rules were fairly adequate. In the remainder of the paper we will therefore assume that the monetary and fiscal rules based on the estimates of Table 2 (and since we confirm them, also the estimates of the policy rules in Table 1) are a relatively accurate representation of *actual* policies in the EA. The posterior distributions always have a smaller dispersion than the distribution of the priors suggesting that the information that prior densities carry out can be made substantially more precise by confronting them with the actual data of the euro-area.

5. The effects of macroeconomic shocks: A simulation analysis.

This section uses simulations to illustrate a number of insights that can be obtained from the model introduced in Section 2 and estimated in Section 4. We simulate the effects of demand shocks, cost-push shocks, potential output shocks, fiscal shocks, exchange rate shocks and foreign shocks in the model of the EA. All shocks are 1 percent in size, occur in period 0, are unanticipated, uncorrelated with each other and have zero persistence. The assumption of zero persistence of shocks is needed here to be able to strictly concentrate on the impact of shocks and their subsequent propagation by the dynamics of the model and macroeconomic policy actions (e.g. in terms of commitment and discretion)¹².

¹² In case of persistent shocks such an analysis is no longer possible and the effects are a combination of persistence of shocks, structural model dynamics and dynamics of policy. In that case a simulation analysis would have little (if any) ability to analyze e.g. the effects of different policy regimes -like we want to do in this paper- as one could not disentangle the dynamics produced by the persistence of the shock from the dynamics inherent in the macro-economic structure and macro-economic policies.

As outlined above, we compare the adjustments under three scenarios: (i) optimal monetary policy in case of policy discretion, (ii) optimal monetary policy in case of commitment, and (iii) an ad-hoc monetary policy rule. The last regime can be interpreted as (a close approximation of) the actual monetary policy strategy of the ECB and the fiscal policy in the EA, given that these policy rules were estimated with accuracy in the previous section. The simulations of the shocks provide (a) impulse response functions that give the dynamics adjustments resulting from the shocks, including the transmission of macroeconomic policies, and (b) variances and welfare losses resulting from stochastic simulations of these shocks (based on 100 replications), allowing us to investigate into more detail aspects of efficiency. In these simulations we in particular want to obtain insights into: (i) optimal monetary policies of the ECB both under discretion and commitment and in comparison to a simple monetary policy rule, (ii) the workings of fiscal policy rules in the EA, and (iii) the effects of foreign shocks, the dynamics of the euro exchange rate and the EA trade balance.

The parameters of the IS curve $(\alpha, \eta, \sigma, \delta, \gamma, \tau)$, Phillips curve (ψ, ω) and monetary and fiscal policy rules $(\lambda_i, \phi_i, \chi_i, \mu_i, \lambda_g, \chi_g)$ are set to the values estimated for the EA in the previous section and presented in Table 2. The values of the monetary policy preference parameters $(\Gamma, \beta, \xi, \nu, \kappa)$ are set equal to $[0.995, 1, 0.5, 0.5, 0]$ in the baseline. Naturally, outcomes may be more or less specific to this set of baseline assumptions. In case of small changes in the parameters, the differences compared to the baseline are typically of a quantitative nature rather than a qualitative nature. If changes get larger, the results can also change qualitatively. At the end of this section we summarize some results of a small sensitivity analysis. To some extent our results are likely to be model-specific as well. However, we noted that in several cases larger, estimated EA models yield similar adjustments as in our model in case comparable shocks are studied, cf. the Dieppe and Henry (2004) Area-Wide Model that gives comparable adjustment dynamics as our model in case of a demand shocks, fiscal shocks and productivity shocks. Smets and Wouters (2002) model gives qualitatively similar outcomes in case of exchange rate shocks, foreign output shocks and productivity shocks.

i) A positive demand shock

Figure 2 displays the adjustments that are produced by a positive one percent demand shock in the EA at $t = 0$ ($v^d(0) = 1\%$). Outcomes under discretion, commitment, and the Taylor rule are denoted by “_dis”, “_com” and “_rul”, respectively.

[Insert Figure 2 here]

The demand shock increases output in the short-run which induces inflation. The ECB reacts by raising the interest rate. This causes an initial appreciation after which the exchange rate depreciates according to the UIP condition, in other words exchange rate overshooting occurs. The increase of the real interest rate and the (nominal and real) appreciation contribute to a stabilization of output and inflation. The automatic stabilizers of the fiscal policy rule generate a fiscal surplus which also contributes to the stabilization of output and inflation. The real appreciation and increase in output causes a current account deficit. It is seen that the monetary policy regime has some, but limited, impact on the outcomes produced by the demand shock. Compared to discretion,

commitment results in a more smooth adjustment of the interest rate and inflation, reflecting the stabilization bias present under discretion as noted in the introduction. The actual monetary policy rule case with strong interest rate smoothing is marked by a somewhat higher persistence in the adjustments compared to optimal policies under commitment and discretion. Because of the high degree of interest rate and deficit smoothing, macroeconomic policies react too slowly and the policies are moreover persistent, implying that at some point in time they actually may contribute to fluctuations in output and inflation.

Table 3 provides the variances of output, inflation, changes in interest rates and exchange rates and the welfare losses that result in the different regimes and for the type of shocks studied in this section, based on the stochastic simulation exercise indicated above. Two calculations are provided: in column I variances and losses are calculated based on the estimated standard deviations and autocorrelations of the respective shocks found in Table 2. In column II calculations are provided for a hypothetical case where all shocks would have the same standard deviation, $\sigma_{v^i} = 0.1$, and have no persistence, $\rho^{v^i} = 0$. This case of column II is also interesting because it enables to disentangle again strictly impulses from their propagation in the economy. It enables to compare directly the impact of different shocks in terms of variance of variables and losses. E.g. column II finds that cost-push shocks have a relatively larger effect on volatility of output and inflation than the other type of shocks. If shocks differ in variance and persistence (as in column I) such a comparison across shocks is non-informative. It even allows us to compare different types and different types of regimes, e.g. the effects of cost-push shocks under discretion with exchange rate shocks under commitment.

It is directly seen that in case of demand shocks, commitment reduces in particular inflation variability compared to discretion, contributing to the lower losses under commitment. The Taylor rule case leads to the highest variance of inflation and interest rate changes. The difference in losses between commitment and discretion and between discretion and the Taylor rule based on actual estimates for the EA are substantial (in the order of 25-50% mostly), but not dramatic an observation that is also seen in the other examples below.

[Insert Table 3 here]

ii) A positive cost-push shock

Next, we analyse the effects of a non-persistent one percent cost-push shock in Figure 3 ($v^s(0) = 1\%$):

[Insert Figure 3 here]

A cost-push shock results in stagflation: there is a substantial decline in output and a burst in inflation. Given the prevalence of inflation stabilization in its motives, the ECB raises the interest rate. The inflation and initial appreciation erode competitiveness and the current account deteriorates. The prolonged recession and the presence of deficit smoothing imply a substantial fiscal deficit. This implies a policy conflict with the ECB: whereas the ECB follows a restrictive policy, the fiscal policy is expansionary. That in particular cost-push shocks are prone to policy conflicts as monetary and fiscal policies tend to act as policy substitutes rather than complements, has also

been noted in several empirical studies, see e.g. Muscatelli *et al.* (2004) for an insightful application to the U.S. case.

The difference in adjustment dynamics between commitment and discretion are considerable and more substantial than in the previous case. Commitment produces a smoother stabilization of inflation and less strong monetary policy intervention than discretion. The difference essentially results from the ECB being able to credibly commit to the optimal path of its instrument, thereby effectively managing inflation expectations and avoiding a short-term stabilization bias. The Taylor rule induces adjustment patterns that lie somewhere between discretion and commitment. The resulting losses in Table 3 show that commitment leads to considerably lower losses than discretion and the Taylor rule case. The results in column II can be directly compared with the case of the demand shock: for a given policy setting, a 1% cost-push shock has considerably stronger effects on the variability of inflation, output gap and interest rates than a 1% demand shock. Also, commitment is relatively more valuable when facing cost-push shocks than when facing demand-shocks.

iii) A positive productivity shock

The effects of a purely transitory one percent productivity shock ($v^{\bar{y}}(0) = 1\%$) are provided in Figure 4.

[Insert Figure 4 here]

The negative output gap that initially results and that turns positive thereafter is a combination of the initial shock to potential output and the resulting increase in actual output. Inflation tends to drop initially, especially in the case of discretion and the simple rule case, thereby evoking an expansionary monetary policy in the form of lower interest rates. The exchange rate depreciation that is produced stimulates inflation. The depreciation also contributes to output and a current account surplus: it boosts competitiveness as the real exchange rate also depreciates. The small fiscal surplus is resulting from the increase in output.

Under commitment, inflation is less volatile and stabilizes again faster as in the other cases. As noted earlier, commitment avoids the emergence of a suboptimal stabilization bias that is present in the discretion case. The resulting lower volatility of inflation, interest rates and exchange rates is a general feature of the commitment regime also found in the other examples (cf. Table 3). In most cases the initial output fluctuations are larger under commitment but thereafter also output tends to stabilize faster under commitment. Compared to optimal policies, the monetary policy rule regime is marked by higher persistence in the fluctuations in particular in inflation but also in other variables. Most of the observations concerning losses and variances for different monetary policy regimes in the previous examples are also seen here.

Interestingly, this example (like the first example concerning demand shocks) illustrates that the conclusion of Jensen (2002) that the distinction between commitment and discretion is practically only relevant in case of cost-push shocks needs to be modified in this more general setting of the NK model. The presence of backward-looking output and inflation dynamics, an interest rate smoothing objective, the presence of fiscal policy and the link between interest rates and exchange rates in an open economy context, imply that commitment and discretion result in different outcomes also in case of demand and productivity shocks.

iv) *A positive fiscal shock*

The effects of a fiscal shock ($v^g(0) = 1\%$) are shown in Figure 5.

[Insert Figure 5 here]

A very important effect produced by fiscal shocks comes from the fiscal rule itself: the initial shock leads to a dynamic adjustment process in the fiscal deficit itself due to the deficit smoothing mechanism. Persistence in the fiscal rule implies that the initial fiscal shock has strong persistence as well. This is clearly seen in the adjustment of the deficit in Figure 5, where a clear deficit bias is seen. Some of the adjustments are related to the adjustments we saw in Figure 2: a fiscal shock is in the first place also an aggregate demand shock. The expansionary fiscal policy is counteracted by a restrictive monetary policy in order to combat inflation. In contrast to Figure 2, where the automatic stabilizers result in a counter-cyclical fiscal policy that is supportive of monetary policy, we observe the opposite. The pro-cyclical fiscal policy seen now is not in line with the restrictive monetary policy that aims at combating inflation. The induced appreciation of the exchange rate reduces the competitiveness so that net exports are crowded out and the current account remains in deficit. Concerning variability of output, inflation, interest rate and welfare losses we reach similar conclusions as in case of demand shocks. Commitment hardly achieves gains over discretion here.

v) *A positive exchange rate shock*

As discussed earlier, adjustment of the euro is an important variable in the dynamic adjustments in the EA model. Figure 6 displays the effects from a one-time shock to the euro ($v^e(0) = 1\%$).

[Insert Figure 6 here]

The (euro depreciation) shock induces modest but highly cyclical fluctuations in output and inflation. A depreciation both contributes to higher output and inflation. Commitment delivers significant gains in stabilizing inflation and output compared to discretionary monetary policy and monetary policy based on simple rules.

vi) *A positive foreign output shock*

Since the EA is an open economy, it is interesting to analyze the transmission of foreign shocks in the EA and how these shocks affect the monetary policy of the ECB. Figure 7 shows the adjustments produced by a foreign output shock ($v^{y^*}(0) = 1\%$).

[Insert Figure 7 here]

The direction of the effects are very similar to those produced by a demand shock but the size of the effects are smaller given that net exports are only a fraction of total demand. In addition, the foreign output shock leads to a

current account surplus rather than a deficit. The results concerning welfare losses and variability of inflation, output, interest rates and exchange rates in the different regimes are essentially the same as in the case of the demand shock in (i).

The results obtained above were based on the set of parameters in Table 2. Though their values seemed plausible, e.g. also when comparing them with other empirical estimations in the literature, it may well be that some values were estimated imprecisely, as some confidence intervals suggested. It is therefore interesting and useful to check if the results change if we change parameters from their estimated (baseline) values. In a small robustness analysis, we focused on two parameters in the model that play a crucial role as they are crucially related to the design and effects of monetary and fiscal policy. We analyzed¹³ the effects of varying them from 0 to 1 taking into account the three monetary regimes and different types of shocks. This is important since the effects of varying parameters on the impulse response functions (Figures 2-7) and the welfare effects (Table 3) are likely to depend –among other things- also on the monetary policy regime and the type of shock so conclusions may even differ for different policy regimes and shocks.

(i) the degree of forward-looking of the Phillips curve, ω . Since ω determines the relative importance of forward and backward looking inflation expectations, it plays a crucial role in the AS curve and the effects of commitment vs. discretion. Commitment becomes more important in a more forward-looking model and in case of cost-push shocks since it is especially in these conditions where commitment can make a difference. Clearly, the higher the degree of forward-looking, the more commitment matters, and the more adjustment under commitment differs from discretion, think e.g. of the stabilization bias problem associated with discretion. Therefore, the amount of forward-looking in the Phillips curves plays a crucial role in the transmission of shocks and policymaking. Note, however, that even in case of a more backward-looking model and with different type of shocks than cost-push, commitment continues to play some role. This insight extends the conclusions by Jensen (2002) as indicated in the introduction.

(ii) the degree of fiscal policy flexibility, λ_g . The degree of fiscal policy activism/inertia λ_g is a crucial parameter in the fiscal policy rule: with a increasing value of λ_g fiscal policy gets more and more inflexible in terms of reacting to output fluctuations. It is therefore interesting to compare outcomes when fiscal policy gets less and less flexible. In case of demand shocks, less fiscal flexibility raises the variance of the output gap and inflation and implies higher losses. The effects are particularly strong on output and inflation variability under commitment: given that monetary management is set in an optimal manner, a very inflexible and inadequate fiscal policy leads to inefficiently high output and inflation fluctuations. Optimal results would be obtained by granting full fiscal flexibility. Under cost-push shocks the picture is quite different: less fiscal flexibility leads to lower losses initially, only when λ_g increases above about 0.7, losses start to increase again. This suggests that from the perspective of the monetary policymaker (or society if one interprets the loss function of the monetary authorities as representing also society's preferences), fiscal flexibility is preferred in case of demand shocks, but in case of cost-push shocks constraints on fiscal flexibility are needed; but there is also an upper limit on the restraint of fiscal flexibility. This outcome is robust across the three monetary policy regimes.

¹³ For the sake of brevity graphs are not included here, but available upon request to the interested reader.

This notion that the effects of monetary and fiscal policy¹⁴ depend very much on the type of shocks the policy maker is facing, the type of monetary policy regime is in place and the structural characteristics of the economy, can be made more explicit by working out the sensitivity analysis above even further. In a final exercise we analyzed how for the different type of shocks and policy regimes, the best outcomes the monetary authorities can obtain in terms of variability of both output and inflation evolve in each policy regime and for different type of shocks, with different values of ω and λ_g . This set of s.c. “efficient frontiers” illustrates that the effects of more forward-looking inflation expectations and/or of more fiscal flexibility differ greatly across shocks, the different monetary regimes, the type of macro-economic shocks and the structure of the economy. This also implies that is difficult to draw general conclusions and e.g. to advocate (under all circumstances) the desirability in general of more (or less) fiscal flexibility in the EA. Redesigning the SGP to increase its efficiency is clearly a delicate balance act.

Conclusions

In this paper, we focused on the role of the monetary policy regime using a stylized NK model and applied the framework to the case of the EA. We analyzed the effects of a series of macroeconomic shocks to assess their impact on monetary policy in the EA model. The effects of monetary policy were shown to depend upon the monetary policy regime: whether monetary policy was implemented under commitment, discretion or a rule-based framework was seen to have important consequences.

The existing NK literature on optimal monetary policy under commitment and discretion typically concentrates on cost-push shocks and to a setting with purely forward-looking expectations, in a closed economy and ignoring the absence of interest rate smoothing objectives and an active fiscal policy. It finds that in that setting, the difference between commitment and discretion is only important in case of cost-push shocks since potential output and demand shocks are always fully stabilized in both cases.

This setting, however, is not likely to adequately represent conditions in the EA. Our analysis indeed showed that the introduction of backward-looking expectations, an interest rate smoothing objective, active fiscal policy and an open economy setting, implies that the existing results on monetary policy in the NK model may need modifications. In particular, it was seen that when extensions of the NK model are undertaken, the distinction between commitment and discretion is important not only in case of cost-push shocks but also in case of demand, potential output and foreign shocks.

We highlighted the role of external factors and fiscal policy for monetary policy in the EA. In an open economy like the EA, exchange rate adjustment and foreign shocks are of fundamental importance and may substantially change adjustment dynamics compared to a closed economy setting. This has implications for monetary policy in the EA: not only the interest rate channel of monetary policy will determine outcomes, but also the exchange rate channel, via pass-through and competitiveness effects. Fiscal policies matter significantly for the monetary policymaker in our analysis: in particular the degree of deficit smoothing and the cyclical sensitivity

¹⁴ In the dynamic simulation examples in Figures 2-7 we saw already how the monetary policy reaction itself depends on the type of shock and the policy regime in place. A next important question addressed here is how the effect of monetary policy

of the deficit have a strong influence. Clearly, the design and implementation of the SGP will have consequences for monetary management. Moreover, the effects of fiscal policy itself are also conditional upon the monetary policy regime and the type of shock facing the EA. A small sensitivity analysis indicated that varying the degree of fiscal flexibility has different effects across the different type of shocks and the different type of monetary regimes. This hints at a more general issue: designing monetary and fiscal regimes in the EA is very much interdependent and conditional upon the economic structure and presence of different types of shocks.

We extend the results in the literature in three directions using simulations of an estimated model of the EA. Firstly, we show that both monetary policy itself and the transmission of monetary policy are dependent on the type of monetary policy regime, the type of macroeconomic shocks and the structural characteristics of the economy, including the fiscal policy regime. It is showed that if output and inflation expectations also contain backward-looking elements, the results of the literature indicated above need to be modified further as the backward-looking components generate persistence of output and price adjustments prohibiting immediate full stabilization of demand and productivity shocks.

Secondly, the presence of an active fiscal policy and an open economy setting may complicate the management of monetary policy. Fiscal policy can both support and frustrate the objectives of the monetary policymakers, e.g. in case of a positive demand shock, the monetary policy will be restrictive to contain inflationary pressure. In those conditions, an expansionary fiscal policy shock will run counter to the monetary policy objectives, evoking a policy conflict between the monetary and fiscal policymakers. In an open economy setting, the management of monetary policy is complicated further. Commitment is even more important in an open economy setting: the exchange rate becomes an important channel of transmission of monetary policy affecting thereby real and nominal adjustments after macroeconomic shocks. The introduction of another forward-looking variable in form of exchange rate expectations implies additional time-inconsistency problems for the monetary policymaker related to the exchange rate channel of monetary policy.

Thirdly, policymakers are typically also concerned about instrument smoothing. In case of instrument smoothing policymakers perceive instrument variability as undesirable/costly and thus prefer lower and more gradual adjustment of the policy instruments to high and rapid changes in policy variables. The inclusion of interest rate smoothing generates history dependence in monetary policy even in an otherwise purely forward-looking model. Similarly, deficit smoothing will lead to a fiscal policy that only gradually adjusts. This implies that several results need to be modified, e.g. the immediate full stabilization of demand and potential output shocks will not be optimal because of the implied interest rate variability and adjustments under monetary policy with commitment and discretion will differ.

Appendix

I. Aggregate demand

A typical small open economy is inhabited by representative households who seek to maximize an intertemporal utility function that features present and lagged consumption and amount of hours worked as arguments. The period utility function takes the form of:

reaction depends on the type of shock, the policy regime in place and the structure of the economy.

$$U(C_t, C_{t-1}, N_t) = \Psi \frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$$

where N_t denotes hours of labor, and C_t is a composite consumption index. Utility depends on current, past consumption and hours of labour. Households will maximize utility subject to their budget constraint: labour income plus interest income is spent on consumption and saving. Solving the first-order conditions yields the following Euler condition:

$$1 = \beta R_t E_t \left[\left(\frac{C_{t+1} - hC_t}{C_t - hC_{t-1}} \right) \left(\frac{P_t}{P_{t-1}} \right) \right]$$

which is approximated in log-linear form as:

$$c_t = a_1 c_{t-1} + a_2 E_t c_{t+1} - a_3 (i_t - E_t \Delta p_{t+1} - \bar{r}) \quad (\text{A.1}).$$

a_i are reduced form parameters whose values are calculated from their definitions in terms of the structural model parameters.

Assume that imported goods are used solely as inputs for the production of domestic goods. In case of a constant elasticity of substitution between domestic and foreign inputs, it can be shown that imports, m_t depend on the level of domestic output and the relative price of foreign inputs/competitiveness, which are measured by the real exchange rate. In a similar fashion, exports, x_t , depend on foreign output and competitiveness. Foreign variables are denoted by a star and follow first-order autoregressive processes (see section 2).

$$m_t = a_4 y_t - a_5 (e_t + p_t^* - p_t) \quad (\text{A.2})$$

$$x_t = a_6 y_t^* + a_7 (e_t + p_t^* - p_t)$$

Ignoring investment and denoting net government spending by g_t , we obtain the log-linearized resource constraint of the small open economy:

$$y_t = a_8 c_t + a_9 g_t + a_{10} x_t - a_{11} m_t \quad (\text{A.3}),$$

where weights $a_8 - a_{11}$ denote steady-state shares in output of the respective variables. Combining (A.1)-(A.3), renaming parameters and adding demand/preference shocks, we obtain (1) in the main text. Net government spending is set according to (4) in the main text. Net exports are a function of foreign output and price competitiveness and a random disturbance: net exports = $a_{12} y_t^* - a_{13} y_t + a_{14} (e_t + p_t^* - p_t) + u_t^{nx}$. Exchange rates adjust, according to the UIP hypothesis augmented with a random exchange rate shock, u^r , in (2).

II. Aggregate supply

Domestic goods are produced by a continuum of identical firms in a monopolistic competition setting and using a linear production technology: $Y_t = A_t N_t$, where A denotes productivity and N labor. Productivity shocks, u^y increase potential output. Firms aim at maximizing profits. Price setting is governed in a staggered way a la Calvo (1983). A fraction of firms adjusts prices in an optimal forward-looking manner: firms calculate optimal prices for their products considering expected average inflation and also expected marginal costs, which are assumed to be proportional to the output gap, $y_t - \bar{y}_t$. The remaining share of firms uses “rules-of-thumb” or backward-looking price adjustment. As a result, prices of goods produced domestically adjust according to a ‘hybrid Phillips curve’ and are in addition subject to random cost-push/mark-up shocks, u^s :

$$\Delta p_t^H = b_1 \Delta p_{t-1}^H + b_2 E_t \Delta p_{t+1}^H + b_3 (y_t - \bar{y}_t) + u_t^s \quad (\text{A.4}).$$

The general price level is defined as a weighted average of the price of domestic goods and the price of imported foreign goods. Increases of the price of foreign goods and exchange rate fluctuations $\Delta(e_t + p_t^*)$ are transmitted into import prices because of “pass-through”. Taken together and redefining parameters, we obtain (2) in the main text. The model (1)-(4) can be written in state-space form:

$$\begin{bmatrix} X_{t+1} \\ x_{t+1} \end{bmatrix} = A \begin{bmatrix} X_t \\ x_t \end{bmatrix} + B i_t + C v_{t+1} \quad (\text{A.5}),$$

where $X_t = [y_{t-1} \Delta p_{t-1} e_{t-1} p_{t-1} p_{t-1}^* u_t^d \bar{y}_t \bar{r}_t u_t^s u_t^e y_t^* p_t^* i_t^* i_{t-1} g_t p_t]$ is a 16*1 vector of predetermined variables in the model, $x_t = [y_t \Delta p_t e_t]$ a 3*1 vector of forward-looking variables, $i_t = [i_t]$ a 1*1 vector of instruments and $v_t = [v_t^d \bar{v}_t^y \bar{v}_t^r \bar{v}_t^s \bar{v}_t^e \bar{v}_t^{y^*} \bar{v}_t^{p^*} \bar{v}_t^{i^*} \bar{v}_t^g]$ a 9*1 vector of macroeconomic shocks. Transient matrix A , and the system vectors B and C together determine the system dynamics and are defined by the model parameters.

III. Monetary policy

The objective function of the policymaker (5) can be rewritten as:

$$\min_{i_t} L_t^E = E_t \sum_{\tau=0}^{\infty} \Gamma^\tau Y_{t+\tau} ' W Y_{t+\tau} \quad \text{s.t. (A.5)} \quad (\text{A.6}),$$

where $Y_t = [y_t - \bar{y}_t, \pi_t, i_t - i_{t-1}, e_t - e_{t-1}]'$ is a 4*1 vector of target variables and $W = \text{diag}(\beta, \xi, \nu, \kappa)$, the matrix of relative weights to the target variables.

The model (A.5)-(A.6) is a standard linear stochastic regulator problem with rational expectations and forward-looking variables. Determinacy and stability conditions of this class of models are laid out in the seminal paper of Blanchard and Kahn (1980). Optimal policies can be determined (a) under a regime of policy commitment, (b) under policy discretion (see e.g. Oudiz and Sachs (1985), Backus and Driffill (1986), and Söderlind (1999), Jensen (2002) for the detailed working out of the optima; policies under commitment and discretion cases).

In the discretion case, the policymaker reoptimizes each period by taking the process by which private agents form their expectations as given, where the expectations are consistent with actual policies. The optimal reaction function and forward-looking variables will be linear functions of the predetermined variables. The dynamics of the economy are then described by:

$$\begin{aligned} X_{t+1} &= M_{11}X_t + v_{t+1}, \quad x_t = HX_t, \quad i_t = FX_t, \\ Y_t &= (C_1 + C_2H + C_3F)X_t \end{aligned} \quad (\text{A.7})$$

where $M \equiv (I - F)^{-1}(A + BF)$ and $M = \begin{bmatrix} M_{11} & M_{21} \\ M_{12} & M_{22} \end{bmatrix}$, $C = \begin{bmatrix} C_1 \\ C_2 \end{bmatrix}$ are partitioned according to X_t and x_t . Standard solution algorithms (see Söderlind (1999)) are used to determine H and F and derive the adjustment dynamics and variance-covariance matrices under discretion.

In the commitment case, the policymaker optimizes at the beginning of the planning period. The policymaker acts as a Stackelberg leader w.r.t. the private sector, taking into the equations of motion of the forward looking variables (i.e. the expectations of the private agents) as additional constraints. It adopts this optimal policy and sticks to it during the entire planning period. The optimal reaction function and the forward-looking variables depend not only on the predetermined variables but also depend on the shadow prices of the forward-looking variables. The latter measure the costs from reneging upon the committed policy. The optimal reaction function commitment solution is determined by a decomposition of the stable eigenvalues from the first-order conditions of the optimization problem (A.2) subject to the transition equation (A.1), see e.g. Söderlind (1999) for the different optimization procedures. In the simple policy rule regime, the Taylor interest rate rule (6) is inserted as $i_t = QX_t$ into the dynamic system (A.7) instead of the optimal policy; see again Söderlind (1999) on the simple rule regime.

References

- Anderton, B. (2003), Extra-Euro Area manufacturing import prices and exchange rate pass-through, ECB working paper no.219.
- Backus, D. and J. Driffill (1986), The consistency of optimal policy in stochastic rational expectations models, CEPR discussion paper 124.
- Ballabriga, F. and C. Martinez-Mongay (2002), Macroeconomic policy rules for the EU and the extent of EMU policy shift, mimeo.
- Batini, N., R. Harrison, and S. Millard (2003), Monetary policy rules for an open economy, *Journal of Economic Dynamics and Control*, vol.27, p.2059-2094.
- Blanchard, O. and C. Kahn (1980), The solution of linear difference models under rational expectations, *Econometrica*, vol. 48(5), p.1305-1311.
- Casares, M. (2004), On monetary policy rules for the Euro Area, mimeo.
- Clarida, R., J. Gali, and M. Gertler (1999), The science of monetary policy: A New Keynesian perspective, *Journal of Economic Literature*, vol.37, p.1661-1707.
- Clarida, R. (2001), The empirics of monetary policy rules in open economies, NBER Working Paper no. 8603.
- Coenen, G. and V. Wieland (2002), Inflation dynamics and international linkages: A model of the United States, the Euro Area and Japan, Board of Governors of the Federal Reserve System, International finance discussion papers, no.745.
- Dieppe, A. and J. Henry (2004), The Euro Area viewed as a single economy: How does it respond to shocks? *Economic Modelling*, vol.21, p.833-875.
- Djoudat, R. and C. Gauthier (2003), A small dynamic hybrid model for the Euro Area, Bank of Canada working paper 03/19.
- Domenech, R., M. Ledo, D. Taguas (2001), A small forward-looking macroeconomic model for EMU, mimeo.
- Domenech, R., M. Ledo, D. Taguas (2002), Some new results on interest rate rules in EMU and in the US, *Journal of Economics and Business*, vol. 54(4), p. 431-446.
- Ehrmann, M. and Smets (2003), Uncertain potential output: Implications for monetary policy, *Journal of Economics and Dynamics*, vol.27, p.1611-1638.
- Faruqee, H. (2004), Exchange rate pass-through in the Euro Area: The role of asymmetric pricing behavior, IMF Working Paper no.04/14.

- Fuhrer, J. and G. Moore (1995), Monetary policy trade-offs and the correlation between nominal interest rates and real output, *American Economic Review*, vol.85(1), p.219-239.
- Gagnon, J. and J. Ihrig (2004), Monetary policy and exchange rate pass-through, International Finance Discussion Papers 704, FED.
- Gali, J, M. Gertler and D. Lopez-Salido (2003), Erratum to “European inflation dynamics” [European Economic Review 45 (2001), 1237-1270], *European Economic Review*, vol.47, p.759-760.
- Gerdesmeier, D. and B. Roffia (2003), Empirical Estimates of Reaction Functions for the Euro Area, ECB Working Paper No. 206.
- Giammarioli, N. and N. Valla (2003), The natural real rate of interest in the Euro-Area, ECB Working Paper no.233.
- Giordani, P. (2004), Evaluating New-Keynesian models of a small open economy, *Oxford Bulletin of Economics and Statistics*, vol.66, p.713-733.
- Huh, C. and K. Lansing (2000), Expectations, credibility, and disinflation in a small macroeconomic model, *Journal of Economics and Business*, vol.51(1-2), p.51-86.
- Jeanne, O. and A. Rose (2002), Noise trading and exchange rate regimes, *Quarterly Journal of Economics*, vol. 117(2), p.537-69.
- Jensen, H. (2002), Targeting nominal income growth or inflation?, *American Economic Review*, vol.92(4), p.928-956.
- Jondeau, E. and H. Le Bihan (2005), Testing for the New Keynesian Phillips curve. Additional international evidence, *Economic Modelling*, vol.22, p.521-550.
- Juillard M. (2005), DYNARE Manual, Version 3.0, 2005, Mimeo.
- Leitemo, K. O. Roisland and R. Torvik (2002), Time inconsistency and the exchange rate channel of monetary policy, *Scandinavian Journal of Economics*, vol.104(3), p.391-397.
- Leith, C. and J. Malley (2002), Estimated general equilibrium models for the evaluation of monetary policy in the US and Europe, CESifo Working Paper no.699.
- Levin, A., A. Onatski, J. Williams and N. Williams (2005), Monetary policy under uncertainty in micro-founded macroeconomic models, in M. Gertler and K. Rogoff (eds.), NBER Macroeconomics Annual, MIT Press, p.229-269.
- Lubik T. and F. Schorfheide (2005), A Bayesian look at the New Open Economy Macroeconomics, in M. Gertler and K. Rogoff (eds.), NBER Macroeconomics Annual, MIT Press.
- Monacelli, T. (1999), Open economy policy rules under imperfect pass-through, mimeo, New York University, April.
- McCallum, B. and E. Nelson (1999), Nominal income targeting in an open-economy optimizing model, *Journal of Monetary Economics*, vol.43, p.553-78.
- McCallum, B. T. (2001), Should monetary policy respond strongly to output gaps, *AEA Papers and Proceedings*, vol. 91(2), p.258-62.
- Muscattelli, V., P. Tirelli and C. Trecroci (2004), Fiscal and monetary policy interactions: Empirical evidence and optimal policy using a structural New-Keynesian model, *Journal of Macroeconomics*, vol.26, p.257-280.
- Onatski A. and N. Williams (2003), Modeling model uncertainly, *Journal of the European Economic Association*, vol.1, p.1087-1122.
- Oudiz, G. and J. Sachs (1985), International policy coordination in dynamic macroeconomic models. In Buiters, W. and R. Marston (eds.), International Economic Policy Coordination. Cambridge University Press.
- Peersman, G. and F. Smets (1999), The Taylor rule, a useful monetary policy benchmark for the Euro area?, *International Finance*, vol. 1, p.85-116.
- Ratto, M., W. Roeger, J. in't Veld and R. Girardi (2005), An estimated New Keynesian dynamic stochastic general equilibrium of the Euro area, *European Economy*, Economic Papers no.220, European Commission.
- Sahuc, J. (2002), A ‘hybrid’ monetary policy model: Evidence from the Euro Area, *Applied Economics*, vol. 9, p. 949-955.
- Smets, F. (2003), Maintaining price stability: How long is the medium term?, *Journal of Monetary Economics*, vol.50, p.1293-1309.
- Smets, F. and R. Wouters (2002), Openness, imperfect exchange rate pass-through and monetary policy, *Journal of Monetary Economics*, vol.49(5), p.947-981.
- Smets, F. and R. Wouters (2003), An estimated stochastic dynamic general equilibrium model of the Euro Area, *Journal of the European Economic Association*, vol.1, p.1123-1175.
- Söderlind, P. (1999), Solution and estimation of RE macromodels with optimal policy, *European Economic Review*, vol.43, p.813-823.
- Svensson, L. (2000), Open-economy inflation targeting, *Journal of International Economics*, vol.50, p.155-183.
- Taylor, J. (2000), Reassessing discretionary fiscal Policy, *Journal of Economic Perspectives*, vol.14(3), p.21-36.
- Taylor, J. (2001), The role of the exchange rate in monetary-policy rules, *American Economic Review*, *AEA Papers and Proceedings*, vol. 91(2), May, p.263-267.
- Vega, J. and M. Wynne (2003), A first assessment of some measures of core inflation for the Euro Area, *German Economic Review*, vol.4(3), p.269-306.
- Woodford, M. (2001), The Taylor rule and optimal monetary policy, *American Economic Review*, *AEA Papers and Proceedings*, vol. 91(2), May, p.232-237.
- Woodford, M. (2003), Interest and prices: Foundations of a theory of monetary policy. Princeton University Press.

Authors	Method	Period	ψ	α	δ	ω	γ	τ	λ_i	ϕ_i	χ_i	μ_i	λ_g	χ_g
ES (2002), Smets (2003)	CAL.		0.44	0.06		0.48	0.18							
CW (2002)	VAR	75:I-00:IV	0.97	0.08	0.02		0.02		0.77	0.87				
Casares (2004)	CAL.		0.30	0.11			0.04		0.80	1.00	0.90			
Smets (2003)	GMM	1977-1997	0.44	0.06										
GGL (2003)	GMM					0.13	0.07							
DLT (2001)	GMM	86:I-00:IV	0.50	0.08		0.46	0.06							
DLT (2001)	GMM	70:III-99:IV							0.83	2.02	1.00			
LM (2002)	GMM	71:II-97:IV	0.22	0.06		0.24	0.02							
DG (2003)	GMM	83:I-00:IV	0.45	0.03		0.33	0.17		0.90	1.40	3.20			
Sahuc (2002)	FIML	1974-2000	0.49	0.06		0.54	0.06		0.88	1.73	2.61			
JB (2005)	GMM	70:I-99:IV				0.63	0.12							
Faruqee (2004)	VAR	90:I-02:IV						0.15						
BM (2002)	GMM	1979-1998							0.87	1.29	1.00		0.61	0.42
GR (2003)	GMM	85:I-02:IV							0.87	1.93	0.28			
PS (1999)	2SLS	80:I-97:IV							0.76	1.20	0.76			
PS (1999)	2SLS	79:I-97:12							0.94	1.29	0.32	0.52		
<i>memo: our prior</i>			0.5	0.3	0.7	0.25	0.5	0.1	0.7	1.5	0.5	0.1	0.7	0.4

Table 1: Estimations of the IS and Phillips curves, Taylor rules characteristics for the euro-area.

Notes: ^a Germany. Lacking empirical estimates, priors for σ and η have been set to 0.25 and 0.7, respectively.

ES (2002): Ehrmann and Smets (2002), CW (2002): Coenen and Wieland (2002), GGL (2003): Gali, Gertler and Lopez-Salido (2003) DLT (2003):Domenech, Ledo and Taguas (2001), LM (2002): Leith and Malley (2002), DG (2003): Djoudad and Gauthier (2003), JB (2005): Jondeau and Bihan (2005), BM (2002): Ballabriga and Mongay (2002), GR (2003): Gerdesmeier and Roffia (2003), PS (1999):Peersman and Smets.

Parameter	Prior density	Prior mean	Post. mean	90% Conf. interval
ψ	normal	0.5	0.6058	0.6050 0.6113
α	normal	0.3	0.2347	0.2304 0.2382
η	normal	0.7	0.6238	0.5455 0.7011
σ	normal	0.25	0.2529	0.2378 0.2686
ζ	normal	0.25	0.1402	0.1135 0.1553
δ	normal	0.25	0.1974	0.1957 0.1994
ω	normal	0.5	0.4551	0.4420 0.4661
γ	normal	0.1	0.0849	0.0722 0.0959
τ	normal	0.1	0.0510	0.0508 0.0511
λ_i	normal	0.7	0.7474	0.7445 0.7500
ϕ_i	normal	1.5	1.5151	1.5131 1.5174
χ_i	normal	0.5	0.4311	0.4310 0.4312
μ_i	normal	0.1	0.1163	0.1147 0.1180
λ_g	normal	0.7	0.7066	0.7052 0.7079
χ_g	normal	0.4	0.4022	0.4007 0.4029
$\sigma(v_d)$	inv gamma	0.1	0.0452	0.0407 0.0475
$\sigma(v_e)$	inv gamma	0.1	0.1794	0.1709 0.1865
$\sigma(v_s)$	inv gamma	0.1	0.0745	0.0586 0.0901
$\sigma(v_g)$	inv gamma	0.1	0.0850	0.0811 0.0886
$\sigma(v_i)$	inv gamma	0.1	0.2746	0.2744 0.2750
$\sigma(v_{\bar{y}})$	inv gamma	0.1	0.6775	0.6775 0.6717
$\sigma(v_{\bar{r}})$	inv gamma	0.1	0.0454	0.0444 0.0461
$\sigma(v_{y^*})$	inv gamma	0.1	0.0748	0.0694 0.0797
$\sigma(v_{p^*})$	inv gamma	0.1	0.0376	0.0375 0.0377
$\sigma(v_{i^*})$	inv gamma	0.1	0.0611	0.0499 0.0716

Table 2: Bayesian system estimation results of the EA model.
(Prior standard deviation of parameters was set to 0.1 in all cases)

Shock		Discretion		Commitment		Rules	
		I	II	I	II	I	II
v^d	$\text{var}(\pi)$	0.0004	0.0008	0.0001	0.0001	0.0002	0.0007
	$\text{var}(y - \bar{y})$	0.0007	0.0055	0.0005	0.0049	0.0018	0.0111
	$\text{var}(i)$	0.0050	0.0092	0.0020	0.0046	0.0038	0.0062
	L	0.1499	0.6200	0.0623	0.3654	0.3916	1.2031
v^s	$\text{var}(\pi)$	0.1774	0.0553	0.0469	0.0254	0.1365	0.0488
	$\text{var}(y - \bar{y})$	0.2108	0.0287	0.1742	0.0408	0.1883	0.0285
	$\text{var}(i)$	0.2414	0.0544	0.0162	0.0544	0.1631	0.0367
	L	30.3721	7.8609	13.2274	4.5892	34.6185	9.2913
$v^{\bar{y}}$	$\text{var}(\pi)$	0.0063	0.0001	0.0021	0.0001	0.0059	0.0001
	$\text{var}(y - \bar{y})$	0.1437	0.0070	0.1106	0.0064	0.2402	0.0090
	$\text{var}(i)$	0.1104	0.0012	0.0592	0.0008	0.0654	0.0005
	L	11.8102	0.43826	7.7473	0.3591	18.9066	0.5224
v^g	$\text{var}(\pi)$	0.0029	0.0009	0.0015	0.0007	0.0030	0.0007
	$\text{var}(y - \bar{y})$	0.0026	0.0017	0.0074	0.0027	0.0034	0.0014
	$\text{var}(i)$	0.0126	0.0067	0.0063	0.0029	0.0081	0.0048
	L	0.5646	0.2105	0.5524	0.2124	0.9010	0.3396
v^e	$\text{var}(\pi)$	0.0008	0.0007	0.0011	0.0006	0.0005	0.0004
	$\text{var}(y - \bar{y})$	0.0027	0.0028	0.0019	0.0013	0.0048	0.0014
	$\text{var}(i)$	0.0167	0.0032	0.0118	0.0036	0.0130	0.0060
	L	0.3970	0.2235	0.3433	0.1495	1.0513	0.4156
v^{**}	$\text{var}(\pi)$	0.0010	0.0009	0.0007	0.0007	0.0007	0.0007
	$\text{var}(y - \bar{y})$	0.0018	0.0021	0.0028	0.0030	0.0017	0.0021
	$\text{var}(i)$	0.0075	0.0072	0.0032	0.0032	0.0055	0.0052
	L	0.2370	0.2501	0.2235	0.2358	0.4086	0.4166

Table 3: Variance analysis and losses from various shocks.

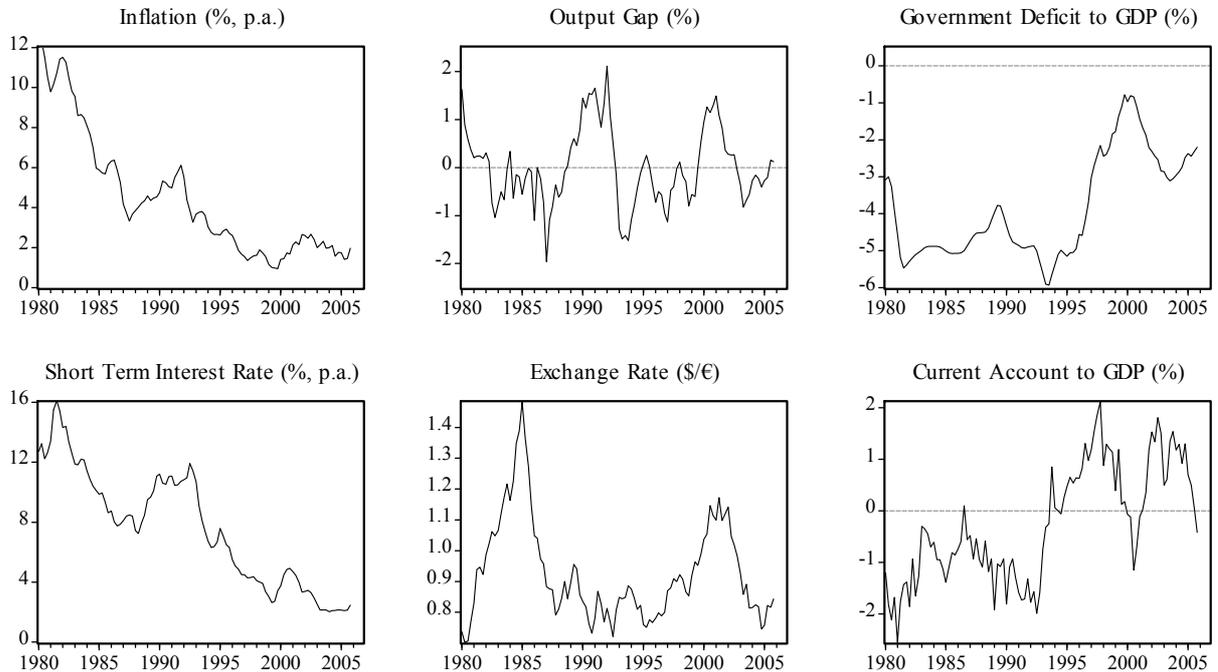


Figure 1: Adjustments in the Euro Area 1980-2005

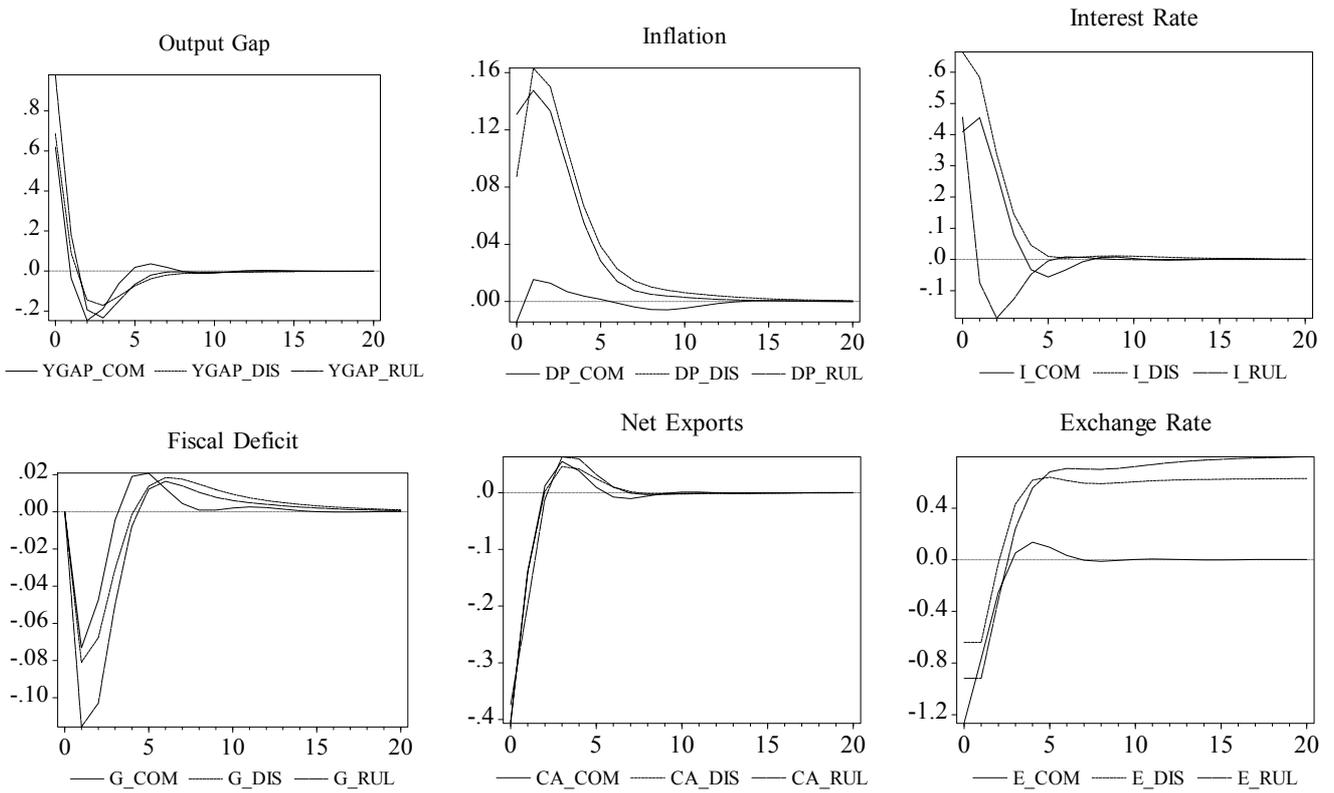


Figure 2: Effects of a demand shock.

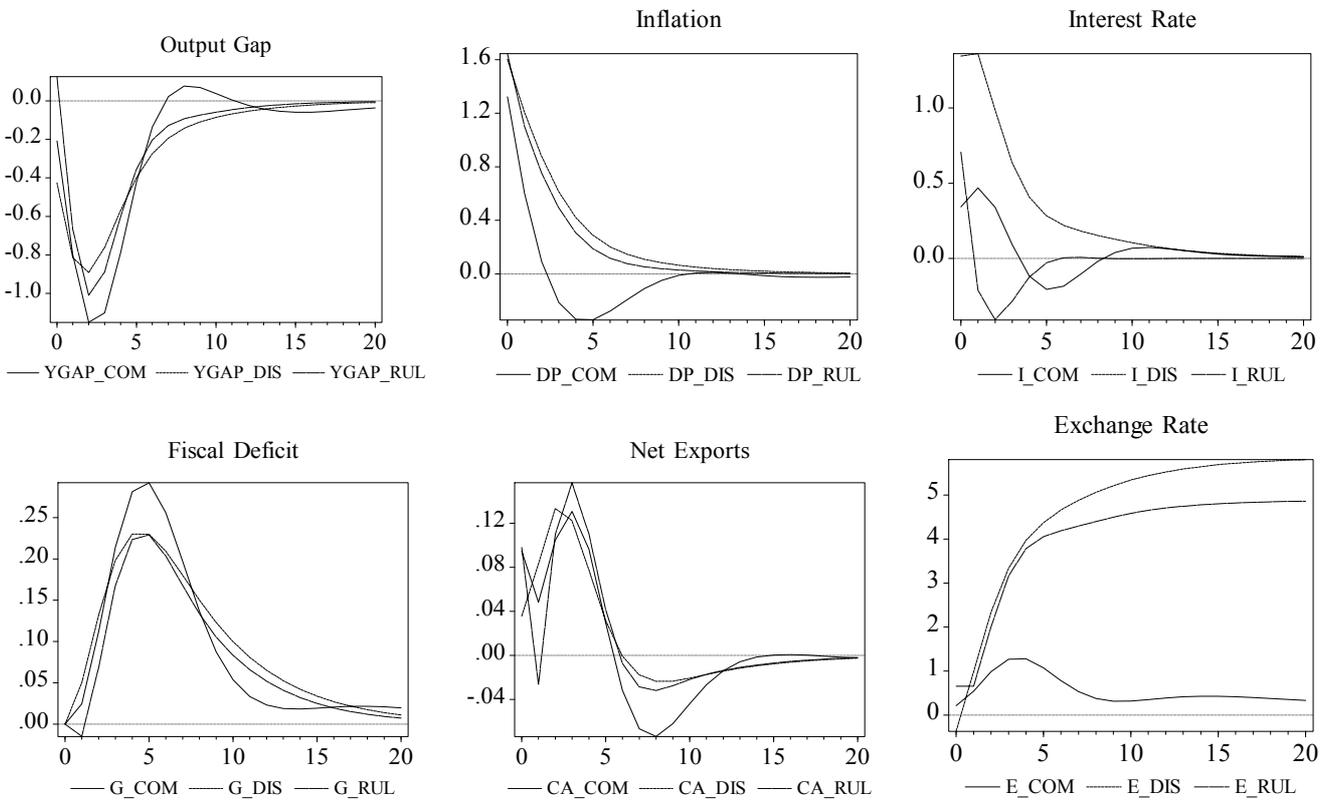


Figure 3: Effects of a cost-push shock.

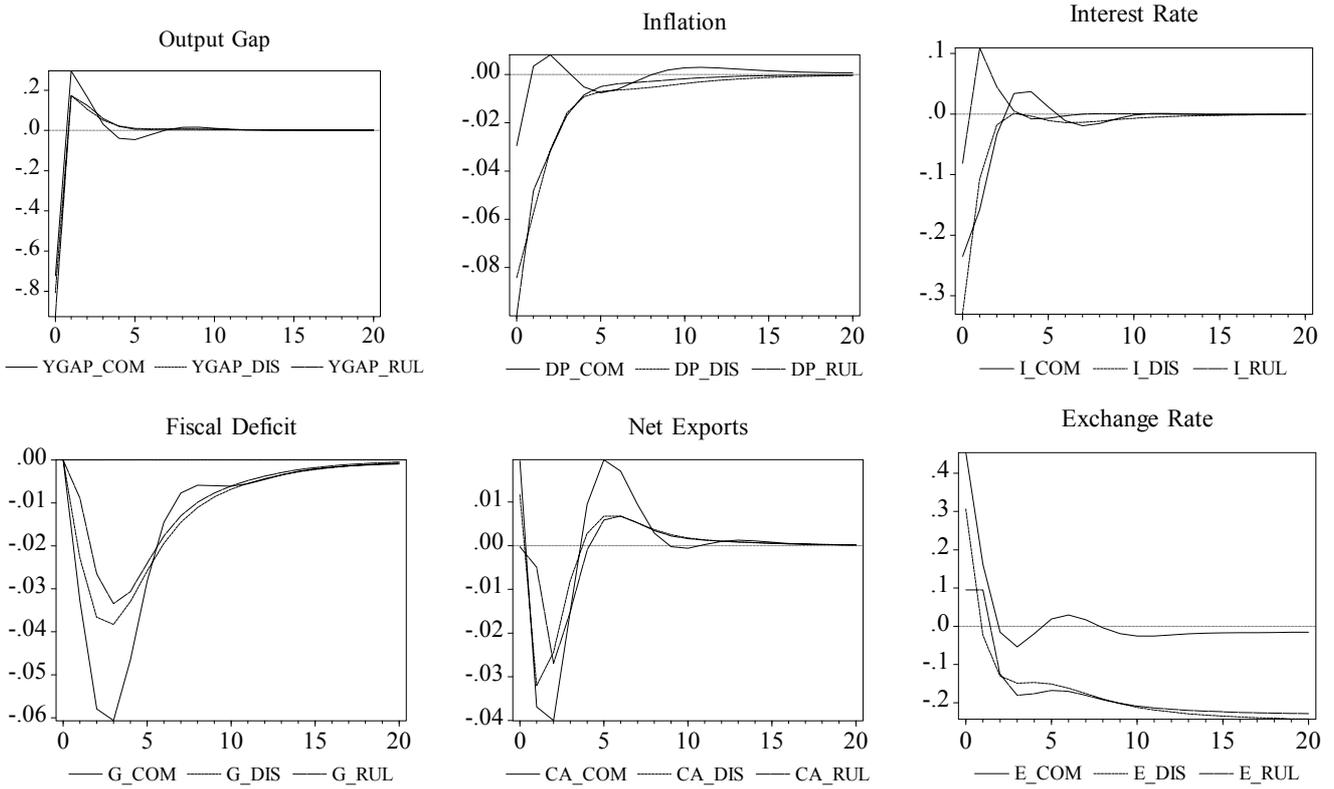


Figure 4: Effects of a potential output shock.

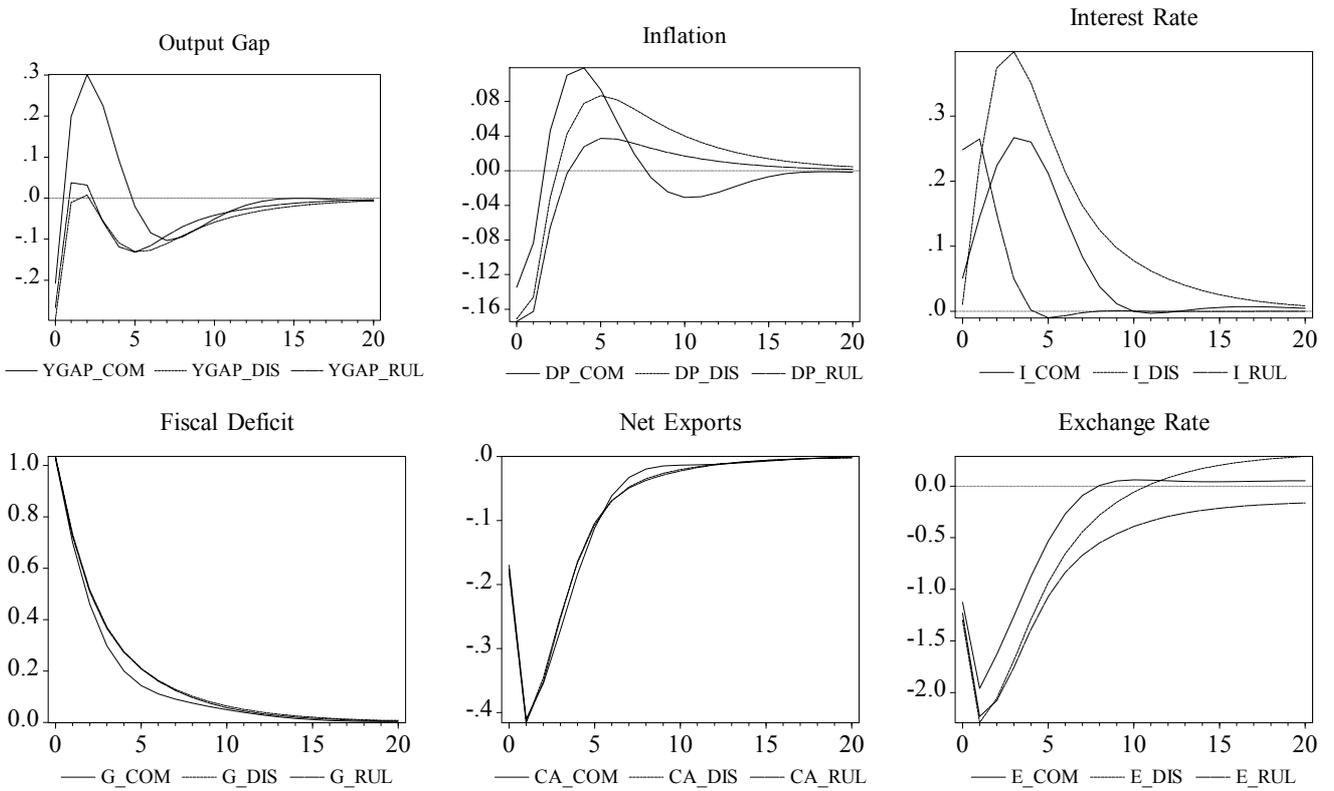


Figure 5: Effects of a fiscal shock.

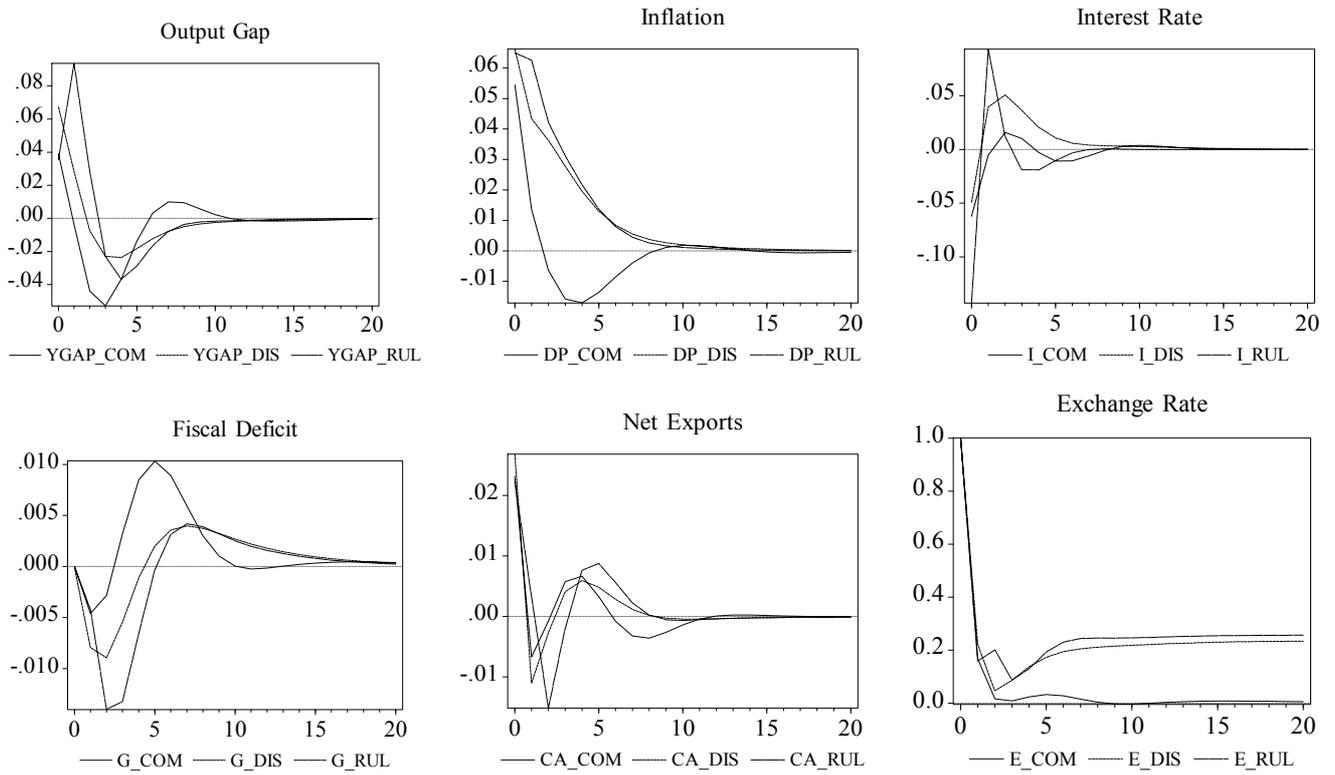


Figure 6: Effects of an exchange rate shock.

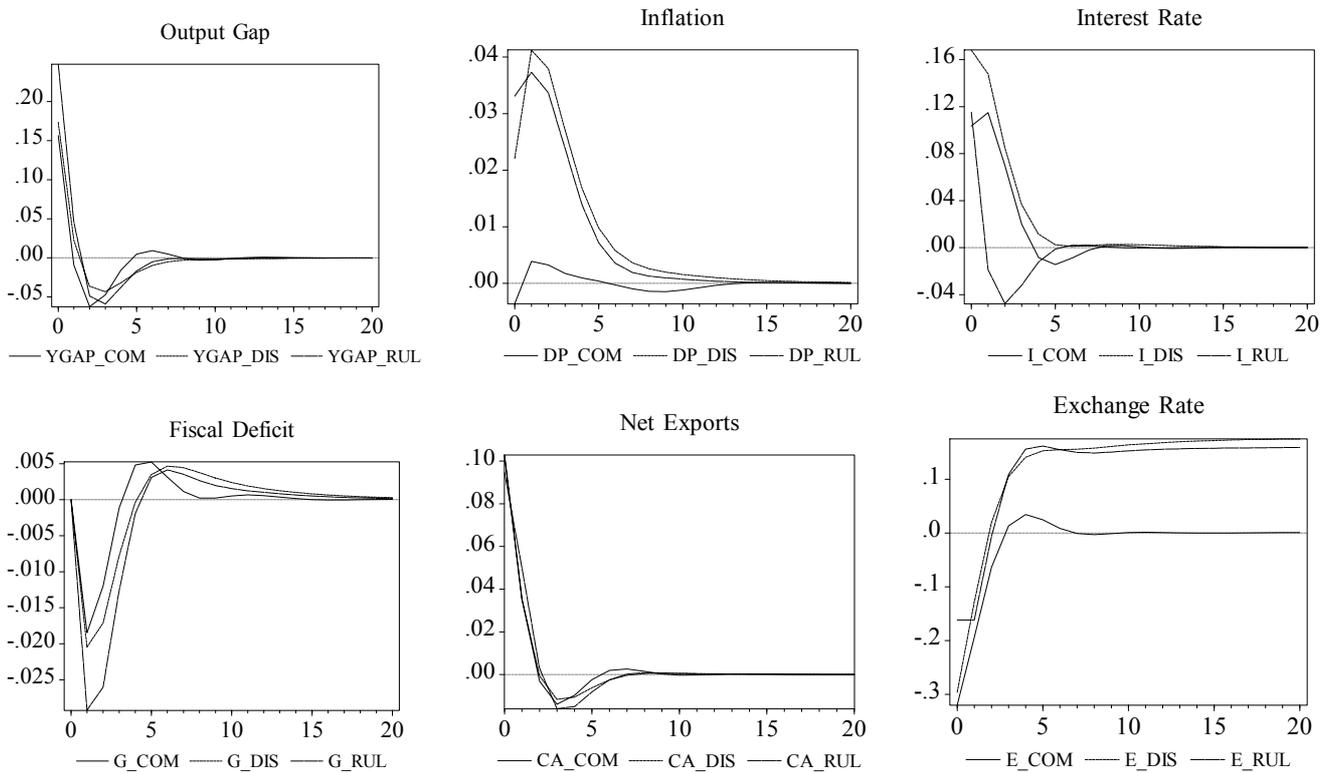


Figure 7: Effects of a foreign output shock.