Trend inflation and monetary policy in Eastern Europe*

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Abstract

I use a simple two-country DSGE model with a non-zero steady state inflation to study the behaviour of the Eastern European central banks. The Bayesian analysis that I carry out suggests that this model performs better than the benchmark New Keynesian framework since the existence of trend inflation improves the fit to the data significantly. Furthermore, using a posterior odds test, I show that the hypothesis according to which central banks systematically target CPI inflation rather than PPI inflation is empirically rejected for all the investigated Eastern European countries. This result is robust across several Taylor-type rules. Concerning the conduct of monetary policy for small Eastern European countries, my estimations suggest that the Czech National Bank includes the nominal exchange rate into its monetary policy, whereas the Hungarian and Polish central banks do not.

Keywords: Monetary policy; Small open economy; Exchange rates; DSGE estimation; Bayesian analysis
JEL Classifications: C32; E52; F41

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1 Introduction

For the central bank of a small open economy, inflation targeting translates into adopting a monetary policy rule that may take into account a consumer price index (CPI) or a producer price index (PPI). It may be argued that inflation reflects an average of domestic and imported price fluctuations in the former case, whereas is entirely generated domestically in the latter case. A number of theoretical contributions argue that, under certain conditions, PPI inflation targeting performs better than CPI inflation targeting (in terms of welfare loss). Surprisingly, these findings are at odds with the customary practice in the empirical literature, whose focus is on simple rules with CPI inflation targeting. This paper attempts to shed some light on this matter by comparing the two rules for a number of Eastern European countries (EEC), namely the Czech Republic, Hungary, and Poland. My results suggest that the central banks of the three investigated EEC tend to target PPI inflation rather than CPI inflation.[1]

The sample of countries under examination is key to understand the motivation of this paper. In fact, what type of monetary policy rule is actually implemented may be particularly relevant for transition economies such as the EEC. The reason is that PPI inflation

[1] My work relates to the large branch of the litetature dealing with monetary policy in open economies: for a thorough review, see Corsetti, Dedola and Leduc (2010). The fact that PPI targeting may perform better than CPI targeting is a well-established result in the theoretical literature of monetary policy in open economies: see, *e.g.*, Gali and Monacelli (2005). As observed by Catão and Chang (2015, p.70), on the one hand “the absence of mark-up/cost-push shocks and/or real wage rigidities [...] imply that PPI stabilization is conducive to output stabilization”; on the other hand “small open economies can gain from steering the real exchange rate and the terms of trade. These ‘terms of trade externality’ (Corsetti and Pesenti, 2001) imply that the flexible price equilibrium is not generally optimal, hence raising the question of whether PPI stabilization remains the best policy. Several studies of the model developed by Galí and Monacelli (2005) have provided a basically affirmative answer (*e.g.*, Faia and Monacelli, 2008; Di Paoli, 2009).” Examples of empirical contributions focusing on other indicators than PPI when investigating inflation targeting can be found in, *e.g.*, Lubik and Schorfheide (2007), Justiniano and Preston (2010), Caraiani (2013) and Baxa, Horvath and Vasicek (2014).

targeting might represent a viable solution for central banks to counteract effects of the Balassa-Samuelson type potentially at work in those countries. These effects would arise because productivity growth in sectors producing tradeable goods exceeds that in the non-tradeable sectors. With wages being similar across sectors, faster productivity growth in the tradeable sectors would lead to a rise in wages in all sectors, thereby driving the relative prices of non-tradables to increase. When comparing two countries, therefore, inflation would be higher in the country with faster productivity growth, and PPI inflation would be larger than CPI inflation as it does not account for imported inflation. In this sense, targeting PPI inflation may prove more effective in influencing domestic macroeconomic variables than targeting CPI inflation.[2]

I develop a two-country DSGE model where, in turn, the three EEC represent the small open economy, and Germany is designated as the large economy.[3] The structure of the models closely relates to Galí and Monacelli (2005) and Rabanal and Tuesta (2010). Building on these studies, I introduce a few key assumptions motivated by empirical evidence. I assume incomplete pass-through following Monacelli (2003), and a home bias in consumption leading to deviation from power purchasing parity. I also let the intratemporal elasticity of substitution between domestic and foreign goods differ from unity, allowing the central bank of the small open economy (SOE) to manipulate the terms of trade, which relates to

[2] For a discussion on Balassa-Samuelson effects in developing countries, see, Egert, Drina, Lommatzsch and Rault (2003) and, more recently, Ricci, Milesi-Ferretti and Lee (2013). Caraiani (2013) is a recent contribution investigating monetary policy choices in the Czech Republic, Hungary, and Poland. There, the focus is on whether central banks may be targeting exchange rates, rather than what type of inflation targeting they are implementing, irrespective of the adopted exchange rate targeting regime. In this perspective, the two papers complement one another.

[3] The reason for this choice is that Germany represents the largest trading partner of all selected EEC, and attracts between 25 to 30 percent of the total exports from each of them. The fact that these bilateral trade partnerships are not reciprocal allows me to conclude that Germany behaves as a large economy relative to the EEC.

the relative domestic price. The supply side of the model is characterised by a hybrid New Keynesian Phillips Curve (NKPC), which is derived using a rule of thumb following Galí and Gertler (1999). Last but not least, I follow Ascari and Ropele (2007) and log-linearise this Phillips curve around a non-zero steady state.[4] The monetary policy for both the large and the small economies is specified by using different Taylor-type rules.

The empirical analysis is conducted using a Bayesian methodology. There is a large literature using Bayesian techniques to estimate DSGE models.[5] The first important work in this field considering open economies is Lubik and Schorfheide (2006), who create a symmetric two-country model and estimate it using U.S. and Euro Area data. Since then, a number of contributions entended their work. Using a similar dataset, Rabanal and Tuesta (2010) estimate and compare models with complete and incomplete financial markets. Lubik and Schorfheide (2007) and Justiniano and Preston (2010) investigate the behaviour of central banks in Australia, Canada, New Zealand and UK. More recent contributions in this literature are Caraiani (2013) for the EEC and Baxa, Horváth and Vašíček (2014) for Australia, Canada, New Zealand, Sweden and the UK. While the methodology I use is analogous to those adopted by these papers, my work differs from each of them by the monetary policy issue or the set of countries under examination.

The paper is organized as follows. Section 2 describes the theoretical model, which builds

[4]Thinking of price trends as upward-sloping is such a customary practice that conventional wisdom simply takes positive inflation as given. As a matter of fact, U.S. inflation averaged 3.21% in the last one hundred years, and ranged from 2.04% to 7.06% in the last eight decades; Germany experienced negative inflation only once in the last sixty years; the Czech Republic, Hungary and Poland never in the last twenty. Notwithstanding, most of the literature of monetary economics develops and estimates models without trend inflation. A recend strand of the literature challenges this approach, and finds evidence suggesting that models with non-zero trend inflation fit the data significantly better than those abstracting from it. A remarkable survey of this literature can be found in Ascari and Sbordone (2014).

[5]For a review on DSGE models estimation, see, *e.g.*, Fernández-Villaverde, Rubio-Ramírez and Schorfheide (2016)

on the New Keynesian literature with non zero trend inflation. Section 3 first discusses the model fit following from the Bayesian estimation, then the results that I obtain with regard to the two questions outlined above. Section 4 concludes.

2 The Model

In this section, I first specify the model for a SOE. Then the model is log-linearised around its steady state. After this, I describe the monetary policy rules in simple form. Exogenous disturbances are summarised in the last subsection.

2.1 Demand and Supply Side

I consider two countries: a home country H represents the SOE, and a foreign economy F that is sufficiently large to receive no influence by the SOE.[6] Consumption C is a Dixit-Stiglitz aggregator of home and foreign goods. In country H, at time t this is represented by

$$C_t = \left[(1-\lambda)^{\frac{1}{\theta}} \left(C_{H,t} \right)^{\frac{\theta-1}{\theta}} + \lambda^{\frac{1}{\theta}} \left(C_{F,t} \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{1}$$

with θ denoting the intratemporal elasticity of substitution between domestic and foreign goods. The parameter $\lambda \in [0, 1)$ is the degree of openness of country H. For the foreign economy, the quantity of imports from the SOE are so mariginal that we can assume $C_t^* =$

[6]A detailed appendix about all the equations of the model is available upon request from the author.

$C^*_{F,t}$.[7] The domestic price index equation can be written as

$$P_t = \left[(1-\lambda) \left(P_{H,t}\right)^{1-\theta} + \lambda \left(P_{F,t}\right)^{1-\theta} \right]^{\frac{1}{1-\theta}}. \tag{2}$$

For the foreign economy there is no dispersion between producer and consumer price index, formally $P^*_t = P^*_{F,t}$.

The domestic representative agent preferences are represented by a CRRA utility function as in Galí and Monacelli (2005). From the first order condition of the maximisation problem of the domestic representative household, the following Euler equation for the domestic economy can be derived:

$$E_t \left(\Pi_{t+1} \left[\frac{C_t}{C_{t+1}} \right]^{-\sigma} \frac{\varepsilon_t}{\varepsilon_{t+1}} \right) = \beta R_t \tag{3}$$

where $\Pi_{t+1} = P_{t+1}/P_t$ is a domestic CPI inflation, $\beta \in (0,1]$ is the subjective discount factor and R_t is the gross return on a riskless one year nominal bond. Following Steinbach et al. (2009), the expression $\varepsilon_{t+1}/\varepsilon_t$ can be interpreted as a risk premium on asset holding, *i.e.*, the wedge between the actual return on assets and the interest rate set by the central bank.

I assume that labour is immobile across countries. The domestic households labour supply is given by

$$\tilde{W}_t = \frac{N_t^{\eta}}{C_t^{-\sigma}},$$

where $\tilde{W}_t$ is the real domestic wage.

[7] Starred variables are associated with foreign economy. Generally, they are expressed in foreign currency. However, this rule does not apply to consumption, which is expressed in real terms: in this case, it is only used to distinguish between consumption at home and abroad.

Assuming that the foreign household faces the same maximisation problem, the Euler equation and the labour supply for a foreign economy are expressed analogously.

Because of the strong empirical evidence that the law of one price (LOP) does not hold, I assume incomplete pass-through. The LOP gap is therefore defined as

$$\Psi_t = S_t \frac{P^*_{F,t}}{P_{F,t}}, \tag{4}$$

where the nominal exchange rate S_t denotes the price of the foreign currency in terms of the domestic currency.[8] Additionally, given the different degrees of home bias in consumption between the two countries, PPP does not hold, and the CPI in each country differs. Hence, the real exchange rate can be expressed as the price of foreign goods in term of domestic goods

$$RS_t = \frac{S_t P^*_t}{P_t}. \tag{5}$$

The relationship between domestic and CPI inflation is given by

$$\frac{\Pi_{H,t}}{\Pi_t} = \frac{\tilde{P}_{H,t}}{\tilde{P}_{H,t-1}}, \tag{6}$$

where $\tilde{P}_{H,t} = P_{H,t}/P_t$ is the producer relative price. The relationship between imported and CPI inflation can be expressed as current relative to past import prices, expressed in domestic currency

$$\frac{\Pi_{F,t}}{\Pi_t} = \frac{\tilde{P}_{F,t}}{\tilde{P}_{F,t-1}} \tag{7}$$

with $\tilde{P}_{F,t} = P_{F,t}/P_t$.

[8] Note however that for the domestic price, from the point of view of domestic producer, the low of one price holds, because he gets the price "at the dock".

The total demand for a generic domestic good i, given by

$$Y_t(i) = \left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\varepsilon} \left(\tilde{P}_{H,t}\right)^{-\theta} C_t \left[1 - \lambda + \lambda RS_t^{\theta - \frac{1}{\sigma}}\right], \tag{8}$$

depends on the openness of the domestic economy λ, the dispersion between producer i price and the domestic producer price index $P_{H,t}(i)/P_{H,t}$, the dispersion between domestic producer and consumer price indexes $\tilde{P}_{H,t}$, and the real exchange rate RS_t. Note that a real depreciation of the exchange rate leads to an increase in production of good i.

The aggregate demand for domestic goods is

$$Y_t = \left(\tilde{P}_{H,t}\right)^{-\theta} C_t \left[1 - \lambda + \lambda RS_t^{\theta - \frac{1}{\sigma}}\right], \tag{9}$$

and the aggregate demand for goods produced in large foreign economy is $Y_t^* = C_t^*$.

In my model, I ignore the transaction costs and assume that financial markets are such that consumers from either country have access to both domestic and foreign bonds. The market price of a domestic riskless bond equals the expected discounted nominal return of the bond, and is given by $1/R_t = E_t[Q_{t,t+1}]$. Similarly for a foreign bond expressed in domestic currency, it holds that $S_t/(R_t^*) = E_t[S_{t+1}Q_{t,t+1}]$. With no possibility of arbitrage, the expected returns of these two bonds must be equal. Therefore, the uncovered interest parity equation can be written as the expected change in the real exchange rate and the ratio between domestic and foreign real interest rate

$$\frac{R_t}{R_t^*} E_t\left[\frac{\Pi_{t+1}^*}{\Pi_{t+1}}\right] = E_t\left[\frac{RS_{t+1}}{RS_t}\right]. \tag{10}$$

Under the assumption of complete securities markets, consumption risk is perfectly shared and the stochastic discount factor, expressed in the same currency, is equal across the countries. Assuming steady state condition of zero net foreign assets and the ex-ante identical environment, I obtain the optimal risk sharing, under complete financial markets:

$$RS_t = \left(\frac{C_t^*}{C_t}\right)^{-\sigma} \frac{\varepsilon_t^*}{\varepsilon_t}. \tag{11}$$

Therefore, deviations from power purchasing parity (PPP) imply different consumption levels across the two countries caused by the changes in the real exchange rate. The difference between the world and the domestic preference shock $(\epsilon_t^*/\epsilon_t)$ captures the deviations from optimal risk sharing.

The supply side of the domestic economy consists of two parts. There are producers and import retailers, both setting prices in the manner described by Calvo (1983) and Galí and Gertler (1999). Each producer (resp., retailer) belongs to one of two types of firms. A measure $1-\omega$ set the price optimally, and are labelled f. A measure ω set the price according to a rule-of-thumb, and are labelled b. Firms may face two different situations: i) either they are allowed to set their price with probability $1-\alpha$; ii) or they are not allowed to do so with probability α.

The optimal choice of $(1-\alpha)(1-\omega)$ producers that can set their price at time t is

$$\tilde{P}_t^f(i) = \frac{J_t}{H_t}, \tag{12}$$

where $\tilde{P}_t^f(i) = P_t^f(i)/P_t$ is the relative forward looking price of domestic firm i. The numerator is given by

$$J_t = \mu V_t \left(C_t^{-\sigma} Y_t \widetilde{MC}_t \tilde{P}_{H,t} \right)^{\eta+1} + \alpha\beta E_t \left[\left(\Pi_{H,t+1}\right)^{\varepsilon} J_{t+1} \right],$$

where $\mu = \varepsilon/(\varepsilon - 1)$ is the domestic mark-up, V_t is the mark-up shock and $\widetilde{MC}_t = MC_t/P_{H,t}$ is the real marginal costs. The denominator of (12) is given by

$$H_t = C_t^{-\sigma} Y_t + \alpha\beta E_t \left[\left(\Pi_{H,t+1}\right)^{\varepsilon} \left(\Pi_{t+1}\right)^{-1} H_{t+1} \right].$$

The remaining $(1-\alpha)\omega$ domestic firms set prices at time t according to the rule of thumb

$$P_t^b = \Pi_{H,t-1} X_{t-1}, \tag{13}$$

where X_{t-1} denotes an index of the prices set at date $t-1$, generically expressed by

$$X_t \equiv \left[(1-\omega) P_t^{f(1-\varepsilon)} + \omega P_t^{b(1-\varepsilon)} \right]^{\frac{1}{1-\varepsilon}}. \tag{14}$$

The aggregate producer price level then follows the law of motion

$$P_{H,t} = \left[(1-\alpha) X_t^{1-\varepsilon} + \alpha \left(P_{H,t-1}\right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \tag{15}$$

The set of equations (12)-(15) constitute the hybrid New Keynesian Phillips curve (NKPC), which characterises the producer side of country H. The NKPC for importing retailers is derived analogously, following from the fact that the importers face monopolistic competition. For the large country F, the set of equations leading to the NKPC is derived similarly, however without the dispersion between PPI and CPI.

Log-linearised Form of the Model

The structural equations can be written in the log-linearised form around their steady state. This is assumed to be a perfect-foresight state for both economies, with zero income growth and stable technology. I assume that in the steady state all prices change at the same rate, and the price of the imports increases at the same rate as the price of the domestically produced goods. I can normalise the price indices by imposing $P_H = P_F$. Therefore, it follows that the consumer and producer price index are equal, formally, $P = P_H$. Inflation, as well as the relative prices, do not change and it holds that $\Pi_H = \Pi_F = \Pi = \Pi^*$.

The log-linearised equations characterising the non-policy part are as follows. The domestic Euler equation (3) can be rewritten in terms of deviations from the steady state as

$$\hat{c}_t = E_t\left[\hat{c}_{t+1}\right] - \frac{1}{\sigma}\left(\hat{\imath}_t - E_t\left[\hat{\pi}_{t+1}\right] + E_t\left[\Delta\epsilon_{t+1}\right]\right), \tag{16}$$

where I have used the approximation $log\left(R_t\right) \approx \hat{\imath}_t$. The term $\Delta\epsilon_{t+1} = \log\varepsilon_{t+1} - \log\varepsilon_t$ is the first differences of the structural preference shock. The linearisation of the uncovered interest parity (10) delivers the relationship between real interest rate $\hat{\imath}_t$ and real exchange rate $\widehat{rs}_t$

$$\left(\hat{\imath}_t - E_t\left[\hat{\pi}_{t+1}\right]\right) - \left(\hat{\imath}_t^* - E_t\left[\hat{\pi}_{t+1}^*\right]\right) = E_t\left[\widehat{rs}_{t+1}\right] - \widehat{rs}_t. \tag{17}$$

The risk sharing equation (11) becomes

$$\widehat{rs}_t = \sigma \left(\hat{c}_t - \hat{c}_t^* \right) + \epsilon_t^* - \epsilon_t. \tag{18}$$

The good market clearing condition for domestic market (9) yields

$$\hat{y}_t = -\theta \tilde{p}_{H,t} + \hat{c}_t + \lambda \left(\theta - \frac{1}{\sigma} \right) \widehat{rs}_t. \tag{19}$$

The relationship between relative domestic producer price and relative importer price following from (2) is given by

$$1 = (1 - \lambda) \tilde{p}_{H,t} + \lambda \tilde{p}_{F,t}. \tag{20}$$

The relationships between relative producer price and inflation and relative importer price and inflation from (6) and (7) are given respectively by

$$\tilde{p}_{H,t} - \tilde{p}_{H,t-1} = \hat{\pi}_{H,t} - \hat{\pi}_t \tag{21}$$

and

$$\tilde{p}_{F,t} - \tilde{p}_{F,t-1} = \hat{\pi}_{F,t} - \hat{\pi}_t. \tag{22}$$

The LOP gap (4) is given by

$$\hat{\Psi}_t = \widehat{rs}_t - \tilde{p}_{F,t} \tag{23}$$

The relationship between real and nominal exchange rate in (5) is add as a law of motion

$$\Delta \widehat{rs}_t = \Delta \hat{s}_t + \hat{\pi}_t^* - \hat{\pi}_t + \varepsilon_{rs,t}, \tag{24}$$

where $\varepsilon_{rs,t}$ is an unobservable shock, to capture possible measurement error in the data and to relax the potentially tight cross-equation restrictions in the model.

The log-linearisation of the supply side leads to a hybrid NKPC with a non-zero steady state inflation

$$\hat{\pi}_{H,t} = \chi^{f} E_t \left[\hat{\pi}_{H,t+1}\right] + \chi^{b} \hat{\pi}_{H,t-1} + \kappa_{mc} \left(\widehat{mc}_t + v_t\right) + \chi^{\pi} \left(\hat{h}_t - \left(\hat{y}_t - \sigma \hat{c}_t\right)\right), \tag{25}$$

where the real marginal costs are expressed by

$$\widehat{mc}_t = \eta \hat{y}_t + \sigma \hat{c}_t - (\eta + 1) a_t - \tilde{p}_{H,t} \tag{26}$$

and

$$\hat{h}_t = \left(1 - \alpha\beta\Pi^{\varepsilon-1}\right)\left(\hat{y}_t - \sigma\hat{c}_t\right) + (\alpha\beta)\,\Pi^{\varepsilon-1} E_t \left[\varepsilon \hat{\pi}_{H,t+1} - \hat{\pi}_{t+1} + \hat{h}_{t+1}\right]. \tag{27}$$

Analogously, the NKPC for imported prices can be log-linearised to obtain

$$\hat{\pi}_{F,t} = \chi_F^{f} E_t \left[\hat{\pi}_{F,t+1}\right] + \chi_F^{b} \hat{\pi}_{F,t-1} + \kappa_F \left(\widehat{\Psi}_t + v_t^F\right) + \chi_F^{\pi} \left(\hat{h}_t^F - \left(\hat{c}_t^F - \sigma \hat{c}_t\right)\right) \tag{28}$$

with

$$\hat{h}_t^F = \left(1 - \alpha^F \beta \Pi^{\varepsilon-1}\right)\left(\hat{c}_t^F - \sigma\hat{c}_t\right) + \left(\alpha^F \beta\right) \Pi^{\varepsilon-1} E_t \left[\varepsilon \hat{\pi}_{F,t+1} - \hat{\pi}_{t+1} + \hat{h}_{t+1}^F\right] \tag{29}$$

and

$$\hat{c}_{F,t} = \hat{c}_t - \theta \tilde{p}_{F,t}, \tag{30}$$

where $\hat{c}_{F,t}$ is the part of the consumption dedicated to the foreign imported goods.

The market clearing condition for the large economy is

$$\hat{y}_t^* = \hat{c}_t^*, \tag{31}$$

the foreign Euler Equation yields

$$\hat{c}_t^* = E_t\left[\hat{c}_{t+1}^*\right] - \frac{1}{\sigma}\left(\hat{\imath}_t^* - E_t\left[\hat{\pi}_{t+1}^*\right] + E_t\left[\Delta\varepsilon_{t+1}^*\right]\right), \tag{32}$$

the Phillips curve with a backward looking and non-zero inflation component is identical to the one for closed economy

$$\hat{\pi}_t^* = \chi_f^* E_t\left[\hat{\pi}_{t+1}^*\right] + \chi_b^* \hat{\pi}_{t-1}^* + \kappa_{mc}^*\left(\widehat{mc}_t^* + v_t^*\right) + \chi_\pi^*\left[\hat{h}_t^* + (\sigma - 1)\,\hat{y}_t^*\right], \tag{33}$$

where

$$\hat{h}_t^* = \left(1 - \alpha\beta\Pi^{\varepsilon-1}\right)\left(\hat{y}_t^* - \sigma\hat{c}_t^*\right) + (\alpha\beta)\,\Pi^{\varepsilon-1} E_t\left[(\varepsilon - 1)\,\hat{\pi}_{t+1}^* + \hat{h}_{t+1}\right] \tag{34}$$

and the marginal costs are

$$\widehat{mc}_t^* = (\eta + \sigma)\,\hat{y}_t^* - (1 + \eta)\,a_t^*. \tag{35}$$

2.2 Monetary Policy Rules

To close the model, a monetary policy rule needs to be specified. For estimation purposes, several authors, *e.g.* Smets and Wouters (2003), use a generalised Taylor rule. Analysing the effect of such a simple rule has some advantages relative to the optimal monetary policy, as it is more likely to be used in practice because it is more easily implemented. Additionally, the parameters are more robust to the model specification than the structural parameters of the optimal rule. This paper compares a number of different simple targeting rules of the Taylor type for both economies.

For the relatively large closed economy, three monetary policy rules are analysed. The first one is a common Taylor rule with an interest rate smoothing component. In the second one, following Smets and Wouters (2003), the central bank also responds to the speed of inflation $\Delta\pi_t^*$. The third rule takes the form of the optimal monetary policy rule identified using a welfare loss function (see, *e.g.*, Steinsson, 2003). The following equations formally describe the three rules:

$$\hat{\imath}_t^* = \rho_i^* \hat{\imath}_{t-1}^* + \phi_\pi^* \hat{\pi}_t^* + \phi_y^* \hat{y}_t^* + \varepsilon_{u,t}^*, \tag{36}$$

$$\hat{\imath}_t^* = \rho_i^* \hat{\imath}_{t-1}^* + \phi_\pi^* \hat{\pi}_t^* + \phi_y^* \hat{y}_t^* + \phi_{\Delta\pi}^* \Delta\hat{\pi}_t^* + \varepsilon_{u,t}^*, \tag{37}$$

$$\hat{\imath}_t^* = \rho_i^* \hat{\imath}_{t-1}^* + \phi_\pi^* \hat{\pi}_t^* + \phi_y^* \hat{y}_t^* + \phi_{\Delta 1}^* \Delta\hat{\pi}_t^* + \phi_{\Delta 2}^* \Delta\hat{\pi}_{t+1}^* + \phi_{\Delta y}^* \Delta\hat{y}_t^* + \varepsilon_{u,t}^*, \tag{38}$$

where $\varepsilon_{u,t}^*$ is an exogenous monetary policy shock. The aim of using the different rules is to find out whether the Bundesbank (and later the European Central Bank), acting as the large economy in this model, conducts monetary policy using a simple Taylor rule or incorporates any of the additional terms. I then set the most suitable of these rules as the one adopted by the large economy when estimating the model using, in turn, data from the Czech Republic, Hungary or Poland.

For the small economy, I modify the three monetary policy rules as follows. The first one corresponds to (37), though the central bank additionally targets the changes in inflation and in the exchange rate. The second rule is analogous to (38). Alternatively, I also assume that the central bank targets exchange rate strictly

$$\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + \phi_\Delta \Delta\hat{\pi}_t + \phi_S \Delta\hat{s}_t + \varepsilon_{u,t}, \tag{39}$$

$$\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + \phi_{\Delta 1} \Delta\hat{\pi}_t + \phi_{\Delta 2} \Delta\hat{\pi}_{t+1} + \phi_{\Delta y} \Delta\hat{y}_t + \phi_S \Delta\hat{s}_t + \varepsilon_{u,t}, \tag{40}$$

$$\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + \phi_S \Delta\hat{s}_t + \varepsilon_{u,t}. \tag{41}$$

An interesting fact is that, although the theoretical work emphasises that a targeting PPI inflation performs better in terms of welfare loss, the empirical literature usually assumes a simple rule with consumer price index inflation targeting. In fact, by moving the interest rate, the central bank can either target producer domestic inflation or CPI inflation. On the one hand, Galí and Monacelli (2005) as well as Sutherland (2002) point out that if the economy's non-stochastic steady state is at its optimum and no (or only very small) cost push distortions are present, the optimal monetary policy purely targets domestic inflation (e.g., $\hat{\pi}_{H,t} = 0$). On the other hand, Sutherland argues that when cost push shocks have larger variance, CPI targeting may obtain better results.

To investigate whether the central bank targets domestic producer inflation instead of CPI inflation, I compare Rule 1 (39) and Rule 2 (40) with the corresponding rules in terms of PPI inflation, simply obtained by replacing $\hat{\pi}_t$ with $\hat{\pi}_{H,t}$. As I show later, in both cases, the difference in the model fit is significant. Second, following Lubik and Shorfheide (2007), I study to what extent the central banks of the EEC respond not only to the changes in inflation and output, but also to the changes in inflation and exchange rate, *e.g.*, whether the parameter ϕ_S plays an important rule. I compare the simple rules with their equivalents by assuming that $\phi_S = 0$.

2.3 Exogenous Disturbances

The model contains seven exogenous shocks that follow autoregressive processes expressed in a log-linearised form. The country-specific TFP for domestic and foreign country are defined respectively by

$$a_t = \rho_a a_{t-1} + \varepsilon_{a,t},$$

$$a_t^* = \rho_{a^*} a_{t-1}^* + \varepsilon_{a,t}^*;$$

the preference innovations are given for domestic and foreign consumers respectively by

$$\epsilon_t = \rho_e \epsilon_{t-1} + \varepsilon_{e,t},$$

$$\epsilon_t^* = \rho_{e^*} \epsilon_{t-1}^* + \varepsilon_{e,t}^*.$$

Finally, the cost push for domestic producers and for domestic retailers are expressed by

$$v_t = \rho_v v_{t-1} + \varepsilon_{v,t},$$

$$v_t^F = \rho_{v^F} v_{t-1}^F + \varepsilon_{v^F,t},$$

whereas for foreign producers by

$$v_t^* = \rho_{v^*} v_{t-1}^* + \varepsilon_{v,t}^*.$$

To summarise, the model exhibits nine structural shocks, of which seven are white noise entering the above AR(1) processes, namely $\varepsilon_{a,t}$, $\varepsilon^*_{a,t}$, $\varepsilon_{e,t}$, $\varepsilon^*_{e,t}$, $\varepsilon_{v,t}$, $\varepsilon_{v^F,t}$, $\varepsilon^*_{v,t}$, and two are exogenous monetary policy shocks, namely $\varepsilon_{u,t}$ and $\varepsilon^*_{u,t}$; plus one measurement error, $\varepsilon_{rs,t}$.

3 Estimation Method and Results

This section is divided into four parts. After a brief look at the data, I describe my choice of priors in the context of the existing literature on this field. Then, I present the estimation results and the impulse responses.

3.1 Data

The small open economy equations are estimated on data from three EEC countries, namely the Czech Republic, Hungary and Poland. The large economy is represented by Germany. I choose time series data on inflation, output growth, interest rates, exchange rates and unit labour costs; the sources of the raw data are Datastream and the FRED database. The empirical estimation is based on a data sample over the period 1996 - 2012 for Germany and the Czech Republic, and 1998 - 2012 for Hungary and Poland. All observations are quarterly and seasonally adjusted using the defaults settings of the X12 filter.

For the empirical analysis of my DSGE model, I adopt a Bayesian estimation approach that, using the estimated log data density of the model, facilitates comparisons of the goodness of fit of the different models. I use a random walk Metropolis-Hasting algorithm to approximate the posterior distribution of the estimated parameters.

3.2 Choice of Prior

In the case that just a small sample of data is available, a prior distribution is additional information that enables more stability in the optimisation algorithm. The prior distributions for large economy follows closely Smets and Wouters (2003), and are illustrated in Table 1. The priors for the interest rate rule coefficients have rather wide confidence intervals. They are distributed around a mean given by the Taylor rule, following Lubik and Schorfheide (2006). To avoid identification issues, I estimate the composite structural coefficients of the NKPC rather than the underlying primitives. The values of the NKPC parameters χ^b, χ^f and κ_{mc} reported in the literature are controversial. Therefore, the priors chosen here are consistent with the middle case, with a standard deviation large enough to ensure that the estimate is mainly determined by the data. The parameter χ^π is normally distributed around a zero mean, since it might take both positive and negative values. The prior of the inflation trend Π is gamma distributed around the average of the trend value, and it is lower-bounded at one. For Germany, the average inflation of the estimated sample

Table 1. Prior Distribution for Large Economy

Parameter	Distribution	Mean	Standard error
$\sigma(\varepsilon_a^*)$	Inverse Gamma	1	10
$\sigma(\varepsilon_e^*)$	Inverse Gamma	1	10
$\sigma(\varepsilon_v^*)$	Inverse Gamma	1	10
$\sigma(\varepsilon_u^*)$	Inverse Gamma	1	10
ρ_a^*	Beta	0.8	0.1
ρ_e^*	Beta	0.8	0.1
ρ_v^*	Beta	0.8	0.1
ρ_i^*	Beta	0.5	0.2
ϕ_π^*	Gamma	1.5	0.1
ϕ_y^*	Gamma	0.125	0.05
$\phi_{\Delta 1}^*$	Gamma	0.3	0.1
$\phi_{\Delta 2}^*$	Gamma	0.3	0.1
$\phi_{\Delta y}^*$	Gamma	0.0625	0.05
χ_f^*	Beta	0.5	0.2
χ_b^*	Beta	0.5	0.2
κ_{mc}^*	Gamma	0.1	0.05
χ_π^*	Normal	0	0.05
Π	Gamma	1.005	0.003

corresponds to $\Pi = 1.005$.

The parameters for the SOE, illustrated in Table 2, have similar priors as those for the closed economy. Most of the parameters are not imposed to be the same for all countries, but it is merely assumed that they have identical priors. The steady state inflation Π is the same for the Czech Republic and Germany, and for Hungary and Poland, it corresponds to $\Pi = 1.0153$ and $\Pi = 1.0154$, respectively. The degree of openness λ is set corresponding to the average import/GDP ratio over the data sample that is 0.6 for the Czech Republic, 0.7 for Hungary and 0.36 for Poland.

Table 2. Prior Distribution for the SOE

Parameter	Distribution	Mean	Standard error
$\sigma(\varepsilon_a)$	Inverse Gamma	1	10
$\sigma(\varepsilon_e)$	Inverse Gamma	1	10
$\sigma(\varepsilon_u)$	Inverse Gamma	1	10
$\sigma(\varepsilon_v)$	Inverse Gamma	1	10
$\sigma(\varepsilon_{v^F})$	Inverse Gamma	1	10
$\sigma(\varepsilon_{rs})$	Inverse Gamma	1	10
ρ_a	Beta	0.8	0.1
ρ_e	Beta	0.8	0.1
ρ_v	Beta	0.8	0.1
ρ_{v^F}	Beta	0.8	0.1
ρ_i	Beta	0.5	0.2
ϕ_π	Gamma	1.5	0.1
ϕ_y	Gamma	0.125	0.05
$\phi_{\Delta 1}$	Gamma	0.3	0.1
$\phi_{\Delta 2}$	Gamma	0.3	0.1
$\phi_{\Delta y}$	Gamma	0.0625	0.05
ϕ_S	Gamma	0.3	0.1
χ^f	Beta	0.5	0.2
χ^b	Beta	0.5	0.2
κ_{mc}	Gamma	0.1	0.05
χ^π	Normal	0	0.05
χ_F^f	Beta	0.5	0.2
χ_F^b	Beta	0.5	0.2
κ_F	Gamma	0.1	0.05
χ_F^π	Normal	0	0.05
Π	Gamma	1.005	0.003

3.3 Estimation Results

The composite structural parameters are estimated in two steps. The first step contains the estimation of the model for the closed economy, obtained using German data. The second step estimates the model for the SOE, using the data from EEC. I use the best fitting monetary policy rule for the closed economy, and estimate domestic and foreign parameters

Table 3. Posterior Odds Test

Monetary policy rule	Log Data Density		Posterior odds
	A1	A2	
Rule 1 (36)	-178.15	-173.8	0.013
Rule 2 (37)	-170.67	-161.55	0.000
Rule 3 (38)	-166.39	-156.05	0.000

Note: the table reports posterior odds test for German data on the hypothesis H0: $\chi_\pi^* = 0$ against the alternative $\chi_\pi^* \neq 0$.

using EEC's and German data together. Along with the estimates for the SOE Phillips curve, where I analyse the importance of the non-zero inflation part of the Phillips curve given by parameters χ_π and χ_{π^F}, I wish to identify what monetary policy fits the data best.

Given German data, I estimate each of the three simple rules applying two different approaches, to assess the importance of the estimation of the non-zero steady state inflation part in the NKPC. The first approach (A1) assumes that the steady state inflation is zero, which leads to a backward looking NKPC with $\chi_\pi^* = 0$. The second approach (A2) estimates the parameter χ_π^*. The log marginal data densities and the odds for these two specifications are illustrated in Table 3.

Two results emerge from the analysis of the log marginal likelihood and posterior odds.[9] First, the estimation of the model with the A2 approach improves the fit to the data relatively to imposing a zero steady state rate of inflation. The posterior odds show that the hypothesis H0 can be in fact rejected for all the rules. Second, it follows that the more

[9] To compare the performance across models, assume the null hypothesis that a model M1 is preferred to a model M2. The marginal data density is given for M1 by $\pi_{0,T}$, and for M2 by $\pi_{1,T}$. Following Lubik and Schorfheide (2007), the posterior odds can be interpreted as follows. Evidence against H0 is: null if $\pi_{0,T}/\pi_{1,T} > 1$; weak if $1 > \pi_{0,T}/\pi_{1,T} > 10^{-1/2}$; substantial if $10^{-1/2} > \pi_{0,T}/\pi_{1,T} > 10^{-1}$; strong if $10^{-1} > \pi_{0,T}/\pi_{1,T} > 10^{-3/2}$; very strong if $10^{-3/2} > \pi_{0,T}/\pi_{1,T} > 10^{-2}$; decisive if $10^{-2} > \pi_{0,T}/\pi_{1,T}$.

complex the rule is, the better the performance of the model (regardless the approach considered). The traditional Taylor rule (36) performs worse, whereas the "optimal" simple rule fits the data best. This evidence suggests that the central bank takes into account all the elements following from the welfare maximisation of the loss function, as derived in presence of backward looking firms. Given the log density, it is apparent that including inflation change targeting improves the fit significantly.

The Bayesian estimated posterior distribution, based on the A2 approach and the monetary rule (38), is reported in Table 4.[10] The table displays the mode and standard error resulting from the posterior maximisation, the estimation results, such as the posterior mean and the interdecile posterior probability interval for both the estimated parameters and the standard deviation of shocks.

The first posterior density decile suggest that the estimated parameters are all greater than zero. In particular, Table 4 shows that my estimation proposes a value around 0.2 for parameter χ_{π}^{*}, which is higher than that assumed in the prior distribution. The value is robust and lies in the confidence interval using both approaches. The estimates for the parameter χ_{π}^{*} are lower when assuming the simple Taylor rule (36) – around 0.13 for both approaches. For the remaining two other rules, the values are surprisingly stable, and lie between 0.22 and 0.26. My estimate suggests a value of lagged inflation χ_{b}^{*} of around 0.3, in line with other empirical findings such as Galí and Gertler (1999) and Galí, Gertler, and Lopez-Salido (2001). Moreover, the monetary policy rules parameters are very robust and they all lie, independent of the estimation approach and rule, in the

[10]The results obtained using the other rules and approach A1 are similar to those reported in Table 4, and are available from the author upon request.

Table 4. **Parameter Estimation Results for Germany**

Parameter	**Mode**	**S.D.**	**10%**	**Mean**	**90%**
$\sigma\left(\varepsilon_a^*\right)$	1.0194	0.0790	0.9022	1.0321	1.1597
$\sigma\left(\varepsilon_e^*\right)$	5.5972	0.6983	3.0235	6.8599	11.2815
$\sigma\left(\varepsilon_v^*\right)$	0.3324	0.0515	0.28711	0.3526	0.4181
$\sigma\left(\varepsilon_u^*\right)$	0.5434	0.0417	0.3976	0.5278	0.6536
ρ_a^*	0.9944	0.0052	0.9866	0.9924	0.9985
ρ_e^*	0.9802	0.0064	0.9699	0.9802	0.9937
ρ_v^*	0.8417	0.0128	0.7074	0.8168	0.9313
ρ_i^*	0.9588	0.0256	0.8988	0.9418	0.9892
ϕ_π^*	1.4353	0.0316	1.3081	1.4642	1.6021
ϕ_y^*	0.0199	0.0055	0.0100	0.0232	0.0361
$\phi_{\Delta 1}^*$	0.5348	0.0195	0.2440	0.4504	0.6584
$\phi_{\Delta 2}^*$	0.3584	0.0328	0.1939	0.3845	0.5728
$\phi_{\Delta y}^*$	0.0716	0.0074	0.0084	0.0995	0.1724
χ_f^*	0.9452	0.0352	0.8041	0.8970	0.9889
χ_b^*	0.3026	0.0566	0.1288	0.2717	0.4158
κ_{mc}^*	0.4861	0.0110	0.4860	0.6213	0.7924
χ_π^*	0.2709	0.0244	0.1569	0.2248	0.2975
Π	1.0033	0.0005	1.0006	1.0045	1.0083

confidence interval.

For the SOE, the summary of the marginal data densities resulting from several different tests can be found in Table 5. The results of the estimations are explained in Tables 6-8 below. First, I test whether the central bank targets CPI or PPI inflation. The results of the posterior odds test, displayed in Table 6 suggests that there is a clear evidence in favor of PPI inflation targeting over CPI inflation targeting. This is in line with the theoretical literature, which shows that responding to the PPI inflation rather than the CPI deliv-

Table 5. Marginal Data Densities under Different Approaches and Monetary Policy Rules

Log Data Density			Czech Rep.	Hungary	Poland
A2	CPI targeting, $\phi_S > 0$	Rule 1	-659.26	-630.38	-740.57
		Rule 2	-659.94	-633.51	-723.96
	PPI targeting, $\phi_S > 0$	Rule 1	-637.50	-603.98	-714.12
		Rule 2	-640.11	-595.45	-705.25
	PPI targeting, $\phi_S = 0$	Rule 1	-641.27	-602.56	-711.64
		Rule 2	-648.80	-594.13	-705.05
	Pure exchange rate	Rule 3	-706.85	-630.78	-842.91
A1	PPI targeting, $\phi_S > 0$	Rule 2	-646.27	-604.06	-721.94

ers lower welfare losses. About pure exchange rate targeting, this policy can be rejected as the policy being implemented by two out of the three countries considered, since this rule exhibit a significantly lower performance on both Czech and Polish data.

Second, to show how important it is to include the non-zero component into the Phillips curve, I test the hypothesis $\chi^\pi = 0$ against the hypothesis $\chi^\pi \neq 0$. Given the result obtained in Table 6, Table 7 displays the posterior odds test for rules with PPI inflation targeting only. The marginal data densities there suggest that including an estimation of χ^π improves the fit to the data for all tested rules.

Third, I test whether the central bank responds to variations in the exchange rate. I first estimate each rule assuming that $\phi_S > 0$. Then, I estimate the same rule, but assuming that the central bank is not interested in exchange rate targeting, and sets $\phi_S = 0$. Table 8 illustrates the case of Rule 1 with PPI targeting. The results suggest that the Czech National Bank targets the exchange rate, but the Central Banks of Hungary and Poland do not.

Table 6. Posterior Odds Test (CPI inflation targeting)

	Rule 1		
	H0	H1	Post. Odds
Czech Rep	−659.26	−637.50	0.000
Hungary	−630.38	−603.98	0.000
Poland	−740.57	−714.12	0.000
	Rule 2		
	H0	H1	Post. Odds
Czech Rep	−659.94	−640.11	0.000
Hungary	−633.51	−595.45	0.000
Poland	−723.96	−705.25	0.000

Note: hypothesis H0 that the central bank uses a CPI inflation targeting vs. hypothesis H1 that the central bank uses PPI inflation targeting.

Table 7. Posterior Odds Test (trend inflation)

	H0	H1	Posterior Odds
Czech Rep	−646.27	−640.11	0.002
Hungary	−604.06	−595.45	0.000
Poland	−721.94	−705.25	0.000

Note: The table reports posterior odds test for the EEC on the hypothesis H0: $\chi_\pi = 0$ and $\chi_{\pi^F} = 0$ against the alternative $\chi_\pi \neq 0$ and $\chi_{\pi^F} \neq 0$.

Table 8. Posterior Odds Test (no exchange rate targeting)

	H0	H1	Posterior Odds
Czech Rep	−641.27	−637.50	0.023
Hungary	−602.56	−603.98	4.161
Poland	−711.64	−714.12	11.876

Note: The table reports posterior odds test for the EEC on the hypothesis H0: $\phi_S = 0$ against the alternative $\phi_S \neq 0$.

Table 9. Parameter Estimation Results (Czech Republic)

Parameter	Mode	S.D.	10%	Mean	90%
$\sigma(\varepsilon_a)$	0.7227	0.1556	0.5380	0.7714	0.9883
$\sigma(\varepsilon_e)$	3.0276	0.4826	2.3178	3.1085	3.9074
$\sigma(\varepsilon_u)$	1.5490	0.1977	1.2970	1.6581	2.0258
$\sigma(\varepsilon_v)$	1.7389	0.2642	1.3114	1.5946	1.8639
$\sigma(\varepsilon_{v^F})$	10.7510	3.0950	0.2225	10.6040	20.3485
$\sigma(\varepsilon_{rs})$	4.9429	0.4970	4.2216	5.0141	5.7741
ρ_a	0.9247	0.0110	0.7732	0.8873	0.9888
ρ_e	0.8766	0.0176	0.8282	0.8763	0.9307
ρ_v	0.7025	0.0237	0.6174	0.7254	0.8318
ρ_{v^F}	0.8752	0.0225	0.7582	0.8508	0.9686
ρ_i	0.9256	0.0416	0.8079	0.8948	0.9843
ϕ_π	1.3994	0.0314	1.3291	1.4661	1.6052
ϕ_y	0.0539	0.0176	0.0229	0.0640	0.1049
$\phi_{\Delta 1}$	0.3508	0.0376	0.2291	0.3760	0.5248
$\phi_{\Delta 2}$	0.3387	0.0239	0.1735	0.3276	0.4908
$\phi_{\Delta y}$	0.1024	0.0118	0.0013	0.0476	0.0929
ϕ_S	0.1392	0.0210	0.0871	0.1440	0.2050
χ^f	0.9077	0.0364	0.6890	0.8258	0.9671
χ^b	0.3063	0.0318	0.1148	0.2788	0.4334
κ_{mc}	0.2922	0.0123	0.3357	0.4149	0.5098
χ^π	0.1036	0.0191	0.0130	0.0770	0.1472
χ_F^f	0.6355	0.1010	0.2573	0.5403	0.7991
χ_F^b	0.1928	0.0260	0.0628	0.2377	0.3873
κ_F	0.0586	0.0104	0.0202	0.0691	0.1214
χ_F^π	0.0076	0.0080	-0.0989	-0.0126	0.0709
Π	1.0041	0.0004	1.0007	1.0053	1.0097

The resulting parameters are similar for the three countries and can be found in Table 9-11. The backward looking component for producer inflation lies between 0.2 and 0.35 for all countries. Compared to Germany, the non-zero steady state inflation component is lower,

Table 10. Parameter Estimation Results: (Hungary)

Parameter	Mode	S.D.	10%	Mean	90%
$\sigma(\varepsilon_a)$	0.5770	0.1148	0.5589	0.7989	1.0704
$\sigma(\varepsilon_e)$	6.5825	0.5749	5.2662	6.6646	8.0768
$\sigma(\varepsilon_u)$	1.9111	0.2379	1.6213	2.0654	2.4917
$\sigma(\varepsilon_v)$	1.7238	0.2345	1.3308	1.6808	2.0113
$\sigma(\varepsilon_{v^F})$	10.5052	1.1955	0.2216	1.9184	5.2044
$\sigma(\varepsilon_{rs})$	7.0219	0.4958	5.8129	6.9522	8.0079
ρ_a	0.7869	0.0202	0.8477	0.9042	0.9626
ρ_e	0.9143	0.0089	0.8872	0.9088	0.9314
ρ_v	0.6560	0.0097	0.5739	0.6655	0.7501
ρ_{v^F}	0.8515	0.0160	0.7020	0.8312	0.9723
ρ_i	0.8868	0.0174	0.7804	0.8709	0.9634
ϕ_π	1.5100	0.0351	1.3622	1.5075	1.6407
ϕ_y	0.0404	0.0060	0.0185	0.0522	0.0854
$\phi_{\Delta 1}$	0.2777	0.0253	0.1725	0.2758	0.3749
$\phi_{\Delta 2}$	0.4318	0.0206	0.1201	0.3077	0.4223
$\phi_{\Delta y}$	0.0510	0.0095	0.0004	0.0372	0.0748
ϕ_S	0.1451	0.0107	0.0772	0.1521	0.2302
χ^f	0.8227	0.0357	0.6184	0.7971	0.9564
χ^b	0.3723	0.0468	0.1998	0.3399	0.4819
κ_{mc}	0.4320	0.0090	0.4160	0.4889	0.5653
χ^π	0.0741	0.0056	-0.0210	0.0565	0.1283
χ_F^f	0.4061	0.0358	0.0880	0.4329	0.7770
χ_F^b	0.2545	0.0164	0.0394	0.2188	0.3606
κ_F	0.0843	0.0076	0.0105	0.0493	0.0873
χ_F^π	-0.0715	0.0041	-0.1092	-0.0415	0.0235
Π	1.0097	0.0004	1.0017	1.0062	1.0102

but still positive and significantly different from zero. For the retailers' Phillips curve, the parameter χ^π is positive, whereas χ_F^π is slightly negative for Czech Republic and Hungary, and all are significantly different from zero. The central bank of all three countries respond

Table 11. Parameter Estimation Results: (Poland)

Parameter	Mode	S.D.	10%	Mean	90%
$\sigma(\varepsilon_a)$	1.1451	0.1256	0.8682	1.0746	1.2679
$\sigma(\varepsilon_e)$	7.0226	0.7007	5.1819	6.5509	7.8704
$\sigma(\varepsilon_u)$	1.5254	0.2327	1.3060	1.6315	1.9452
$\sigma(\varepsilon_v)$	1.3775	0.1799	1.0422	1.2815	1.5081
$\sigma(\varepsilon_{v^F})$	0.4572	0.4848	0.2284	0.8527	1.5687
$\sigma(\varepsilon_{rs})$	6.9759	0.5465	5.9946	7.0510	8.0882
ρ_a	0.9627	0.0101	0.9144	0.9471	0.9807
ρ_e	0.9128	0.0103	0.8989	0.9181	0.9394
ρ_v	0.7359	0.0133	0.4996	0.6548	0.7981
ρ_{v^F}	0.8895	0.0180	0.7818	0.8811	0.9770
ρ_i	0.8601	0.0267	0.5576	0.7165	0.8671
ϕ_π	1.5237	0.0138	1.3934	1.5019	1.6300
ϕ_y	0.0599	0.0082	0.0452	0.0866	0.1357
$\phi_{\Delta 1}$	0.3017	0.0165	0.1375	0.2259	0.3056
$\phi_{\Delta 2}$	0.3714	0.0260	0.1770	0.3229	0.4748
$\phi_{\Delta y}$	0.0939	0.0106	0.0055	0.1105	0.2116
ϕ_S	0.1120	0.0343	0.0702	0.1127	0.1551
χ^f	0.9221	0.0200	0.6402	0.7843	0.9490
χ^b	0.3732	0.0375	0.1794	0.3276	0.4820
κ_{mc}	0.4439	0.0137	0.4857	0.5697	0.6630
χ^π	0.0665	0.0109	0.0174	0.0800	0.1756
χ_F^f	0.3279	0.0369	0.3319	0.5075	0.7006
χ_F^b	0.3022	0.0486	0.4359	0.5423	0.6778
κ_F	0.0373	0.0053	0.0010	0.0106	0.0188
χ_F^π	-0.0509	0.0107	-0.0115	0.0415	0.1096
Π	1.0025	0.0006	1.0006	1.0035	1.0062

much more actively to inflation (both to current and past changes) than to output (and its change). It is worth noting that the estimates for exchange rate targeting in the monetary policy rule are higher, for all the three countries, than the prior values.

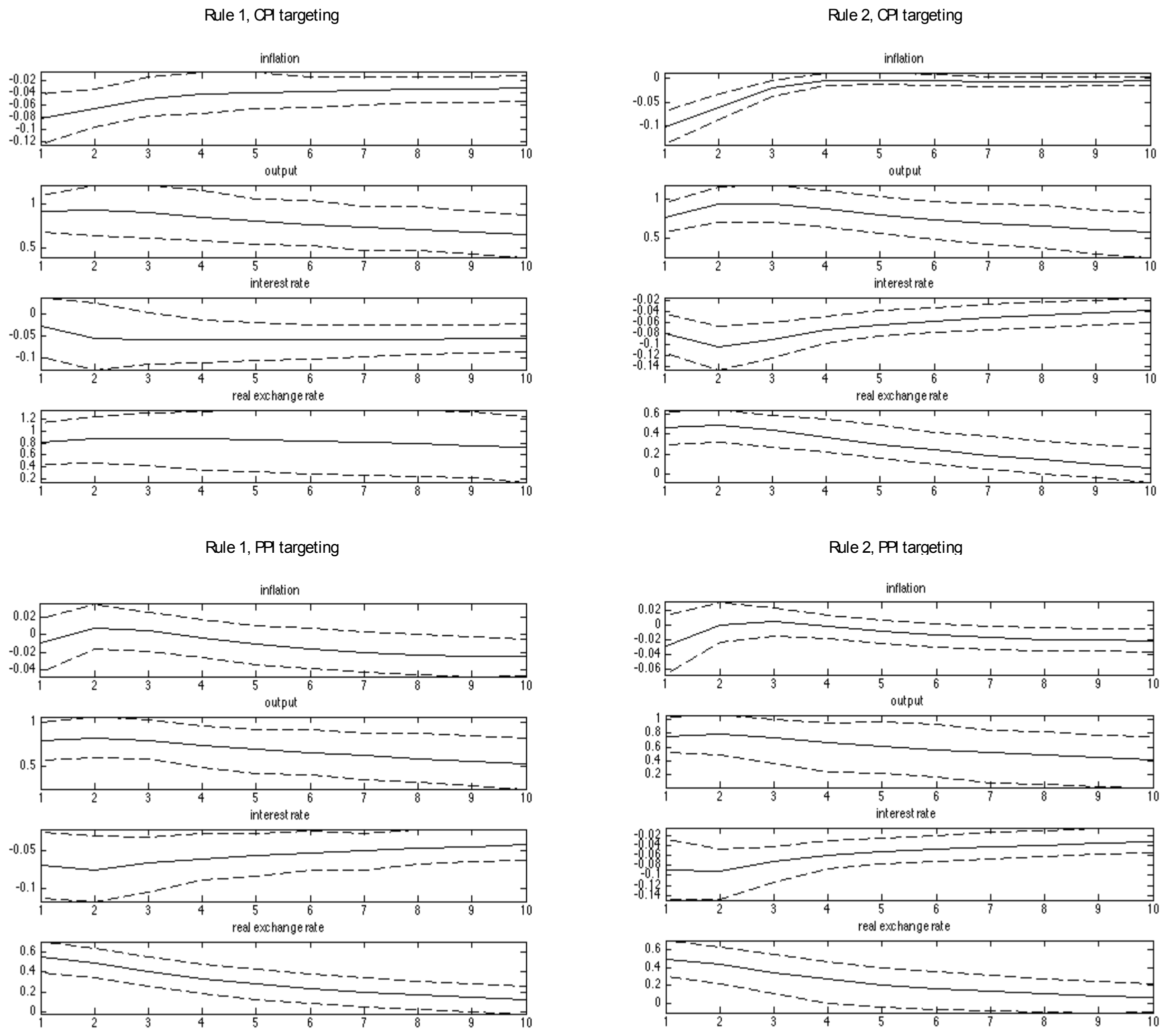
3.4 Impulse Response Functions Analysis

Figures 1-9 illustrate how the endogenous variables respond to the structural shocks over the following 10 periods, comparing (39) and (40) with CPI and PPI inflation targeting. Because of the similarities in the dynamic behavior of the three EEC, I only report the results of the estimates relative to the Czech Republic. The solid line is the median response, and the area within the dashed lines represents the 90% HPD interval. Figure 1 displays the responses of the domestic variables to a positive domestic TFP shock. It follows that the overall inflation decreases more in the case of CPI inflation targeting than with PPI inflation targeting. When targeted, PPI inflation fluctuates less and therefore the price for the domestic good is more stable. The decrease in PPI inflation is partly offset by the increase in imported inflation, thus the overall inflation is less volatile than in the case of CPI targeting. It may also be noted that output and real exchange rate vary only marginally, regardless the choice of the policy target.

The responses to a domestic monetary shock are presented in Figure 2. A higher interest rate implies a higher return on domestic assets, and therefore makes the domestic currency more attractive. The nominal appreciation, making imports cheaper, leads to a drop in the demand for domestic goods. In turn, a downward shift in demand for domestic goods results in lower inflation and aggregate output.

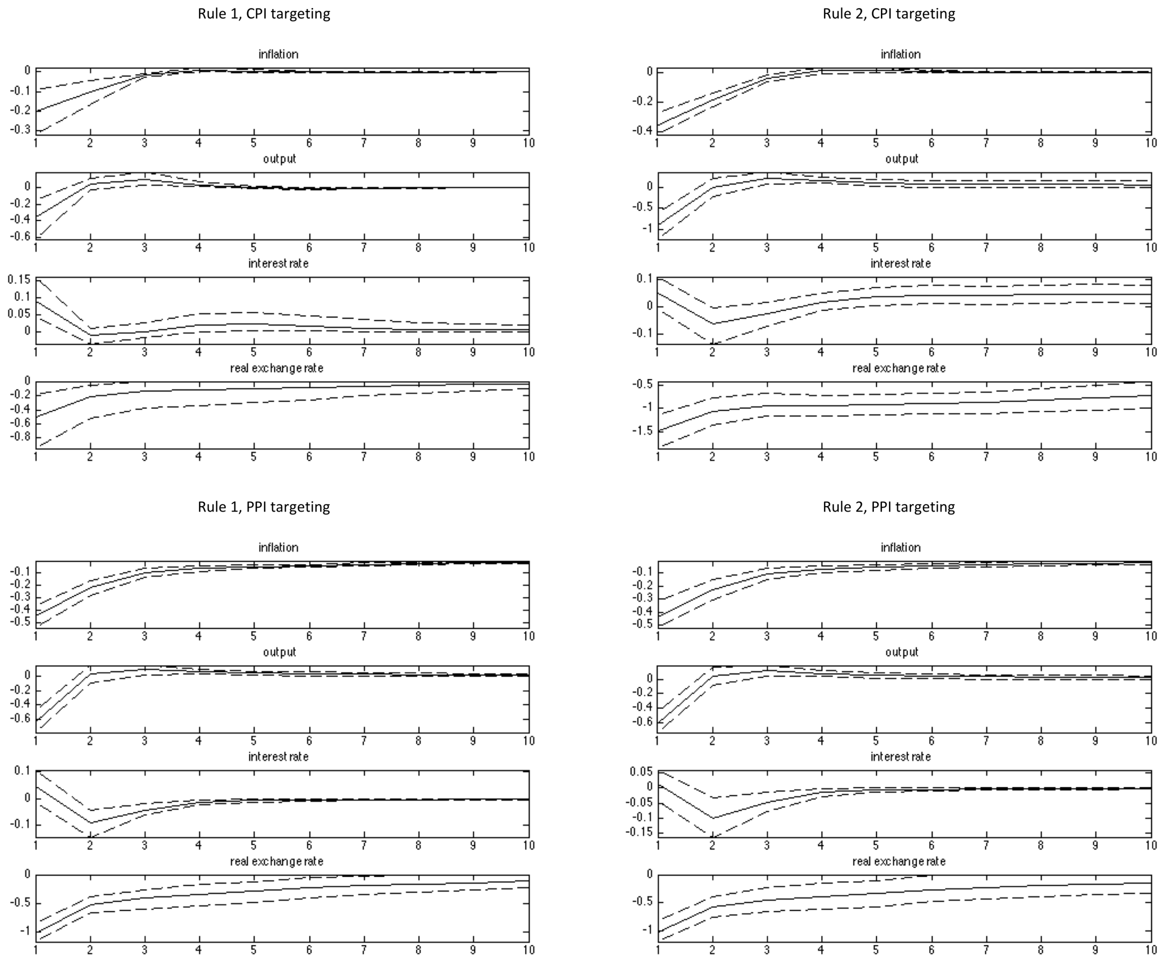
Figure 3 plots the responses to a domestic cost push shock that immediately increases producer inflation. The higher relative domestic price reduces the overall demand for domestic good, and therefore results in a drop in aggregate domestic output. Overall inflation also increases. Thus, the central bank reacts by raising the interest rate, which leads to

Figure 1. Impulse Responses to a Domestic TFP shock



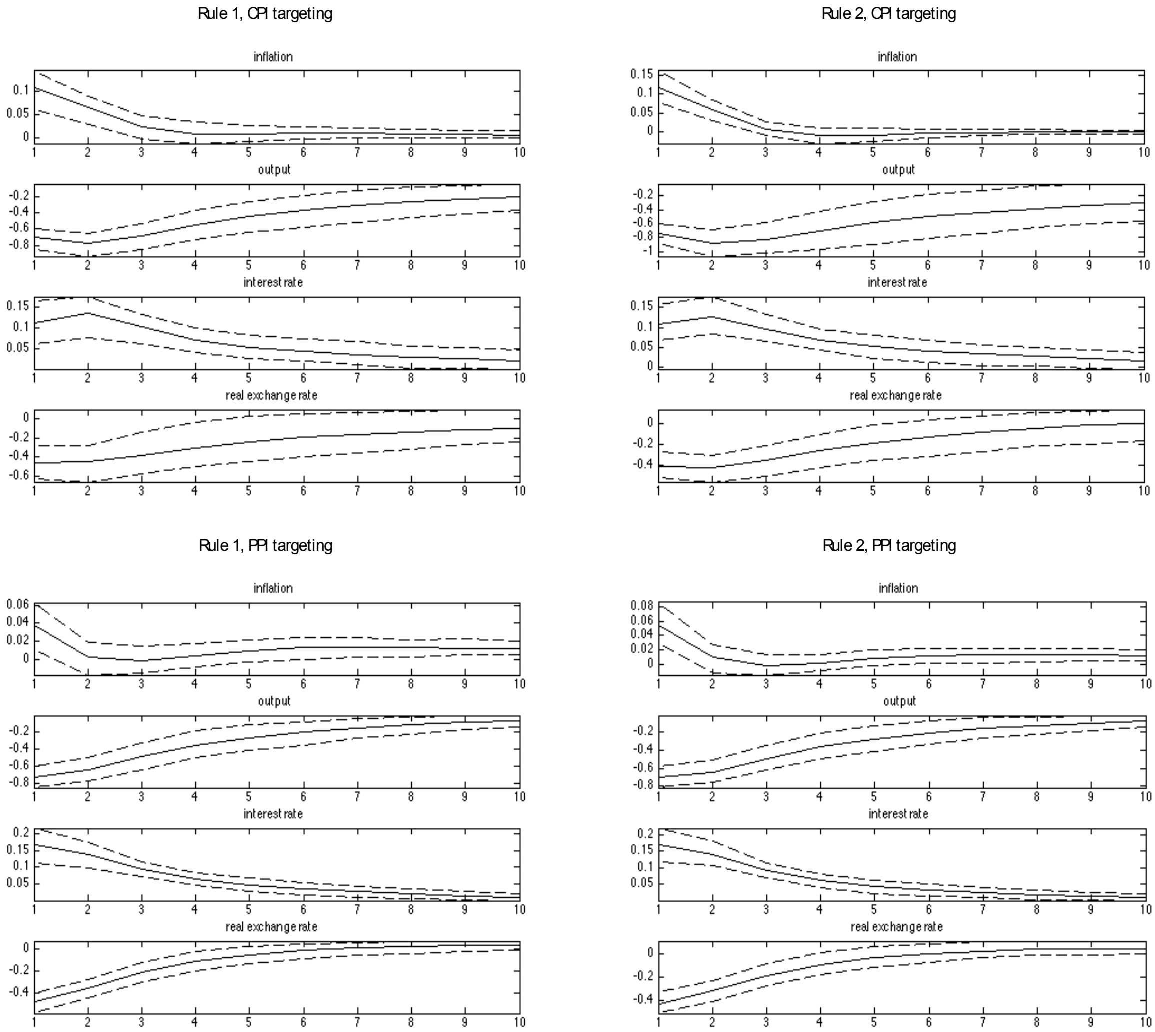
an appreciation of the exchange rate and, furthermore, depresses the competitiveness of the domestic goods in the international markets. Also in the case of a cost push shock, overall inflation is less volatile if the central bank directly targets producer inflation. The initial response of the aggregate output, however, is seemingly independent of the policy rule adopted.

Figure 2. Impulse Responses to a Domestic Monetary Shock



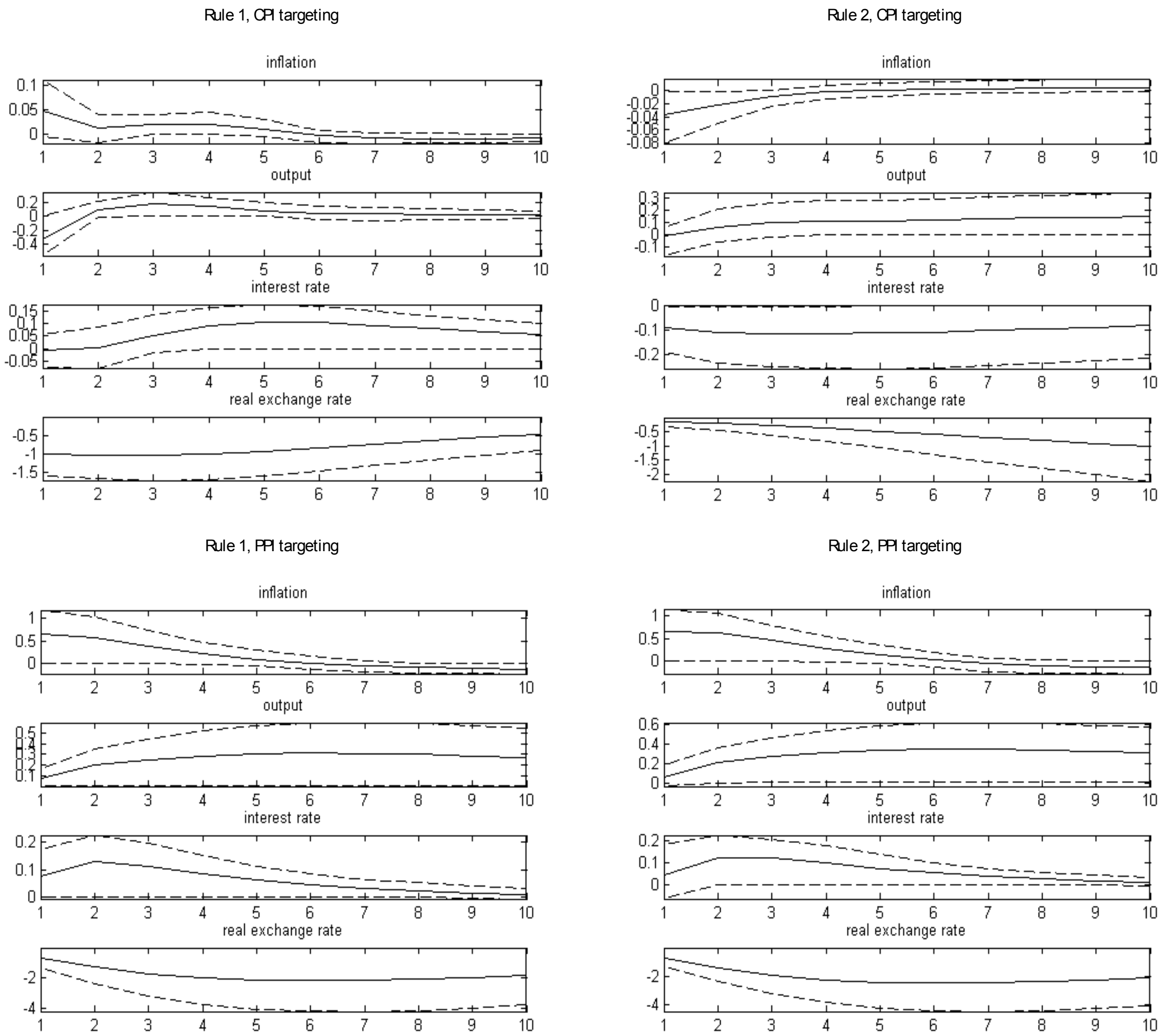
In the presence of an importer cost push shock, the difference between PPI inflation and CPI inflation targeting is more obvious than in the previous cases. Depending on the rule, the very dynamics of the main economic variables change. The impulse responses are illustrated in Figure 4. An importer cost push shock increases immediately the inflation of the imported goods. Thus, the price of these goods increases relative to the price of

Figure 3. Impulse Responses to a Domestic Producer Cost Push Shock



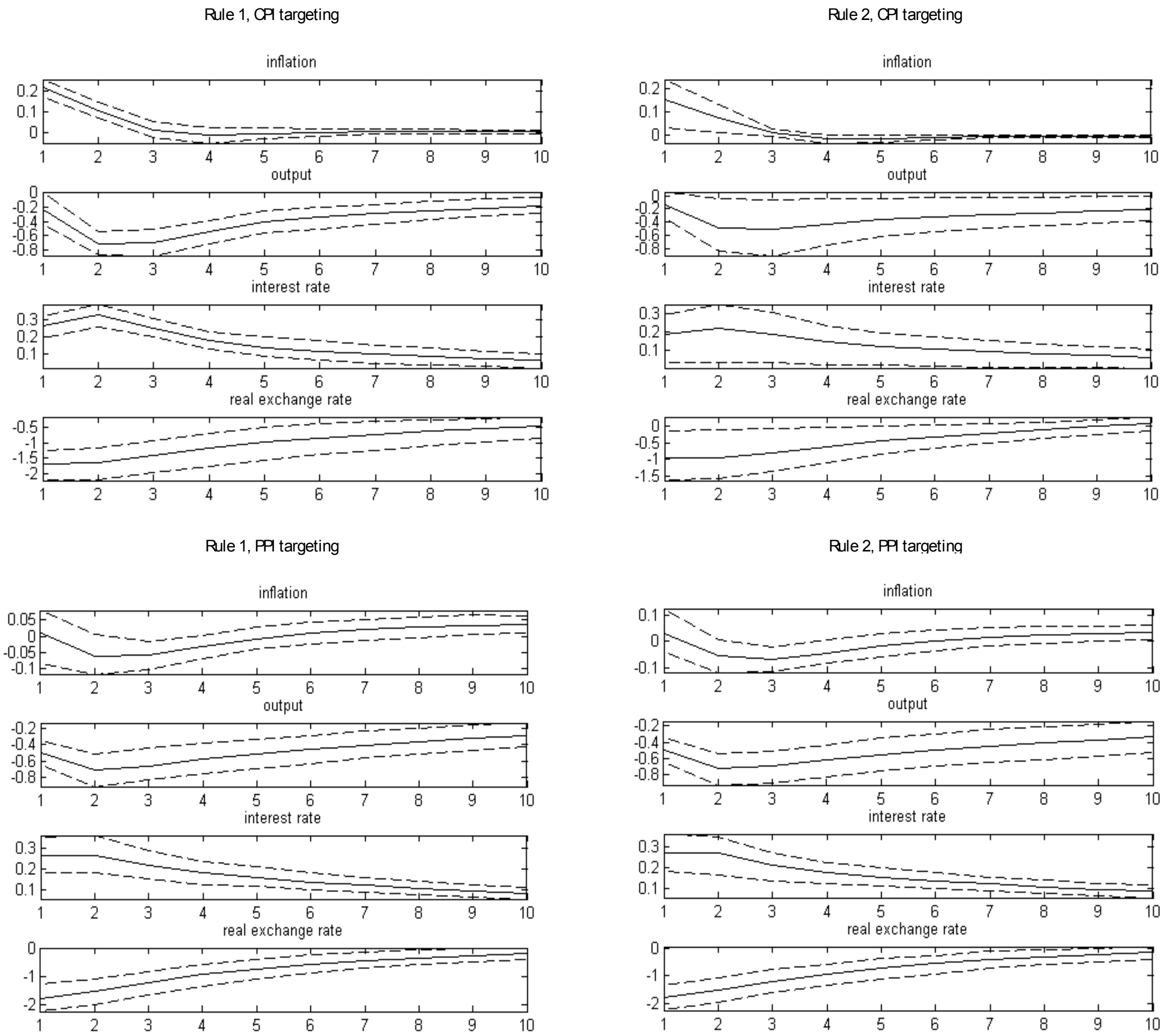
the domestically produced goods. Imports fall, and overall domestic consumption decreases, increasing the marginal utility of consumption. However, a rise in domestic production occurs, due to a higher domestic demand for domestic goods. Given the fact that risk sharing holds, the real exchange rate appreciates, which reduces the competitive advantage on the in-

Figure 4. Impulse Responses to an Importer Cost Push Shock



ternational market. Therefore, the resulting effect on the domestic output is ambiguous. In the case of PPI targeting, the response of the central bank to the rising inflation is milder. As a result, output slightly increases, but this also implies a substantial rise in inflation. Under CPI targeting, the central bank intervention is stronger: this entails lower output, but inflation growth is very small.

Figure 5. Impulse Responses to a Domestic Preference Shock

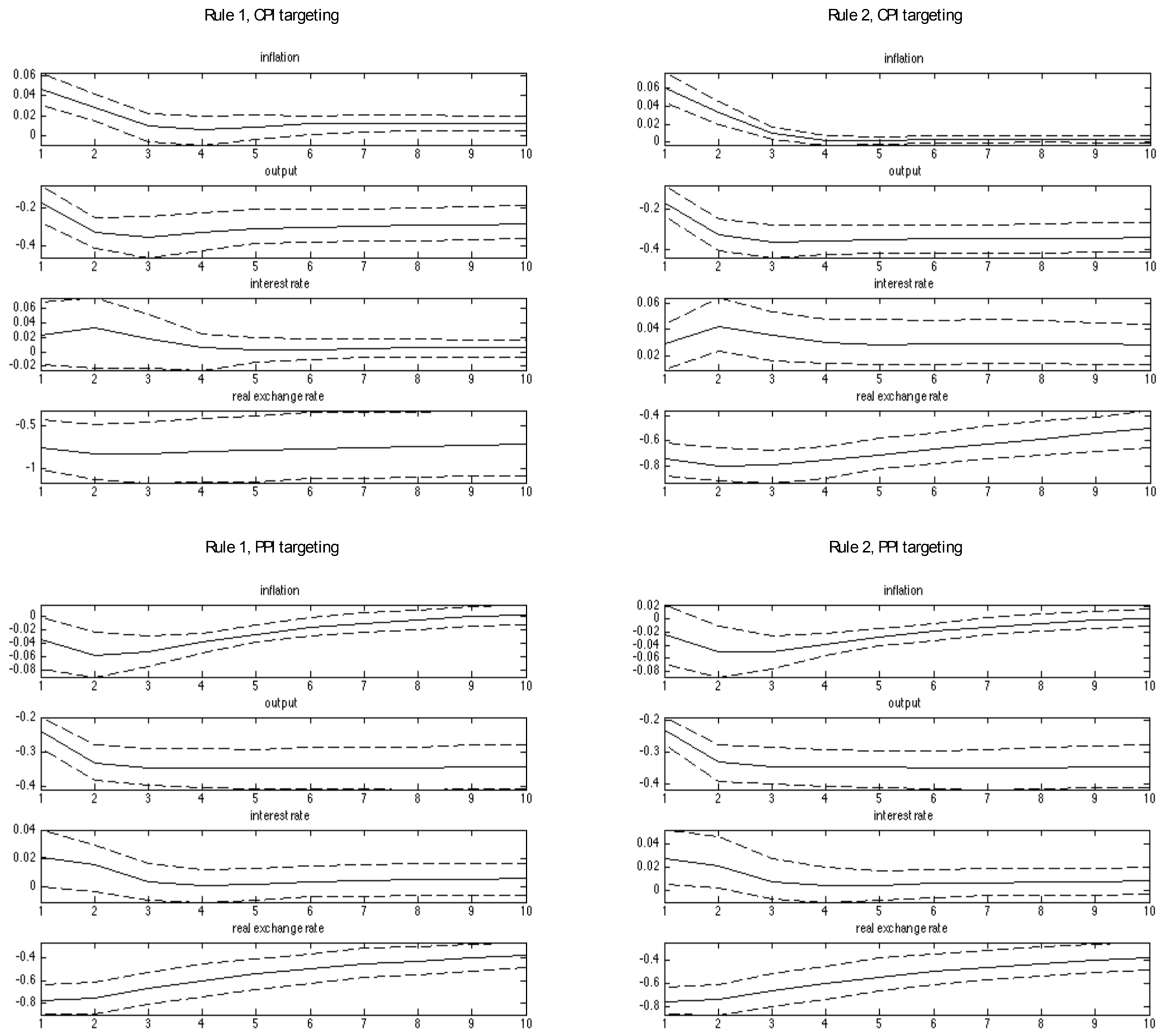


A domestic demand shock, illustrated in Figure 5, increases overall consumption. Assuming that risk sharing holds, the resulting decrease in the marginal utility of consumption implies an appreciation in the domestic currency, and therefore an increase in relative domestic price. As a consequence, the LOP gap decreases, and so does imported inflation. The demand for domestic goods decreases, whereas demand for foreign goods increases more than proportionally. With the increase in consumption, the marginal utility of consumption decreases and the wage increases. This is due to the fact that when agents optimise they equate the ratio of marginal disutility of labour to the marginal utility of consumption and also to the real wage. This would imply that, whenever consumption increases, agents tend to lower their labour supply for a given wage. Since in equilibrium labour does not decrease sufficiently to keep the ratio constant, the real wage grows. This leads to an increase in marginal costs which is partly offset by the increase in the relative domestic price. Finally, an increase in marginal costs leads to a rise in PPI inflation. The overall rate of inflation increases. Thus, the central bank tightens its policy by increasing the interest rate.

If a TFP shock hits the foreign large economy, the rate of inflation in that country falls, domestic aggregate output increases, and the central bank lowers the interest rate. The impact on the domestic variables is shown in Figure 6. The domestic currency appreciates relative to the foreign currency. The relative price for foreign good decrease, hence demand shifts toward the foreign produced goods. Foreign inflation lowers (decrease in LOP gap) and domestic inflation rises (increase in real wage, hence in real marginal costs). In the case of PPI targeting, the overall inflation may fall, however by CPI targeting, the CPI inflation increases initially. After the initial drop, the output decreases further as a consequence of the rise in the interest rate, having its trough in the second to third period, and afterwards returning back to its equilibrium very slowly.

A positive foreign monetary policy shock, illustrated in Figure 7, causes an immediate appreciation in the foreign currency. The domestic currency depreciates and, as a consequence, the domestic goods become cheaper relative to the foreign one. Thus, the demand

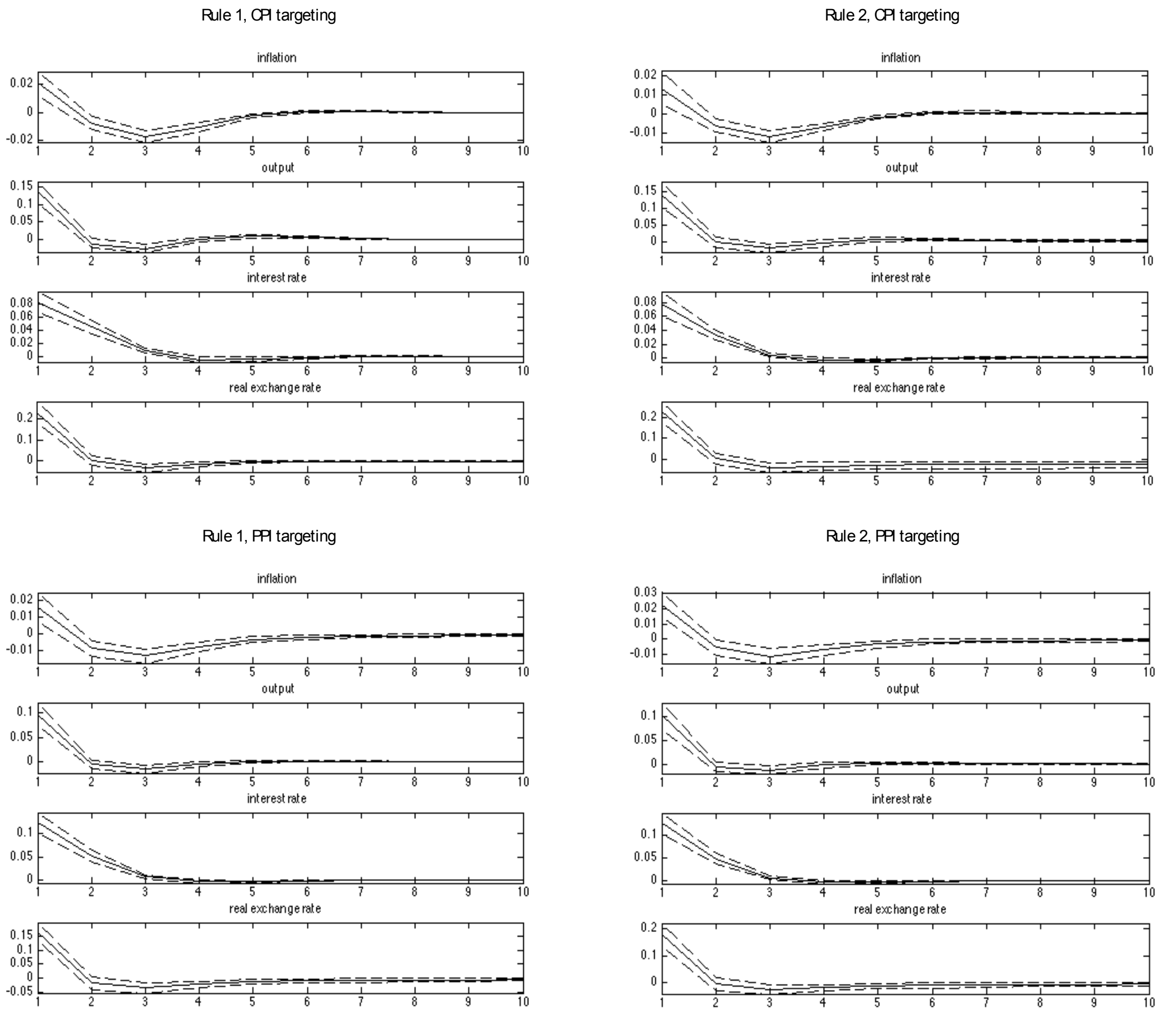
Figure 6. Impulse Responses to a Foreign TFP Shock



for domestic good increases and so does aggregate domestic output. The overall inflation rises as well, as a consequence of an increase in domestic inflation. Therefore, the central bank opts for a contractionary monetary policy, which entails a return of the exchange rate quickly –after two periods– back to its equilibrium.

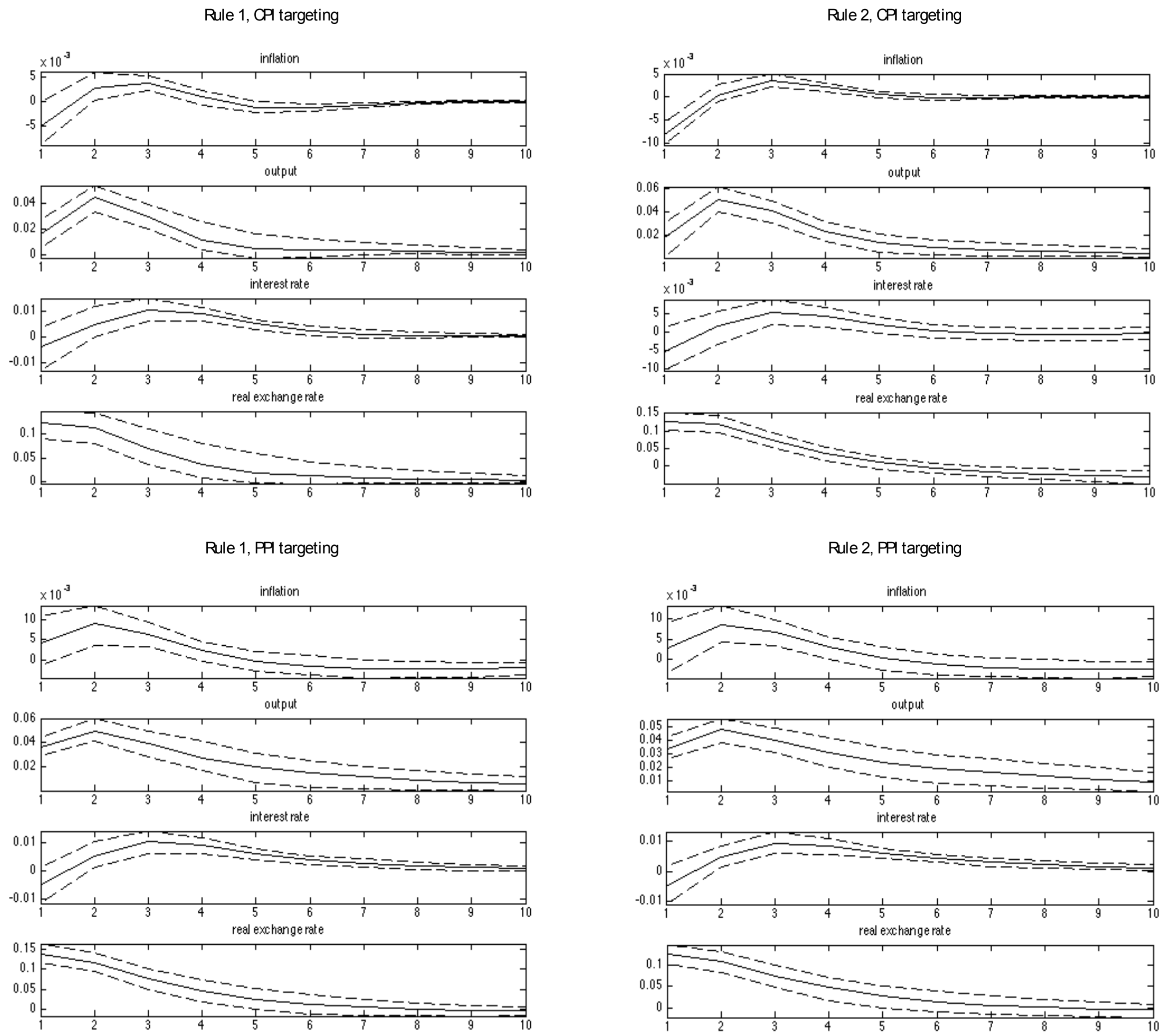
Figure 8 shows that a foreign cost push shock leads to a currency depreciation and a

Figure 7. Impulse Responses to a Foreign Monetary Shock



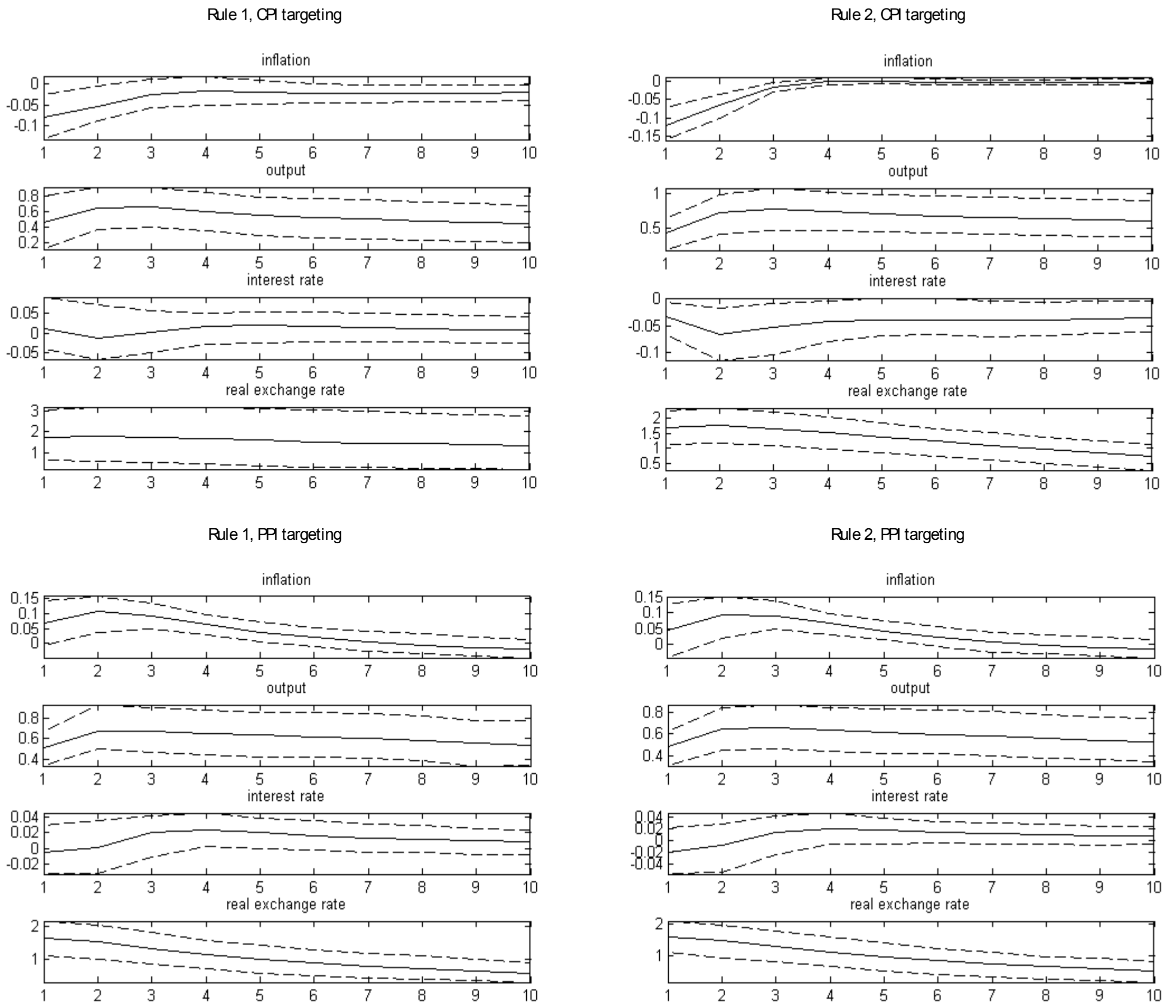
rise in domestic aggregate output. For the large foreign economy, the shock leads to an increase in inflation and a drop in consumption and output. The central bank increases the interest rate. As a consequence, the domestic currency depreciates and domestic goods gain a relative price advantage, which results in a demand shift toward domestic goods. Domestic aggregate output increases, but overall domestic consumption falls due to higher prices.

Figure 8. Impulse Responses to a Foreign Cost Push Shock



This leads to a decrease in the real wage, and a drop in the real marginal costs. Thus, PPI inflation decreases. Overall inflation decreases if it is subject to the central bank's targeting. Nevertheless, if the central bank targets PPI inflation, the overall inflation may increase, since the rise in foreign inflation outweighs the effect of the decrease in PPI inflation. All in all, the central bank decreases the interest rate in response to a foreign cost push shock.

Figure 9. Impulse Responses to a Foreign Preference Shock



Similarly to a foreign cost push shock, the foreign demand shock increases domestic output. Foreign consumption initially increases, leading to a lower marginal utility of consumption in the large economy and the foreign central bank reacts with an increase in the interest rate, which has the effect of leading domestic currency to depreciates. The responses to the shock are presented in Figure 9. If the domestic central bank targets the PPI, overall inflation may increase. By contrast, targeting CPI leads to a drop in overall inflation. As a consequence, the latter results in an expansionary monetary policy.

To conclude, note that in most of the cases targeting PPI leads to lower volatility in CPI inflation than with CPI targeting. The effect of different inflation targets on output is not that strong, hence it causes only limited changes to output. In line with the typical arguments in the theoretical literature, which maintain that PPI targeting leads to lower welfare losses, the impulse responses clearly show that such welfare gains are mainly due to the different effects on inflation generated by targeting the two alternative price indices.

4 Concluding Remarks

This work considered the characteristics and performance of simple monetary policy rules using a two-country model. First, I developed a small-scale two-country DSGE model with a microfounded Phillips curve, that is log-linearised around a non-zero steady state inflation. In line with well-established empirical evidence, I assumed imperfect pass-through, home bias preferences and non-unit intratemporal elasticity of substitution between domestic and foreign goods.

I carried out Bayesian inference to measure the performance of this model against data of several European countries. First, using only the part of the model related to the large economy, I tested several simple nominal interest rate rules, using German data. Firstly, I showed that a simple monetary policy rule mimicking an optimal rule gives the best outcome. Additionally, I showed that the estimation of the structural parameters of the model are robust to the choice of the monetary policy rule, and that the non-zero inflation part included in the Phillips curve improves the model fit significantly.

To study the model for the SOE, I used the data of three EEC, namely the Czech Republic, Hungary and Poland, for the years 1996-2012. Performing a posterior odds test, I found evidence that the central banks of all these countries target a PPI inflation instead of CPI inflation, contrary to what is usually assumed in the empirical literature. I showed that, also in the case of a SOE, the model with a non-zero steady state inflation performs substantially better. Comparing the non-zero steady state inflation component between the three EEC and Germany, I find that the magnitude is lower for the latter, though it remains positive and significantly different from zero. Further analysis about the monetary policy rules showed that a pure exchange rate target can be rejected for all three EEC, and that only the Czech Republic appears to respond to exchange rate movements.

It might be argued that the DSGE model presented here is perhaps too generic, and as such unable to fully address several issues raised in the literature: for instance, the role of FDI flows, non-traded goods, the price of energy, EU transfers, and remittances associated with the growing labor mobility, particularly the outflows of workers to other EU countries (see, *e.g.*, Belka, 2013, for an account of all theses factors). While it would be interesting and useful to account for these issues by including additional variables to our model, the robustness of our result would be greatly undermined. Moreover, it is not obvious which way accounting for each of those issues, on top of the variables already included in the analysis, would actually influence monetary policy determination. Therefore, I opted for more stylized approach, which also has the advantage to be readily comparable with most of the existing literature on the matter.

Finally, also due to data limitations, this paper was unable to address another issue that has been raised by some observers: the fact that the Euro zone and the EU may have experienced a regime change in 2010 (see, *e.g.*, Gerlach and Lewis, 2014). In this sense, it would have been useful to investigate these issue separately for the periods before and after 2010. Unfortunately, data availability does not allow for a robust analysis of the period post-2010. As a result, this paper might not offer a precise representation about the current and very recent behavior of EEC central banks.

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