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TREND INFLATION AND MONETARY POLICY IN EASTERN EUROPE

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I use a two-country dynamic stochastic general equilibrium (DSGE) model with a nonzero steady-state inflation to study monetary policy in transition economies. In particular, my analysis focuses on whether inflation targeting is based on a consumer price index (CPI) or its producer counterpart, producer price index (PPI). This issue is specifically relevant for transition economies as they might be subject to Balassa–Samuelson effects arising from trading in international markets. Under these circumstances, domestic inflation is possibly higher than imported inflation, hence targeting PPI inflation may prove more effective in influencing domestic macroeconomic variables than targeting CPI inflation. Using a Bayesian methodology, I find that the central banks of three Eastern European countries (namely, the Czech Republic, Hungary, and Poland) are likely to target PPI inflation rather than CPI inflation. This result is in line with the theoretical predictions in the literature, and is robust across several Taylor-type rules.

Keywords: Trend Inflation, Monetary Policy, Transition Economy, Bayesian DSGE Estimation

1. INTRODUCTION

For the central bank of a small open economy (SOE), 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). A number of theoretical contributions show 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 further light on this matter by comparing the two targets for a number of Eastern European

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countries (EECs), namely the Czech Republic, Hungary, and Poland. My results suggest that the central banks of the three investigated EECs 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 EECs. The reason is that PPI inflation 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 nontradeable 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 nontradables 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.[2] In this sense, targeting PPI inflation may prove more effective in influencing domestic macroeconomic variables than targeting CPI inflation.[3]

I use a two-country dynamic stochastic general equilibrium (DSGE) model where, in turn, the three EECs represent the SOE, and Germany is designated as the large economy.[4] The structure of the model closely relates to Galì 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 (2005), and a home bias in consumption leading to deviation from purchasing power parity (PPP). I also let the intratemporal elasticity of substitution between domestic and foreign goods differ from unity, allowing the central bank of the SOE to manipulate the terms of trade, which relates to the relative domestic price. The supply side of the model is characterized by a hybrid New Keynesian Phillips Curve (NKPC), which is derived using a rule of thumb following Galì and Gertler (1999). Last but not least, I follow Ascari and Ropele (2007) and log-linearize this Phillips curve around a nonzero steady state.[5] The monetary policy for both the large and the small economy 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.[6] The first important work in this field considering open economies is Lubik and Schorfheide (2005), who create a symmetric two-country model and estimate it using US and Euro Area data. Since then, a number of contributions extended their work. Using a similar data set, 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 behavior of central banks in Australia, Canada, New Zealand, and the United Kingdom. More recent contributions in this literature are Caraiani (2013) for the EECs and Baxa et al. (2014) for Australia, Canada, New Zealand, Sweden, and the United Kingdom. While the methodology I use is analogous to those adopted by these papers, my work differs from each of them by either the monetary policy issue analyzed or the motivation giving rise to the research question.

The paper is organized as follows. Section 2 describes the theoretical model, which builds on the New Keynesian literature with nonzero trend inflation. Section 3 discusses the Bayesian estimation. Section 4 concludes.

2. THE MODEL

I consider two countries: a home country H, which represents the SOE; and a foreign country F, which is sufficiently large to receive no influence by the SOE. In the home country, consumption is a Dixit–Stiglitz aggregator of domestic and foreign goods. For the foreign economy, the quantity of imports from the SOE is so marginal that it can be assumed that consumption only comprises foreign goods. For the same reason, in the foreign economy, there is no dispersion between producer and CPI. In both countries, preferences are represented by a constant relative risk aversion (CRRA) utility function, with curvature σ.[7]

From the first-order condition of the domestic representative household's maximization problem, I derive the Euler equation for the home country, which can be written in terms of deviations from the steady state as $\hat{c}_t = E_t\left[\hat{c}_{t+1}\right] - (\hat{\imath}_t - E_t\left[\hat{\pi}_{t+1}\right] + E_t\left[\Delta\epsilon_{t+1}\right])/\sigma$, where for the gross return on a riskless 1 year nominal bond I have used the approximation $\log(R_t) \approx \hat{\imath}_t$. All terms are expressed as first differences: $\hat{c}_t$ refers to log consumption, $\hat{\pi}_{t+1}$ is domestic CPI inflation, and $\Delta\epsilon_{t+1} = \log\varepsilon_{t+1} - \log\varepsilon_t$ is the first difference of the structural preference shock. The last term 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. Since the foreign household is assumed to face the same maximization problem, the Euler equation for country F is expressed analogously.

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 any riskless bond, expressed in the currency of the issuing country, equals the expected discounted nominal return of the bond. With no possibility of arbitrage, the expected returns of the two bonds must be equal. Therefore, uncovered interest parity can be expressed by equating the expected change in the real exchange rate, $\widehat{rs}_t$, and the ratio between domestic and foreign real interest rate: $\left[\hat{\imath}_t - E_t\left(\hat{\pi}_{t+1}\right)\right] - \left[\hat{\imath}^*_t - E_t\left(\hat{\pi}^*_{t+1}\right)\right] = E_t\left[\widehat{rs}_{t+1}\right] - \widehat{rs}_t$.[8]

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 countries. Assuming a zero steady-state net demand for foreign assets and an ex-ante identical environment, I obtain the optimal risk sharing condition under complete financial markets, $\widehat{rs}_t = \sigma\left(\hat{c}_t - \hat{c}^*_t\right) + \epsilon^*_t - \epsilon_t$. The clearing condition for domestic consumption goods market is $\hat{y}_t = -\theta\,\tilde{p}_{H,t} + \hat{c}_t + \lambda\left(\theta - 1/\sigma\right)\widehat{rs}_t$, where θ is the parameter governing the intratemporal elasticity of substitution between domestic and foreign goods. Hence, output log-deviation from the steady

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state, $\hat{y}_t$, depends on consumption deviation, the openness of the domestic economy, λ, the dispersion between domestic producer and consumer price indices $\tilde{p}_{H,t}$, and the real exchange rate deviation $\widehat{rs}_t$.

From the definition of domestic price index, I can derive the relationship between relative domestic producer price and relative importer price, $\tilde{p}_{F,t}$, expressed by the equation $1 = (1-\lambda)\,\tilde{p}_{H,t} + \lambda\tilde{p}_{F,t}$. Furthermore, the relationships between inflation and relative producer price on the one hand, and relative importer price on the other are, respectively, given by $\tilde{p}_{H,t} - \tilde{p}_{H,t-1} = \hat{\pi}_{H,t} - \hat{\pi}_t$ and $\tilde{p}_{F,t} - \tilde{p}_{F,t-1} = \hat{\pi}_{F,t} - \hat{\pi}_t$, where $\hat{\pi}_{H,t}$ is PPI inflation and $\hat{\pi}_{F,t}$ is inflation of imported goods. 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 $\hat{\Psi}_t \equiv \widehat{rs}_t - \tilde{p}_{F,t}$. Additionally, given the different degrees of home bias in consumption between the two countries, PPP does not hold, and the CPI differs across countries. Hence, the real exchange rate can be expressed as the price of foreign goods in term of domestic goods, that is $\Delta\widehat{rs}_t = \Delta\hat{s}_t + \hat{\pi}^*_t - \hat{\pi}_t + \varepsilon_{rs,t}$, where $\Delta\hat{s}_t$ denotes the deviation of the price of the foreign currency in terms of the domestic currency and $\varepsilon_{rs,t}$ is an unobservable shock, introduced to capture possible measurement error in the data and to relax the potentially tight cross-equation restrictions in the model.

The log-linearization of the supply side leads to a hybrid NKPC with a nonzero steady-state inflation, $\hat{\pi}_{H,t} = \chi^f E_t[\hat{\pi}_{H,t+1}] + \chi^b\hat{\pi}_{H,t-1} + \kappa_{mc}(\widehat{mc}_t + v_t) + \chi^\pi[\hat{h}_t - (\hat{y}_t - \sigma\hat{c}_t)]$, where χ^f, χ^b, χ^π, and κ_{mc} are functions of technological parameters, the real marginal cost is $\widehat{mc}_t = \eta\hat{y}_t + \sigma\hat{c}_t - (\eta+1)a_t - \tilde{p}_{H,t}$, v_t is the importer mark up shock, and $\hat{h}_t = (1-\alpha\beta\Pi^{\varepsilon-1})(\hat{y}_t - \sigma\hat{c}_t) + (\alpha\beta)\,\Pi^{\varepsilon-1}E_t[\varepsilon\hat{\pi}_{H,t+1} - \hat{\pi}_{t+1} + \hat{h}_{t+1}]$; Π is the steady-state level of inflation, α a technological parameter, β and η preference parameters. Analogous expression can be derived for the NKPC for imported prices. Consumption of imported foreign goods is $\hat{c}_{F,t} = \hat{c}_t - \theta\tilde{p}_{F,t}$. The market clearing condition for the large economy is $\hat{y}^*_t = \hat{c}^*_t$. The foreign Euler equation, the NKPC with backward looking and nonzero inflation component, and marginal cost are given by analogous expression to those for a closed economy.

To close the model, a monetary policy rule needs to be specified. For estimation purposes, it is customary to use a generalized Taylor rule. Analyzing the effect of such a simple rule has some advantages relative to the optimal monetary policy, e.g., it is more likely 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 Taylor-type targeting rules. For the large economy, I consider three monetary policy rules. The first one is a common Taylor rule with an interest rate smoothing component. In the second one, the central bank also responds to the speed of inflation $\Delta\pi^*_t$. The third rule takes the form of an optimal monetary policy rule, identified using a welfare loss function [see, e.g., Steinsson (2003)]. The following equations formally describe

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the three rules:

$$\hat{\imath}_t^* = \rho_i^* \hat{\imath}_{t-1}^* + \phi_\pi^* \hat{\pi}_t^* + \phi_y^* \hat{y}_t^* + \varepsilon_{u,t}^*, \qquad \textbf{(Rule 1)}$$

$$\hat{\imath}_t^* = \rho_i^* \hat{\imath}_{t-1}^* + \phi_\pi^* \hat{\pi}_t^* + \phi_y^* \hat{y}_t^* + \phi_{\Delta\pi}^* \Delta\hat{\pi}_t^* + \varepsilon_{u,t}^*, \qquad \textbf{(Rule 2)}$$

$$\hat{\imath}_t^* = \rho_i^* \hat{\imath}_{t-1}^* + \phi_\pi^* \hat{\pi}_t^* + \phi_y^* \hat{y}_t^* + \phi_{\Delta 1}^* \Delta\hat{\pi}_t^* + \phi_{\Delta 2}^* \Delta\hat{\pi}_{t+1}^* + \phi_{\Delta y}^* \Delta\hat{y}_t^* + \varepsilon_{u,t}^*, \qquad \textbf{(Rule 3)}$$

where $\varepsilon_{u,t}^*$ is an exogenous monetary policy shock. I 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 Rule 2, though the central bank additionally targets the changes in inflation and in the exchange rate. The second one is analogous to Rule 3. In the third, I assume that the central bank may strictly target the exchange rate. Formally,

$$\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + \phi_\Delta \Delta\hat{\pi}_t + \phi_S \Delta\hat{s}_t + \varepsilon_{u,t}, \qquad \textbf{(Rule 4)}$$

$$\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + \phi_{\Delta 1} \Delta\hat{\pi}_t + \phi_{\Delta 2} \Delta\hat{\pi}_{t+1} + \phi_{\Delta y} \Delta\hat{y}_t + \phi_S \Delta\hat{s}_t + \varepsilon_{u,t}, \qquad \textbf{(Rule 5)}$$

$$\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + \phi_S \Delta\hat{s}_t + \varepsilon_{u,t}. \qquad \textbf{(Rule 6)}$$

As discussed in the introductory section, although the theoretical literature emphasizes that targeting PPI inflation performs better in terms of welfare loss, the empirical literature usually assumes a simple rule with CPI inflation targeting. In fact, by adjusting the interest rate, the central bank can either target producer domestic inflation or CPI inflation. On the one hand, if the economy's nonstochastic 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, when cost push shocks have larger variance, CPI targeting may obtain better results.

To investigate whether the central bank targets domestic producer inflation or CPI inflation, I compare Rules 4 and 5 with the corresponding ones 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. Furthermore, following Lubik and Schorfheide (2007), I study to what extent the central banks of the EECs 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 respective counterparts by setting $\phi_S = 0$.

The model contains seven exogenous shocks that follow autoregressive processes expressed in a log-linearized form, two exogenous monetary policy shocks, namely $\varepsilon_{u,t}$ and $\varepsilon_{u,t}^*$; and one measurement error, $\varepsilon_{rs,t}$. The country-specific total factor productivity (TFP) for domestic and foreign country are defined,

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respectively, by $a_t = \rho_a a_{t-1} + \varepsilon_{a,t}$ and $a_t^* = \rho_{a^*} a_{t-1}^* + \varepsilon_{a,t}^*$. The preference innovations for domestic and foreign consumers are, respectively, given by $\epsilon_t = \rho_e \epsilon_{t-1} + \varepsilon_{e,t}$ and $\epsilon_t^* = \rho_{e^*} \epsilon_{t-1}^* + \varepsilon_{e,t}^*$. Finally, the cost push for domestic producers and for domestic retailers is expressed by $v_t = \rho_v v_{t-1} + \varepsilon_{v,t}$ and $v_t^F = \rho_{v^F} v_{t-1}^F + \varepsilon_{v^F,t}$, whereas for foreign producers by $v_t^* = \rho_{v^*} v_{t-1}^* + \varepsilon_{v,t}^*$.

3. ESTIMATION METHODOLOGY AND RESULTS

The model described in the preceding section has 27 endogenous macro variables. I use nine time series for the empirical estimation. The SOE equations are estimated, in turn, on data from the Czech Republic, Hungary, and Poland. The large economy is represented by Germany. I include those variables that are most commonly used in the literature: inflation, output growth, interest rate, and exchange rate.[9] In order to estimate the NKPC, most of the empirical papers take the marginal cost as a latent variable. Schorfheide (2008) argues that the resulting estimations of the NKPC parameters may vary significantly. For this reason, I follow Sbordone (2002) and Galì and Gertler (1999), who estimate the NKPC using unit labor cost as a proxy for real marginal cost. These authors also show that unit labor cost is a more appropriate measure for real marginal cost in the NKPC than the output gap.

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.

3.1. Choice of Priors

In the case that only a small sample of data is available, a prior distribution is additional information that enables more stability in the optimization algorithm. The prior distributions for the large economy follow closely those used by Smets and Wouters (2003). 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 (2005). To avoid identification issues, I estimate the composite structural coefficients of the NKPC rather than the underlying primitives. A number of rather different values of the NKPC parameters χ^b, χ^f, and κ_{mc} are reported in the literature. Therefore, the priors chosen here are consistent with the middle cases, 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 corresponds to $\Pi = 1.005$.

The parameters for the SOE have similar priors as those for the large economy. Most of the parameters are not imposed to be the same for all countries, but it

TABLE 1. Posterior odds test

Monetary policy rule	Log data density A1	Log data density A2	Posterior odds
Rule 1	−178.15	−173.8	0.013
Rule 2	−170.67	−161.55	0.000
Rule 3	−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 $\chi_\pi^* \neq 0$.

is merely assumed that they have identical priors. The Czech Republic's steady-state inflation Π is the same as Germany's, whereas for Hungary and Poland it corresponds to $\Pi = 1.0153$ and $\Pi = 1.0154$, respectively. The degree of openness λ is set to equate 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.[10]

3.2. Estimation Results

The composite structural parameters are estimated in two steps. The first step contains the estimation of the model, obtained using German data, for the large economy considered in isolation. The second step estimates the model for the SOE, using the data of each EEC in turn. I use the best-fitting monetary policy rule for the large economy, and estimate domestic and foreign parameters using jointly German and (in turn each) EEC's data. Along with the estimates of the parameters of the SOE NKPC, among which the nonzero inflation parameters χ_π and χ_{π^F} are particularly important, I wish to identify what monetary policy best fits the data.

Using German data, I estimate each of the three simple rules through two different approaches, in order to assess the importance of the estimation of the nonzero steady-state inflation part of the NKPC. The first approach (A1) assumes that the steady-state inflation is zero, which leads to a (A2) estimates the parameter χ_π^*. Table 1 reports the log backward looking NKPC with $\chi_\pi^* = 0$. The second approach marginal data densities and the posterior odds for these two specifications.

Two results emerge from the analysis of the log marginal likelihood and posterior odds.[11] First, the estimation of the model with the A2 approach improves the fit to the data, relative 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 complex the rule is, the better the performance of the model (regardless the approach considered). The traditional Taylor rule (Rule 1) performs worse, whereas the "optimal" simple rule (Rule 4) fits the data best. This evidence suggests that the central bank takes into account all the elements following from the welfare maximization of the loss function, as derived in presence of backward

TABLE 2. Parameter estimation results for Germany

Parameter	Mode	S.D.	10%	Mean	90%	Parameter	Mode	S.D.	10%	Mean	90%
$\sigma\left(\varepsilon_a^*\right)$	1.019	0.079	0.902	1.032	1.160	ϕ_y^*	0.020	0.006	0.010	0.023	0.036
$\sigma\left(\varepsilon_e^*\right)$	5.597	0.698	3.024	6.860	11.28	$\phi_{\Delta 1}^*$	0.535	0.020	0.244	0.450	0.658
$\sigma\left(\varepsilon_v^*\right)$	0.332	0.052	0.287	0.353	0.418	$\phi_{\Delta 2}^*$	0.358	0.032	0.194	0.385	0.573
$\sigma\left(\varepsilon_u^*\right)$	0.543	0.042	0.398	0.528	0.654	$\phi_{\Delta y}^*$	0.072	0.007	0.008	0.099	0.172
ρ_a^*	0.994	0.005	0.987	0.992	0.999	χ_f^*	0.945	0.035	0.804	0.897	0.989
ρ_e^*	0.980	0.006	0.970	0.980	0.994	χ_b^*	0.303	0.057	0.129	0.272	0.416
ρ_v^*	0.842	0.013	0.707	0.817	0.931	κ_{mc}^*	0.486	0.011	0.486	0.621	0.792
ρ_i^*	0.959	0.026	0.899	0.942	0.989	χ_π^*	0.271	0.024	0.157	0.225	0.298
ϕ_π^*	1.435	0.032	1.308	1.464	1.602	Π	1.003	0.001	1.001	1.005	1.008

TABLE 3. Marginal data densities

	Log data density		Czech Republic	Hungary	Poland
A2	CPI targeting, $\phi_S > 0$	Rule 4	−659.26	−630.38	−740.57
		Rule 5	−659.94	−633.51	−723.96
	PPI targeting, $\phi_S > 0$	Rule 4	−637.50	−603.98	−714.12
		Rule 5	−640.11	−595.45	−705.25
	PPI targeting, $\phi_S = 0$	Rule 4	−641.27	−602.56	−711.64
		Rule 5	−648.80	−594.13	−705.05
	Pure exchange rate	Rule 6	−706.85	−630.78	−842.91
A1	PPI targeting, $\phi_S > 0$	Rule 5	−646.27	−604.06	−721.94

looking firms. Given the log density, it is apparent that including inflation change targeting improves the fit significantly.

The estimated Bayesian posterior distribution, based on the A2 approach and Rule 3, is reported in Table 2. The table displays the mode and standard error resulting from the posterior maximization, as well as moments of the estimation results distribution, i.e., the posterior mean and the interdecile posterior probability interval for both the estimated parameters and the standard deviation of shocks.[12]

The first posterior density decile suggests that the estimated parameters are all greater than zero. In particular, Table 2 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 (Rule 1): around 0.13 for both approaches. For the other two rules, the values are remarkably 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 Galì and Gertler (1999) and Galì et al. (2001). Moreover, the estimated parameters are very robust, and they all lie in the confidence interval, regardless the estimation approach and rule.

TABLE 4. Posterior odds test: CPI inflation targeting

	Rule 4				Rule 5		
	H0	H1	Posterior odds		H0	H1	Posterior odds
Czech Republic	−659.26	−637.50	0.000	Czech Republic	−659.94	−640.11	0.000
Hungary	−630.38	−603.98	0.000	Hungary	−633.51	−595.45	0.000
Poland	−740.57	−714.12	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 5. Posterior odds test: Trend inflation and no exchange rate targeting

	Trend inflation				No exchange rate targeting		
	H0	H1	Posterior odds		H0	H1	Posterior odds
Czech Republic	−646.27	−640.11	0.002	Czech Republic	−641.27	−637.50	0.023
Hungary	−604.06	−595.45	0.000	Hungary	−602.56	−603.98	4.161
Poland	−721.94	−705.25	0.000	Poland	−711.64	−714.12	11.88

Note: The table reports posterior odds test for the EECs on the hypothesis H0 ($\chi_\pi = 0$, $\chi_{\pi^F} = 0$) against the H1 ($\chi_\pi \neq 0$, $\chi_{\pi^F} \neq 0$) (left-hand panel); and on the hypothesis H0 ($\phi_S = 0$) against the H1 ($\phi_S \neq 0$) (right-hand panel).

For the SOE, the summary of the marginal data densities resulting from several different tests can be found in Table 3. The results of the estimations are illustrated in Tables 4 and 5. First, I test whether the central bank targets CPI or PPI inflation. The results of the posterior odds test, displayed in Table 4, suggest that there exists 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 delivers lower welfare losses. About pure exchange rate targeting, Table 3 suggest that this policy is unlikely being implemented, since Rule 6 invariably exhibits a significantly lower performance, especially on Czech and Polish data.

Second, to show how important it is to include the nonzero component into the Phillips curve, I test the hypothesis $\chi^\pi = 0$ against the hypothesis $\chi^\pi \neq 0$. In light of the result obtained in Table 4, the left-hand panel of Table 5 displays the posterior odds test for Rule 5 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.

Table 6. Parameter estimation results: Czech Republic

Parameter	Mode	S.D.	10%	Mean	90%
$\sigma\ (\varepsilon_a)$	0.723	0.156	0.538	0.771	0.988
$\sigma\ (\varepsilon_e)$	3.028	0.483	2.318	3.109	3.907
$\sigma\ (\varepsilon_u)$	1.549	0.198	1.297	1.658	2.026
$\sigma\ (\varepsilon_v)$	1.739	0.264	1.311	1.595	1.864
$\sigma\ (\varepsilon_{v^F})$	10.75	3.095	0.223	10.60	20.35
$\sigma\ (\varepsilon_{rs})$	4.943	0.497	4.222	5.014	5.774
ρ_a	0.925	0.011	0.773	0.887	0.989
ρ_e	0.877	0.018	0.828	0.876	0.931
ρ_v	0.703	0.024	0.617	0.725	0.832
ρ_{v^F}	0.875	0.023	0.758	0.851	0.969
ρ_i	0.926	0.042	0.808	0.895	0.984
ϕ_π	1.399	0.031	1.329	1.466	1.605
ϕ_y	0.054	0.018	0.023	0.064	0.105
$\phi_{\Delta 1}$	0.351	0.038	0.229	0.376	0.525
$\phi_{\Delta 2}$	0.339	0.024	0.174	0.328	0.491
$\phi_{\Delta y}$	0.102	0.012	0.001	0.048	0.093
ϕ_S	0.139	0.021	0.087	0.144	0.205
χ^f	0.908	0.036	0.689	0.826	0.967
χ^b	0.306	0.032	0.115	0.279	0.433
κ_{mc}	0.292	0.012	0.336	0.415	0.510
χ^π	0.104	0.019	0.013	0.077	0.147
χ_F^f	0.636	0.101	0.257	0.540	0.799
χ_F^b	0.193	0.026	0.063	0.238	0.387
κ_F	0.059	0.010	0.020	0.069	0.121
χ_F^π	0.008	0.008	−0.01	−0.01	0.071
Π	1.004	0.001	1.001	1.005	1.010

Third, I test whether the central bank responds to variations in the exchange rate. I first estimate each rule setting $\phi_S > 0$. Then, I estimate the same rule but, assuming that the central bank is uninterested in exchange rate targeting, I set $\phi_S = 0$. The right-hand panel of Table 5 illustrates the case of Rule 4 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.

The resulting parameters are similar for the three countries and can be found in Tables 6–8. The backward looking component for producer inflation lies between 0.2 and 0.35 for all countries. Compared to Germany, the nonzero steady-state inflation component is lower, 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; still they all are significantly different from zero. Central bank of the three EECs respond much more actively to inflation than to output. Note that the estimates for exchange rate targeting are higher, for all the three countries, than the prior values.

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TABLE 7. Parameter estimation results: Hungary

Parameter	Mode	S.D.	10%	Mean	90%
$\sigma\ (\varepsilon_a)$	0.577	0.115	0.559	0.799	1.070
$\sigma\ (\varepsilon_e)$	6.583	0.575	5.266	6.665	8.077
$\sigma\ (\varepsilon_u)$	1.911	0.238	1.621	2.065	2.492
$\sigma\ (\varepsilon_v)$	1.724	0.235	1.331	1.681	2.011
$\sigma\ (\varepsilon_{v^F})$	10.51	1.196	0.222	1.918	5.204
$\sigma\ (\varepsilon_{rs})$	7.022	0.496	5.813	6.952	8.008
ρ_a	0.787	0.020	0.848	0.904	0.963
ρ_e	0.914	0.009	0.887	0.909	0.931
ρ_v	0.656	0.010	0.574	0.666	0.750
ρ_{v^F}	0.852	0.016	0.702	0.831	0.972
ρ_i	0.887	0.017	0.780	0.871	0.963
ϕ_π	1.510	0.035	1.362	1.508	1.641
ϕ_y	0.040	0.006	0.019	0.052	0.085
$\phi_{\Delta 1}$	0.278	0.025	0.173	0.276	0.375
$\phi_{\Delta 2}$	0.432	0.021	0.120	0.308	0.422
$\phi_{\Delta y}$	0.051	0.010	0.000	0.037	0.075
ϕ_S	0.145	0.011	0.077	0.152	0.230
χ^f	0.823	0.036	0.618	0.797	0.956
χ^b	0.372	0.047	0.200	0.340	0.482
κ_{mc}	0.432	0.009	0.416	0.489	0.565
χ^π	0.074	0.006	−0.02	0.057	0.128
χ_F^f	0.406	0.036	0.088	0.433	0.777
χ_F^b	0.255	0.016	0.039	0.219	0.361
κ_F	0.084	0.008	0.011	0.049	0.087
χ_F^π	−0.07	0.004	−0.11	−0.04	0.024
Π	1.010	0.001	1.002	1.006	1.010

Finally, it is worth noting that an investigation of the impulse responses of the key macroeconomic variables involved in my analysis shows that targeting PPI generally leads to a lower volatility in CPI inflation than with CPI targeting.[13] The effect of different inflation targets on output is not that strong, causing only limited variations to it. In line with the typical arguments in the theoretical literature, which maintain that PPI targeting leads to lower welfare losses, the impulse responses show that such welfare gains are mainly due to the different effects on inflation generated by the two alternative price targeting.

4. CONCLUDING REMARKS

This work has considered the characteristics and performance of simple monetary policy rules using a two-country model. First, I have developed a small-scale two-country DSGE model with a microfounded Phillips curve, log-linearized around a nonzero steady-state inflation. In line with well-established empirical

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TABLE 8. Parameter estimation results: Poland

Parameter	Mode	S.D.	10%	Mean	90%
$\sigma\ (\varepsilon_a)$	1.145	0.126	0.868	1.075	1.268
$\sigma\ (\varepsilon_e)$	7.023	0.701	5.182	6.551	7.870
$\sigma\ (\varepsilon_u)$	1.525	0.233	1.306	1.632	1.945
$\sigma\ (\varepsilon_v)$	1.378	0.180	1.042	1.282	1.508
$\sigma\ (\varepsilon_{v^F})$	0.457	0.485	0.228	0.853	1.569
$\sigma\ (\varepsilon_{rs})$	6.976	0.547	5.995	7.051	8.088
ρ_a	0.963	0.010	0.914	0.947	0.981
ρ_e	0.913	0.010	0.899	0.918	0.939
ρ_v	0.736	0.013	0.500	0.655	0.798
ρ_{v^F}	0.890	0.018	0.782	0.881	0.977
ρ_i	0.860	0.027	0.558	0.717	0.867
ϕ_π	1.524	0.014	1.393	1.502	1.630
ϕ_y	0.060	0.008	0.045	0.087	0.136
$\phi_{\Delta 1}$	0.302	0.017	0.138	0.226	0.306
$\phi_{\Delta 2}$	0.371	0.026	0.177	0.323	0.475
$\phi_{\Delta y}$	0.094	0.011	0.006	0.111	0.212
ϕ_S	0.112	0.034	0.070	0.113	0.155
χ^f	0.922	0.020	0.640	0.784	0.949
χ^b	0.373	0.038	0.179	0.328	0.482
κ_{mc}	0.444	0.014	0.486	0.570	0.663
χ^π	0.067	0.011	0.017	0.080	0.176
χ_F^f	0.328	0.037	0.332	0.508	0.701
χ_F^b	0.302	0.049	0.436	0.542	0.678
κ_F	0.037	0.005	0.001	0.011	0.019
χ_F^π	−0.05	0.011	−0.01	0.042	0.110
Π	1.003	0.001	1.001	1.004	1.006

evidence, I have assumed imperfect pass-through, home bias preferences, and nonunit intratemporal elasticity of substitution between domestic and foreign goods.

I have carried out Bayesian inference to measure the performance of this model against 1996–2012 data of several European countries: namely, Germany as the large economy and, in turn, the Czech Republic, Hungary, and Poland as the SOE. Performing a posterior odds test, I have found evidence that the central banks of all these countries target PPI inflation instead of CPI inflation, contrary to what is usually assumed in the empirical literature. I have shown that, also in the case of a SOE, the model with a nonzero steady-state inflation performs substantially better. Further analysis about the monetary policy rules has shown that a pure exchange rate target can be rejected for all three EECs, 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, nontraded goods, the price of energy, EU transfers, and remittances associated with the growing labor mobility, particularly the outflows of workers to other EU countries. While it would be interesting and useful to account for these issues by including additional variables to my model, due to data limitations the robustness of my results 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 have 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 has been unable to address another issue raised by some observers: The fact that the EECs, as well as the Euro zone, may have experienced some regime switches in their monetary policy since 2010 [see, e.g., Gerlach and Lewis (2014)]. In this sense, it would have been useful to investigate these issues separately for the periods before and after each regime switch. Unfortunately, data availability does not yet allow for a robust analysis of such short post-2010 periods.

NOTES

1. The fact that PPI targeting may perform better than CPI targeting is a well-established theoretical result in the literature of monetary policy in open economies: see, e.g., Corsetti and Pesenti (2001), Galì and Monacelli (2005), Faia and Monacelli (2008), Ferrero et al. (2008), De Paoli (2009), and Catão and Chang (2015). Examples of empirical contributions focusing on other indicators than PPI, when investigating inflation targeting, can be found in, e.g., Lubik and Schorfheide (2007), Kolasa (2009), Jakab and Világi (2008), Justiniano and Preston (2010), Tonner et al. (2011), Caraiani (2013), Baxa et al. (2014), and Drygalla (2015). For a thorough review of the literature dealing with monetary policy in open economies, see Corsetti et al. (2010).

2. For a discussion on Balassa–Samuelson effects in developing countries, see, e.g., Egert et al. (2003) and Ricci et al. (2013).

3. Caraiani (2013) also investigates 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. In this perspective, the two papers complement one another.

4. The reason for this choice is that Germany represents the largest trading partner of all selected EECs, attracting 25% to 30% of the total exports from each of them. Being not reciprocal, these trade figures suggest that Germany behaves as a large economy relative to the EECs.

5. A remarkable survey of this literature can be found in Ascari and Sbordone (2014).

6. For a review of this literature, see Fernández-Villaverde et al. (2016).

7. For the sake of brevity, the formal details of the model are kept to a minimum. For the full specification, see the online appendix (Sections A and B), available at http://sites.google.com/site/junickemonika/research.

8. Starred variables are associated with the foreign economy.

9. All observations are quarterly, seasonally adjusted data over the periods 1996–2011 for Germany and the Czech Republic, and 1998–2012 for Hungary and Poland. Online Appendix C offers a detailed description of the data, their source and manipulation.

10. Online Appendix D contains a detailed description of the parameters governing the prior distributions, along with a graphical representation of the differences between prior and posterior distributions.

11. 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 as follows: 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 $10^{-2} > \pi_{0,T}/\pi_{1,T}$.

12. The results obtained using the other rules and/or approach A1 are similar to those reported in Table 2, and are available from the author upon request.

13. The full set of figures illustrating the impulse response functions is available in online Appendix E.

REFERENCES

Ascari, Guido and Tiziano Ropele (2007) Optimal monetary policy under low trend inflation. *Journal of Monetary Economics* 54, 2568–2583.

Ascari, Guido and Argia M. Sbordone (2014) The macroeconomics of trend inflation. *Journal of Economic Literature* 52, 679–739.

Baxa, Jaromír, Roman Horváth, and Bořek Vašíček (2014) How does monetary policy change? Evidence on inflation-targeting countries. *Macroeconomic Dynamics* 18, 593–630.

Caraiani, Petre (2013) Comparing monetary policy rules in CEE economies: A Bayesian approach. *Economic Modelling* 32, 233–246.

Catão, Luis A. V. and Roberto Chang (2015) World food prices and monetary policy. *Journal of Monetary Economics* 75, 69–88.

Corsetti, Giancarlo, Luca Dedola, and Sylvain Leduc (2010) Optimal monetary policy in open economies. In Benjamin M. Friedman and Michael Woodford (eds.), *Handbook of Monetary Economics,* vol. 3, pp. 861–933. Amsterdam: North Holland, Elsevier.

Corsetti, Giancarlo and Paolo Pesenti (2001) Welfare and macroeconomic interdependence. *Quarterly Journal of Economics* 116, 421–445.

De Paoli, Bianca (2009) Monetary policy and welfare in a small open economy. *Journal of International Economics* 77, 11–22.

Drygalla, Andrej (2015) Switching to Exchange Rate Flexibility? The Case of Central and Eastern European Inflation Targeters. FIW working paper 139.

Égert, Balázs, Imed Drine, and Kirsten Lommatzsch (2003) The Balassa–Samuelson effect in central and eastern Europe: Myth or reality? *Journal of Comparative Economics* 31, 552–572.

Faia, Ester and Tommaso Monacelli (2008) Optimal monetary policy in a small open economy with home bias. *Journal of Money, Credit and Banking* 40, 721–750.

Fernández-Villaverde, Jesús, Juan Francisco Rubio-Ramírez, and Frank Schorfheide (2016) Solution and estimation methods for DSGE models. In John B. Taylor and Harald Uhlig (eds.), *Handbook of Macroeconomics,* vol. 2, pp. 527–724. Amsterdam: North Holland, Elsevier.

Ferrero, Andrea, Mark Gertler, and Lars E. O. Svensson (2008) Current Account Dynamics and Monetary Policy. NBER working paper w13906.

Galì, Jordi and Mark Gertler (1999) Inflation dynamics: A structural econometric analysis. *Journal of Monetary Economics* 44, 195–222.

Galì, Jordi, Mark Gertler, and J. David Lopez-Salido (2001) European inflation dynamics. *European Economic Review* 45, 1237–1270.

Galì, Jordi and Tommaso Monacelli (2005) Monetary policy and exchange rate volatility in a small open economy. *Review of Economic Studies* 72, 707–734.

Gerlach, Stefan and John Lewis (2014) Zero lower bound, ECB interest rate policy and the financial crisis. *Empirical Economics* 46, 865–886.

Jakab, Zoltán M. and Balázs Világi (2008) An Estimated DSGE Model of the Hungarian Economy. MNB working paper 2008/9.

Justiniano, Alejandro and Bruce Preston (2010) Monetary policy and uncertainty in an empirical small open-economy model. *Journal of Applied Econometrics* 25, 93–128.

Kolasa, Marcin (2009) Structural heterogeneity or asymmetric shocks? Poland and the euro area through the lens of a two-country DSGE model. *Economic Modelling* 26, 1245–1269.

Lubik, Thomas A. and Frank Schorfheide (2005) A Bayesian look at new open economy macroeconomics. *NBER Macroeconomics Annual* 20, 313–366.

Lubik, Thomas A. and Frank Schorfheide (2007) Do central banks respond to exchange rate movements? A structural investigation. *Journal of Monetary Economics* 54, 1069–1087.

Monacelli, Tommaso (2005) Monetary policy in a low pass-through environment. *Journal of Money, Credit and Banking* 37, 1047–1066.

Rabanal, Pau and Vicente Tuesta (2010) Euro-dollar real exchange rate dynamics in an estimated two-country model: An assessment. *Journal of Economic Dynamics and Control* 34, 780–797.

Ricci, Luca Antonio, Gian Maria Milesi-Ferretti, and Jaewoo Lee (2013) Real exchange rates and fundamentals: A cross-country perspective. *Journal of Money, Credit and Banking* 45, 845–865.

Sbordone, Argia M. (2002) Prices and unit labor costs: A new test of price stickiness. *Journal of Monetary Economics* 49, 265–292.

Schorfheide, Frank (2008) DSGE model-based estimation of the New Keynesian Phillips curve. *Economic Quarterly* 94, 397–433.

Smets, Frank and Raf Wouters (2003) An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association* 1, 1123–1175.

Steinsson, Jon (2003) Optimal monetary policy in an economy with inflation persistence. *Journal of Monetary Economics* 50, 1425–1456.

Tonner, Jaromir, Jiri Polansky, and Osvald Vašíček (2011) Parameter drifting in a DSGE model estimated on Czech data. *Czech Journal of Economics and Finance* 61, 510–524.