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SWITCHING TO GOOD POLICY? THE CASE OF CENTRAL AND EASTERN EUROPEAN INFLATION TARGETERS

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The paper analyzes how actual monetary policy changed following the official adoption of inflation targeting in the Czech Republic, Hungary, and Poland and how it affected the volatilities of important macroeconomic variables in the years thereafter. To disentangle the effects of the policy shift from exogenous changes in the volatilities of these variables, a Markov-switching dynamic stochastic general equilibrium model is estimated that allows for regime switches in the policy parameters and the volatilities of shocks hitting the economies. Whereas estimation results reveal periods of high and low volatility for all three economies, the presence of different policy regimes is supported by the underlying data for the Czech Republic and Poland, only. In both economies, monetary policy switched from weak and unsystematic to strong and systematic responses to inflation dynamics. Simulation results suggest that the policy shifts of both central banks successfully reduced inflation volatility in the following years. The observed reduction in output volatility, on the other hand, is attributed more to a reduction in the size of external shocks.

Keywords: Markov-Switching DSGE Models, Inflation Targeting, Small Open Economy

1. INTRODUCTION

The Central and Eastern European (CEE) transition economies of the Czech Republic, Poland, and Hungary, among other countries, adopted the monetary strategy of inflation targeting (IT) around the turn of the millennium. Officially announced inflation targets started to act as nominal anchors for monetary policy. Following the regime switch, the volatilities of key macroeconomic variables, in particular inflation, significantly decreased in all three economies. Given the *de jure* changes in the conduct of monetary policy and the subsequent favorable development of the newly targeted variable, this work assesses the extent to which the latter can actually be explained by the new policy strategy as opposed to a more favorable, less volatile macroeconomic environment. To this end, I estimate

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a Markov-switching dynamic stochastic general equilibrium (MS-DSGE) model in order to identify and characterize different monetary policy and (external) shock volatility regimes. Subsequently, I simulate the model with different actual and fictitious combinations of policy and volatility regimes to assess which policy strategy performed better under identical conditions. Based on the simulation results, I draw conclusions on whether the improved macroeconomic performance can be attributed to a change in the systematic conduct of monetary policy.

Prior to the introduction of IT, all three central banks had been explicitly targeting their exchange rates. The Czech National Bank (CNB) that has been committing to an exchange rate target against a currency basket composed of the German mark and the US dollar, let the koruna float after not being able to sustain devaluation pressures in May 1997. Consequently, IT was introduced as a new nominal anchor for monetary policy in the beginning of 1998. For most of the time since then, the exchange rate has been given minor attention. However, at the end of 2013, the CNB announced that it would prevent an appreciation of its currency below 27 koruna per euro to tackle an ongoing undershooting of its inflation target while being confronted with the zero lower bound for policy rates. The story of the Hungarian forint reads somewhat differently. Prior to the introduction of IT, the national bank (Magyar Nemzeti Bank (MNB)) has been operating a narrow ±2.25% crawling band regime for its currency. In the presence of large capital inflows, the MNB was not able to prevent an excessive appreciation while at the same time sufficiently sterilizing the interventions in order to limit inflation pressures. Therefore, in May 2001, the exchange rate band was widened to 15% around the target rate against the euro.[1] An explicit inflation target to replace the exchange rate as a nominal anchor for monetary policy was introduced shortly thereafter. Hence, unlike in the Czech Republic, the introduction of the IT framework did not come as a consequence of the central bank not being able to meet its exchange rate target due to capital outflows and the resulting devaluation pressures. In Hungary, the switch from exchange rate to IT can rather be seen as an intentional policy change to better fulfill the major objective of price stability. Nearly the same applies to Poland in the 1990s, where the national bank (Narodowy Bank Polski (NBP)) gradually widened the band around a preannounced depreciation rate of its currency. The crawling band was finally abolished, converting the zloty into a free-floating currency in April 2000. IT as a new framework for monetary policy was already introduced by the beginning of 1999.

However, the *de jure* shifts in the policy anchor do not need to have automatically translated into systematic changes in the *de facto* conduct of monetary policy. At least regarding the reaction to exchange rate movements, there is mixed evidence on whether policy attention actually changed. According to the International Monetary Fund (IMF) exchange rate regime classification, the Polish and Czech currencies have become more flexible by moving from managed floating to free floating (Poland), and from a fixed to a managed floating regime (Czech Republic), respectively, whereas the forint remained classified as

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a managed float. Following the *de facto* classifications of Ilzetzki et al. (2010), none of the currencies has become more flexible. The strategy in terms of monetary policy responses to exchange rate movements before and after the target shift that was actually realized remains vague for all three central banks. Nor is it obvious whether or not the central banks have increased their attention to inflation dynamics under the new policy anchor. In order to assess the performance of monetary policy before and after the policy switch, the actual changes in its conduct first need to be quantified.

Following the seminal work of Taylor (1993), a broad field of literature on the estimation of monetary policy rules has emerged to quantify the importance of specific variables when setting policy rates. Whereas these rules can be specified in detail to best fit historical data, they are most commonly estimated in a stand-alone manner, and do not account for interactions between the monetary authority and the behavior of other agents in the economy. In particular, the extent to which policy measures can have an impact on the private sector's actions and expectations is not taken into account. In this context, DSGE models have gained importance. In contrast to univariate analyses, they provide a consistent framework and thereby a clearer interpretation of domestic and foreign economic shocks, and the channels through which they affect particular variables. However, as outlined before, the economies under consideration in this paper have experienced structural and economic changes over the past decades. Due to their microfoundations, parameters of estimated DSGE models were initially regarded as invariant to policy changes, prompting a large body of literature to emerge, arguing for the opposite. As one of the first, Fernández-Villaverde and Rubio-Ramírez (2007) have found that standard DSGE model parameters are subject to drifts. In a more recent study, Hurtado (2014) built on their analysis and showed that estimated values of model parameters strongly depend on the underlying sample. In addition to drifts in the values of structural parameters, there also seems to be a time variance in the volatility of variables and disturbances hitting the economy, as suggested by the episode of the Great Moderation and the more turbulent periods before and thereafter.

To adequately account for these changes as well as to quantify them, a simple small open economy model that allows for Markov switches in its parameters and the volatilities of shocks is estimated in this paper. In doing so, it adds to the emerging literature on estimated MS-DSGE models. As one of the first, Davig and Doh (2008) as well as Bianchi (2010) estimated simple models for the USA, putting a focus on switches in the interest rate rule. A more complex model based on the work of Justiniano and Preston (2010) has been estimated for the United Kingdom by Liu and Mumtaz (2010) and for Hong Kong by Blagov and Funke (2018). Kriwoluzky et al. (2015) employed a medium-sized, regime-switching, rational expectations model to study the effects of exits from currency unions. A simpler model of the UK economy by Chen and MacDonald (2012) and based on Lubik and Schorfheide (2007) analyzes optimal and realized policy rules in a regime-switching context. The same model setup is used by Alstadheim et al.

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(2013) to estimate the central banks' responses to exchange rate movements in Canada, Norway, Sweden, and the UK.

By applying the same framework to the Czech Republic, Hungary, and Poland, this study is the first, to the best of my knowledge, that analyzes systematic monetary policy changes and their effects on macroeconomic performance in CEE countries within an MS-DSGE model framework. The identification and characterization of different policy, as well as volatility regimes, enables an assessment of the existing monetary policy strategy compared to fictitious scenarios in which different policy and volatility regimes are mixed. Macroeconomic performance can thereby be classified as either a result of good policy or rather the presence of a favorable environment ("good luck"), similar to the vast economic literature that attempts to explain the factors behind the Great Moderation [Stock and Watson (2002), Boivin and Giannoni (2006)]. In doing so, I also complement the work of Lipińska (2015) who employs a DSGE model calibrated to the Czech Republic to find that optimal monetary policy in the CEE transition economies violates the Maastricht convergence criteria for joining the European Economic and Monetary Union.

The remainder of the paper is organized as follows: macroeconomic performance before and after the introduction of IT is discussed in Section 2, Section 3 outlines the model framework, the estimation process is described in Section 4, estimation results and an assessment of the monetary policies are presented in Section 5, and Section 6 presents the conclusions.

2. MACROECONOMIC PERFORMANCE

The introduction of IT marked a seemingly important point in the transition from planned to market economies. The beginning of the 1990s, when the economies of the Czech Republic, Hungary, and Poland entered the period of transition, has been characterized by severe downturns in economic activity, high inflation, and strong currency devaluations. According to figures from the IMF, the Czech and Hungarian economies contracted by nearly 12% in 1991. The decline in Polish GDP in the same year amounted to 7%. Inflation soared to double-digit levels in all three economies. Poland experienced the most severe episode of inflation with prices nearly tripling within 2 years from 1990 until 1992. In the Czech Republic and Hungary, inflation rates peaked at 21% and 35%, respectively.

In the following years, economic activity recovered and inflation softened. However, the latter remained high and volatile until the end of the decade. Following the official implementation of IT, macroeconomic performance further improved in all three countries, and the volatility of the newly targeted variable decreased noticeably. Inflation rates came down from double-digit numbers to levels only slightly above targets in advanced economies. Compared to the respective pre-IT samples, the average increase in price levels slowed down by more than three times in the Czech Republic and Hungary and nearly fivefold in Poland (Table 1). The reductions in inflation rate levels have been accompanied

TABLE 1. First and second moments of inflation, nominal effective exchange rate (NEER) appreciation, and output growth

	Czech Republic			Hungary			Poland		
	Pre-IT	IT	ITxc	Pre-IT	IT	ITxc.	Pre-IT	IT	ITxc
Inflation									
Mean	8.85	2.72	2.79	15.07	4.56	4.67	16.67	3.43	3.41
StDev	5.69	4.25	4.25	7.34	4.35	4.37	8.71	3.71	3.72
ΔNEER									
Mean	−0.19	0.20	0.26	−0.83	−0.07	0.08	−0.72	0.01	0.18
StDev	1.14	1.59	1.46	1.45	2.09	1.90	2.14	2.30	2.06
ΔGDP									
Mean	0.81	0.61	0.72	0.73	0.40	0.57	1.38	0.93	0.96
StDev	1.23	0.92	0.67	0.51	1.08	0.69	1.68	0.63	0.61

Notes: "Pre-IT" and "IT" samples are set according to the *de jure* announcements by the respective central banks. "ITxc" excludes the financial crisis. Inflation is measured as the average quarterly change in seasonally adjusted headline CPI expressed on an annualized basis.

by significant decreases in their volatilities. Here again, the finding is particularly true for the Polish economy. Given that the de jure focus of monetary policy has shifted to a stabilization of inflation instead of the exchange rate, it is reasonable to expect that the volatilities of the two variables have evolved differently following the policy shift. Indeed, the three exchange rates have become more volatile under the new strategy. Volatility, in particular, increased for the respective rates against the dollar. Effective rates and bilateral rates against the euro increased less sharply.

Given that a substantial part of the catching-up process had been concluded by then, it does not surprise that GDP growth rates have been lower since the introduction of IT. However, output growth volatility remarkably decreased in the Czech Republic and Poland under the new policy regime. This finding holds even truer when excluding the Great Recession. In Hungary where output growth proved to be remarkably less volatile prior to IT, volatility slightly increased.

In general, under the new policy regime, inflation and output growth became less volatile. One potential factor for the favorable development of key economic variables could have been, among others, a better-performing monetary policy as a result of increased expertise as well as greater credibility. Following this, private sector expectations of price-level movements are expected to have increasingly mirrored the central banks' targets and by that substantially facilitated the achievement of the latter. On the other hand, a less volatile macroeconomic environment could have led to the observed success in the evolution of targeted variables. This factor seems to be particularly relevant for the highly open economies of the Czech Republic and Hungary. With exports and imports amounting to approximately two-thirds of the respective GDP, they are strongly affected by foreign disturbances.

The extent to which monetary policy and the volatilities of shocks have actually changed as well as how much both potential factors have contributed to the development of target variables is quantified in a simple, small open economy framework that is outlined in the following section.

3. MODEL

The model follows the simplified version of Galí and Monacelli (2005), as outlined in Lubik and Schorfheide (2007). It consists of a forward-looking IS curve, a Phillips curve, a monetary policy rule and an equation-linking CPI inflation, the nominal exchange rate, and the terms of trade. By assuming a perfect substitutability among a variety of goods produced in one country, a unit elasticity of substitution between home and foreign goods, a unit-elastic labor supply, and by abstracting from investment and government spending, the standard Euler equation of utility-maximizing households results in the following log-linearized IS curve for output y_t:[2]

$$\begin{aligned} y_t = E_t y_{t+1} - (\tau + \mu)(R_t - E_t \pi_{t+1} - \rho_z z_t) - \alpha(\tau + \mu) E_t \Delta q_{t+1} \\ + \alpha(2-\alpha)\tfrac{1-\tau}{\tau} E_t \Delta y^*_{t+1}, \end{aligned} \quad (1)$$

where α is the share of imported goods in consumption, τ is the intertemporal elasticity of substitution, and $\mu = \alpha(2-\alpha)(1-\tau)$. Intertemporal optimization of households results in consumption smoothing. Current values for consumption and thus output depend on their expected future realizations as well as the opportunity cost of current consumption in terms of foregone savings, the expected real interest rate $R_t - E_t \pi_{t+1}$. Furthermore, the rate of change in the terms of trade Δq_t, the relative price of imports in terms of exports, affects domestic output via the substitution of domestic for foreign goods. z_t is the growth rate of the global technology process, reflecting the non-stationary part of domestic as well as foreign output y^*_t. ρ_z is the degree of its autoregressive process.

Firms set their prices in the manner of Calvo (1983). Each period, only a random fraction of $(1-\theta)$ firms adjust their prices to their optimal values in terms of profit maximization. Because the set price is likely to be fix for some periods, firms take into account expected future price levels in the current price setting. For the aggregate economy's price level, it follows that:

$$\pi_t = \beta E_t \pi_{t+1} + \alpha \beta E_t \Delta q_{t+1} + \alpha \Delta q_t + \frac{\kappa}{\tau + \mu} y_t + \frac{\kappa + \mu}{\tau(\tau + \mu)} y^*_t, \quad (2)$$

where β is a discount parameter and $\kappa = (1-\theta)(1-\theta\beta)/\theta$ is a measure of the degree of price rigidity dependent on the Calvo parameter θ. The impact of import prices on consumer price inflation is captured by the dynamics of the terms of trade. The last two factors describe the impact of the degree of capacity utilization on the price level.

Domestic and foreign inflation, the terms of trade, and the depreciation of the nominal exchange rate are linked under the assumption of purchasing power parity:

$$\Delta e_t = \pi_t - (1-\alpha)\Delta q_t - \pi_t^*. \quad (3)$$

Monetary policy is characterized by a Taylor (1993)-type rule. The central bank sets the nominal interest rate R_t in reaction to movements in the inflation rate, output, and the nominal exchange rate depreciation:

$$R_t = \rho_R R_{t-1} + (1-\rho_R)(\psi_1 \pi_t + \psi_2 y_t + \psi_3 \Delta e_t) + \epsilon_t^R. \quad (4)$$

The remaining model variables, the terms of trade, technology, foreign output, and inflation are assumed to follow AR(1) processes in logs:

$$\Delta q_t = \rho_q \Delta q_{t-1} + \epsilon_t^q, \quad (5)$$

$$z_t = \rho_z z_{t-1} + \epsilon_t^z, \quad (6)$$

$$y_t^* = \rho_{y^*} y_{t-1}^* + \epsilon_t^{y^*}, \quad (7)$$

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \epsilon_t^{\pi^*}, \quad (8)$$

with $\epsilon_t^x \sim NID(0, \sigma_x^2)$ for $x \in \{q, z, y^*, \pi^*\}$.

4. ESTIMATION

4.1. Regime Switching

To detect and quantify changes in the conduct of monetary policy following the official implementation of a new target and to assess its contribution to the favorable development of important macroeconomic variables thereafter, the estimated model specification allows for regime switches. Following the notation in Alstadheim et al. (2013), the model presented above can be expressed in a general Markov-switching rational expectations model form:

$$E_t \left\{ A_{s_{t+1}}^+ x_{t+1}(\bullet, s_t) + A_{s_t}^0 x_t(s_t, s_{t-1}) + A_{s_t}^- x_{t-1}(s_{t-1}, s_{t-2}) + B_{s_t}\epsilon_t \right\} = 0, \quad (9)$$

where x_t is a vector of endogenous variables and ϵ_t a vector of exogenous shocks. The superscripts $+$, 0, and $-$ of the coefficient matrices A refer to future, current, and past variables, respectively. The latent variable s_t is an exogenous stochastic process $s_t \in \{1, \ldots, M\}$ with M being the number of regimes that a Markov chain is allowed to follow. For $M = 2$, the corresponding transition probabilities describing the likelihood of being in a particular state today, conditional on the state in the previous period, are given by:

$$\Pr[s_t = 1 \mid s_{t-1} = 1] = p_{11}, \quad (10)$$

$$\Pr[s_t = 2 \mid s_{t-1} = 1] = p_{12}, \quad (11)$$

$$\Pr[s_t = 1 \mid s_{t-1} = 2] = p_{21}, \quad (12)$$

$$\Pr[s_t = 2 \mid s_{t-1} = 2] = p_{22}. \quad (13)$$

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The matrix of transition probabilities for a two-state Markov chain can then be written as:

$$P = \begin{bmatrix} p_{11} & p_{11} \\ p_{21} & p_{22} \end{bmatrix}. \tag{14}$$

When forming expectations about the future, agents explicitly take into account the transition probabilities, since a switch to another regime in the following periods would result in different parameter values, thereby altering the dynamics of the model variables. Expectations about the next period's values of the endogenous variables in (9) are hence a combination of their state-dependent values and the respective state probabilities. Thus, for the two-state case and following the notation in (9):

$$E_t A^+_{s_{t+1}} x_{t+1}(\bullet, s_t) \equiv A^+_{s_{t+1}} \sum_{s_{t+1}=1}^{2} p_{s_t, s_{t+1}} E_t x_{t+1}(s_{t+1}, s_t). \tag{15}$$

The system is solved according to the Newton method outlined in Maih (2015), an extension of the minimum state variables solution proposed by Farmer et al. (2011), and estimated by means of Bayesian techniques using the RISE toolbox for MATLAB. However, due to the introduction of Markov-switching parameters and their unobserved states, the standard Kalman filter cannot be applied to compute the value of the likelihood, since it would take into account all possible combinations of Markov states in the past. Instead, an algorithm proposed by Kim and Nelson (1999) is adopted that approximates the Kalman filter by limiting the number of states that is carried forward at each period, so that the Kalman filter becomes workable.

Along with the benchmark model M_0 with time-invariant parameters and shocks, four alternative specifications are estimated. M_1 allows for switches in the parameters of the interest rate rule, while M_2 is characterized by two regimes for the exogenous shocks. M_3 and M_4 combine the latter two specifications by allowing the policy parameters and the shocks to switch simultaneously. Whereas M_3 is characterized by one common Markov chain, M_4 sets up two independent chains for policy parameters and volatility separately. The estimation of different model specifications is motivated to test for the possibility that monetary policy parameters and/or shock volatilities have not changed over the observation sample. Instead of a priori defining the set of time-variant parameters, the approach allows picking the specification for further analysis that is best supported by the underlying data.

Since the estimation is supposed to quantify general changes in the conduct of monetary policy, irrespective of whether systematic or nonsystematic in nature, the error term of the Taylor rule is treated as a policy parameter, and thus follows the same Markov chain as the degree of interest rate smoothing and the three reaction coefficients. In doing so, this work differs from similar analyses such as in Chen and MacDonald (2012) or Alstadheim et al. (2013) that treat ϵ_t^R in the same way as the remaining four disturbances.

4.2. Data

The following five quarterly time series are used for estimation: log difference of real gross domestic product multiplied by 100 (ΔGDP_t), log difference of the consumer price index multiplied by 400 (ΔCPI_t), log difference of the terms of trade and the nominal effective exchange rate (NEER) index multiplied by 100 (ΔTOT_t and $\Delta NEER_t$), and the 3-month interbank rate (INT_t). The estimation sample ranges from 1994 until 2013.

Given the stationary nature of the model, observables are required to be stationary as well. For advanced economies, in general, the variables described are $I(0)$ and could thus enter the model without any further transformation. As outlined in Section 2, however, the economies under consideration in this paper have been particularly characterized by episodes of high inflation (and consequently high nominal interest rates) at the beginning of their transition period. Both rates remarkably decreased over the remaining estimation sample. To render the variables stationary, additional transformations are required that remove the underlying downward trends in the data.

Commonly used statistical filter techniques, however, cannot be applied due to their two-sided nature in the context of DSGE models. Instead, the observable time series are detrended by means of a one-sided Hodrick–Prescott (HP) filter [Stock and Watson (1999)]. While being strictly backward looking, the method is able to adequately capture the mentioned downward trends over time. For reasons of consistency, as argued among others by Pfeifer (2018), all variables are filtered identically. The (demeaned) cyclical components of the abovementioned time series are then linked to the model variables via the following measurement equation:

$$\begin{bmatrix} \Delta GDP_t \\ \Delta CPI_t \\ INT_t \\ \Delta NEER_t \\ \Delta TOT_t \end{bmatrix} = \begin{bmatrix} \Delta y_t \\ 4\pi_t \\ 4R_t \\ \Delta e_t \\ \Delta q_t \end{bmatrix}. \tag{16}$$

It is important to note that, in contrast to constant-parameter models, the HP filtering of observable time series used for estimation is not without consequences in a regime-switching framework. This issue seems to be particularly relevant for the expectational effects of policy shifts, since filtering removes trends and/or shifts in the levels of the data that might have an effect on the behavior of agents and their expectations. The model framework used in this paper, however, does not feature the possibility to introduce shifts in the levels of the variables and/or to explain their underlying trends which would in turn affect their steady states and steady-state ratios. While this is a drawback, it is important for the tractability of the framework, as methods to deal with multiplicity of steady states in the MS-DSGE framework are not widely available. Overall, detrending the observable time series by means of a one-sided HP filter constitutes a fair approach to deal with the non-stationary nature of the data given the simplistic model structure.

4.3. Priors

The choice of priors and standard deviations of shocks (Table A.1) is guided by Lubik and Schorfheide (2007) and the methodologies described therein. For the price rigidity parameter κ and the intertemporal substitution elasticity parameter τ, the prior means are both set at 0.5 with large standard deviations, respectively. The latter is restricted to the interval from 0 to 1 to avoid singularity at $\tau = 1$. Identical priors are also set for the steady-state interest rate $\bar{R}$ that is linked to the discount factor β according to $\beta = \exp(-\bar{R}/400)$ at a mean of 2.5 and a standard deviation of 1. Priors for the import shares are set so as to match the respective ratios of imports to GDP over the sample. For the Czech Republic and Hungary (0.6 and 0.7), these are nearly twice as large as the Polish equivalent (0.35).

Prior beliefs for the AR(1) coefficients of foreign output, foreign inflation and technology, and the respective shock innovations are based on pre-sample estimates of AR(1) processes of the ratio of US to German GDP, German inflation, and German GDP, respectively.[3] The priors for the AR(1) coefficients are centered at 0.3 (technology) and 0.8 (foreign output and inflation). Priors for the respective standard deviations of innovations are set to 0.6, 1.5, and 0.4. Given that due to the unavailability of data, no pre-sample estimated can be conducted for the dynamics of the terms of trade, I refer to the average values in Lubik and Schorfheide (2007). The priors for the AR(1) coefficient are centered around 0.3, whereas the priors for the standard deviations of the shocks are set to 2.

Standard priors are chosen for the parameters of the monetary policy rule: the priors for the reaction parameter to inflation are centered around 1.5, the other two around 0.25, whereas the prior means for the AR coefficient are set to 0.5. For all of the aforementioned parameters, sufficiently large standard deviations are chosen. Finally, the priors for the transition probabilities are set in a way to allow for multiple backward and forward regime switches.

5. RESULTS

5.1. Regime Identification

A comparison of the log marginal data densities of the different estimated model specifications points to a clear inferiority of the time-invariant parameters model compared to the regime-switching specifications (Table 2). Model M_1, only allowing for switches in the parameters of the policy rule, also fits the observed data rather badly in all three economies. To put it differently, models that feature regime-switching shocks outperform those that assume time invariance in the severity of disturbances hitting the economy. For the Czech Republic and Poland, model M_4 fits the data best. For Hungary, specification M_2 is preferred by the data.

TABLE 2. Log marginal data densities of different model specifications

		Czech Rep.	Hungary	Poland
Time invariant	M_0	−831.42	−781.25	−958.75
Policy parameters only	M_1	−744.44	−772.30	−946.00
Volatility only	M_2	−789.81	**−756.95**	−929.57
Policy parameters and volatility (one chain)	M_3	−732.89	−760.82	−952.36
Policy parameters and volatility (two chains)	M_4	**−724.67**	−758.51	**−907.47**

Note: Bold values indicate the respective best-fit model specification.

In other words, the occurrence of two distinct volatility regimes is supported by the underlying data for all three economies, whereas shifts in the conduct of monetary policy can only be identified for the Czech Republic and Poland. Unless otherwise stated, I will refer to the results of the respective best-fit specification for each economy in the remainder of the paper.

Czech Republic. For the Czech Republic, the estimation reveals periods of different monetary policy regimes as well as episodes of high and low volatility (Figure 1). As concerns monetary policy, the two regimes are characterized by low and high responses to inflation rate dynamics and more particularly the size of the nonsystematic component, measured by the error term ϵ_t^R, that is substantially lower under the high-inflation response regime (Table A.2). The smoothed probabilities of being in either of the two policy regimes suggest that the more recent strategy (high inflation response) has been in place since the year 2000, and thus around 2 years after the official implementation of IT. However, the results do not clearly point at an exclusive presence of the other regime in the years before. In particular, during 2 years in the mid-1990s, the smoothed probability of being in the high inflation response regime is as high as it was from 2001 onwards.

One potential explanation for this finding could be that regime identification is to some extent also driven by the size of the error term in the policy rule. This is supported by the fact that the widening of the exchange rate band from May 1997 onwards is associated with the more volatile policy regime. In that sense, Czech monetary policy did not increase its attention to inflation dynamics. More importantly, the CNB seems to have conducted a more systematic, rule-based policy after the turn of the millennium. By the same token, it became also less volatile as the much larger degree of interest rate smoothing compared to the former strategy suggests. Estimation results further reveal that the reactions of the CNB to movements of the exchange rate have decreased by more than half following the strategy change. However, the estimated small absolute size of the respective reaction coefficient also under the exchange rate targeting strategy does not hint at a stabilization of the koruna's external value via the policy rate alone. Rather, direct interventions on the foreign exchange market seem to have been important as well. Output stabilization, on the other hand, is estimated to have received a larger attention under the more recent regime.

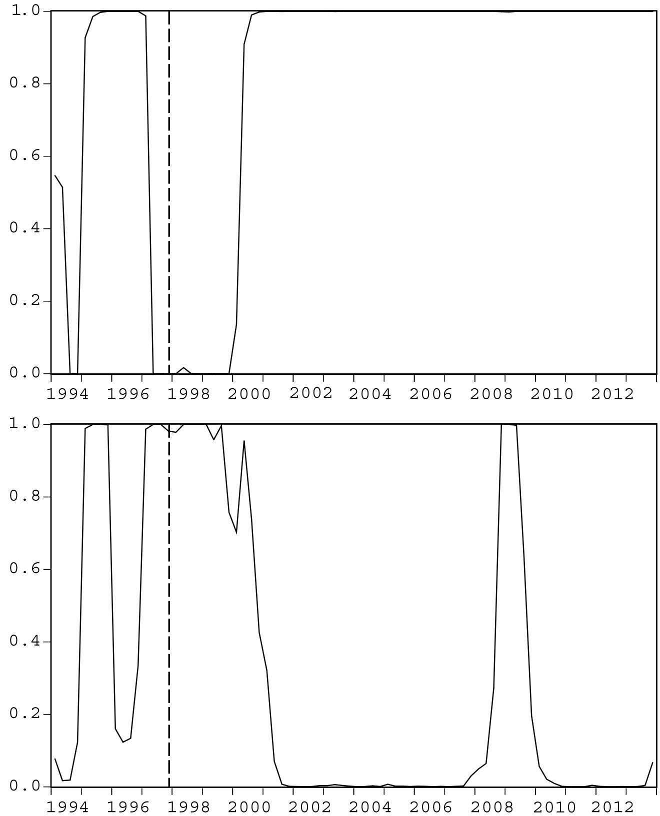

FIGURE 1. Smoothed regime probabilities in the Czech Republic for the high-inflation response (upper) and high-volatility (lower) regimes according to M_4. The vertical dashed lines mark the official introduction of IT.

As concerns the volatilities of shocks that hit the Czech economy, estimation results suggest that the country was in the high-volatility regime during the 1990s, and in the low-volatility regime for the most time thereafter. Apart from the financial crisis that started to erupt in the second half of 2007, the Czech Republic has remained in the low-volatility regime since the year 2000. The sizes of the shocks vary substantially between the two identified regimes. All four are on average more than twice as large in the more turbulent environment.

The overall higher persistence of the current policy and volatility regimes compared to their former counterparts are expressed in substantially lower transition probabilities.

Hungary. For Hungary, the estimation does not identify switches between different monetary policy strategies. This result points to the conclusion that the MNB's policy has not substantially changed over the estimation sample and,

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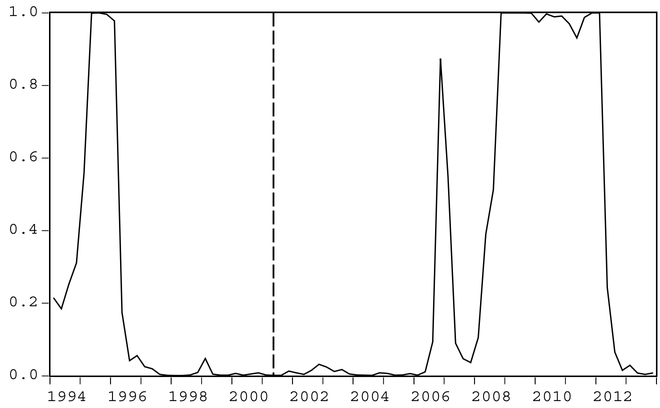

FIGURE 2. Smoothed regime probability in Hungary for the high-volatility regime according to M_2. The vertical dashed line marks the official introduction of IT.

in particular, after the official implementation of IT. This finding can probably be best explained by the ongoing effort of the MNB to stabilize the forint's exchange rate under the IT regime [IMF (2015)]. This explanation is supported by the results of the second-best-fit specification (M_4) allowing for policy regime switches. According to the estimates, the interest rate reaction to exchange rate movements is nearly identical under both regimes, and hence over the whole sample.

Estimation results of the best-fit specification (M_2) suggest that the MNB reacted rather weakly to inflation over the whole sample, in fact violating the Taylor principle, and thus casting doubt about an appropriate implementation of IT (Table A.3). Besides the continuing exchange rate management, obstacles to a more effective and systematic conduct of monetary policy can probably be found in institutional factors. In particular, these include frequent changes to the legal framework of the MNB, which may have had an impact on its governance [ECB (2008)]. More recently, also political efforts to undermine the independence of the MNB may have played a role [ECB (2011)].

As concerns the volatility of external shocks, the estimation reveals two distinct regimes (Figure 2). In contrast to the Czech Republic, the smoothed regime probabilities suggest that the Hungarian economy has been in the low-volatility regime for most of the 1990s. The high-volatility regime, on the other hand, is particularly associated with the financial crisis and its aftermath. Different from the other two economies, the high-volatility episode around the Great Recession lasted much longer in Hungary. This result suggests that the economy has been hit particularly hard by the global financial market turbulences and its real economic consequences.

Poland. For Poland, the estimation reveals a regime switch in the conduct of monetary policy around the year 2002, as well as different episodes of high and low volatility (Figure 3). Therefore, a *de facto* policy change occurred about 4 years after the official introduction of IT. Similar to the Czech Republic, the more recent policy strategy is characterized by a higher attention to inflation, a higher degree of interest rate smoothing, and a lower volatility of the shock term in the Taylor rule (Table A.4). Thus, the results suggest that the NBP also moved to a more systematic, rule-based IT. Its focus on the stabilization of the exchange rate and particularly output, on the other hand, has remarkably decreased. Smoothed regime probabilities suggest that during the Great Recession, the NBP somewhat adapted its policy to the more turbulent environment. In particular, it lowered the policy rate more strongly than implied by the estimated policy rule under the IT regime.

Apart from that, the Polish economy has experienced a rather calm macroeconomic environment since 2004. Compared to the high-volatility regime that was previously in place, shock volatilities decreased substantially. Their relative reduction is larger than for the Czech and Hungarian economies.

5.2. Policy Evaluation

As the estimation results suggest, monetary policy in the Czech Republic and Poland changed following the official introduction of IT. The more recent policy regimes are each characterized by a higher attention to inflation and, in general, a more systematic setting of the policy rate. Nearly at the same time, the volatilities of shocks have remarkably decreased. In most of the quarters under consideration, the high-inflation response regimes have been in place when the respective economy has been in the low-volatility regime, and vice versa. Only a few periods have been identified in which the low-inflation response regime was operating in a low-volatility setting or the high-inflation response strategy in a high-volatility environment, respectively. The combination "high-inflation response/low volatility" is the regime combination that has prevailed recently.

In both countries, the magnitudes of shocks hitting the economy have substantially decreased over time, which facilitated the conduct of monetary policy. Thus, it remains unclear whether the favorable macroeconomic performances outlined in Section 2 can be seen as a result of the strategy changes or because of a more favorable environment. Hence, for a correct assessment of the monetary policy performances, the different settings have to be correctly accounted for. Therefore, simulations are conducted for different combinations of policy and volatility regimes. The current monetary policy serves as a benchmark in facing the current small-sized shocks to foreign output, foreign inflation, the terms of trade, and technology. The impacts of disturbances on the volatilities of model variables are quantified and compared to a scenario in which the current policy is confronted with the former, highly volatile environment, a setup in which the old monetary policy regime faces the lower disturbances of the more recent years, and the old policy in the former high-volatility environment.

To accurately account for policy changes and the regimes of high and low volatility, the two economies are analyzed based on the estimation results of the

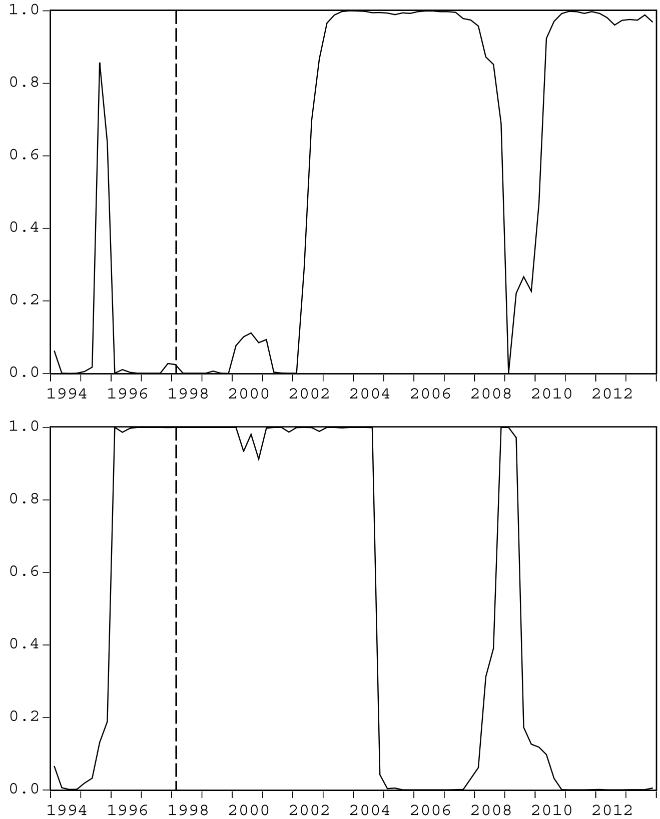

FIGURE 3. Smoothed regime probabilities in Poland for the high-inflation response (upper) and high-volatility (lower) regimes according to M_4. The vertical dashed lines mark the official introduction of IT.

model specification M_4 in which policy and volatility switches occur independently from each other. Shocks and model parameters, including the coefficients of the monetary policy rule, are set to their respective posterior modes. The calibrated models are simulated over 10,000 periods, dropping the first 3000 observations.

Based on the simulation results, the extents to which the efforts of monetary authorities ("good policy") and the smoother macroeconomic environment ("good luck") have contributed to the favorable development of target variables are assessed. A central bank is considered to have had "good luck" when the old policy strategy was equally effective, in terms of unconditional variances of model variables, as the strategy in place when facing the same environment. Lower unconditional variances and effects on particular variables under the more recent strategy in the presence of equal-sized shocks would point at a "good policy," with the current regime being able to better handle disturbances of the same intensity.

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TABLE 3. Unconditional simulated standard deviations of model variables following one-standard deviation shocks under different policy and volatility regime combinations

	Low Volatility		High Volatility	
	High Inflation Response	Low Inflation Response	High Inflation Response	Low Inflation Response
	Czech Republic			
y	0.6427	0.6413	1.6172	1.6145
π	0.4570	1.3274	1.1550	3.3351
R	0.2182	1.2119	0.5488	3.0468
Δe	1.7357	2.1045	4.0023	5.0224
	Poland			
y	1.9629	1.9506	16.0976	15.9958
π	0.1712	0.2424	1.4088	1.9874
R	0.0581	0.1637	0.4829	1.3553
Δe	10.8665	10.8690	73.4618	73.6138

Czech Republic. In the Czech Republic, the current monetary policy regime that is characterized by a higher attention to inflation dynamics has led to remarkably lower volatilities for most of the domestic variables in the model (Table 3). Simulation results show that the unconditional standard deviations of inflation, the interest rate, and the exchange rate in response to standardized shocks are all smaller under the more recent policy strategy compared to the previous one. The former regime is clearly outperformed with respect to the variances of inflation and the interest rate, which can mostly be explained by the much higher degree of interest rate smoothing. The impact on both variables under the more recent strategy is even lower in the high-volatility regime compared to the former policy in the low-volatility environment, providing strong evidence that "good policy" rather than "good luck" was responsible for the reduction in the respective volatilities. Assuming a preference for some exchange rate stability, the lower attention to it (as implied by a lower respective Taylor rule coefficient) has not led to a higher volatility, but rather a lower volatility in the presence of all considered shocks. Hence, it was not the departure from exchange rate targeting, but rather external shocks, in particular, crisis episodes that led to the higher exchange rate volatility shown in Table 1. The variance of output is virtually identical under both regimes in response to equal-sized disturbances, despite an increase in the respective Taylor rule coefficient.

Impulse responses for the different variables and shocks are shown in Figure 4. According to them, the Czech economy, in particular, has become much less prone to foreign output and inflation shocks.

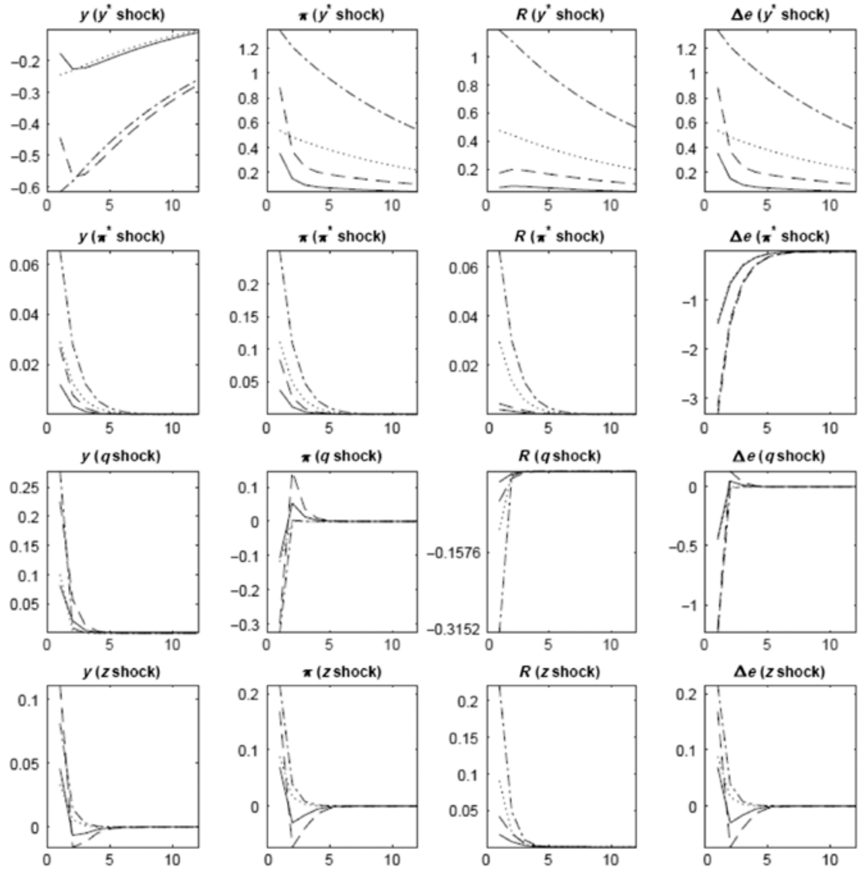

FIGURE 4. Impulse responses for the Czech Republic to one-standard deviation shocks under the following regime combinations: high-inflation response/low volatility (solid), high-inflation response/high volatility (dashed), low-inflation response/low volatility (dotted), and low-inflation response/high volatility (dash–dot).

Poland. Simulations for Poland reveal a superiority of the current policy regime compared to the former regime with regard to the stabilization of inflation and the interest rate (Table 3). Compared to the Czech Republic, however, the relative reduction in the unconditional variances of both variables in response to equal-sized shocks is smaller following the regime switch. This finding can be explained by a relatively high reaction coefficient to inflation and a high degree of interest rate smoothing already under the former regime. Their increase under the recent strategy was therefore smaller than in the Czech case. On the other hand, the impact of shocks on inflation and the interest rate had already been low. In general, their variances have been lower independent of the policy regime, even though the standard deviations of the shocks hitting the economy are estimated to

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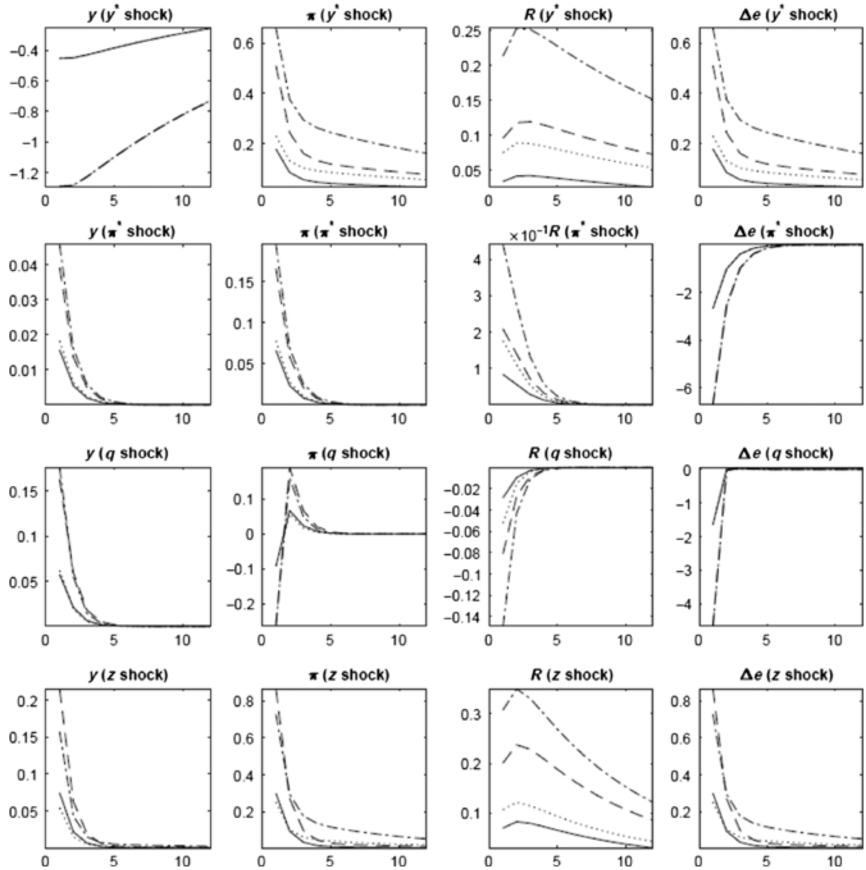

FIGURE 5. Impulse responses for Poland to one-standard deviation shocks under the following regime combinations: high-inflation response/low volatility (solid), high-inflation response/high volatility (dashed), low-inflation response/low volatility (dotted), and low-inflation response/high volatility (dash–dot).

be larger than for the Czech Republic. Although not fully comparable, this points to a lower sensitivity of Polish inflation to (external) disturbances and, therefore, to a relative stability of the prime policy target. In that sense, the NBP further improved its already "good policy" by further increasing its attention to inflation dynamics and conducting a more systematic monetary policy. Fostered by a smoother macroeconomic environment from 2004 onwards, this finding is in line with the significantly lower volatility of Polish inflation after the introduction of IT, as outlined in Section 2. At the same time, other potential target variables did not become more volatile. The effects of equal-sized shocks on output and the exchange rate are virtually identical for both policy regimes, despite smaller estimated reaction parameters to both variables under the current strategy.

Impulse responses for the different variables and shocks are shown in Figure 5. According to them and similar to the Czech case, Polish inflation has particularly become less prone to foreign output and inflation shocks.

6. CONCLUSIONS

In a simple Markov-switching small open economy framework, this paper analyzes the extent to which monetary policy that followed the official implementation of IT as a new monetary policy strategy in the Czech Republic, Hungary, and Poland has contributed to the subsequent, observed reduction in the volatilities of target variables. For the Czech Republic and Poland, the estimation reveals actual switches from low- to high-inflation response regimes and, in general, a more systematic monetary policy that goes along with a reduction in the volatility of shocks hitting the economies. The consideration of exchange rate movements in the conduct of monetary policy decreased only slightly for both central banks, more sharply for the CNB. Finally, the smoothed regime probabilities suggest that the actual switch to a new policy strategy occurred well after the *de jure* implementation of IT. For Hungary, a systematic change in the conduct of monetary policy following the implementation of IT is not supported by the underlying data, mainly reflecting the continuing exchange rate management by the MNB.

Simulations of the model calibrated to allow the different policy regimes to operate under identical conditions characterized by equal-sized shocks point to the success of monetary policy in the Czech Republic and Poland in stabilizing inflation in recent years. The reduction in the volatility of output, on the other hand, is to a larger extent attributable to the decrease in the magnitude of external shocks. Finally, simulation results do not point to the policy of the Czech and Polish central banks having contributed to the observed increased volatilities of their respective exchange rates. This finding can instead be explained by the discrepancies in the *de jure* and *de facto* implementations of the new policy strategy, as well as the volatile period of the financial crisis.

NOTES

1. According to the IMF, “[v]arious pegs and crawling pegs [remained in place] until 2008," and thus well after the official introduction of IT, “arguably to prevent the revaluation of foreign currency denominated loans in case of excessive exchange rate volatility" [IMF (2015)].

2. For the specification of the IS curve, I follow its explicit derivation in the model version of Del Negro and Schorfheide (2009), according to which the technology process ($\rho_z z_t$) is multiplied by the same factor as the expected real interest rate ($R_t - E_t\pi_{t+1}$).

3. Due to data availability, I differ from Lubik and Schorfheide (2007) who fit AR(1) processes to the ratio of US to domestic GDP as well as to domestic GDP in forming prior beliefs for the foreign output and technology processes. The rationale behind their methodology is, however, not violated by my choice of the dependent variable.

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APPENDIX A

TABLE A.1. Prior distributions

		Czech Rep.		Hungary		Poland	
	Dens.	Mean	S.d.	Mean	S.d.	Mean	S.d.
$\bar{R}$	G	2.50	1.00	2.50	1.00	2.50	1.00
α	B	0.60	0.05	0.70	0.05	0.35	0.05
τ	B	0.50	0.20	0.50	0.20	0.50	0.20
κ	G	0.50	0.25	0.50	0.25	0.50	0.25
ψ_1	G	1.50	0.50	1.50	0.50	1.50	0.50
ψ_2	G	0.25	0.15	0.25	0.15	0.25	0.15
ψ_3	G	0.25	0.15	0.25	0.15	0.25	0.15
ρ_R	B	0.50	0.25	0.50	0.25	0.50	0.25
ρ_q	B	0.30	0.15	0.30	0.15	0.30	0.15
ρ_z	B	0.30	0.15	0.30	0.15	0.30	0.15
ρ_{y^*}	B	0.80	0.10	0.80	0.10	0.80	0.10
ρ_{π^*}	B	0.80	0.10	0.80	0.10	0.80	0.10
σ_R	InvG	0.50	4.00	0.50	4.00	0.50	4.00
σ_q	InvG	2.00	4.00	2.00	4.00	2.00	4.00
σ_z	InvG	0.60	4.00	0.60	4.00	0.60	4.00
σ_{y^*}	InvG	1.50	4.00	1.50	4.00	1.50	4.00
σ_{π^*}	InvG	0.40	4.00	0.40	4.00	0.40	4.00
P_{12}	B	0.10	0.05	0.10	0.05	0.10	0.05
P_{21}	B	0.10	0.05	0.10	0.05	0.10	0.05
Q_{12}	B	0.10	0.05	0.10	0.05	0.10	0.05
Q_{21}	B	0.10	0.05	0.10	0.05	0.10	0.05

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TABLE A.2. Estimation results for the Czech Republic according to model specification M_4.

	Prior			Posterior									
	Dens.	Mean	S.d.	Mode	S.d.	Mode	S.d.	Mode	S.d.	Mode	S.d.	Mode	S.d.
$\bar{R}$	B	2.50	1.00	2.1288	1.0018								
α	B	0.60	0.05	0.5095	0.0617								
τ	B	0.50	0.20	0.5330	0.0528								
κ	G	0.50	0.25	1.9342	0.4648								
ψ_1	G	1.50	0.50			0.9431	0.1400	1.2507	0.2134				
ψ_2	G	0.25	0.15			0.1759	0.1322	0.2698	0.0828				
ψ_3	G	0.25	0.15			0.0564	0.0365	0.0260	0.0171				
ρ_R	B	0.50	0.25			0.0396	0.0078	0.8303	0.0453				
ρ_q	B	0.30	0.15	0.0160	0.0083								
ρ_z	B	0.30	0.15	0.2066	0.0765								
ρ_{y^*}	B	0.80	0.10	0.9225	0.0256								
ρ_{π^*}	B	0.80	0.10	0.4407	0.0869								
σ_R	IG	0.50	4.00			1.1560	0.2085	0.0947	0.0103				
σ_q	IG	2.00	4.00							1.8589	0.22739	0.6707	0.0742
σ_z	IG	0.60	4.00							1.2447	0.16201	0.5106	0.0646
σ_{y^*}	IG	1.50	4.00							1.0224	0.2176	0.4071	0.0588
σ_{π^*}	IG	0.40	4.00							3.4097	0.48877	1.5148	0.1518
p_{12}	B	0.10	0.05	0.0860	0.0855								
p_{21}	B	0.10	0.05	0.0183	0.0216								
q_{12}	B	0.10	0.05	0.0860	0.0855								
q_{21}	B	0.10	0.05	0.0624	0.0236								

Note: For the regime-switching parameters, the results in the right two columns refer to the high-inflation response and low-volatility regime, respectively.

TABLE A.3. Estimation results for Hungary according to model specification M_2.

	Prior			Posterior					
	Dens.	Mean	S.d.	Mode	S.d.	Mode	S.d.	Mode	S.d.
$\bar{R}$	B	2.50	1.00	2.0910	0.7207				
α	B	0.70	0.05	0.5749	0.0559				
τ	B	0.50	0.20	0.6045	0.0662				
κ	G	0.50	0.25	2.2885	0.3028				
ψ_1	G	1.50	0.50	0.9574	0.0758				
ψ_2	G	0.25	0.15	0.2150	0.1167				
ψ_3	G	0.25	0.15	0.0725	0.0318				
ρ_R	B	0.50	0.25	0.5834	0.0793				
ρ_q	B	0.30	0.15	0.0550	0.0413				
ρ_z	B	0.30	0.15	0.1348	0.0719				
ρ_{y^*}	B	0.80	0.10	0.9503	0.0243				
ρ_{π^*}	B	0.80	0.10	0.3704	0.0754				
σ_R	IG	0.50	4.00	0.3293	0.0434				
σ_q	IG	2.00	4.00			1.3117	0.2429	0.9132	0.1628
σ_z	IG	0.60	4.00			1.0954	0.1739	0.3829	0.1181
σ_{y^*}	IG	1.50	4.00			0.5520	0.1731	0.3877	0.1072
σ_{π^*}	IG	0.40	4.00			4.2276	0.4385	1.6070	0.2094
q_{12}	B	0.10	0.05	0.0602	0.0263				
q_{21}	B	0.10	0.05	0.1077	0.0478				

Note: For the regime-switching parameters, the results in the right two columns refer to the low-volatility regime.

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TABLE A.4. Estimation results for Poland according to model specification M_4.

	Prior			Posterior									
	Dens.	Mean	S.d.	Mode	S.d.	Mode	S.d.	Mode	S.d.	Mode	S.d.	Mode	S.d.
$\bar{R}$	B	2.50	1.00	2.0923	4.1013								
α	B	0.35	0.05	0.1767	0.0485								
τ	B	0.50	0.20	0.1952	0.1440								
κ	G	0.50	0.25	1.2557	0.2748								
ψ_1	G	1.50	0.50			1.5213	0.2028	1.6928	0.5372				
ψ_2	G	0.25	0.15			0.1725	0.1041	0.1226	0.0393				
ψ_3	G	0.25	0.15			0.0431	0.0329	0.0402	0.0659				
ρ_R	B	0.50	0.25			0.7354	0.0554	0.8681	0.0476				
ρ_q	B	0.30	0.15	0.0452	0.0812								
ρ_z	B	0.30	0.15	0.8929	0.0765								
ρ_{y^*}	B	0.80	0.10	0.9433	0.0490								
ρ_{π^*}	B	0.80	0.10	0.3820	0.2926								
σ_R	IG	0.50	4.00			0.3346	0.1321	0.0779	0.0163				
σ_q	IG	2.00	4.00							5.3629	0.6077	1.8827	0.3793
σ_z	IG	0.60	4.00							0.2966	0.1734	0.1026	0.0287
σ_{y^*}	IG	1.50	4.00							1.0493	0.9285	0.3664	0.4314
σ_{π^*}	IG	0.40	4.00							6.8851	0.9943	2.7472	0.2811
p_{12}	B	0.10	0.05	0.0617	0.0430								
p_{21}	B	0.10	0.05	0.0733	0.0499								
q_{12}	B	0.10	0.05	0.0727	0.0323								
q_{21}	B	0.10	0.05	0.0598	0.1272								

Note: For the regime-switching parameters, the results in the right two columns refer to the high-inflation response and low-volatility regime, respectively.

APPENDIX B

FIGURE B.1. Smoothed regime probabilities (best-fit specification) and observable time series used for estimation for the Czech Republic (left), Hungary (middle), and Poland (right). Details on the original variables and its transformations are provided in Section 4.2.

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