Exchange Rate Dynamics and its Effect on Macroeconomic Volatility in Selected CEE Countries

Volha Audzei and František Brázdik *

Abstract

Structural asymmetries between the countries and loss of exchange rate and monetary policy adjustment channels are important aspects to consider when forming a monetary union. In this paper we study the role of the structural shocks in generating macroeconomic volatility for selected Central and East European countries, existing and potential members of Eurozone. We use two country structural VAR models identified by the sign restriction. Our findings suggest that there are structural asymmetries both within the group CEE countries and with their Euro area counterparts. We assess the dynamic properties of macro-variables and examine if the exchange rate could be considered as a shock-absorber. We identified countries, where shocks are predominantly symmetric relative to the neighbor, as well as countries with strong contribution of real exchange rate shocks. In general, for all considered countries the shock absorbing nature of real exchange rate can be suggested. Finally, the significant role of the symmetric monetary policy shocks for movement in real exchange rate is found for some of the countries.

JEL Codes: C32, E32, F31, F41.

Keywords: Sign restrictions, Real exchange rates, Structural vector autoregression, Monetary union, Central and Eastern Europe.

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1. Introduction

Several countries from large pool of CEE accession countries recently joined Economic and Monetary Union, will probably join EMU in the near future or are facing the choice to join the Eurozone. A key assumption of the Optimal Currency Area (OCA) theory is that the exchange rate provides the means of absorbtion of the idiosyncratic shocks. According to this theory, the members of OCA should experience similar movements of the business cycle. As when differences in cyclical situations of members are present, a single stance of monetary policy is then sub-optimal for the individual countries when common currency or exchange rate peg is adopted as the monetary regime. Also, when losing nominal exchange rate as an adjustment mechanism, the adjustment role of real exchange rate becomes more important.

The aim of this work is to assess the theoretical properties of the exchange rate as stabilization mechanism for the macroeconomic volatility. We investigate the extent to which the symmetric and asymmetric shocks drive the business cycles in the selected CEE countries. As the theoretical role of exchange rate for for business cycles volatility depends on the relative importance of symmetric and asymmetric shocks. Only if shocks are predominantly asymmetric is the exchange rate needed to absorb such shocks.

Our work focuses on a group of Central and Eastern Europe (CEE) countries (Czech Republic, Slovakia, Poland, Hungary, Lithuania, Latvia, Estonia, Slovenia, Bulgaria and Romania), where some of them are already members of the Eurozone and some are obliged to enter Eurozone in the future as members of European Union.

This analysis is motivated by the theoretical role of the real exchange rate as an important adjustment mechanism available in the presence of asymmetries (for empirical of asymmetries presence for core Eurozone see Berka et al. 2012 and Berka et al. 2014). This adjustment mechanism is important also for countries within Eurozone as these countries either adopted common currency or fixed it nominal exchange rate and the monetary policy is centrally decided by ECB. However, there exist economies such the real exchange rate could itself be a source of shocks that are driving macroeconomic volatility. Therefore, we focus on the importance of asymmetric and real exchange rate shocks for considered countries.

We contribute to the discussion by studying the relative importance of symmetric and asymmetric shocks in the selected CEE countries, as well as their frequency in the data. We further decompose historical movements in model variables to look into historical contribution of each shock to a country's business cycle. Our analysis follows with the decomposition of the variance of the model's variables with focus on the contribution of the real exchange rate shocks to business cycle volatility.

Our work extends and refers to recent works on the role of the exchange rate for the business cycle fluctuations. Theoretical background for the structural model is setup in the seminal paper by Clarida and Gali (1994), where the the importance of nominal shocks in real exchange rate fluctuations is questioned. Clarida and Gali (1994) claim that a demand shock is able to explain most of the variance in the real exchange rate, which was therefore claimed to be a shock absorber. Recent work by Juvenal (2011) these findings and extend them with statement that demand shocks are also important for generating real exchange rate fluctuations. Authors such as Rogers (1999), Eichenbaum and Evans (1995), and Bluedorn and Bowdler (2005) have found that nominal shocks contribute significantly to business cycle volatility.

However, the theoretical view of the exchange rate as a shock absorber has been challenged recently by a number of authors, who have used alternative approaches and identified cases where the exchange rate takes the role of generator of the business cycle volatility. Authors such as Eichenbaum and Evans (1995), Rogers (1999), Bluedorn and Bowdler (2005) have found that nominal shocks contribute significantly to business cycle volatility. Also, Farrant and Peersman (2006a), and Artis and Ehrmann (2006), and Peersman (2011) consider exchange rate as a source of shocks instead of a shock absorber. The wide spectrum of results in the aforementioned studies, together with our earlier attempt, Audzei and Brázdik (2012), motivates us to assess the role of the exchange rate in absorbing economic shocks for selected Central and East European countries.

Structural VAR models have become one of the most widely used tools for identifying structural shocks. However, models formulated in relative terms like in Clarida and Gali (1994) or Farrant and Peersman (2006b) do not provide information on the importance of asymmetric shock for the country as a whole. Due to the relative nature of the used models, we are not able to identify the fraction of volatility explained by the asymmetric shocks. Therefore, we follow approach sketched by Peersman (2011) and define sign restrictions so that the contribution of symmetric and asymmetric shocks can be identified while keeping consistency with the scheme used in the relative models.

As we are focusing on transition countries, we also have to cope with the limited data span. Therefore, we rely on the sign restriction method for converting a VAR model into a structural VAR model. The advantage of this method is that it does not require short-run zero constraints to be imposed on the contemporaneous impact or on the long-run effects of shocks. Instead of this, only the signs of the impulse responses are restricted. The sign restriction method was introduced by Uhlig (2005) and has been developing constantly since then. Sign restriction methodology is basic analytical tool for a large part of the modern macroeconomic theory. Recently, Scholl and Uhlig (2008), Mallick and Rafiq (2008) and Peersman (2011) employ this methodology to analyze the contribution of shocks to macroeconomic volatility. A thorough discussion of this method is presented in Fry and Pagan (2011) and we address many of the mentioned shortcomings in implementation of the sign restrictions.

Our findings suggest that the CEE region is formed by heterogeneous countries with asymmetries present both within the region and with the rest of the Eurozone. This asymmetries are partially attributed to different monetary policy and exchange rate regimes (for non-member countries) and to structural differences (e.g. TFP levels, level of nominal prices). At the same time, our results are consistent with the shock absorbing role of the real exchange rate. Our analysis does not allow us to reject similar adjustment mechanism for CEE countries.

In the following section, we briefly describe the implementation of the sign restriction method. Further, the properties of the used data are discussed. The estimation and identification of the structural VAR model setup is presented, identification properties are discussed. The fifth section presents properties of the baseline model estimation results, its impulse responses and sources of the macroeconomic volatility is discussed. Finally, the sixth section summarizes our findings.

2. Implementing Sign Restrictions

In this work, we estimate a structural VAR (SVAR) model of a small open economy. The common approaches to identify SVAR impose various short or long-term restrictions on the responses of the variables to shocks or impose contemporaneous restrictions via the recursive ordering. As Farrant and Peersman (2006a) show, long-term zero response restrictions can deliver biased results. Also, Uhlig (2005) summarizes that ordering approach often leads to the emergence of anomalies such as the price puzzle or delayed overshooting puzzles.

Therefore, we employ the sign restriction identification method pioneered by Faust (1998) and developed by Uhlig (2005). In the sign restriction approach, shocks are identified by imposing restrictions on the signs of the impulse responses to structural shocks. These restrictions are usually imposed in the short to medium term to represent the structural effects of the shocks. The restrictions applied to the impulse responses can avoid the different puzzles that can occur when alternative estimation procedures are employed. Also, to avoid the use of strong restrictions on the variable relationships, long-term restrictions are not applied.

Assume that a structural VAR model of order p with n variables, where X is a vector of endogenous variables, can be stated as:

$$BX_t \quad = \quad A(p)X_{t-1} + \varepsilon_t. \tag{2.1}$$

Here, $A(p)$ is a polynomial of order p of matrices of size $n \times n$; B is a matrix of size $n \times n$; and ε_t is an $n \times 1$ vector of normally i.i.d. shock disturbances with zero mean and variance-covariance matrix Σ. The reduced-form VAR can be then written:

$$X_t \quad = \quad \Pi(p)X_{t-1} + e_t, \tag{2.2}$$

where $\Pi(L) = B^{-1}A(L)$ and e_t is an $n \times 1$ vector of normally i.i.d. shock disturbances with zero mean and variance-covariance matrix V. The general-form shocks are related to the structural representation of the model in the following manner:

$$e_t = B^{-1}\varepsilon_t \qquad V = E(e_t e_t') = HH'. \tag{2.3}$$

The impulse responses of the structural representation are characterized by impulse matrix B^{-1}. The identification problem arises if there are not enough restrictions to pin down V as $HH' = B^{-1}\Sigma B^{-1'}$. The multiplicity originates from the orthonormal property of matrices, as for any orthonormal matrix $Q, V = (HQ)(HQ)'$. Thus e_t has the same variance matrix but is associated with different impulse responses generated by impulse matrix $B^{-1}Q$.

As Berg (2010) claims, the ability to generate multiple impulse responses makes the sign restriction approach advantageous in comparison to recursive identification schemes, as it provides a larger number of factorizations. The IRIS toolbox used in this paper implements the following algorithm. First, the reduced-form VAR model is estimated to obtain matrix V. Second, the lower triangular factor of V is computed. Third, a random $n \times n$ matrix W is drawn from the multivariate standard normal distribution. Further, W is decomposed so that $W = QR$ and $QQ' = QQ' = I$. Fourth, the impulse response matrix $B^{-1}Q$ is created and responses are calculated. Finally, the restrictions are checked and if all are fulfilled the draw is kept; otherwise it is discarded. A large number of Ws is considered so we can draw inference from collected draws.

This approach is similar to the procedure described in Fry and Pagan (2011), where sign restriction methods are reviewed in detail. Fry and Pagan (2011) describe QR decomposition methods for the generation of rotation matrices and note their advantages for large systems. A Givens rotation, which is numerically identical to QR decomposition, is constructed from the orthonormal matrices, which take a prescribed form and their elements are characterized by θ, where $\theta \in (0, \pi)$. When looking for candidate rotations a grid for θ is formed, and for each θ a corresponding Q is calculated.

Only those Q that produce impulse responses complying with the sign restrictions are kept for the analysis. However, the number of complying responses cannot be foreseen. Therefore, to avoid possible biases originating from this uncertainty, we apply the procedure by Berg (2010), which originates from Rubio-Ramírez et al. (2005). This provides the required amount of successful draws.

Theoretically, as the sign restrictions is Bayesian type of methods, there can be an infinite number of the admissible set of parameters. Therefore, the popular approach is to report median response at each horizon for each variable but this approach may not provide consistent results. Fry and Pagan (2011) criticize this approach, as the median responses may be infeasible because they originate from different models (different parameterizations).

For consistency in reporting results, we use the closest-to-median approach proposed by Fry and Pagan (2011). The representative model is parameterized by solution to the closest to the median optimization problem given by:

$$\min_j M(j) = \sum_{i=1}^{q} (\overline{\phi_i} - \phi_j)(\overline{\phi_i} - \phi_j)', \tag{2.4}$$

where the search runs over all successful draws j, and $\overline{\phi_i}$ is the median impulse for each period i over all successful draws ϕ_j. In here, $\overline{\phi_i}$ and ϕ_js are $n \times n$ matrices.

In order to analyze the role of the exchange rate in generating economic volatility, we decompose the variance of the model variables. Forecast error variance decomposition indicates how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. In accordance with the Fry and Pagan (2011) critique of the multiplicity of parameterizations, the variance decomposition of the closest-to-median model is analyzed. This choice ensures that the shocks in the calculation are truly uncorrelated.

3. Data

Time series used in this work are from the Eurostat database. In this analysis, we consider Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia in the framework of the small open economy. For all the countries the foreign economy is described by their effective foreign aggregate of European countries. For each of the country, we have to take into account the specific data availability. All the series used in the analysis are seasonally adjusted and converted to the quarterly frequency. For most of the countries sample period covers the period from the first quarter of 1998 to the fourth quarter of 2013, so they are 63 observations.

In our model, we characterize each country by the use of harmonized index of consumer prices (HICP), real gross domestic product (GDP), short term interest rate and real exchange rate. To describe the foreign counterpart, we use effective indicators for foreign HICP, interest rate and real GDP. These effective indicators are constructed as weighted averages from the corresponding series for euro area countries. Used weights originate from the shares in domestic export for country under consideration.

In our data set, the real GDP is constructed by deflating the nominal GDP by its deflator.

Short-term interest rates are described by the 3-month money market rates that apply to deposits or loans between banks with an original maturity of three months. As Slovenia adopted euro in 2007, followed by Slovakia in 2009 and Estonia in 2011, the three-month interbank rate is represented by euro interbank offered rate (Euribor) after adoption. Latvia joined euro in 2014 but as our sample ends by the fourth quarter of 2013, this does not affect our data.

The real exchange rate aims to assess a country's (or currency area's) price or cost competitiveness relative to its principal competitors in international markets. Changes in real exchange rate depend not only on exchange rate movements but also on cost and price trends. Series from Eurostat use double export weights are used to calculate real exchange rate, reflecting not only competition in the home markets of the various competitors, but also competition in export markets elsewhere. A rise in the real exchange rate index means a loss of competitiveness.

Table 1 presents summary of the monetary policy settings in the considered countries over the period 1998–2013. Although CEE accession countries are aiming at the adoption of the Euro in the medium-term future, their experience with exchange rate regimes is quite diverse. This summary shows that inflation targeting has gained popularity in the considered countries. Countries in the advanced stage of transition abandoned exchange-rate targeting in favor of inflation targeting as the framework for monetary policies.

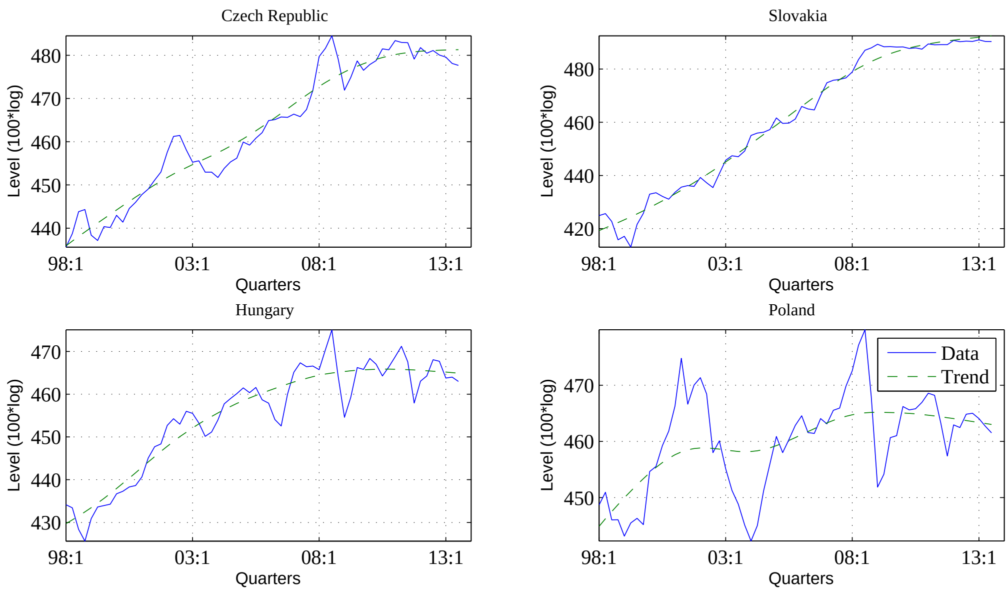
Table 1: Monetary Policy Strategies

Country	Exchange Rate Regime	Monetary Policy	Note
Bulgaria	Peg to Euro	Exchange rate targeting	Currency board
Czech Republic	Free float	Inflation targeting	
Estonia	Peg to Euro	Exchange rate targeting	Euro - 2011
Hungary	Managed/Free float	Ex. rate-Inflation targeting	Free float from 2008
Latvia	Conventional fixed peg	Exchange rate targeting	Euro - 2014
Lithuania	Managed float	Exchange rate targeting	Euro - 2015
Poland	Managed/Free float	Inflation targeting	Free float from 2000
Romania	Managed float	Ex. rate-Inflation targeting	
Slovakia	Managed float	Inflation targeting	Euro - 2009
Slovenia	Managed float	Ex. rate-Inflation targeting	Euro - 2007

Note that we are focusing on the countries that are subject to economic transformation over the considered period. Transformation and catching-up process is mainly fueled by faster productivity growth in the considered countries comparing to the relatively richer EU countries. Also, as most of the considered economies use inflation targeting, trends are also present in the price level data. Figure 1 shows trends in real exchange rate for countries with different characteristics. Therefore, the transformation of data is needed to handle the presence of the trends. Also, as the visual inspection of data shows these trend are time varying.

To remove time varying trends, we consider trend-cycle decomposition of all variables in the model. To do this, we detrend the data with HP filter by setting $\lambda = 1600$ after taking logs and rescaling series by factor of 100. This transformation and detrending removes time varying characteristics of the transformation process and handles the presence of the unit roots in the series. The use of trend-cycle in this form is equivalent to introduction of trend as exogenous components in the observation equations of the model's state space form. This approach does not change the cross-equation restrictions of the model and implies that trends are purely statistical decomposition devices with no particular economic interpretation. However, the advantageous byproduct of the applied pro-

Figure 1: Real Exchange Rates: Data and Trends



cedure is transformation of all the data in to percentage deviations from the trend thus easing the interpretation of results.

4. Estimation and Identification

Sign restrictions used in our work originate from two-country models with sticky prices derived by Obstfeld et al. (1985). Our identification setup is the extension of the work by Peersman (2011) and its roots can be traced up to work by Clarida and Gali (1994), Thomas (1997) and Amisano et al. (2009) who estimate their models in the relative terms.[1] Models in relative terms are able to identify asymmetric shocks only, and do not provide information on the relative importance of these shocks for the country under consideration. The relative formulation implies identification of the relative shocks.

Also, the relative form of a model imposes very strict assumptions on the symmetry of responses. As Peersman (2011) points, it is possible that the asymmetric shocks are not the major source of the volatility. In such case, the relative model focuses only on the small portion of the variance. Therefore, Peersman (2011) proposes a model able to identify symmetric and asymmetric shocks.

Following Peersman (2011), we use extended version of the VAR model to assess the distinction between symmetric and asymmetric shocks. Variables used in this VAR model for the country of interest set up following vector: $X_t = \{y_t, p_t, i_t, q_t, y_t^*, p_t^*, i_t^*\}$, where y_t is domestic real GDP, p_t is domestic consumer price index, i_t is domestic interest rate and q_t is real exchange rate (increasing value reflects loss of domestic economy competitiveness). In here, the starred variables characterize the foreign economy, represented by effective foreign aggregate.

[1] Among the examples of the papers studying relative models, for the study of Czech economy see Audzei and Brázdik (2012).

The first step of sign restriction method is to estimate the reduced form VAR model as given by equation 2.2. To estimate reduced form models, we estimate series of models and the lag length is determined by Akaike information criterion (AIC). For all of the considered countries lag determined by use of AIC turns out to be two. In the following work, we search for the structural VAR models by examining impulse responses of the drawn rotation of the reduced form model.

4.1 Search for Shocks

In the structural VAR model, we identify seven structural shocks: a symmetric supply shock, a symmetric demand shock, and a symmetric monetary policy shock, three corresponding asymmetric shocks and a real exchange rate shock. Restrictions presented in Table 2 are consistent with the responses of the two country theoretical model presented in Clarida and Gali (1994), Farrant and Peersman (2006b) and Peersman (2011).[2] This complex set of restrictions is focusing on the identification of the symmetric, asymmetric shocks and real exchange rate shock.[3]

In comparison to relative models (e.g. Thomas, 1997), the distinction between the symmetric and asymmetric shocks is introduced. The identified shocks are standard, when positive supply shock increases output and reduces prices and positive demand shock is characterized by increasing prices and output. Also, the exchange rate appreciation has restrictive influence on the domestic economy.

Table 2: Sign Restrictions – Individual Shocks

Variable Structural Shock	y_t	p_t	i_t	y_t^*	p_t^*	i_t^*	q_t
Symmetric Supply	≥ 0	≤ 0	≤ 0	≥ 0	≤ 0	≤ 0	
Symmetric Demand	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	
Symmetric Monetary Policy	≤ 0	≤ 0	≥ 0	≤ 0	≤ 0	≥ 0	
Asymmetric Supply	≥ 0	≤ 0	≤ 0	≤ 0	≥ 0	≥ 0	
Asymmetric demand	≥ 0	≥ 0	≥ 0	≤ 0	≤ 0	≤ 0	≥ 0
Asymmetric Monetary Policy	≤ 0	≤ 0	≥ 0	≥ 0	≥ 0	≤ 0	≥ 0
Exchange Rate	≤ 0	≤ 0	≤ 0	≥ 0	≥ 0	≥ 0	≥ 0

However, as we consider countries in different stages of transformation, structure and under various policy regimes some of the shocks may be very rare. Therefore, our first exercise is focused on the analysis of the frequency of the shocks. To run this analysis, we identify 7 models for each country. Each of these models is very simple and identifies only one specific shock as given by restrictions in Table 2. In our search for shock we impose restrictions to be contemporaneously binding, as in the closely connected countries even asymmetric shocks can easily and quickly become symmetric shock.

Similar to Peersman and Straub (2006), we use number of draws needed for one accepted draw as a proxy for the shock occurrence. We target 1000 accepted parameterizations. Using the total number of draws, we calculate the average number of draws needed to get a successful draw. Table 3 reports these average numbers over the shocks and countries. The larger is the number, the rarer is the shock. These numbers reveal that for Bulgaria, Estonia and Slovenia, the real exchange rate

[2] In our notation, the increase in the real exchange rate q_t means loss of competitiveness as it is related to appreciation of the currency. Change in notation originates from the data definition.
[3] As we consider countries with the various exchange rate regimes, we focus on the real exchange rate shock, unless explicitly mentioned.

Table 3: Numbers of Draws: Summary

	Countries									
Shock	CZ	SK	HU	PL	EE	LT	LV	RO	BG	SI
S. Supply	17	12	28	20	10	15	17	22	32	11
S. Demand	10	11	15	12	13	11	15	12	12	6
S. Policy	17	17	27	46	13	30	20	35	21	12
A. Supply	69	401	42	41	94	130	119	75	101	379
A. Demand	160	130	166	98	228	380	182	237	78	416
A. Policy	415	850	168	69	2938	504	261	338	8683	3778
Ex. Rate	265	319	127	102	5273	485	179	90	10915	2409

shock is very rare, as well as asymmetric monetary policy shock. This observation originates from the nature of the monetary policy regimes. Bulgaria here represents exchange rate targeting country and Slovenia and Estonia are recent Euro adopters. That is, these countries can not run asymmetric policy as it will put their policy under additional pressures to meet its goals.

Table 4: Ratio of Draws: Omitting Recent Slowdown

	Countries									
Shock	CZ	SK	HU	PL	EE	LT	LV	RO	BG	SI
S. Supply	0.7	0.5	1.0	1.6	0.8	0.5	1.5	0.9	1.0	0.8
S. Demand	0.7	0.6	0.6	0.8	0.6	0.3	0.4	1.3	0.2	0.2
S. Policy	0.6	0.5	1.8	1.4	0.4	1.0	1.3	2.1	1.7	0.3
A. Supply	1.8	4.5	0.4	1.1	2.1	2.5	2.7	1.2	1.6	6.9
A. Demand	1.4	2.8	0.8	1.0	1.2	4.5	0.6	0.3	0.7	2.0
A. Policy	0.9	1.2	0.2	0.3	1.8	0.7	1.5	0.7	1.9	4.8
Ex. Rate	1.2	1.9	0.8	0.2	2.3	4.9	0.6	0.2	1.2	3.1

It might be argued, that the recent recession could amplify structural differences among the countries and occurrence of asymmetric shocks could become higher. As a robustness check, we shortened our sample by omitting data after the third quarter of 2008. Table 4 presents results of this robustness check as a ratio of number of draws needed in the full sample and number of draws needed in the short sample to get a successful draw. In these relative metrics, if the ratio is close to unity, the shock occurrence was not affected by crisis and recession. If ratio is greater than unity, the shock is harder to find in the pre-crisis period. Ratio smaller than unity indicates, that the shock is easier to find in the pre-crisis period.

The simple average ratio for symmetric shocks is 0.9, for asymmetric 1.8 and 1.6 for the real exchange rate. This means that the number of draws needed to test is almost the same for the symmetric shocks in full and short data set. However, ratio larger than unity indicates that the number of draws need for the identification of asymmetric shocks decreases when the 2008–2013 period is omitted. The inclusion of slowdown period delivers easier identification of the asymmetric shocks. As there are only 10 out of 30 (3 shocks and 10 countries) ratios below unity, the asymmetric shocks became more frequent. This means that the recent slowdown increased asymmetries for the sample of considered countries.

When analyzing the presence of individual asymmetric shocks, the largest ratio of draws is needed for the asymmetric supply shock. This is consistent with the situation of higher flexibility of suppliers in the considered countries and less flexible suppliers of their trading partners. For countries with peg or exchange rate targeting (Bulgaria, Romania, Hungary and Latvia) we observe that it is harder to identify asymmetric demand shock in the pre-crisis period. This indicates that inclusion the recession makes it easier to identify asymmetries even in this group.

Also, to assess effects of the Euro adoption for Estonia, Slovakia and Slovenia, we cut the sample at the Euro adoption date so sample does not include the Eurozone membership. Computing the ratio of number of draws between these two samples gives average ratios in range of 0.9–1.1. When breaking down the ratio to individual shocks, all three countries show that the asymmetric supply shock is more likely. In our view, this may be related to economic transition and may not directly be connected to Euro adoption. As the ratio does not noticeably differ from unity in this check, following analysis will be done on the full sample for all considered countries.

When considering the effect of sample length for the real exchange rate shock identification, Table 4 reports average ratio of 1.6. This result suggests that on average real exchange shocks are easier to identify with the inclusion of the recent slowdown period. As the response to slowdown is considered asymmetric, this result is in line with the theoretical role of exchange rate as the shock absorber.

Low occurrence of asymmetric shocks for most of the countries, leads us to omit identification of the individual asymmetric shocks. However, the restrictions on symmetric shocks as presented in the Table 2 assure that none of the symmetric shocks could be confused with the asymmetric one. Therefore, it is possible to apply identification scheme that distinguishes the symmetric shocks from asymmetric ones, even though asymmetric shocks are not explicitly identified individually.

4.2 Effects of Monetary Policy on Output

Evaluation of effects of monetary policy on output has been the focus of a substantial body of the literature.[4] Using sign restrictions methodology, Uhlig (2005) shows that contractionary monetary policy shocks (for example,s Euro area countries experience a rise in ECB policy rates), have an ambiguous effect on the real output. Also, the relative formulation as defined by Clarida and Gali (1994) uses very strict form of symmetry - the response has to be same size, direction and follow the same timing. As transmission channels may have different strength, so the difference in relative size may lead to asymmetry in response of output. We relax the restriction on the same size of response by allowing for asymmetric amplitude of country's response, while keeping the direction of responses aligned as in Peersman (2011).

We take findings by Uhlig (2005) into account and we apply agnostic identification procedure to evaluate the effects of symmetric and asymmetric monetary policy shock on domestic and foreign output. This evaluation helps to check whether our restrictions on output, presented in Table 2, are justified. As in Uhlig (2005), we leave the reaction of domestic and foreign output to symmetric and asymmetric monetary policy shocks unrestricted.

For this evaluation, we consider restriction on symmetric shocks and an asymmetric policy shock as previously reported in the Table 2. For the symmetric monetary policy shock we consider a contractionary shock in both of the countries. For the asymmetric monetary policy shock, a contractionary

[4] Check (Uhlig, 2005) for the list of references.

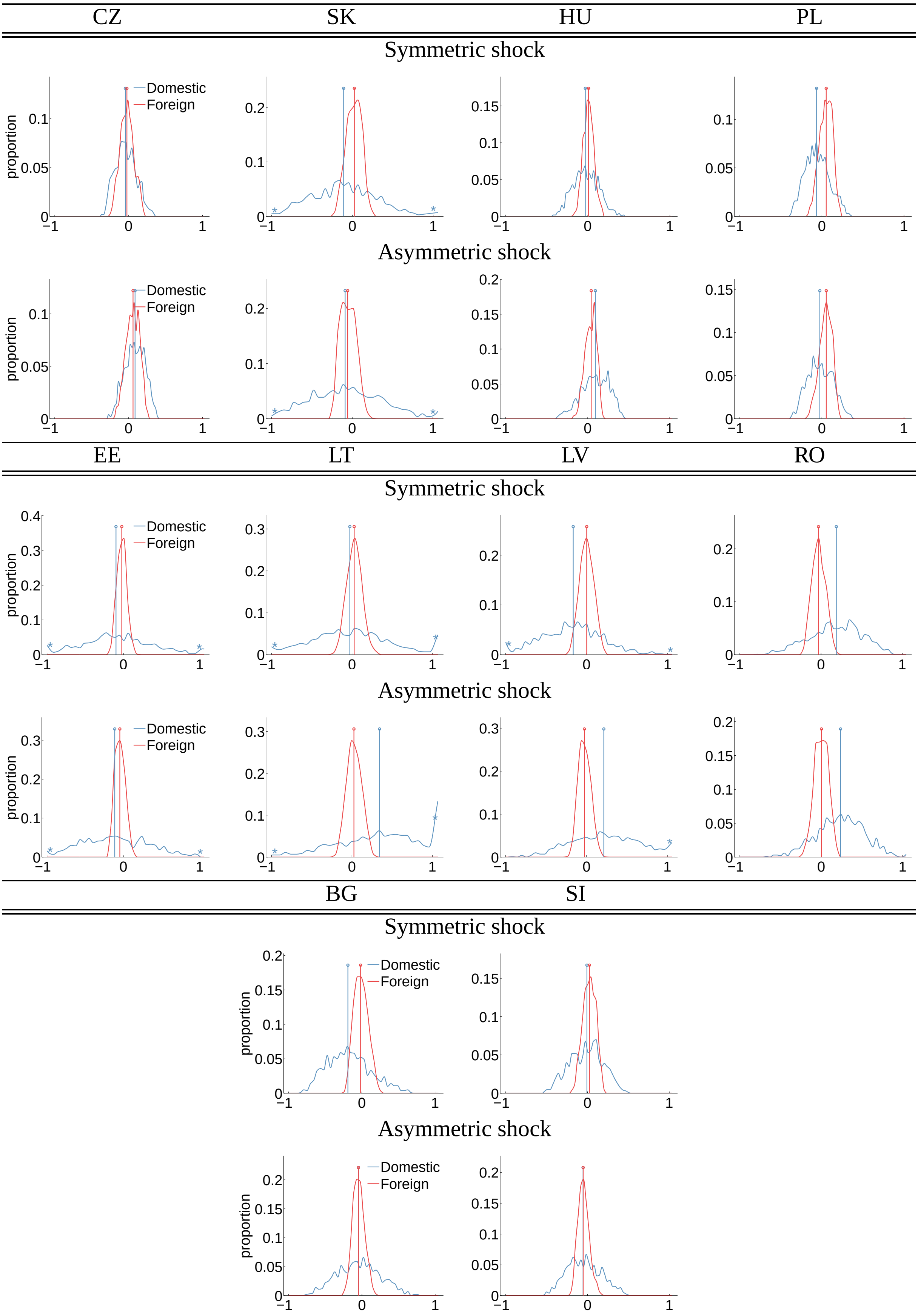
shock hits the domestic country and the foreign country is hit by a expansionary monetary policy shock.

Table 5: Sign Restrictions – Unrestricted Output Response

Variable Structural Shock	y_t	p_t	i_t	y_t^*	p_t^*	i_t^*	q_t
Symmetric Supply	≥ 0	≤ 0		≥ 0	≤ 0		
Symmetric Demand	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	
Symmetric Monetary Policy		≤ 0	≥ 0		≤ 0	≥ 0	
Asymmetric Monetary Policy		≤ 0	≥ 0		≥ 0	≤ 0	

For evaluation of restrictions on output in response to monetary shocks, we collect impulse responses satisfying sign restrictions presented in Table 5; and distributions of responses in the initial period are constructed. Figure 2 reports distributions for the responses of domestic (blue line) and foreign (red line) output to symmetric and asymmetric shock in the first period. Stem lines show the amplitude of the average responses in the initial period. It can be observed that the responses close to zero prevail for the foreign output for symmetric and asymmetric shocks.

Figure 2: Summary of Output Responses



Further, a ratio of number of positive to negative responses to symmetric and asymmetric monetary policy shock in the first period is assessed. The ratio is calculated for domestic and foreign output separately. Value higher than one indicates, that positive responses occur more often than negative.

Table 6: Ratio of Positive to Negative Output Draws

Shock Type	Countries									
	CZ	SK	HU	PL	EE	LT	LV	RO	BG	SI
	Domestic Output									
Symmetric MP	0.63	0.65	0.77	0.53	0.69	0.94	0.45	2.50	0.36	0.95
Asymmetric MP	2.70	0.74	2.28	0.78	0.67	2.73	2.78	3.69	0.81	0.68
	Foreign Output									
Symmetric MP	0.66	1.39	1.26	2.57	0.56	1.63	1.01	0.57	0.81	1.55
Asymmetric MP	2.48	0.45	2.31	2.72	0.34	1.60	0.61	1.04	0.39	0.30

These values, presented presented in Table 6 suggest that in all the countries, except Romania, output response to a contractionary symmetric monetary policy shock tends to be negative. Suggesting that contractionary response of domestic output to positive monetary policy shock is in line with the data. However, when assessing the response of foreign output response to symmetric policy, there is not such clear pattern of contractionary response as for 5 of the countries the foreign block does not contract in the first period. The symmetric increase in policy rate results in both symmetric and asymmetric responses of foreign output.

Poland and Lithuania are countries with the largest difference in positive-to-negative ratio of the foreign output. Recall, that in Table 3 the larger number indicates that the shock is less frequent. To compute the number of draws, the restriction on symmetric monetary policy shock included restriction on symmetric and contractionary responses of domestic and foreign output (symmetric in sense of move in the same direction). The large numbers in Table 3 suggest, that symmetric responses to monetary policy shocks are not easy to find for these two countries; and the current analysis shows that this originates from response of foreign output. Foreign output for Poland in Lithuania tends to move in the opposite direction with the domestic output. However, for the rest of the countries the symmetric responses are quite frequent as illustrated in a Table 3.

Therefore, in our further analysis we proceed with restrictions on output responses for the symmetric monetary policy shock.

Asymmetric monetary policy shocks are quite rare by themselves as suggested by the number of draws reported in Table 3. Also as shown in Table 6, these shocks result in both types of responses. For some countries the contractionary domestic policy shock results in a raise in output, which may be lead by the expansion of foreign economy (which itself reacts to monetary policy easing). This is especially relevant for export oriented countries with large share of import components of their output (e.g. Czech Republic is very good representative).

5. Model Identification and Results

Analysis in the previous sections provides guidelines on the frequency of the considered shocks and directions of responses. We found that asymmetric shocks are relatively rare in comparison with the symmetric or exchange rate shocks. Explicit identification of the individual of all asymmetric shocks makes it very computationally demanding to deliver the enough successful draws of parameterizations.

Table 7: Baseline Model Identification Scheme

Variable Structural Shock	y_t	p_t	i_t	y_t^*	p_t^*	i_t^*	q_t
Symmetric Supply	≥ 0	≤ 0		≥ 0	≤ 0		
Symmetric Demand	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	≥ 0	
Symmetric Monetary Policy	≤ 0	≤ 0	≥ 0	≤ 0	≤ 0	≥ 0	
Exchange Rate	≤ 0	≤ 0		≥ 0		≥ 0	≥ 0

As aforementioned results suggest, we aggregate asymmetric shocks and so the number of individual restrictions is reduced. The reduced set of restrictions is described in Table 7. However, the set of restrictions kept distinguishes each of the symmetric shock from any of the asymmetric shocks as restricted in the Table 2. All asymmetric shocks are aggregated and in the following analysis referred as “Asymmetric shocks”. Restrictions used to identify the baseline model as presented in Table 7 are applied to responses in the first period.

Using set of restrictions presented in Table 7, we collect the parameterizations of the structural VAR models and using the median criterion the representative model is selected. Further, we present the impulse response analysis and examine sources of volatility by variance decomposition. This also allows to discuss the relative importance of the symmetric and asymmetric shocks. Finally, we are able to identify the historical contributions of the considered shocks.

5.1 Impulse Responses

As the sign restriction method delivers a number of parameterizations that passed the restrictions, for the assessment of the impulse responses we use the closest to median parameterization as the representative model. Impulse responses are reported in Figures 4–13 as percentage deviations from the steady state - trend. As the asymmetric shocks are not identified individually, only the responses to symmetric and real exchange rate shocks are presented. Also, the considered countries are small open economies our presentation focuses on the domestic variables responses. Presented bands represent 90 and 95% confidence intervals for responses.

Generally, in response to a symmetric supply shock a persistent increase in domestic output can be observed for all countries. Domestic inflation is restricted to decline in the first period, however it reverts rather quickly. The policy response is not restricted, so it varies across countries. However, patterns are observed as monetary policy eases in Vysegrad countries (Czech Republic, Hungary, Poland and Slovakia), tightens in Bulgaria, Romania, and Lithuania, and tightens a little in Estonia and Latvia. Slovenia responses with the tightening next period. As the policy eases for inflation targeting countries, initial response of exchange rate is depreciation, however as further output growth continues appreciation occurs. Generally, real exchange rate depreciation follow symmetric supply shock that means that export oriented countries profit from lower price and their export is cheaper.

In response to the symmetric demand shock, output, prices, and interest rates rise. Depending on the strength of monetary policy response the positive response of output and inflation is eliminated. After, the initial periods of tightened policy inflation and output start to contract, the policy is eased to restore equilibrium. For all countries, except the case of Lithuania and Romania, exchange rate appreciates in response to initial tightening of the monetary policy. For Lithuania a delayed exchange rate appreciation is observed and can be explained by the lagging nature of the currency board. Presented impulse responses suggest that there are differences across exchange rate responses to demand shock (depreciation in Romania and Latvia). These differences could be driven by monetary policy regimes or could be structural, but the prevailing appreciation is consistent with the growth of net exports of the considered countries.

In case of Romania the depreciation of exchange rate is large and persistent. Despite the competitiveness increase, there is largest and longest decline in output among the countries considered. We believe that this reflects structural problems of Romanian economy and its monetary policy as managing the exchange rate. There may exist conflict between exchange rate-inflation rate targeting, as one can see monetary policy tightening to fight the inflation, which stays long above the equilibrium, partially due to exchange rate fall.

Symmetric monetary policy tightening was restricted to reduce output and inflation. Exchange rate for most of the countries depreciates, with the exception of Latvia, where it rises first and falls after few periods. This response suggests presence of asymmetries in transmission channels, when both domestic and foreign economy raise interest rates while domestic monetary authority avoids appreciation. This prevents too large slowdown of output growth and fosters recovery of price level dynamics.

Restrictions on the exchange rate appreciation shock, as presented in Table 7, require reduction of domestic output and prices, increasing foreign output and foreign interest rate. However, in the following periods output rises very quickly above the steady state except for the case of Hungary, as well as inflation, despite mostly tightening response of domestic monetary policy.

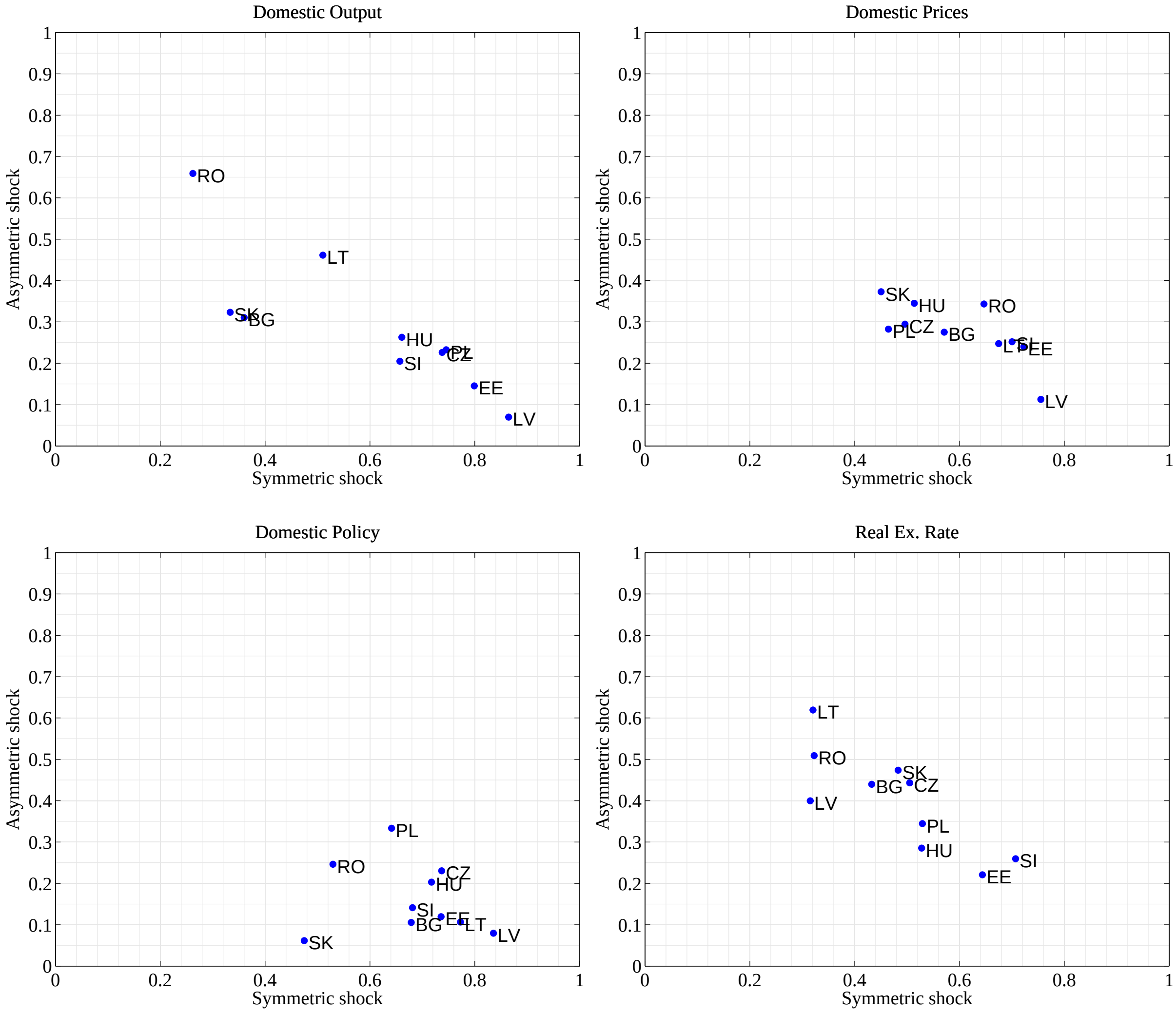
To sum up, the region is represented by the countries with rather heterogeneous economic structure and monetary policy regimes. Some similarities could be found within groups (Vysehrad countries and Baltic countries). In the following section, we analyze the differences in shocks' contribution to economic volatility and historical decomposition of the shocks.

5.2 Relative Importance of Symmetric and Asymmetric Shocks

The following assessment focuses on the importance of symmetric and asymmetric shocks for explanation of the business cycles volatility. To analyze the importance of symmetric and asymmetric shocks, we focus on the contributions of these shocks to the domestic variables volatility. We decompose the forecast error variance in the contributions of individual shocks. Average contribution of symmetric and asymmetric for the closest to median model over the first 20 periods is presented in the Figure 3 and the time evolution of contributions is presented in Figures 14–23. Figures 14–23 presents variance decomposition into the contribution of symmetric supply, demand and monetary policy shocks, real exchange rate and asymmetric shocks for the considered two country models. As we are considering small open economies, each figure shows decomposition of the variables of interests only for the domestic variables of the considered country.

Aggregating the contributions of symmetric and asymmetric shocks allows us to assess how important these contributions are relatively to each other. In case of high the relative contribution of symmetric shocks, synchronization of the business cycles is high and the cost for the considered country to adopt common monetary policy are considered to be rather small. However, if asymmetric shocks contribution is relatively high, the required response of the monetary policy is the

Figure 3: Symmetric vs Asymmetric Shock Contributions



opposite in both countries and giving up an independent monetary policy can be very costly. As a result, to form a monetary union, it is important that the contribution of asymmetric shocks to the business cycle is as limited as possible.

Countries with the substantial contribution of asymmetric shocks to output volatility in the short-run are Romania, Lithuania Slovakia and Bulgaria as it can reach up to 80% in the initial period (Figure 22). The contribution of asymmetric shocks to output volatility is also high in the long-run for these countries, where contributions are in interval 20–60%. For the rest of the countries the long-run contribution asymmetric shocks is below 20%.

The group of the countries with the strongest short-run contribution of asymmetric shocks to domestic prices volatility includes Czech Republic, Hungary, Poland, Lithuania, Romania and Slovakia and the contributions range from 25 to 40%. Results for Czech Republic, reported in Figure 14 reveal significant contribution of asymmetric shocks in the short-run for domestic output which reaches up to 50% of variance. This contribution is only slightly altered downwards when moving to longer run. So, the feature of the is very stable contribution over the time. As our sample includes transition countries, one of the feature consistent with the behavior is high portion of administered prices present in these economies. The adjustment of these prices often follows schemes that are not correlated with other countries cycles, therefore it can result in asymmetries.

Countries with prevailing contribution of asymmetric over the symmetric shocks to real exchange rate in the long-run are Bulgaria, Lithuania, Romania and Slovakia. When, considering the short-run Czech Republic and Latvia join this group and the contribution of asymmetric shocks drops for Bulgaria. Most of the relatively high contribution, almost 80% for Latvia can be explained by choice of the exchange rate peg as policy as the prevailing regime for this group is either exchange rate targeting or exchange rate peg. The substantial contribution of asymmetric shocks is consistent by shock absorbing nature of the real exchange rate or results of low synchronization with its foreign counterpart.

Countries with low contribution of asymmetric shocks to domestic prices are Bulgaria, Estonia and Latvia. For these countries, symmetric shocks account for about 80% of volatility of prices. Variance decompositions for domestic output, prices and policy, presented in Figures 22, 18 and 20, is dominated by contribution of symmetric shocks almost at all horizons. This group of countries is characterized also by peg and fixation of their currencies to Euro. This choice of the monetary policy setups a strong link between domestic and foreign prices and interest rates, thus resulting in limitation for asymmetric shocks presence.

Variance decomposition shows large influence of asymmetric shocks for specific groups of considered economies. Even though each of the asymmetric shocks is not very frequent in the data, together they account for significant portion of output and price volatility. Due to their relative importance for volatilities of considered variables, the frequency of occurrence has to be compensated by their amplitude. The presence of substantial asymmetry originates from asymmetries across the considered countries in terms of productivity, monetary and exchange rate policies. There are striking differences in relative contribution of the asymmetric shocks across countries, as their contribution to output volatility varies from 10 to 80%.

5.3 Role of the Real Exchange Rate

Theoretical role for the real exchange rate is to act as a mechanism which reacts to fundamental shocks and helps stabilizing output and inflation variability. However, there is a lot of evidence that exchange rates are very volatile and may fuel macroeconomic volatility thus disturbing the economy. Therefore, the crucial question is then how idiosyncratic real exchange rate shocks explain exchange rate fluctuations and, what is the impact of these shocks on output, prices and monetary policy volatility.

Figures 14–23 also presents decomposition of the variance of the real exchange rate. In these figures the contribution of exchange rate shocks reflects if the exchange rate acts as a source of shocks. If this contribution is high, there is little role for the exchange rate as a stabilization mechanism.

However, the role of the real exchange rate shock for volatility of output, prices or monetary policy is more important for the effect on the business cycle. If the contribution of real exchange rate is low, idiosyncratic exchange rate fluctuations are not harmful for the rest of economy. This case is consistent with the shock absorbing nature of the real exchange rate.

The short run contribution of the idiosyncratic real exchange rate shock to volatility ranges from tiny 1% in case of Slovenia or approximately 5% for Bulgaria, Czech Republic and Slovakia up to 20% for Hungary and Latvia. This is far below 45 % of Sterling-Euro fluctuations explained by idiosyncratic shock in shor-run as identified by Peersman (2011). In the long-run, the idiosyncratic shock fuels Latvia's real exchange rate volatility by 30%. Meanwhile, most of the countries form two distinct groups, one with contribution approximately 15% and the other one with contribution of 5%. These values are inline with findings by Clarida and Gali (1994) and Farrant and Peersman (2006b). On the other hand, these contributions of exchange rate shocks are still remarkably lower than the results obtained in Artis and Ehrmann (2000) for Denmark, Germany and United Kingdom, where contributions are ranging from 50 to 90%.

Works like Clarida and Gali (1994) and Eichenbaum and Evans (1995) that are attempting to identify contribution of various shocks to the real exchange rate often find that monetary policy shocks are unimportant. However, our results suggest that the symmetric monetary policy shocks deliver important part of the real exchange rate volatility for Czech Republic, Hungary, Poland and Slovenia. Thus, we can support conclusion by Rogers (1999) that the monetary policy shocks matter and that the focus on monetary shocks in the recent dynamic general equilibrium literature is well-founded empirically.

When considering the transition of real exchange rate shocks to domestic output in the short-run, countries can be split into three groups. Slovakia's output is the one significantly driven by exchange rate shock as its contribution reaches up to 25%. For Bulgaria, Estonia and Slovenia the short-run contribution is on average 12%, while for the rest of the countries there is either no effect (Czech Republic) or is it below 5%. In the long-run high contribution of 35% can be is present for Bulgaria and Slovakia, somewhat higher contribution of approximately 15% is present for Slovenia, while the rest of the countries are characterized by the contribution lower than 10%. Interesting pattern can be found for most of the countries, when the contribution of the exchange rate shock is almost nil or very low in the initial periods after the shock, while over the time it starts to increase. This behavior reflect the speed of the pass through of the exchange rate to output.

In the short-run, exchange rate shock substantially contributes to the volatility of domestic prices in Czech Republic, Poland, Hungary and Slovakia by 15–30%. There is the other distinct group of countries – Bulgaria, Estonia, Latvia, Romania and Slovenia, where the short-run pass through is low, below 5%. Long-run largest contribution of real exchange rate shock on domestic prices of 30% characterizes Poland. The group close to average contribution of 15% is dominated by inflation targeting countries – Czech Republic, Slovakia, Latvia and Hungary. Surprisingly, also Bulgaria belongs into this group, while the countries with pegged exchange rate or early Euro adopters like Estonia, Latvia or Slovenia are in the group with long-run contribution below 8%.

The long-run of monetary policy volatility decomposition shows exceptionally high contribution of exchange rate shock for Slovakia, where it reaches up to 45%. So, the Slovakia's monetary policy is highly responsive to movements in the exchange rate. The large effect of exchange rate shock on domestic monetary policy is consistent with the inflation targeting nature of its policy. Countries with the low response of the monetary policy to exchange rate shocks are Czech Republic and Poland as this contribution is below 5%. Remaining countries evenly cover range of contribution from 8% to 22%. As there are many rigidities present, the short-run contributions to volatility are lower than the long-run. However, the ordering of countries does not change much when short run effects are considered.

For most of considered countries (except Bulgaria, Poland and Slovakia) results illustrate that real exchange rate shock does not significantly contribute to volatility of the domestic variables. Generally, the most significant effect exchange rate shock is identified for domestic prices. This is not surprising, given that most of the countries are open and small (relative to the considered foreign counterpart), the movements in real exchange rate is passed into the prices as these are more flexible than the economic growth. For most of countries the transmission of real exchange rate is lagged and it slowly reaches its long-term value of contribution.

To conclude, in the selected countries exchange rate volatility is mostly driven by symmetric and asymmetric shocks. The low contribution of its own shock to its variance indicates that exchange rate does not generate a lot of volatility by itself, but rather responds to domestic and foreign shocks. For the countries with very low impact of exchange rate shocks to other domestic variables, this may imply that exchange rate is not a source of volatility, but a potential absorber of asymmetric shock. The need for exchange rate to be a shock absorber arises when the supply and demand economic shocks are asymmetrical relative to the country's trading partners. Shocks that are predominantly asymmetric require opposed responses of foreign and domestic monetary policy.

5.4 Historical Shocks Estimation

The identification of structural shocks is often a controversial issue, to support our view on choice of technique, we present results of historical shock estimation over the considered sample. As in the previous analysis, this identification is based on the closest to median model which is fitted to the data. The result of this estimation provides us with the overall contribution of the symmetric and asymmetric shocks to the observed business cycles.[5]

Figures 24–33 show period of economic boom preceding the most recent economic slowdown linked to the financial crisis of 2008. Examination of results suggest that there exists a group of countries, where the business cycles were dominantly driven by the symmetric supply and demand shocks. This group includes Czech Republic, Poland, Estonia, Lithuania, and Latvia and these shocks explain substantial portion of the output and prices movement and monetary policy responses.

Asymmetric and real exchange rate shocks were important for output of Romania and Slovakia as they together explain substantial portion of the output fluctuations. The asymmetric shocks were also significantly contributing to evolution of domestic prices. However, the main driver for Romanian prices was symmetric price shock, while this is not present in Slovakia.

We consider the identified substantial role of real exchange rate shocks consistent with the currency board policy of Bulgaria. The idiosyncratic real exchange rate shocks are also the most influential driver of domestic variables. In Bulgaria in pre-crisis and crisis times exchange rate shock dominated output and prices volatility, with its the declining role after 2009. It is similar pattern as observed for Romania but with stronger exchange rate shock influence. This amplification results from the explicit exchange rate targeting in Bulgarian case.

As in the previous sections, we examine the role of the monetary policy on output, we find ample role of the symmetric policy shock for Slovenia on domestic variables. These results are consistent with adoption of Euro and common monetary policy in 2007. However, such behavior is not observed for Slovakia which also adopted Euro.

[5] In here, the asymmetric shocks also include effects of initial state. The general pattern for the contribution of initial state is a significant contribution in the few initial periods (start of the dataset) and negligible contribution in the recent periods. As the initial state also reflects some asymmetry in the setup we aggregate its contribution with asymmetric shocks.

Also, the role of monetary policy of Czech Republic for the evolution of output over the period 2005–2011 should be noted. In the initial stage the symmetric policy shock contributes to positively to growth however as the output deviation becomes too large (early 2007) it turns to be restrictive. After, the slowdown hit economy (early 2009) it again become eased and tries to support recovery. Similar pattern is also observed for domestic prices development. Similar pattern for domestic output within this group is observed also in case of Poland and Latvia. However, in case of Latvia the expansionary policy contribution is observable with some lag as the Latvian economy was severely hit by slowdown of foreign environment.

For Estonia, Poland, and Lithuania monetary policy moves procyclically, however its effects are not always procyclical. It contributes to a fall in output and prices slightly in a recession in Estonia and Latvia; and contributes to output growth in a boom in Poland, Lithuania, and Latvia. Poland and Romania are a rather special case: during the boom faze prices where falling and have a tendency to rise in a recession.

Historical analysis highlights different driving forces for the countries' business cycle, these findings are consistent with their past experience and set of the monetary policy. Generally, the similar property of considered economies it the relatively low contribution of the real exchange rate to the cyclical movements, including its own dynamic. Except Bulgaria and Latvia, real exchange rate has been driven by the shocks other than the idiosyncratic one. Such composition of real exchange rate volatility is consistent with the shock absorbing role.

6. Conclusions

The aim of this work is to assess the theoretical properties of the exchange rate as stabilization mechanism for the macroeconomic volatility. We investigate the extent to which the symmetric and asymmetric shocks drive the business cycles in the selected CEE countries. As the theoretical role of exchange rate for business cycles volatility depends on the relative importance of symmetric and asymmetric shocks. Only if shocks are predominantly asymmetric is the exchange rate needed to absorb such shocks.

In contrast to several earlier works, we chose to explore this role with models not formulated in relative terms to the country's trading partners. Employed specification has the advantage that it enables us to assess whether shocks are mainly symmetric or idiosyncratic in nature while relaxing strict forms of symmetry imposed by relative models.

For the investigation, we use structural VAR model of economic cycle identified by sign restrictions approach. The setup of used sign restrictions is based on the theoretical works for open economy models. We also support these restrictions by agnostic analysis of output and monetary policy relation. This also resulted in support of the theoretical restrictions as they were consistent with our agnostic scheme, when tightened policy showed to be restrictive.

Further, the dynamic responses of variables to structural shocks have been analysed using forecast error variance decompositions. With this methodology, we evaluate the contribution of monetary policy and real exchange rate to macroeconomic volatility.

Our analysis suggests that the structural differences among considered countries are reflected in the contribution of asymmetric and real exchange rate shocks to macroeconomic volatility. There exists a group of countries with the prevailing role of asymmetric shocks for their macroeconomic volatility, this group includes Bulgaria, Lithuania, Romania and Slovakia. For these countries asymmetric shocks explain substantial (30–80%) part of their output volatility. These are also countries with the high contribution (over 40%) of asymmetric shocks to real exchange rate volatility. Latvia is the country with the lowest contribution of asymmetric shocks to output, prices and response of monetary policy. The exchange rate and symmetric shocks are prevailing for all of the considered countries when volatility of domestic prices is considered.

For most of the countries, shock absorbing role could be suggested as the real exchange rate shock is not the substantial contributor to volatility of output and prices. Real exchange rate shock is a large source of volatility (up to 35%) for Bulgaria and Slovakia. These two countries are characterized by fixed exchange rate, respectively Eurozone membership. This may be reflection of the structural differences (e.g. in productivity) between Bulgaria and Slovakia with the respect to trading partners. This is also reflected in the structure of the monetary policy volatility as the highest contribution of the real exchange rate is observed for Slovakia that prior to Eurozone entry was pursuing inflation targeting monetary policy.

The results our analysis could be useful information for the debate on whether CEE countries should be supported in the future euro adoption process. Taking policy recommendations from presented results requires some caution. The extrapolation from data generated over a period when the economies operate under a given regime can face structural changes when the euro is adopted. As with the change of the exchange rate regime some substantial changes can occur, even when Amisano et al. (2009) document that the changes in sources of volatility after adopting Euro in Italy were not significant. However, we believe that results presented in this work are useful for the debate on costs and benefits of monetary union and for backing up set up of structural models and they calibrations.

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Appendix A: Impulse Response Functions

Figure 4: Impulse Response Functions – Czech Republic

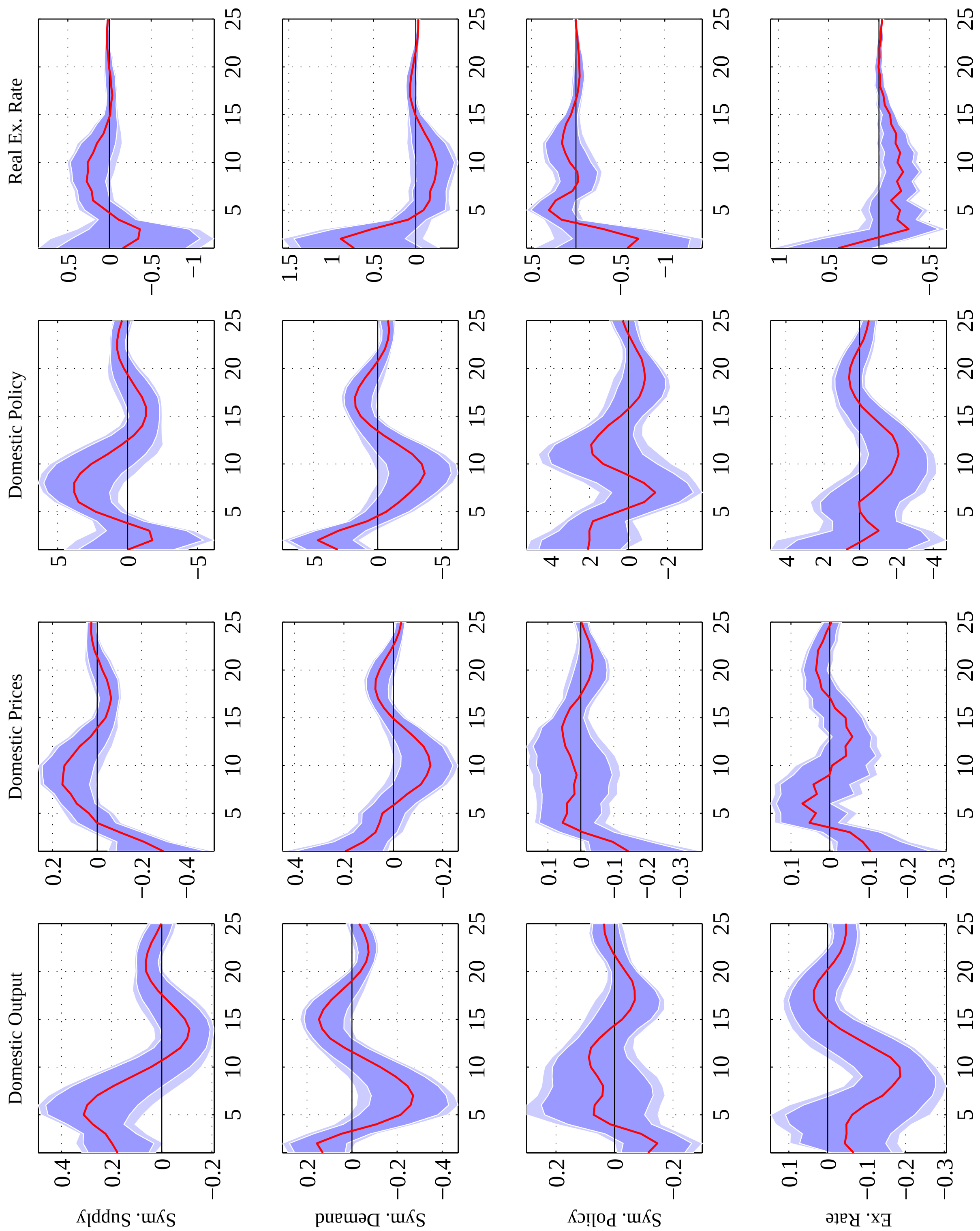
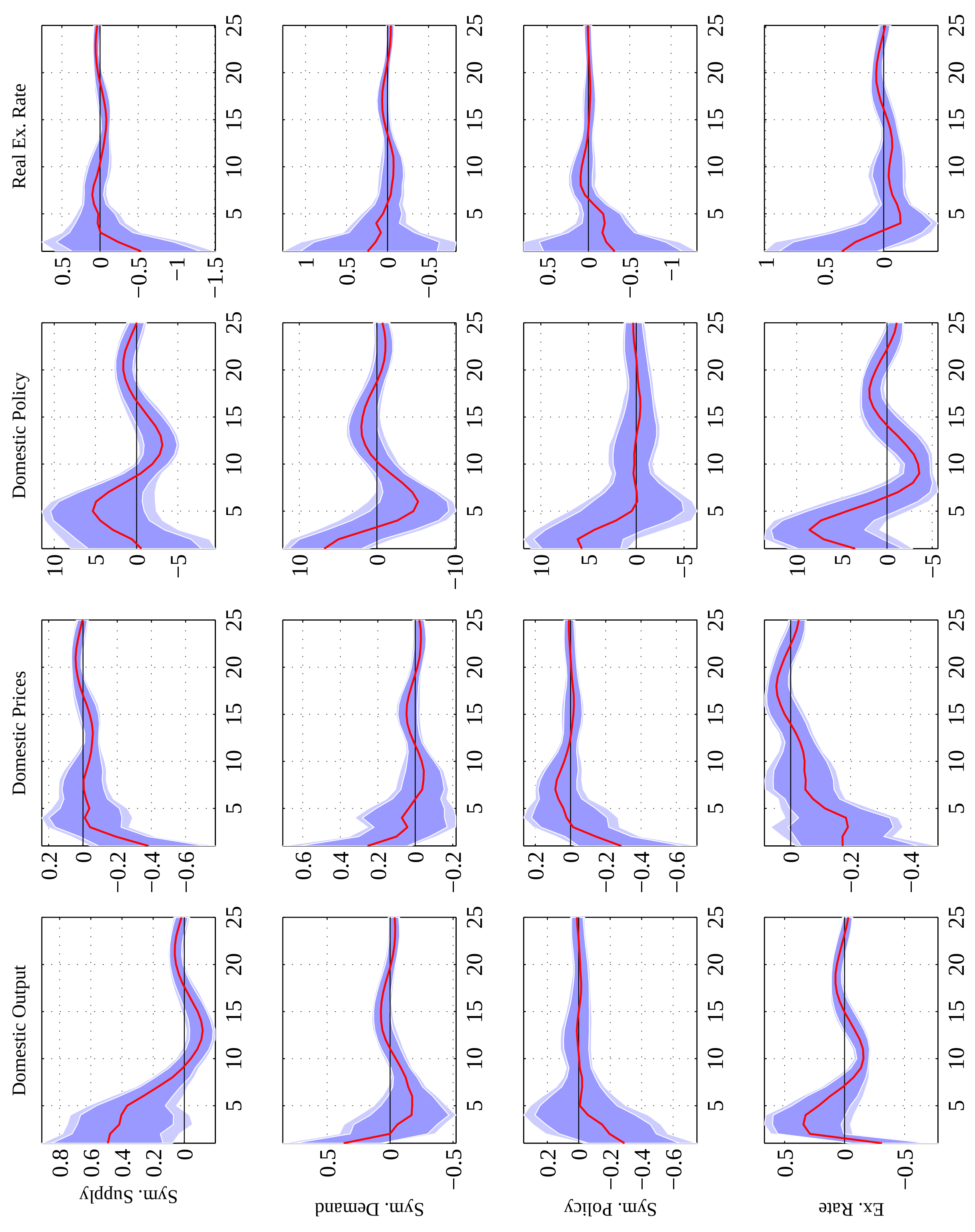


Figure 5: Impulse Response Functions – Slovakia



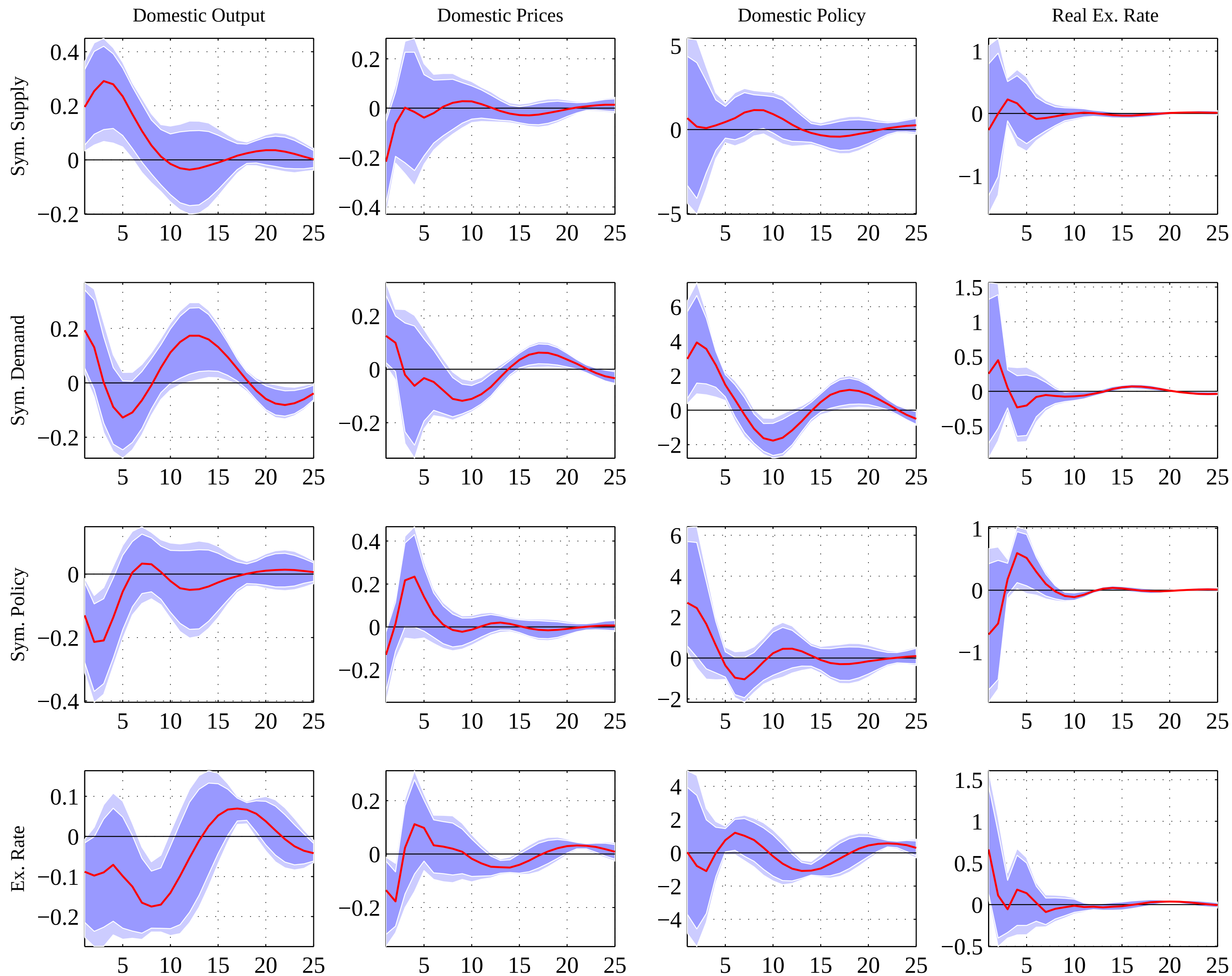


Figure 6: Impulse Response Functions – Hungary

Figure 7: Impulse Response Functions – Poland

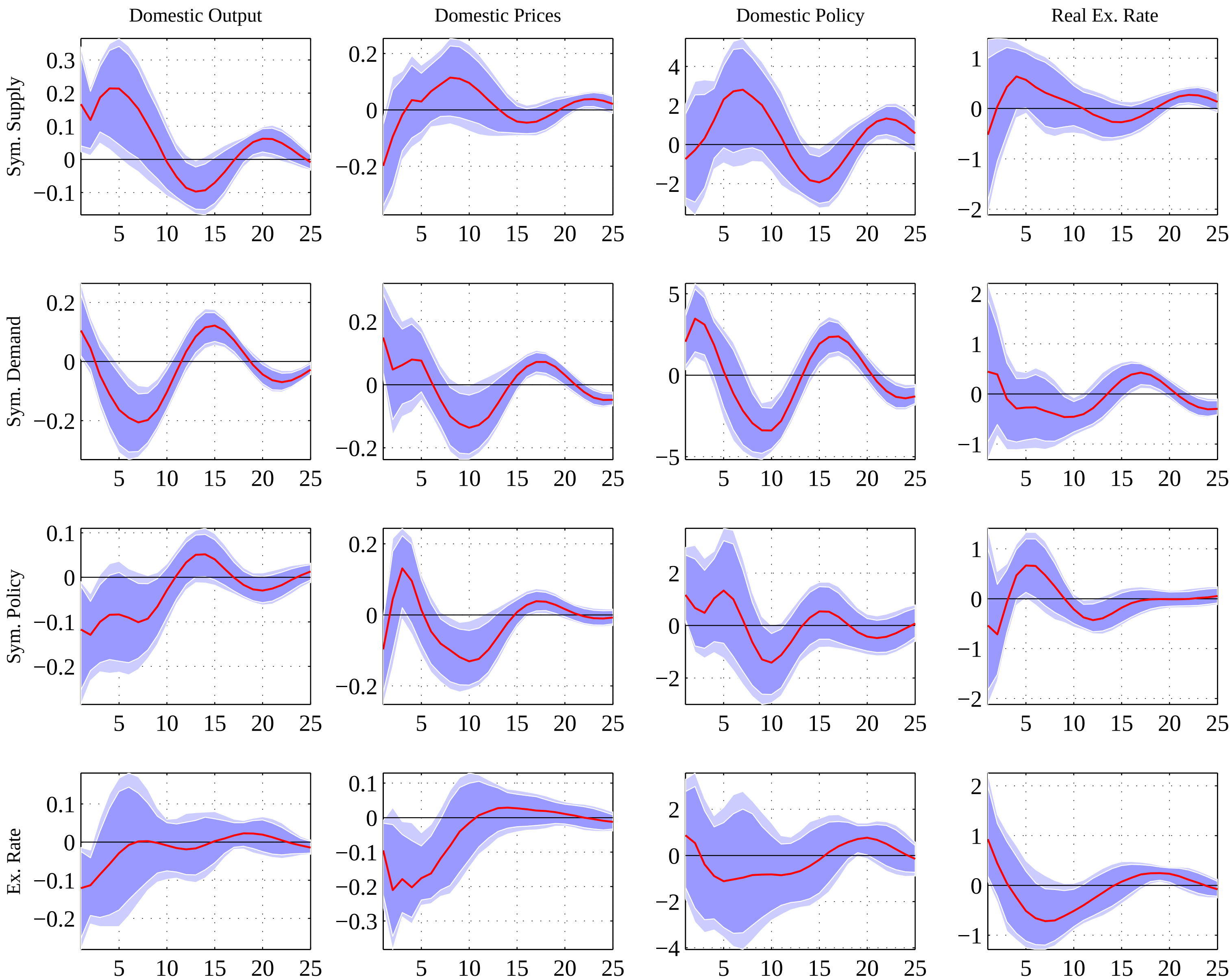
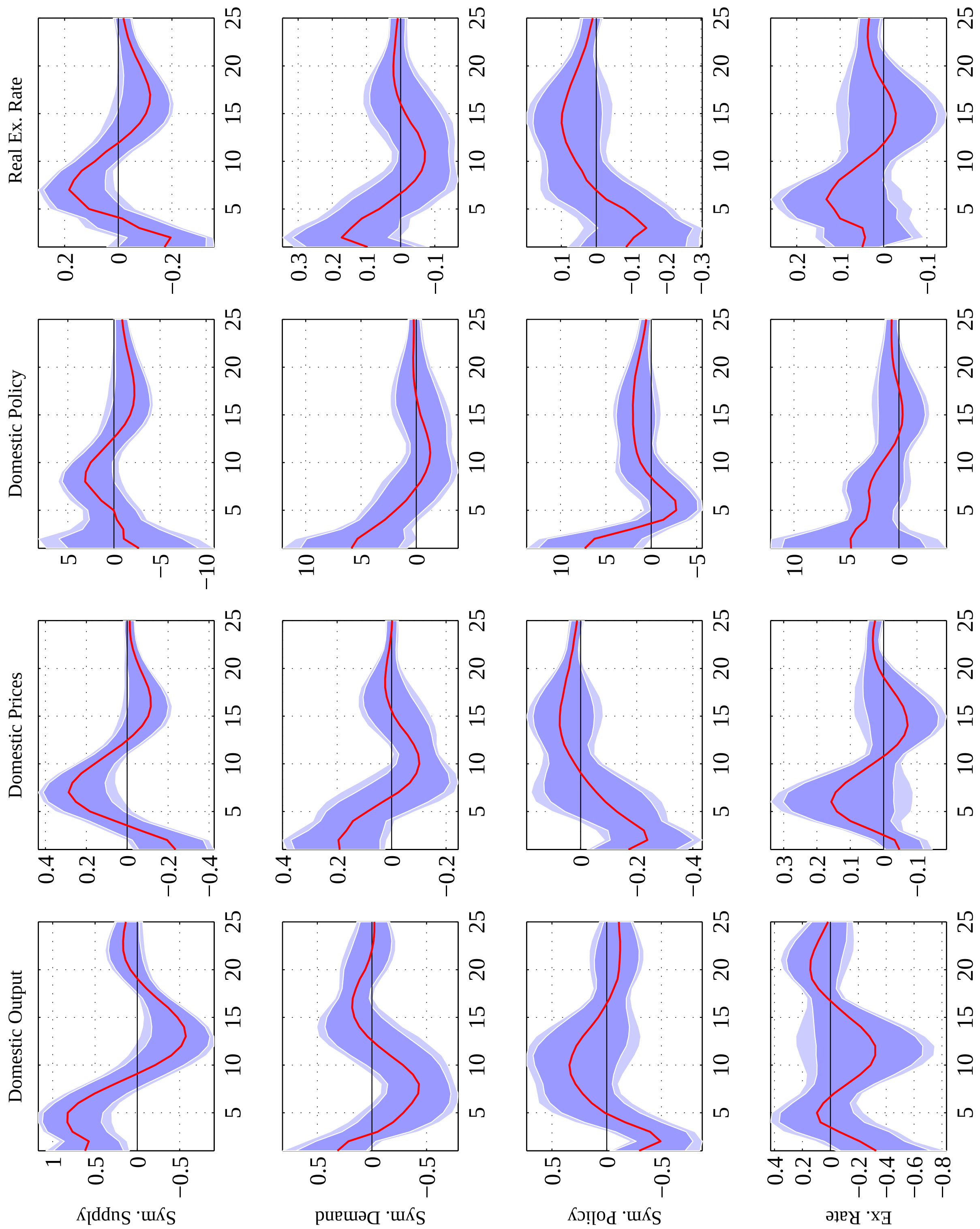


Figure 8: Impulse Response Functions – Estonia



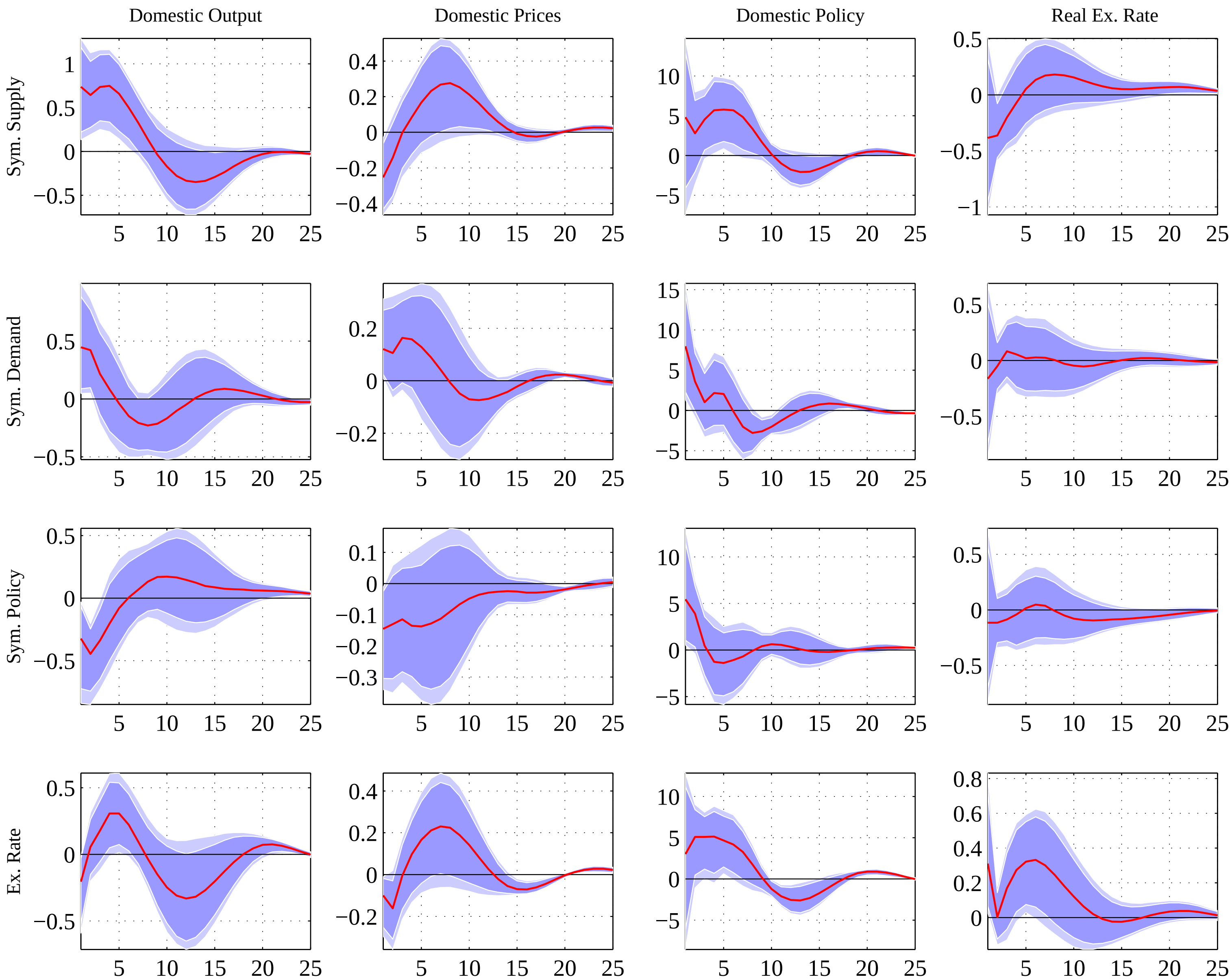


Figure 9: Impulse Response Functions – Lithuania

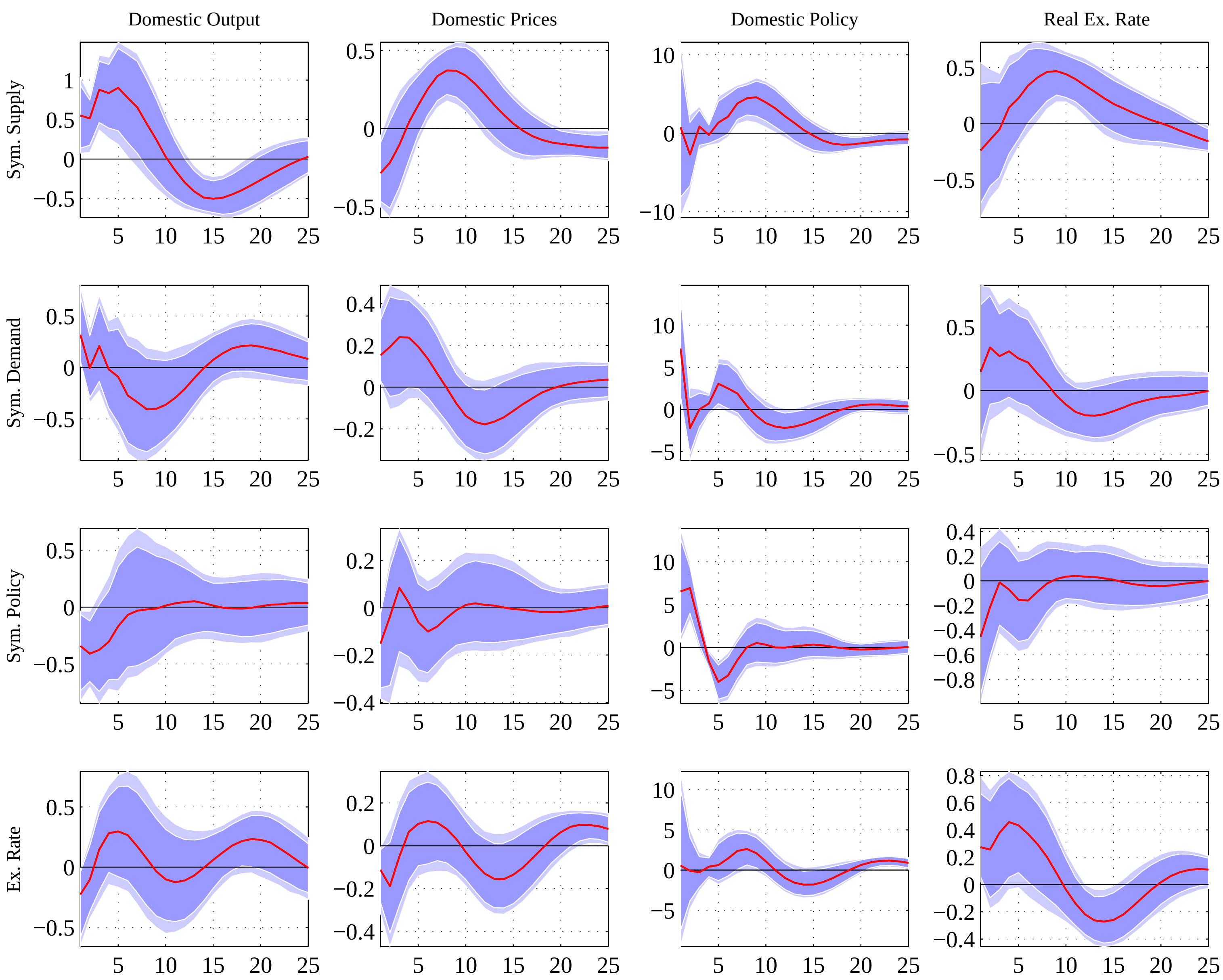


Figure 10: Impulse Response Functions – Latvia

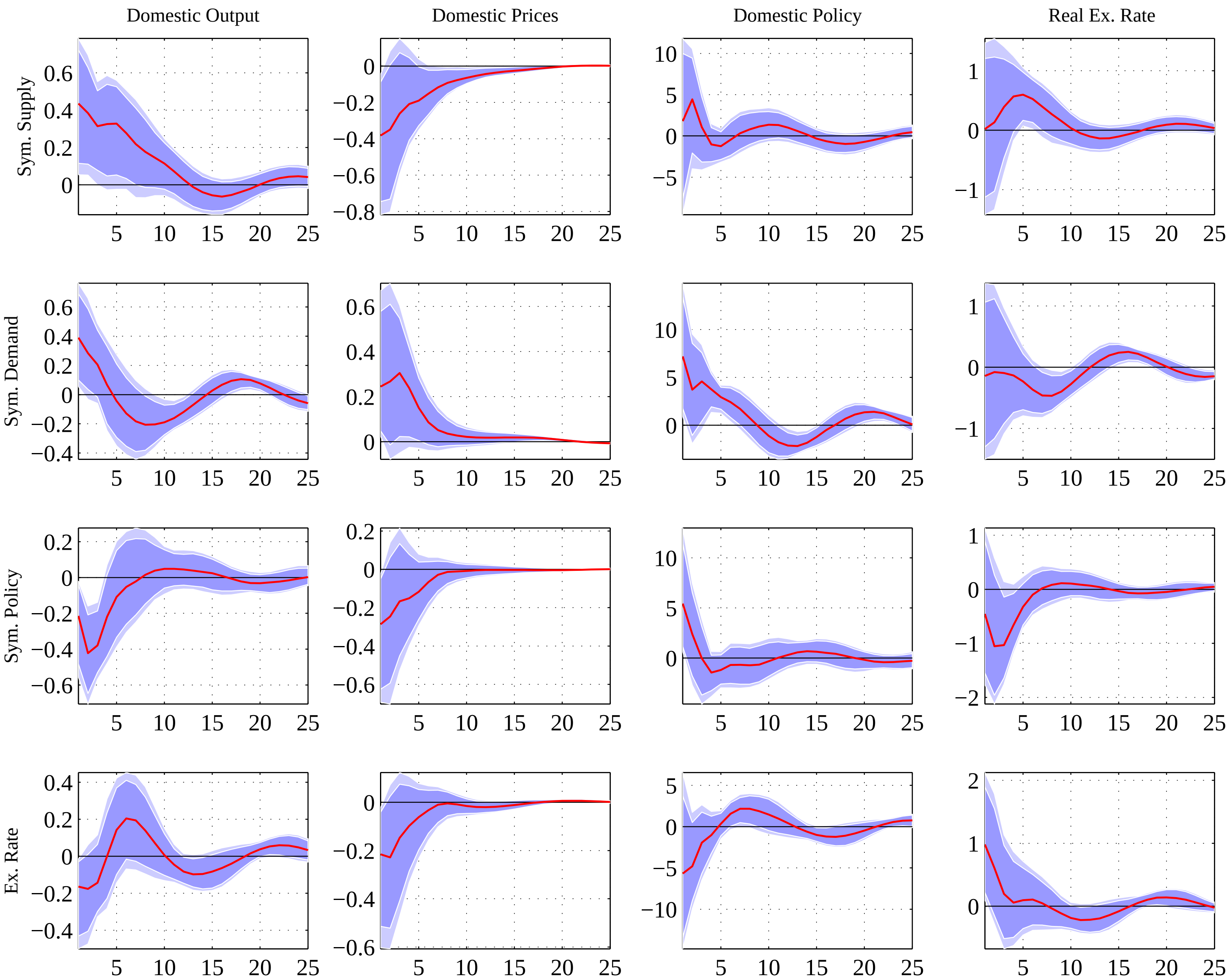


Figure 11: Impulse Response Functions – Romania

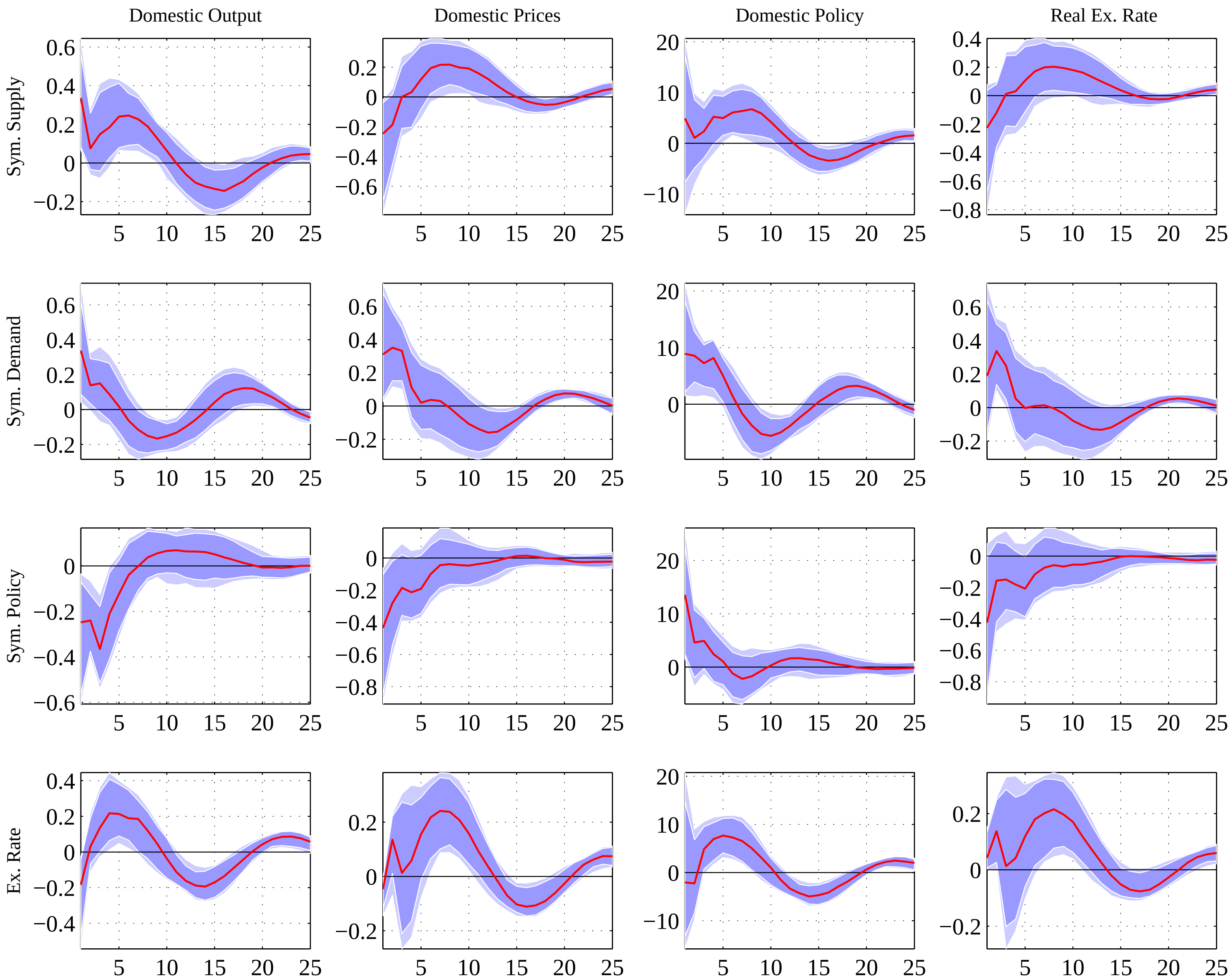
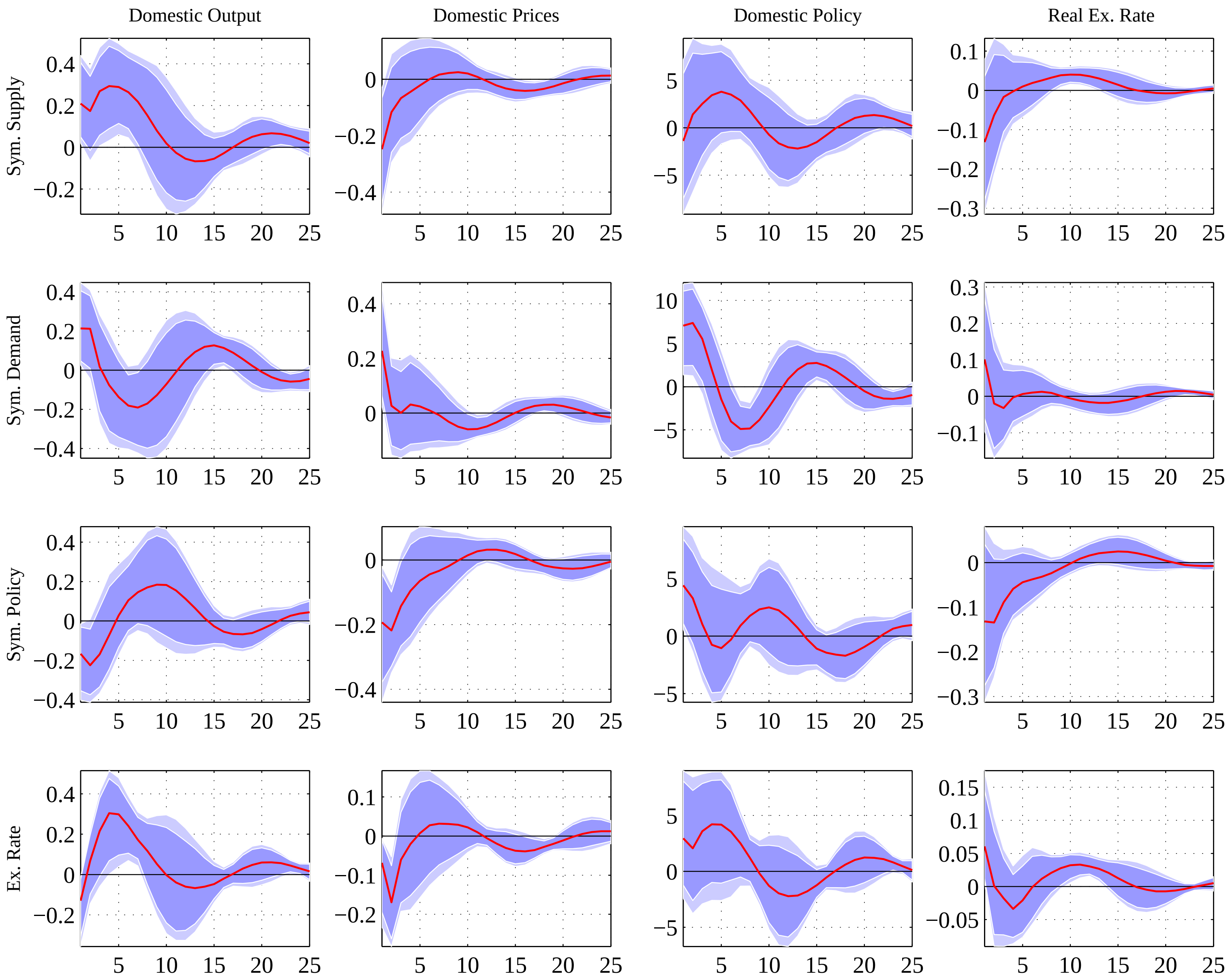


Figure 12: Impulse Response Functions – Bulgaria

Figure 13: Impulse Response Functions – Slovenia



Appendix B: Variance Decomposition

Figure 14: Variance Decomposition: Czech Republic

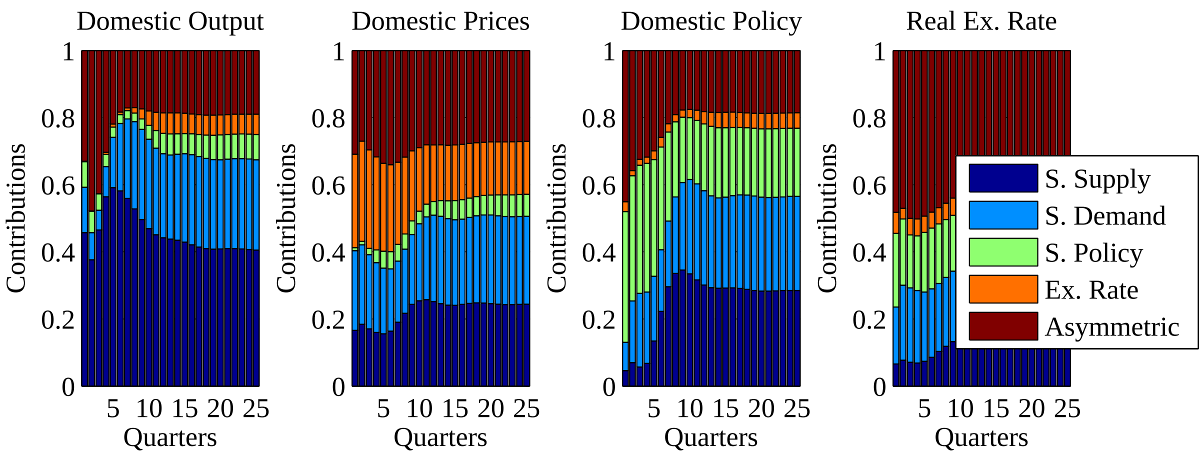


Figure 15: Variance Decomposition: Slovakia

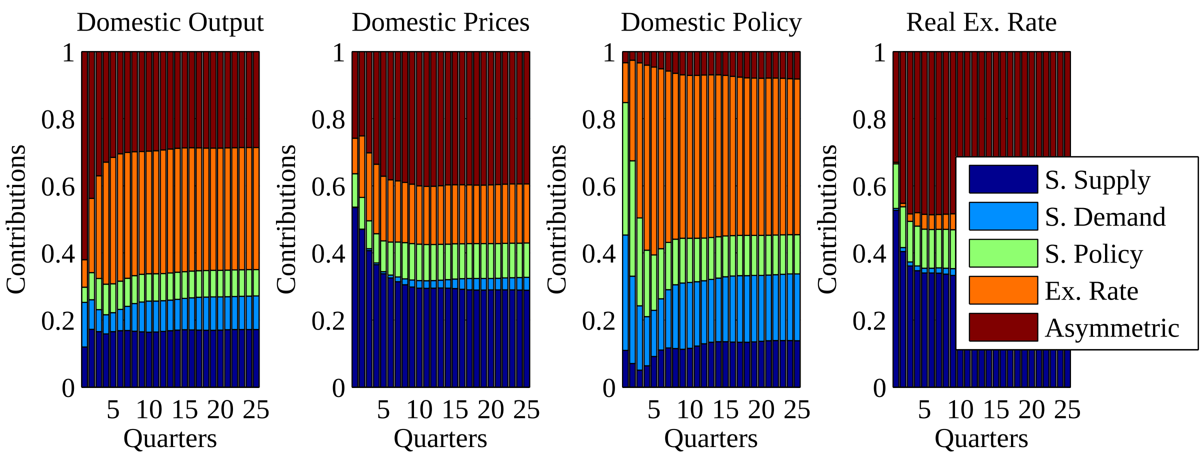


Figure 16: Variance Decomposition: Hungary

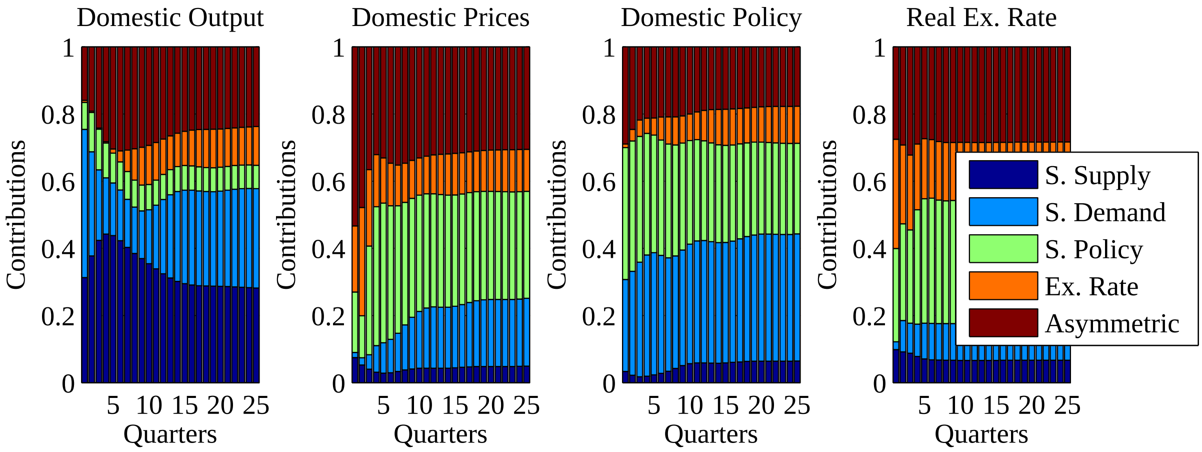


Figure 17: Variance Decomposition: Poland

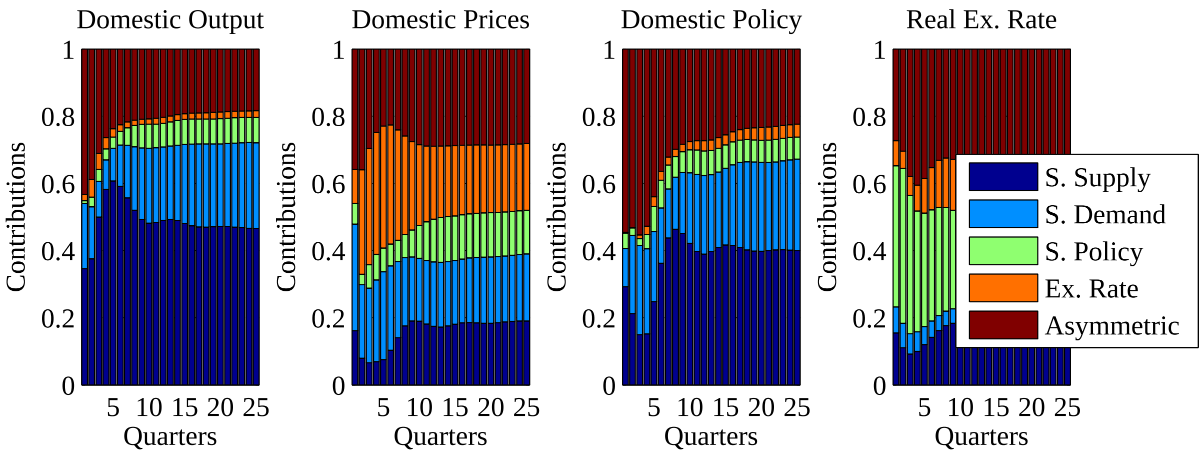


Figure 18: Variance Decomposition: Estonia

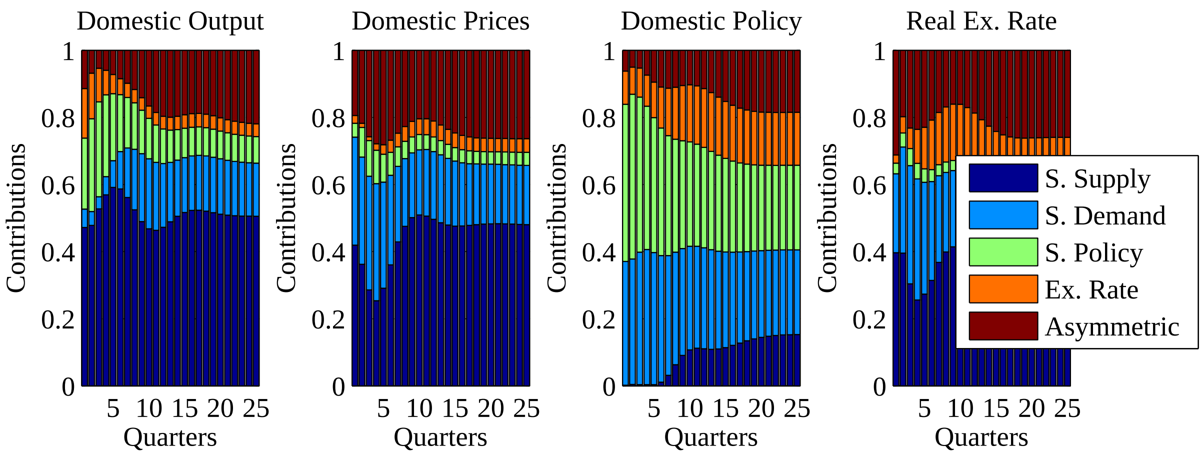


Figure 19: Variance Decomposition: Lithuania

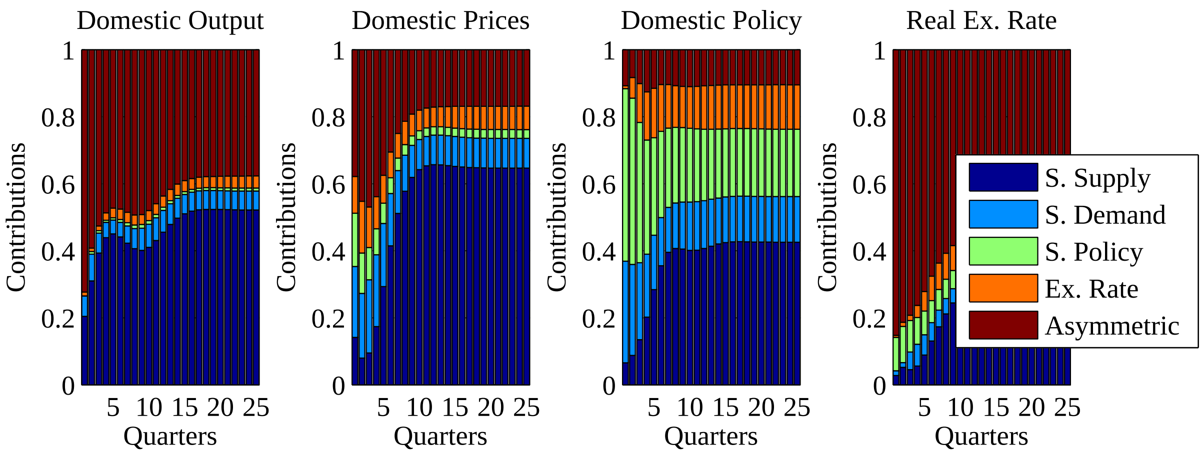


Figure 20: Variance Decomposition: Latvia

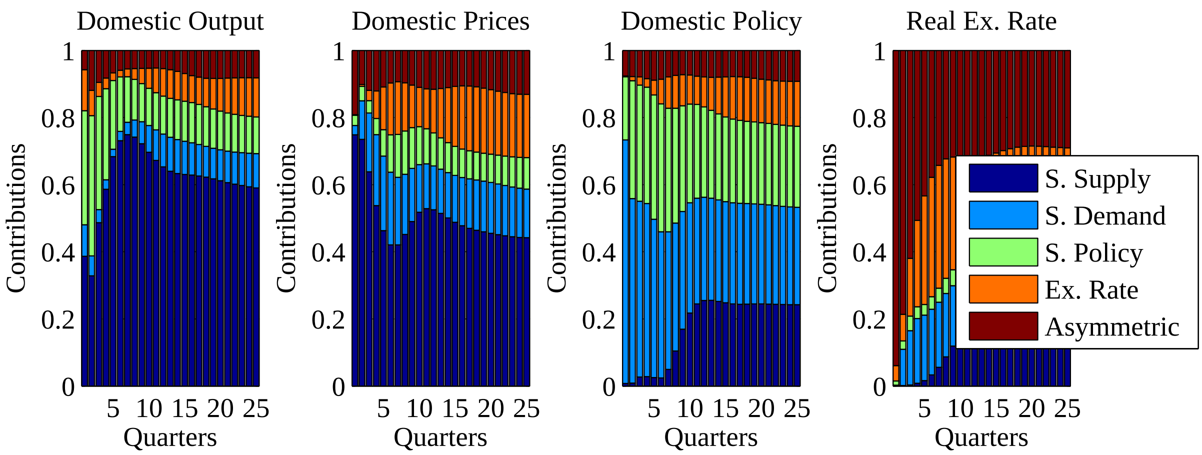


Figure 21: Variance Decomposition: Romania

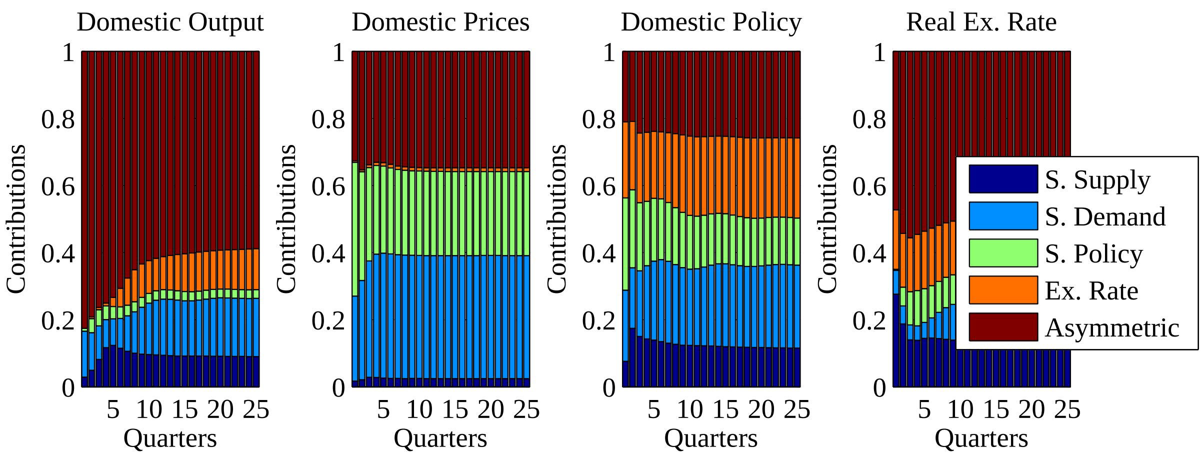


Figure 22: Variance Decomposition: Bulgaria

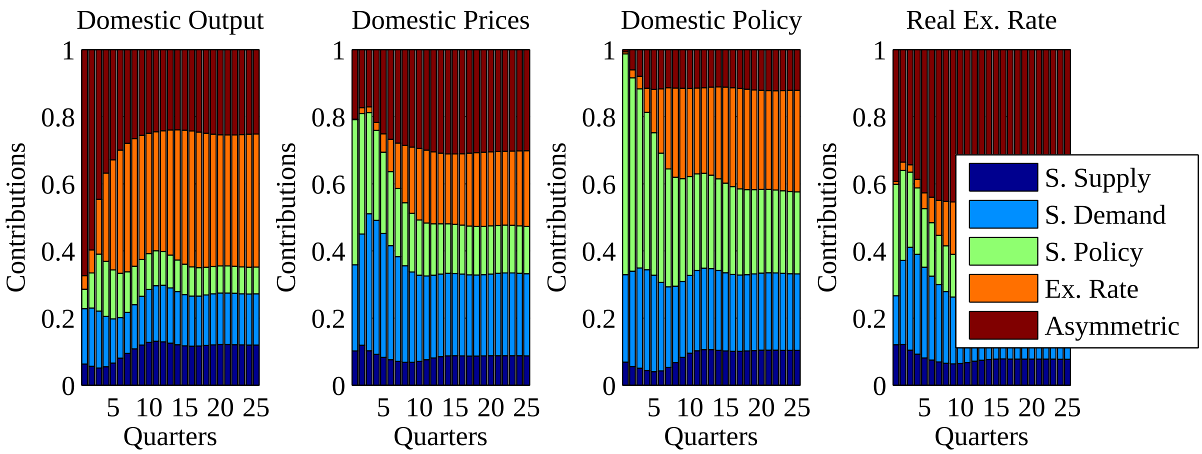
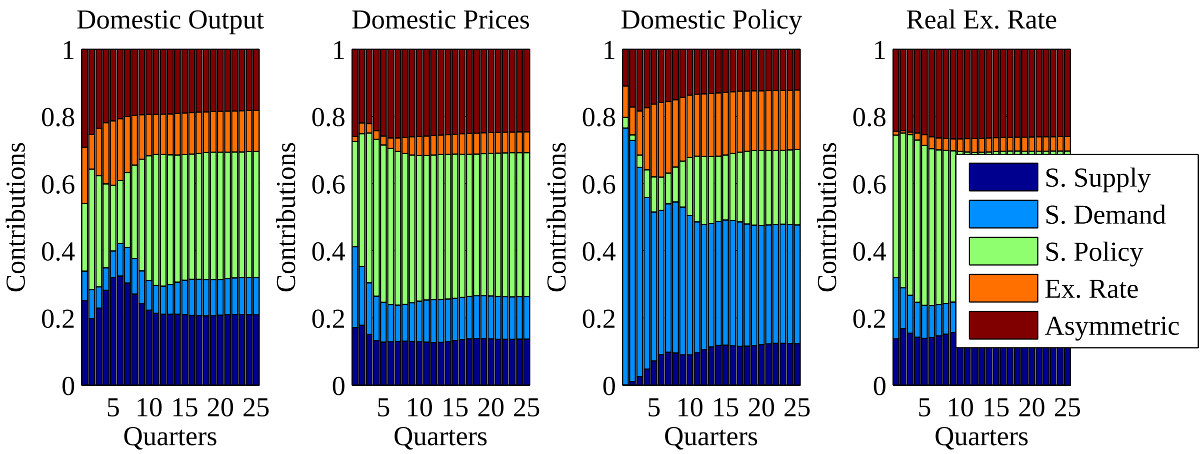


Figure 23: Variance Decomposition: Slovenia



Appendix C: Identified Shocks

Figure 24: Shocks Contributions – Czech Republic

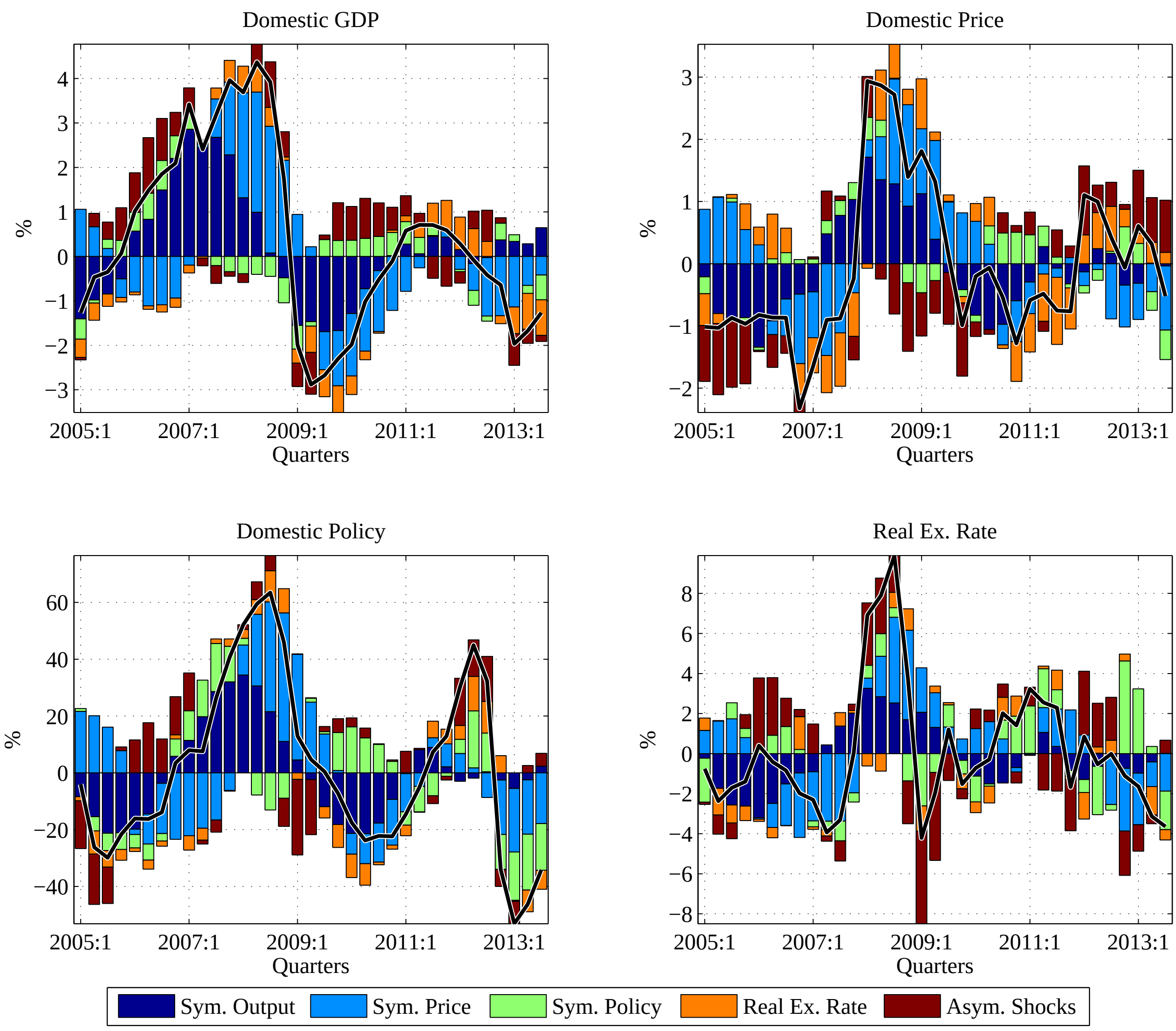


Figure 25: Shocks Contributions – Slovakia

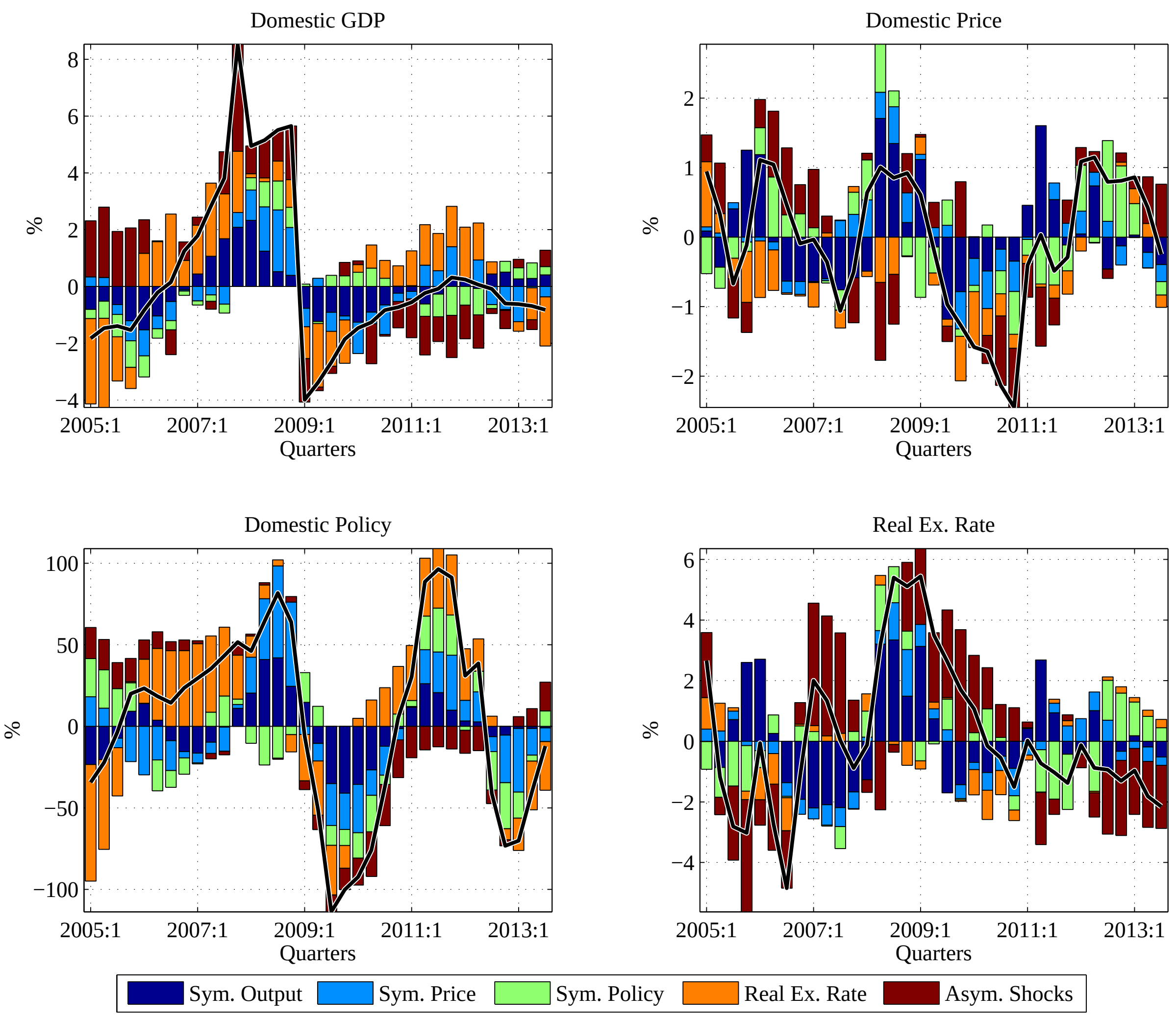


Figure 26: Shocks Contributions – Hungary

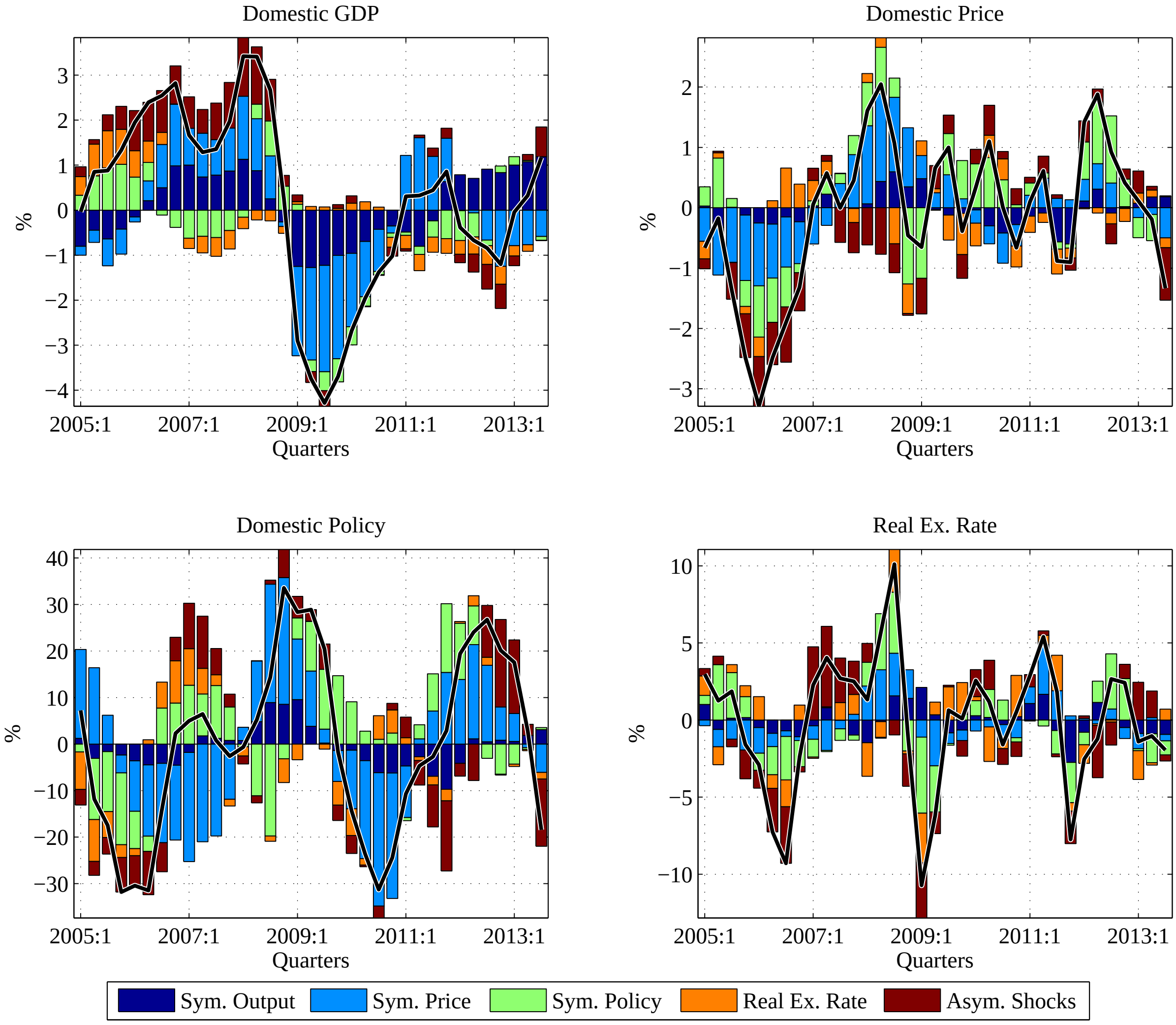


Figure 27: Shocks Contributions – Poland

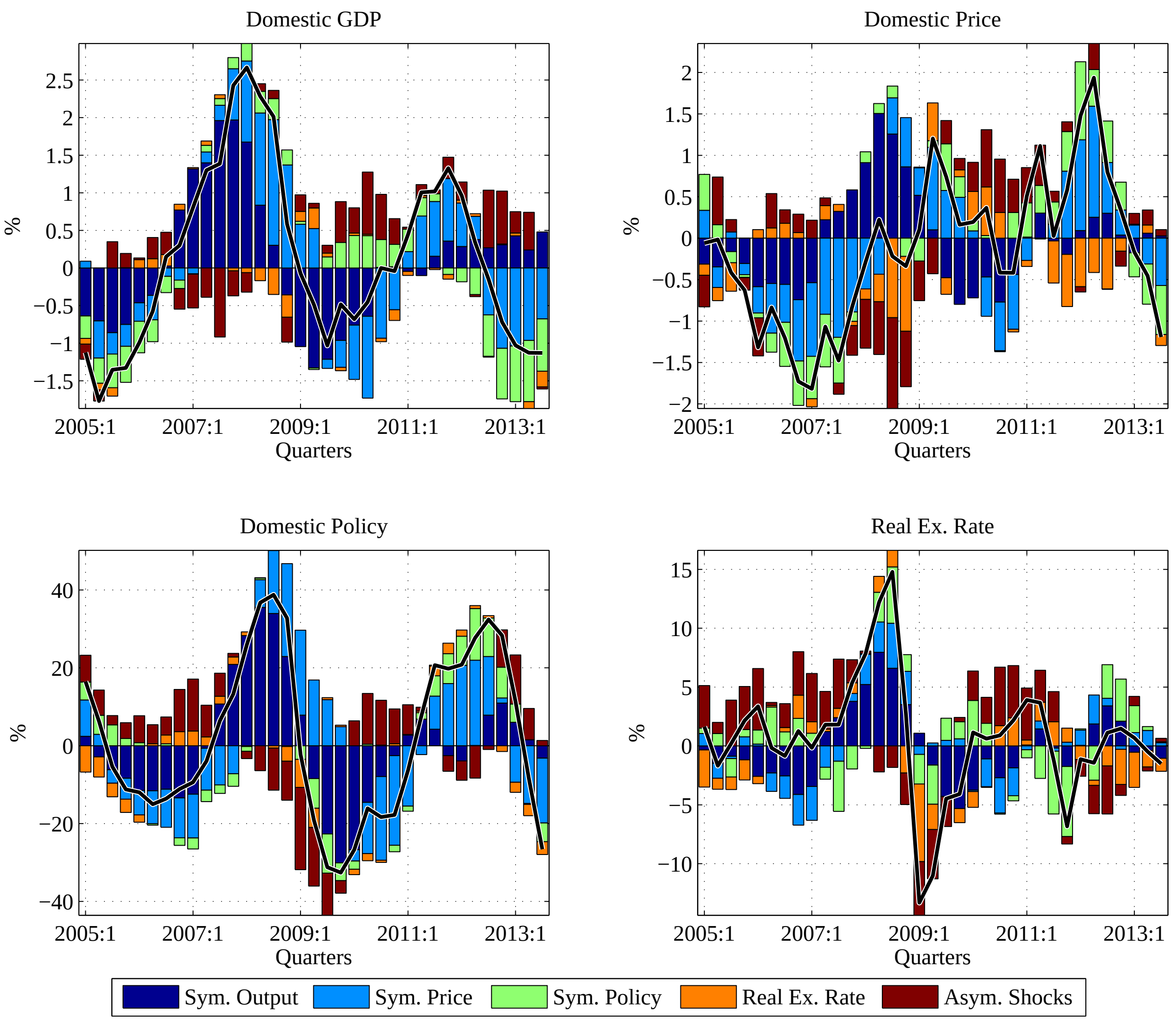


Figure 28: Shocks Contributions – Estonia

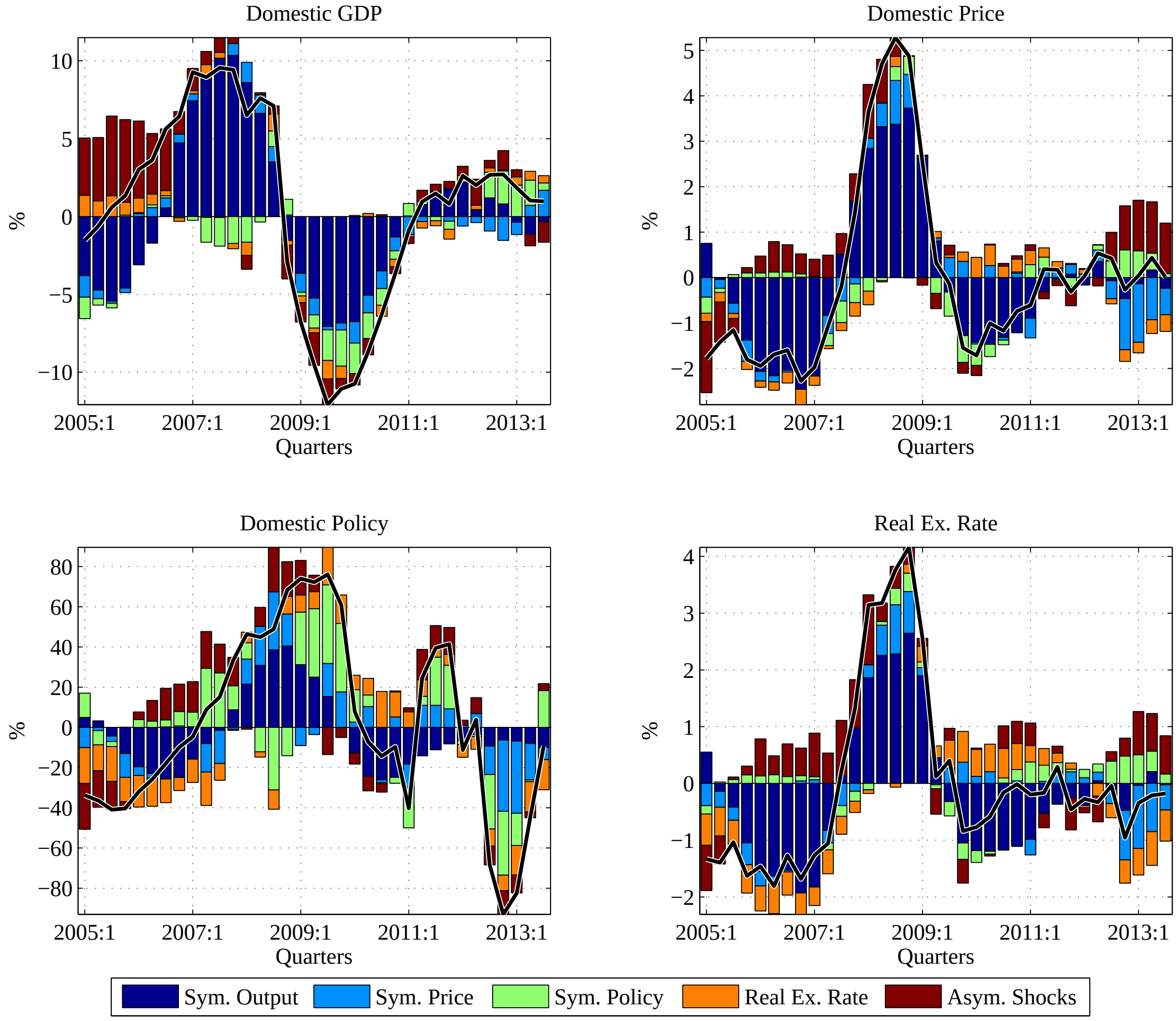


Figure 29: Shocks Contributions – Lithuania

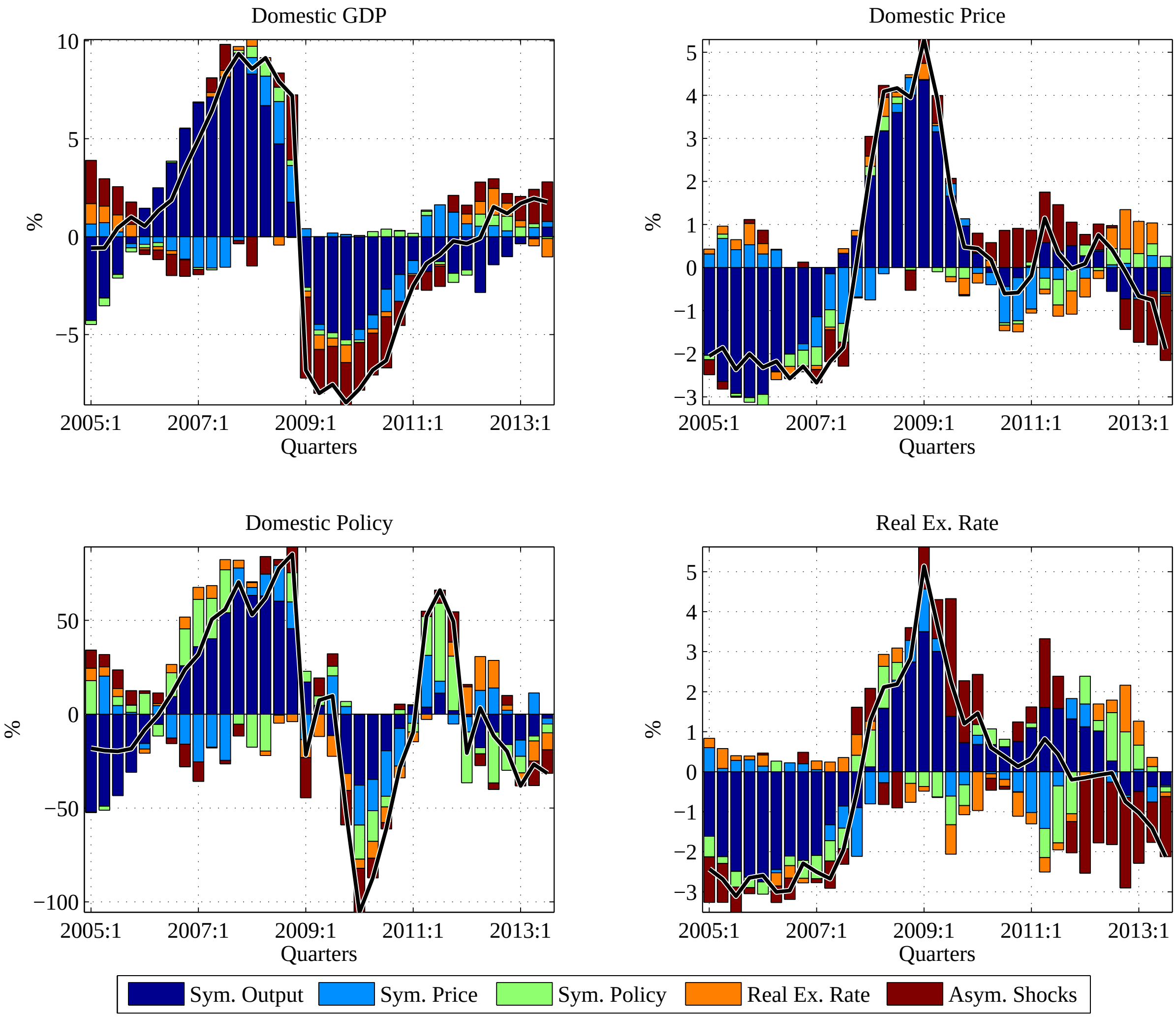


Figure 30: Shocks Contributions – Latvia

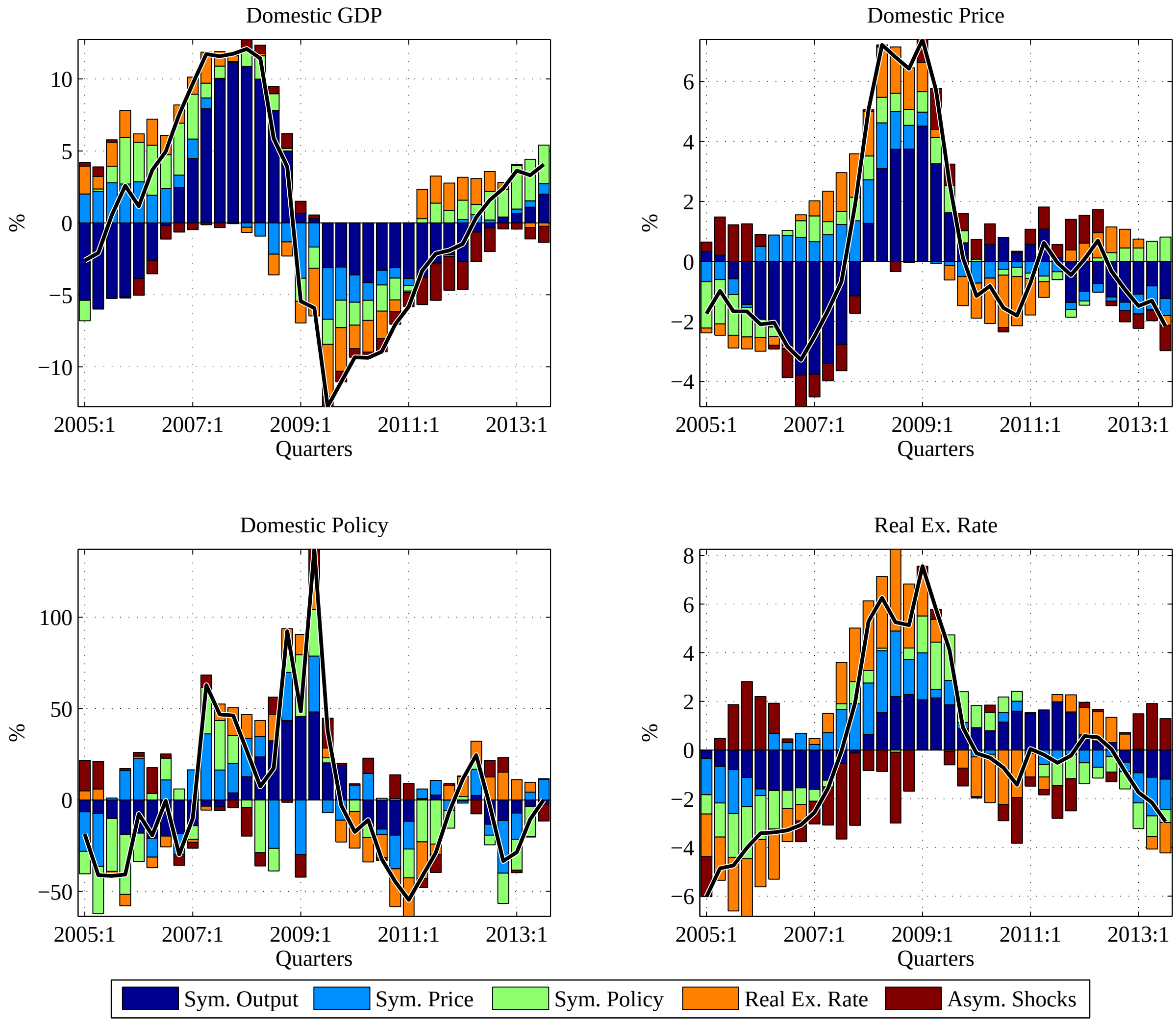


Figure 31: Shocks Contributions – Romania

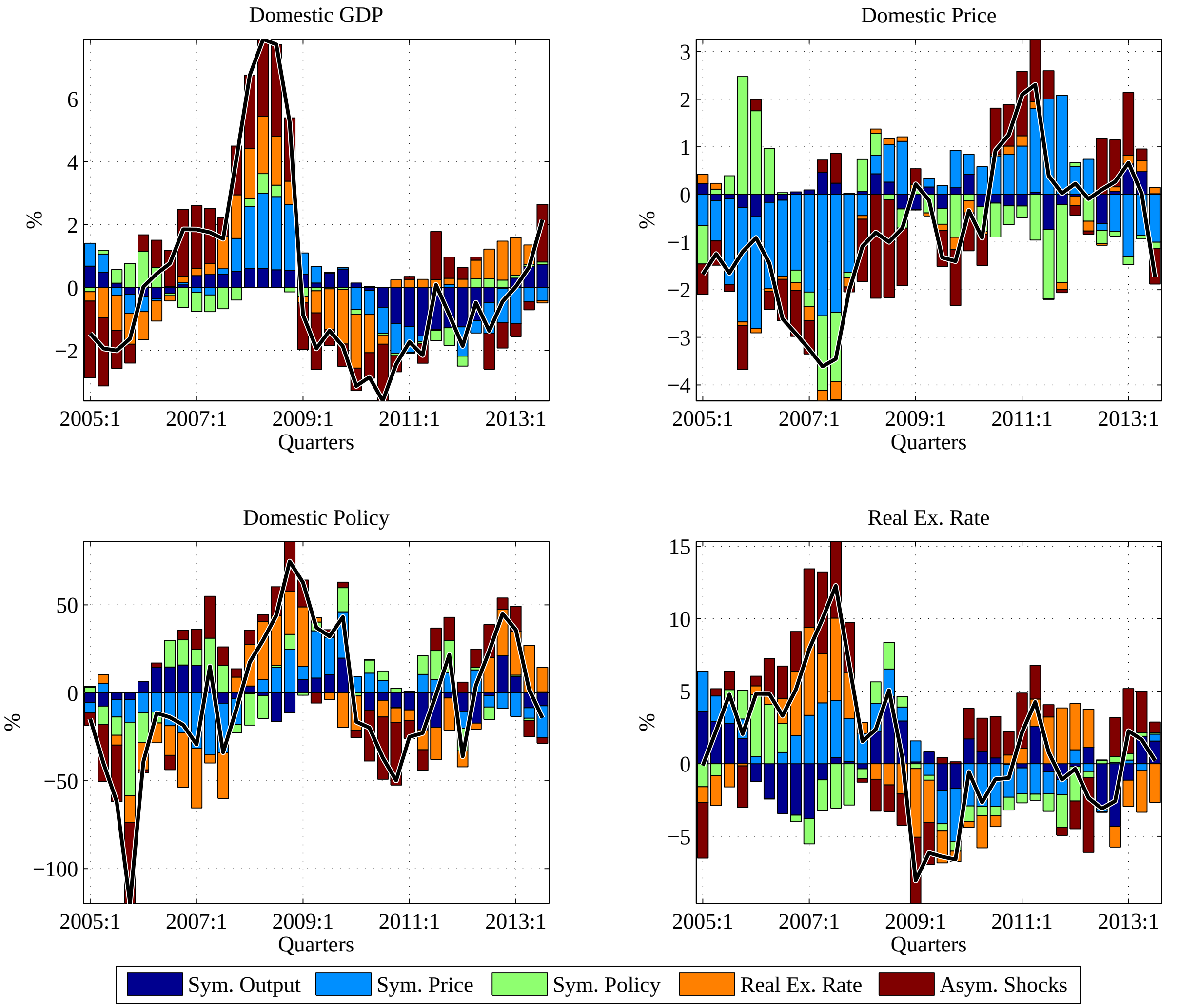


Figure 32: Shocks Contributions – Bulgaria

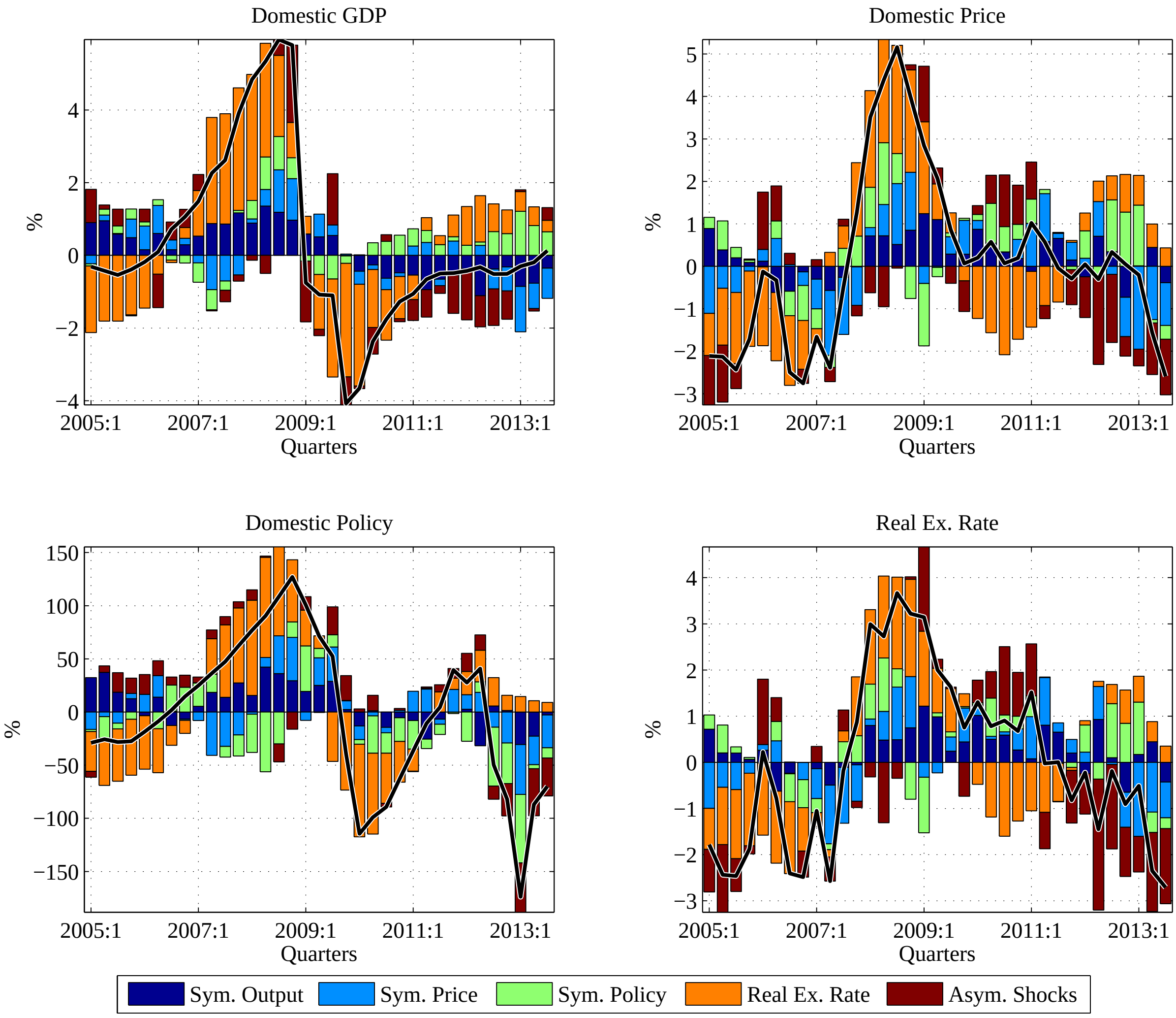


Figure 33: Shocks Contributions – Slovenia