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Monetary Policy and Exchange Rate Dynamics: The Exchange Rate as a Shock Absorber

Volha Audzei and František Brázdik*

Abstract

The traditional view of the exchange rate as a shock absorber has been challenged by a number of studies. Therefore, it is not surprising to identify economies in which exchange rate movements fuel business cycle volatility. We assess whether the Czech economy belongs to this group. We analyze the relations between the exchange rate and other macroeconomic variables within the VAR framework using the sign restriction technique as proposed by Uhlig (2005). The results of variance decomposition of the exchange rate do not allow us to reject a shock-absorbing role of the exchange rate for the Czech economy. To assess the robustness of the results, we also examined the relation between monetary policy and exchange rate volatility. We conclude that the shock-absorbing nature of the exchange rate prevails over shock generating one.

JEL Codes: C32, E32, F31, F41.
Keywords: Czech Republic, exchange rates, sign restrictions, structural vector autoregression.

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Nontechnical Summary

Whether exchange rates are shock absorbers or shock generators is a long-term topic in the empirical literature. In the international macroeconomics two general types of shocks are worth of considering. First, the symmetric shock does not lead to exchange rate response. When symmetric shock occurs exchange rate does not react and its importance as an adjustment mechanism subdued. When an asymmetric shock hits a country, international macroeconomic theory assumes that adjustment of the exchange rate should accommodate the shock and dampen its propagation to the economy. The exchange rate may thus help an inflation-targeting economy to pursue its goal. Contrary to this, exchange rate movements due to market sentiment or shocks hitting main trade partners lead to additional economic volatility. Due to the strong economic links of the Czech Republic to the eurozone countries, this study focuses on the Czech koruna-euro exchange rate and it role as shock absorber or generator.

We analyze the role of the exchange rate using two types of structural vector autoregression models. In all assessed models, the sign restriction identification procedure is used to identify a structural VAR model for evaluation the exchange rate nature. This procedure identifies structural shocks using constraints on the signs of the the variables of interest when responding to shock. The sign restriction procedure allows us to avoid imposing arguable assumptions on the short or long-term effects of shocks or ordering of the shocks. Also, due to its Bayesian nature it is suitable method when the data sample is short.

The applied sign restrictions are in line with theory and the DSGE model for the Czech Republic as presented by Andrle et al. (2009). We assess the time series describing the behavior of the Czech economy over the period from 1998 to 2011. Further, we use the forecast error decomposition of the variables of interest to find the contribution of real and nominal shocks and to assess the contribution of exchange rate shocks to economic volatility.

Even for developed economies the results of studies on exchange rate role widely differ across studies. The seminal paper by Clarida and Gali (1994) concluded that demand shocks are more important in generating economic fluctuations and account for the largest share of the variance in economic variables, leaving the negligible role for nominal shocks.[1] Thus, they found that the exchange rate acts as an absorber of shocks. Studies using different shock identification schemes come to significantly different results. Thomas (1997), Amisano et al. (2009), Farrant and Peersman (2006), and Peersman (2011) conclude that the loss of an independent currency would not generate additional macroeconomic volatility and could even reduce it. The importance of nominal shocks for exchange rate volatility is identified in a number of studies, e.g. Rogers (1999), Eichenbaum and Evans (1995), and Bluedorn and Bowdler (2005). At the same time, Juvenal (2011) supports the findings of Clarida and Gali (1994). However, this comparison of studies has some caveats, as the listed studies differ in methodology, data availability, and the periods they analyze.

Our results from relative models suggest that for CZK–EUR pair the role of shock absorber prevails over the shock generator role. Idiosyncratic exchange rate shock is significant contributor to exchange rate variance but more than half of the exchange rate variance is driven by real shocks. Our analysis shows that the exchange rate shock is not the main contributor to variance

[1] Demand, money and supply shocks are standard types shocks as defined in the IS-LM model developed by Obstfeld et al. (1985). Also, in the referenced literature the terms “nominal” and “monetary” shocks are used interchangeably and usually include the exchange rate and policy shocks.

of relative output and inflation. The relative supply and demand shock can be considered as the main contributors to variance of relative output and inflation.

The model with symmetric and asymmetric shock also identifies a significant contribution of idiosyncratic exchange rate shock to its variance. However, the exchange rate shock together with asymmetric shock are only minor contributors to variance of output growth and inflation. Thus, we cannot reject the hypothesis that the CZK–EUR exchange rate is a shock absorber for the Czech economy.

1. Introduction

Since the seminal paper by Clarida and Gali (1994) there has been increasing interest in research on the sources of exchange rate fluctuations and their propagation to the rest of the economy. These studies (e.g. Thomas, 1997; Amisano et al., 2009) are assessing shock-absorbing or generating nature of the exchange rate. Theoretical models often support the shock-absorbing role of exchange rate. However, there exists a number of studies (e.g. Farrant and Peersman, 2006; Peersman, 2011) that consider as exchange rate a source of shocks instead of a shock absorber.

This variation in results motivates us to assess the role of the exchange rate in propagating and generating economic shocks in the Czech Republic. We analyze contributions of structural shocks in explaining exchange rate volatility, focusing on the role of both nominal shocks and real shocks. Our approach is based on structural vector autoregression (SVAR) models and a sign restriction identification scheme is used for identification.

The literature conventionally considers exchange rates as shock absorbers rather than shock generators. Using VAR models with a triangular identification scheme, Clarida and Gali (1994) questioned the importance of nominal shocks in real exchange rate fluctuations. They proved 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. Recently, Juvenal (2011) supports the findings by Clarida and Gali (1994) that demand shocks are more important in generating real exchange rate fluctuations. However, this 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 Rogers (1999), Eichenbaum and Evans (1995), and Bluedorn and Bowdler (2005) have found that nominal shocks contribute significantly to business cycle volatility.

Our study relates to the literature analyzing the importance of various shocks for the Czech economy. Babecka-Kucharcukova (2009) concentrates on incomplete pass-through of exchange rate shocks. The importance of monetary policy and exchange rate shocks in the Czech Republic is identified in a study by Hurnik et al. (2008), who use a DSGE model to analyze the impact of monetary policy shocks on interest rates and inflation. Skorepa (2008) finds that monetary policy shocks play an important role in inflation undershooting. Our paper differs from the above studies, we focus on the decomposition of the variance of considered variables in the structural VAR model framework.

Structural VAR models have become one of the most widely used tools for identifying structural shocks. As we have to cope the limited data span, we rely on the sign restriction method for converting a VAR model into a structural VAR model. The sign restriction method was introduced by Uhlig (2005) and has been developing constantly since then. This method was used in Farrant and Peersman (2006), Scholl and Uhlig (2008), and Mallick and Rafiq (2008) to analyze the contribution of nominal shocks to macroeconomic volatility. Corsetti et al. (2009) use the sign restriction approach to identify the effects of productivity and demand shocks on the U.S. economy. A thorough description of the method and its possible applications is presented in Fry and Pagan (2011). 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 imposed sign restrictions are collected from theoretical studies and are consistent with the structural model of the Czech economy as presented by Andrle et al. (2009). Therefore, the dynamics of the estimated model are in line with the results of the structural model estimation for the Czech economy. The sign restriction method is implemented via a Bayesian procedure similar to Scholl and Uhlig (2008).

As a baseline specification we consider the model formulated in relative terms by Clarida and Gali (1994). This baseline model does not separate monetary policy and exchange rate shock, therefore we extend the specification to account for monetary policy influence. This extended model is used to to check the robustness of the baseline model predictions. The performance of the identification method is evaluated by assessing the distributions of the initial responses of the model variables to shocks. The analysis of these distributions suggests that accounting for monetary policy in the extended model improves shock identification. Accounting for policy explicitly improves the recovery of the signs of the impulse responses and slightly lowers the uncertainty in the variables' responses.

Our analysis follows with decomposition of the variance of the model's variables with focus on the contribution of exchange rate shocks to business cycle volatility. The analysis of the volatility contributions explores the nature of the exchange rate. The results of the variance decomposition allows us to consider exchange rate as shock absorber rather then a shock generator.

Unlike in aforementioned studies for other countries, we find ample role of real shocks in exchange rate fluctuations. While the exchange rate shock is still found to be an important source of exchange rate volatility, its impact is comparable to a combination of real and demand shocks. Moreover, exchange rate shock does not generate a large portion of the variance in real output and inflation in the two relative models.

The third model, considered in this study, focuses on the effect of monetary policy on the exchange rate. Because the baseline and extended models are specified in relative terms, they do not identify the source of the shocks (domestic or foreign). Therefore, we introduce a more complex model following the studies by Artis and Ehrmann (2006) and Peersman (2011). Using this model and implied forecast error variance decomposition, we conclude that symmetric and asymmetric monetary policy shocks strongly affect the volatility of the exchange rate. Also, we find that exchange rate shocks are not the main source of inflation and output volatility, so the shock-absorbing nature of the exchange rate prevails.

In the following section, we briefly describe the implementation of the sign restriction method. After a description of the methodology, the properties of the data are discussed. The setup of the model and a declaration of the restrictions are then presented. The fourth section presents the model estimation results. Finally, the fifth section summarizes our findings and concludes.

2. Implementing Sign Restrictions

The core of this work is to estimate a structural VAR model of a small open economy. The transformation of a VAR model into a structural VAR (SVAR) one requires identification of structural shocks, which is usually a subject of scrutiny because different approaches can lead to significantly different results. The common approaches impose various short or long-term restrictions on the responses of the variables to shocks. However, as Farrant and Peersman (2006) show, long-term zero response restrictions can deliver biased results. Another common approach is to impose contemporaneous restrictions via the recursive ordering Choleski decomposition. This approach often leads to the emergence of anomalies such as the price puzzle or delayed overshooting puzzles, as Uhlig (2005) summarizes.

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. In this section we briefly describe the sign restriction methodology.

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

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

Here, $A(L)$ 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:

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

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 is delivered by 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.

As the sign restrictions – similarly to Bayesian methods – deliver a set of models, there is no unique model representing the estimation. Therefore, previous studies have reported the median response at each horizon for each variable. However, this approach does not provide consistent results. Fry and Pagan (2011) criticize this procedure, as the median responses may be infeasible because they originate from different models (different parameterization).

To avoid this violation, the closest-to-median approach proposed by Fry and Pagan (2011) is used in creating the estimation summary measure. For period i the median impulse $\overline{\phi_i}$ over all successful draws ϕ_j is computed, where $\overline{\phi_i}$ and ϕ_js are $n \times n$ matrices. The objective is to find the draw that is closest to the median, i.e., solves the following problem:

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

where the search runs over all successful draws j.

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 parameterization, the variance decomposition of the closest-to-median model is analyzed. This choice ensures that the shocks in the calculation are truly uncorrelated. calculation are truly uncorrelated.

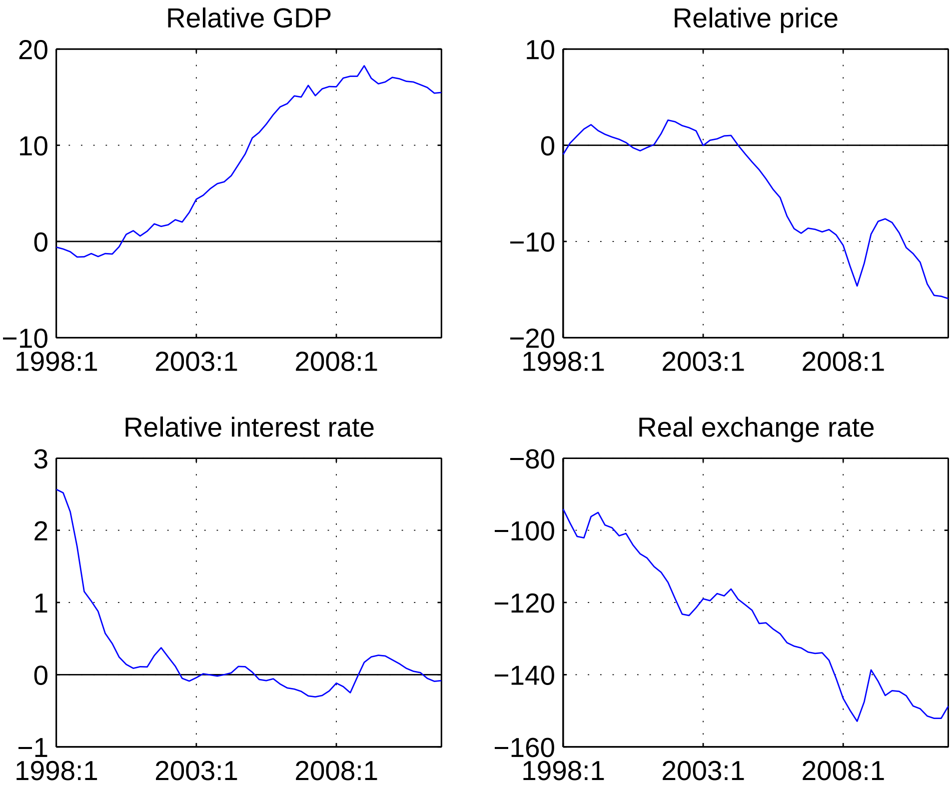
3. Data Description

The time series used are retrieved from the Czech National Bank (CNB) database ARAD, from the Czech Statistical Office, and from Eurostat. The sample period covers the period from the first quarter of 1998 (the launch of the inflation targeting policy by the CNB) to the last quarter of 2011 (the last available data point), representing an era of a consistent type of monetary policy (avoiding significant policy breaks). All the time series collected are at quarterly frequency, producing a sample of 56 observations.

To describe the foreign economy, foreign inflation and demand enter the model in the form of effective indicators. These effective indicators are constructed from the raw euro area country data (source: Statistical Data Warehouse of the European Central Bank) by using the weights of Czech exports to the eurozone countries.

Short-term interest rates are described by the 3M PRIBOR and 3M EURIBOR interbank rates, where the source for the data is the CNB database.

Figure 3.1: Czech Macroeconomic Indicators Relative to Eurozone Effective Indicators



Domestic output is described by the seasonally adjusted domestic real GDP series, which originates from nominal GDP deflated by its deflator. The exchange rate time series are taken from the ARAD database. The exchange rate is defined as the price of one euro in Czech koruna, therefore an decrease of the exchange rate equates to appreciation of koruna.

The CNB does not have to react to the first-round effects of the tax change shock to inflation and may apply an exemption ("escape clause") from its obligation to meet the inflation target. This approach is advocated by the fact that the CNB also takes into account the effect of monetary policy on economic stability when considering the ways to meet the inflation target. Strict elimination of these effects by changing the settings of monetary policy instruments would cause undesirable short-term fluctuations in the economy. As these exemptions are applied, headline CPI inflation is not fully consistent with the responses of the policy and short-term rates. Therefore, domestic inflation is represented by the adjusted net inflation time series, as this measure excludes the primary impacts of tax changes. The use of adjusted net inflation allows us to avoid inconsistencies related to changes in taxes, fiscal policy or related breaks.

Figure 3.1 shows the data used in the estimation of the relative models. During the 1998–2011 period various trends are observed in the data documenting the Czech Republic's economic convergence process. The time period considered also includes several downward changes in the domestic inflation target and the change from net inflation targeting to headline inflation targeting in 2002. These changes are part of the convergence process and result in downwardsloping relative prices. A downward trend can also be observed in the real exchange rate series. It is driven by the appreciation of the koruna over the time period considered.

The observation of trends justifies the removal of trends before estimation. The nature of the relative variables removes common trends, and the use of time series differencing is able to handle the trends in the estimation of the relative models. For non-relative models, linear detrending is used to remove domestic trends originating from the convergence process, and subsequent differencing delivers stationarity.

4. Estimation

The discussion by Obstfeld et al. (1985) and the studies by Artis and Ehrmann (2006) and Amisano et al. (2009) on the role of the exchange rates provide the theoretical basis of our analysis. As in Amisano et al. (2009), we also follow the approach of Clarida and Gali (1994), who set up a small open economy model and relate it to a VAR model specified in relative terms.[2] We believe that this form is appropriate for the case of the Czech Republic, where the large neighbor is replaced by the effective eurozone aggregate. As the baseline structural model is specified by Clarida and Gali (1994), derivation of the structural model is beyond the scope of our analysis.

The motivation for the relative form originates from our focus on the exchange rate, which itself is a "relative" variable. The structural model in relative terms also remains parsimonious. Moreover, under the assumption that foreign variables do not react to domestic shocks, the relative form rules out symmetric shocks and focuses on identification of asymmetric shocks. This assumption can be justified by the fact that the Czech Republic is a relatively small economy within the European union.

The exchange rate to does not respond significantly to symmetric shocks, this behavior is consistent with the setup of relative models that focus on asymmetric shocks. In the presence of asymmetric shocks, the exchange rate may take an important role as a shock absorber. We analyze the role of the exchange rate, examining the response of the real exchange rate to relative demand and supply shocks and its contributions to the variance of the rest of the variables. In the case of a strong response to asymmetric shocks, we will conclude that an independent exchange rate can help stabilize the economy. This strategy is in line with the earlier studies mentioned above.

The reduced form VAR model specified as follows is estimated:

$$x_t = \mu + \Pi(L)x_{t-1} + e_t, \tag{4.5}$$

where x_t is a vector of endogenous variables and e_t is a vector of reduced-form shocks. The vector error correction (VEC) model is not considered, as we did not identify statistically significant and well reasoned co-integrating relationships in the relative time series.

We further follow the estimation procedure by Clarida and Gali (1994) and estimate the following VAR model in the first differences: $\Delta x_t = \{\Delta y_t,\ \Delta p_t,\ \Delta q_t\}$, where y_t is the logarithm of

[2] As the relative formulation has become popular, Artis and Ehrmann (2006) list studies which apply the methodology of Clarida and Gali (1994) in specifying the variables under consideration (e.g., output or inflation) as relative to the corresponding variable of a large neighboring country.

real GDP, p_t is the logarithm of the consumer price index, and q_t is the logarithm of the real exchange rate in direct quotation (negative values reflect domestic currency appreciation). Output and the price index are relative to foreign (effective eurozone) variables, in line with the nature of the exchange rate as a relative variable.

The model is estimated with three structural shocks: a relative supply shock, a relative demand shock, and a relative nominal shock.[3] Structural shocks are identified by the sign restrictions imposed. As the model is in the form of differences, the sign restrictions are applied to the differences. The restrictions follow from previous theoretical and empirical studies such as Berg (2010), Liu (2010), Juvenal (2011), and Clarida and Gali (1994). Table 4.1 summarizes the restriction used in the identification of structural shocks in the baseline model. These restrictions are in line with the impulse responses of the structural model for the Czech Republic presented by Andrle et al. (2009).

Table 4.1: Sign Restrictions – Baseline Model

Variable Structural Shock	Δy_t	Δp_t	Δq_t
Relative supply	> 0	< 0	
Relative demand	> 0	> 0	< 0
Relative nominal	< 0	< 0	< 0

The restrictions listed above are imposed only for the initial period. Furthermore, we require all the restrictions to be satisfied simultaneously.

We identify the supply shock as increasing output growth. Furthermore, we assume that it is not associated with a positive response of inflation. The response of the real exchange rate is left unrestricted, as the short-run effect is uncertain in the Clarida and Gali (1994) model.

The demand shock is identified using the relationship from the model in Clarida and Gali (1994). Following the theoretical model, the demand shock increases relative inflation and appreciates the real exchange rate. Also, we assume that the response of relative output is positive.

The last set of restrictions considers the negative nominal shock as defined in the model by Clarida and Gali (1994). The nominal shock causes real appreciation, and this lowers relative output growth (an immediate deterioration of competitiveness) and relative inflation (a decrease in the growth of prices of the imported consumption component). In line with empirical studies (María-Dolores, 2010), it is assumed that the Czech Republic is characterized by incomplete exchange rate pass-through. This rules out cases where a positive response of domestic and foreign prices can lead to a decrease in the relative price change.

5. Results

The unrestricted relative VAR models were estimated over the period 1998:1–2011:4. The lag length of the relative VAR model was determined by the information criteria summarized in Table 5.1. Both the Akaike and Schwarz criteria suggest a lag length of 2. The sequential

[3] When considering results of relative model, by reference to the supply, demand, and nominal shocks we refer to relative form of the shocks

likelihood test suggests a lag length of 3. As we prefer a parsimonious specification, we use 2 lags for the VAR model estimation.

Table 5.1: Information Criteria

Criterion	Lag length	1	2	3	4	5
AIC		0.644	0.421*	0.545	0.940	0.897
SBC		1.116	1.256*	1.749	2.522	2.864
LR test		29.18	29.39	14.04*	4.646	16.03

* indicates lag order selected by criterion, LR critical level at 5% is 16.92

The results of autocorrelation tests for residuals are reported in Table 5.2. Since the test is able to reject the hypothesis of no autocorrelation only for lag length 1, this confirms our choice of lag length 2 for the relative model.

Table 5.2: Residual Portmanteau Test for Autocorrelation

Lag length	1	2	3	4	5
Statistics	17.00	14.75	13.57	17.13	18.42
Crit. values at 5%	16.91	28.86	40.11	50.99	61.65

In this section, we review the results for the model parameterization that is the closest to the median response over the first four periods. In the estimation, we consider 1,000 successful draws of parameters. These were delivered by a total of 82,220 draws. Figure 5.1 summarizes the responses of the baseline model. In this figure, each chart shows the response of the variable to all identified shocks. As the sign restriction approach does not identify the magnitude of shocks, as Fry and Pagan (2011) discuss, confidence intervals are not plotted in the impulse response charts.

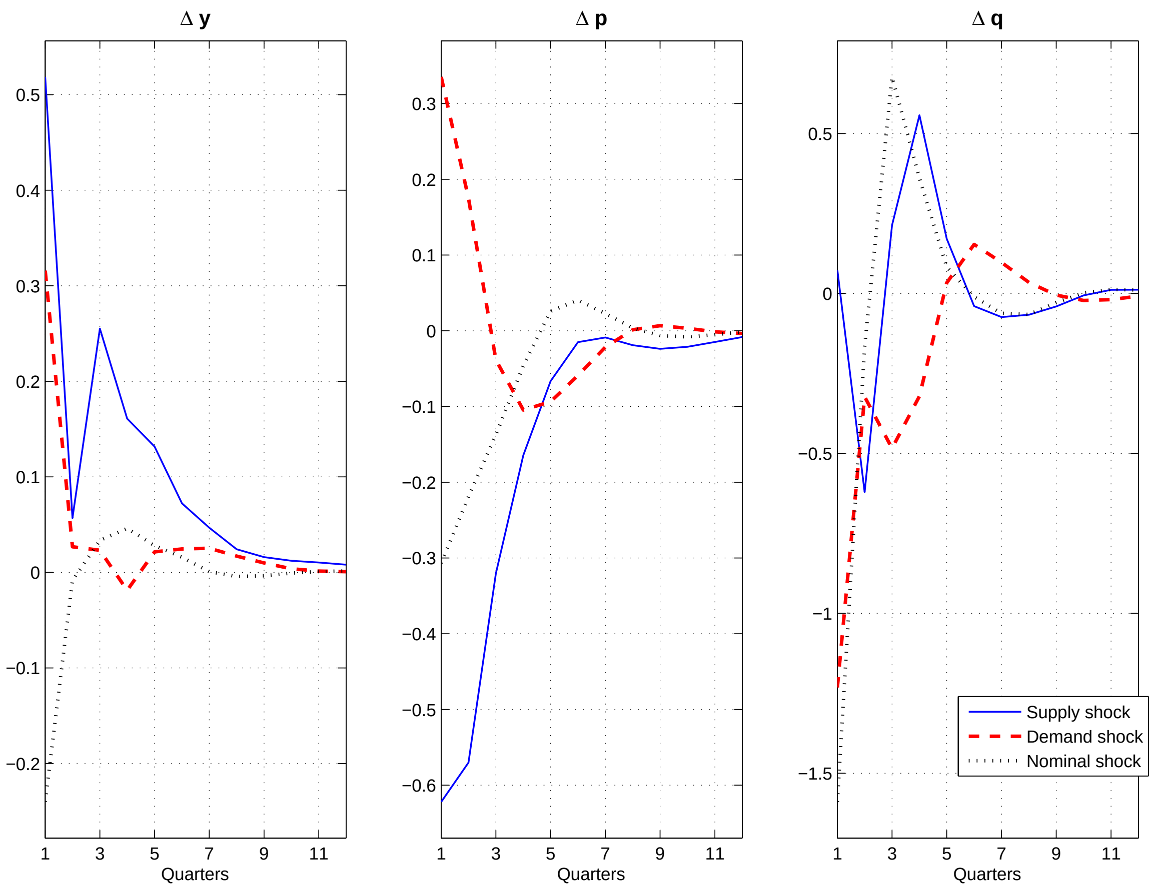
As can be observed, the responses comply with the short-run restrictions summarized in Table 4.1. First, the positive supply shock accelerates relative output growth. This results in an immediate drop in relative inflation, which lasts for several periods. The real exchange rate depreciates with the supply shock. An initial real depreciation in response to a supply shock was also found by Clarida and Gali (1994) for Canada and the UK. The low levels of relative inflation correct the actual and expected relative output growth. The initial depreciation is quickly changed into appreciation. After the correction of the initial response of relative output, the real exchange rate responds by depreciating and the initial shocks are quickly absorbed.

When relative variables are considered, the movements in domestic variables could be offset by the foreign counterpart. However, the responses of relative variables originate from the fact that the Czech Republic is a small open economy and its behavior does not affect the eurozone. Specifically, the subsequent real depreciation (a positive nominal shock) increases domestic exports, but this does not cause a drop in eurozone output.

A positive demand shock leads to an immediate increase in relative inflation and in real appreciation in line with the theory. The demand shock also results in higher relative output growth.

Finally, a negative nominal shock causes real appreciation and suppresses Czech output relative to foreign output because domestic exports become less price competitive on international mar-

Figure 5.1: Impulse Response Functions – Baseline Model



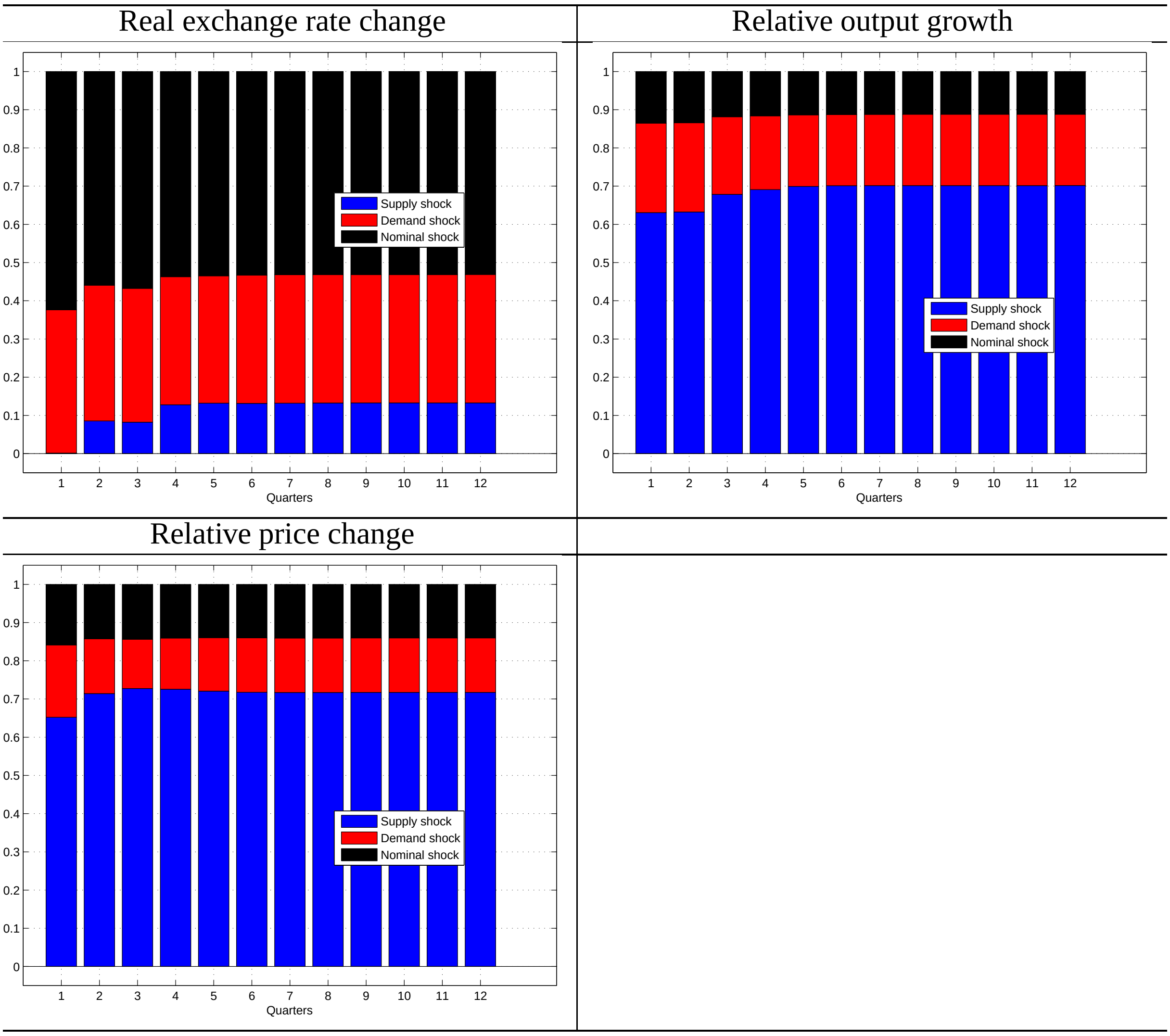
kets. However, this effect is short-lived. After a short period of appreciation, the low relative growth puts upward pressure on the real exchange rate, leading to a very short period of growth of relative output and prices. The dynamics and duration of the response to the nominal shock are in line with the findings of the structural model for the Czech economy.

The reversal in the impulse response of the real exchange rate for relative supply and nominal shocks is in line with our expectations of the real exchange rate returning to its trend. Here, our results differ from Thomas (1997) and Clarida and Gali (1994), who identified long-run effects of supply shocks that are puzzling for most countries.

To assess the amount of variance in the variables that can be attributed to the nominal shock, we employ forecast error variance decomposition. The decompositions are presented in Figure 5.2. As the chart for the real exchange rate illustrates, the relative nominal shock accounts for slightly more than half of the real exchange rate variance. The relative demand shock generates less volatility of the real exchange rate than the relative nominal shock, yet still accounts for about 40% of the real exchange rate volatility. This means that a large fraction of the real exchange rate volatility originates from fundamentals. Moreover, the real exchange rate volatility is driven more by the nominal shock than by the real ones.

From the decomposition of relative output and prices it can be concluded that the real exchange rate accounts for less than 15% of their volatility.

Figure 5.2: Variance Decomposition – Baseline Model



When comparing our results with studies analyzing the driving forces of exchange rates before the common European currency was formed, the following conclusions can be drawn. Contrary to the cases of Austria, Belgium, and France (Thomas, 1997), the supply shock does not play a significant role in real exchange rate volatility. However, our findings are similar to the cases of Sweden and the Netherlands, where demand and nominal shocks are the main driving force of the real exchange rate, as reported by Thomas (1997).

The nominal shock accounts for a much greater fraction (approx. 55%) of the forecast errors in the real exchange rate for the Czech Republic than for countries such as France or the Netherlands (approx. 15%). However, the nominal shock contribution is much lower than for Sweden (approx. 60%). However, the cumulative contribution of supply and nominal shocks to the movement of the real exchange rate is comparable to the core eurozone countries with the exception of the Netherlands, when compared to Thomas (1997). Therefore, losing the exchange rate as a shock absorber could be as costly for the Czech Republic as for the core eurozone countries.

To assess the impact of a supply shock, Hodson (2003) uses the measure of coincidence, which is a simple ratio of the supply shock contribution to the real exchange rate and the supply shock contribution to relative output. If the real exchange rate and relative output are motivated by a different variety of shocks, this measure of coincidence will be zero. In the extreme case, if both variables are stimulated by the same shocks, it will be one. In the case of Czech Republic the coincidence measure is approximately 0.14, which puts the Czech Republic in a group with Austria, Netherlands, and Spain.

Keeping in mind the differences in methodologies and historical periods from the international comparison presented, there are similarities with Austria and Belgium when it comes to the source of real exchange rate volatility. When the importance of supply shocks is considered, countries such as Sweden and the Netherlands are the most similar ones.

As the nominal shock identified in the baseline model may be affected by the monetary policy response, we extend the model to include the policy rate. This extension also allows us to disentangle monetary and exchange rate shocks.

5.1 Extended Model – Monetary Policy

The model of Clarida and Gali (1994) can be extended to include monetary policy, as the baseline model lacks any direct interaction between monetary policy and real variables. The relative interest rate is defined as the ratio of the domestic interest rate to the foreign interest rate. We do not include the relative term structure (which can be based on relative longer-term interest rates), as the problem of interest rate expectations and realizations mismatch would significantly complicate the setting of the restrictions.

The following extended VAR model is estimated: $\Delta x_t = \{\Delta y_t,\, \Delta p_t,\, \Delta q_t,\, i_t\}$. In the extended version, i_t is the relative interest rate (the domestic to foreign 3-month interest rate). The extended model is converted to a structural VAR with the set of impulse restrictions summarized in Table 5.3. The additional restrictions describe the response of the interest rate and follow the nature of the inflation-targeting regime. For the relative demand shock, the relative interest rate increases in response to rising inflation. For the appreciation shock the drop in inflation is followed by an easing of monetary policy. As the last restriction, a tightening of domestic monetary policy is followed by a decrease in output and inflation.

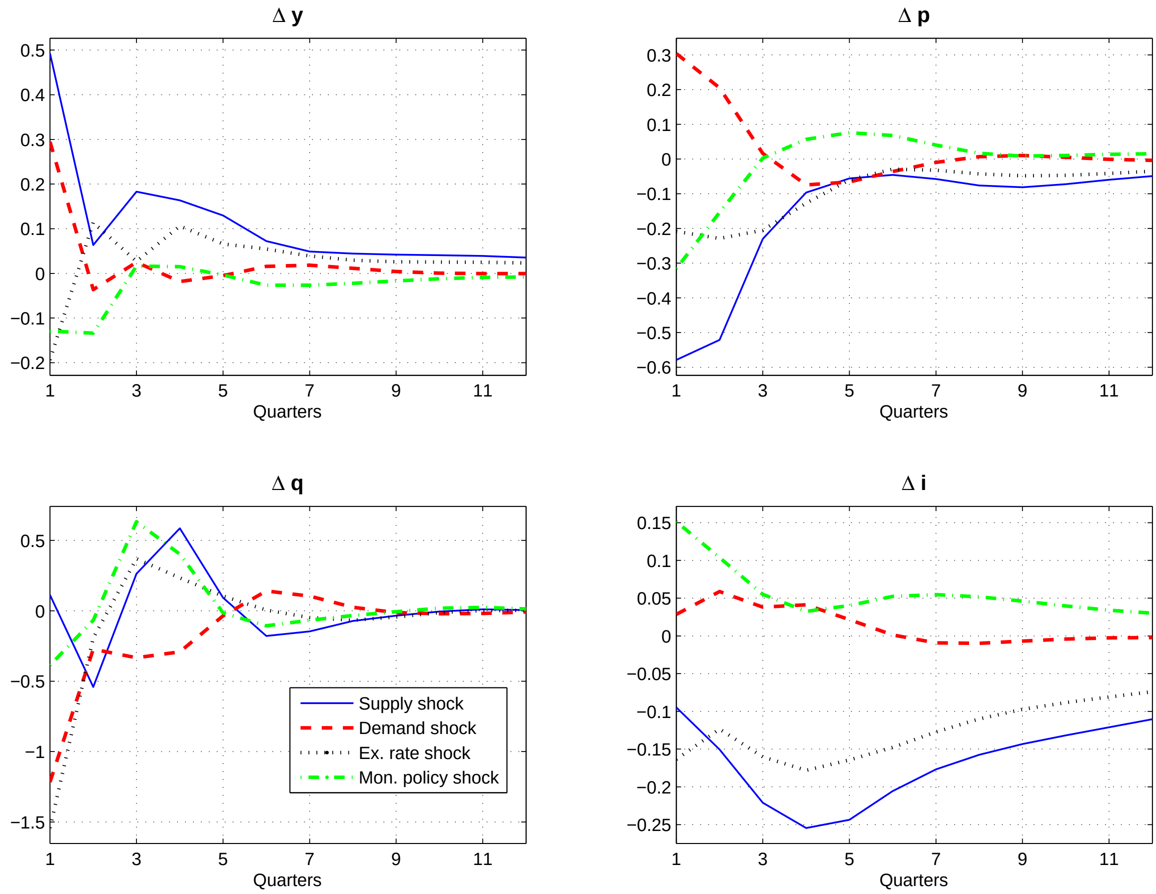
Table 5.3: Sign Restrictions – Extended Model

Variable Structural shock	Δy_t	Δp_t	Δq_t	i_t
Relative supply	> 0	< 0		< 0
Relative demand	> 0	> 0	< 0	> 0
Exchange rate	< 0	< 0	< 0	< 0
Relative monetary policy	< 0	< 0	< 0	> 0

The above-mentioned sign restrictions deliver the impulse responses summarized in Figure 5.3, where each chart shows the response of a given variable to all identified shocks.[4] As can be seen from the closest-to-median responses, the real exchange rate reacts to the relative demand

[4] We report the results of 1,000 successful draws out of 2,511,244 total draws.

Figure 5.3: Impulse Response Functions – Extended Model



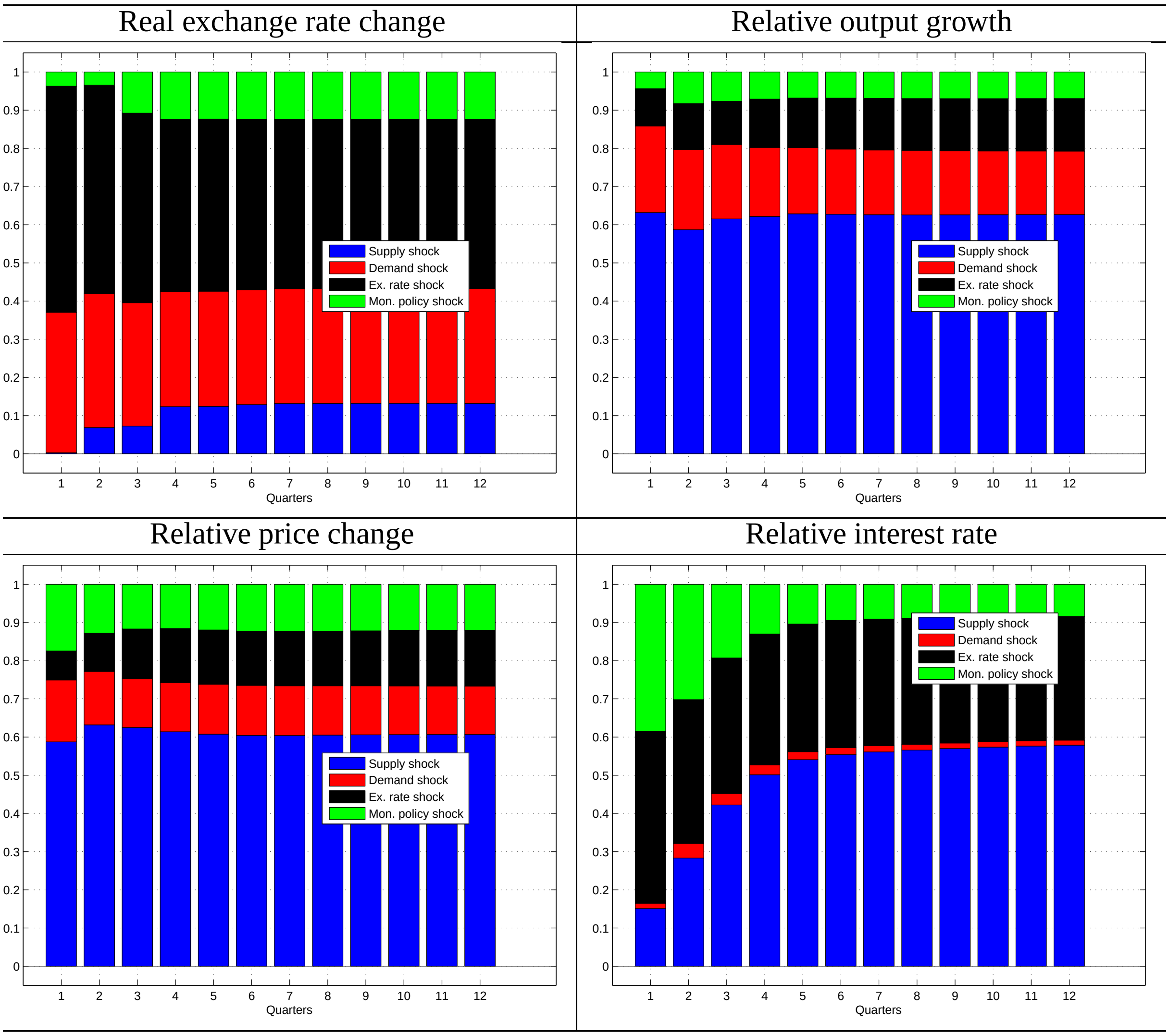
shock by appreciating. This can be explained by the strong response of the monetary authority to inflation.

The real exchange rate appreciation in response to the increasing interest rate is in line with the standard international macroeconomic theory. Here, with the increase in the relative interest rate, the real exchange rate appreciates despite the decline in relative output and this delivers real depreciation in the following periods. As monetary policy is gradually eased (relative interest rate decreases), relative output growth recovers and the depreciation returns the real exchange rate to its trend.

Figure 5.4 summarizes the forecast error variance decomposition of the extended model for the parameterization that delivers the impulse responses closest to the median response.

The extended model delivers results close to the baseline model. In the baseline model, the nominal shock accounts for more than 50% of the real exchange rate volatility. In the extended model, the contribution is now distributed between the real exchange rate shock, accounting for less than 50%, and the relative policy shock, accounting for about 10%. The demand and supply shocks still account for more than 40% of the real exchange rate volatility. Notably, the influence of the supply shock is more pronounced in the extended model. Its share in the variance decomposition is now about 15%, while the impact of the demand shock is reduced to

Figure 5.4: Variance Decomposition – Extended Model



about 30% (see Figure 5.2 for a comparison). The decline in the demand shock contribution to volatility can be explained by the introduction of relative interest rate in our model. Therefore, it can be concluded that the monetary policy response to relative inflation contaminated the relative demand shock contribution in the case of the baseline model.

The share of the nominal shock in generating relative output and inflation volatility is almost unchanged. With an explicit role for monetary policy, the real exchange rate accounts for about 15% for both of the variables.

The share of the supply shock in generating volatility in the variables of interest decreases to 10%. This may suggest that some portion of the interest rate shock contribution was attributed to the supply shock in the baseline model.

Note that the demand shock does not contribute significantly to the volatility of the relative interest rate. This originates from the fact that the demand shock does not significantly contribute to variance of relative inflation and output (10% and 20%, respectively). This finding might imply that inflation expectations are well-anchored and a demand shock does not increase inflation expectations in the Czech Republic. The small reaction of the policy rate to the demand shock is then consistent with the Czech National Bank's inflation-targeting regime.

Comparing our findings with the historical decomposition of interest rate and inflation deviations in Hurnik et al. (2008), one can note that they found historical episodes when an exchange rate shock had a dominant influence on both inflation and interest rate deviations, as well as episodes with a rather negligible impact. Our data covers most of the episodes identified, producing a forecast with a moderate exchange rate shock influence. In line with Hurnik et al. (2008) we find a relatively small influence of a monetary policy shock on the volatility of other variables.

The variance decomposition of the real exchange rate and its relatively small share in relative output growth and inflation volatility suggest that the shock-absorbing role of an independent currency cannot be rejected in the case of the Czech Republic.

5.2 Initial Response

As the response of the real exchange rate to the relative supply shock was intentionally left unrestricted, we can compare the distribution of the responses across these models, as in Uhlig (2005) and Jääskelä and Jennings (2010), to assess the identification properties.

Figures 5.5 and 5.6 show histograms of the initial responses of the variables when all of the successful draws of the identification scheme are considered.

The complete list of initial response distributions is presented in the Appendix. Assessing the figures in Table Appendix A.1 one can see that the distribution of the initial responses is not symmetric around zero. A bias toward positive values can be observed.

Figure 5.5: Distribution of Initial Response of Real Exchange Rate

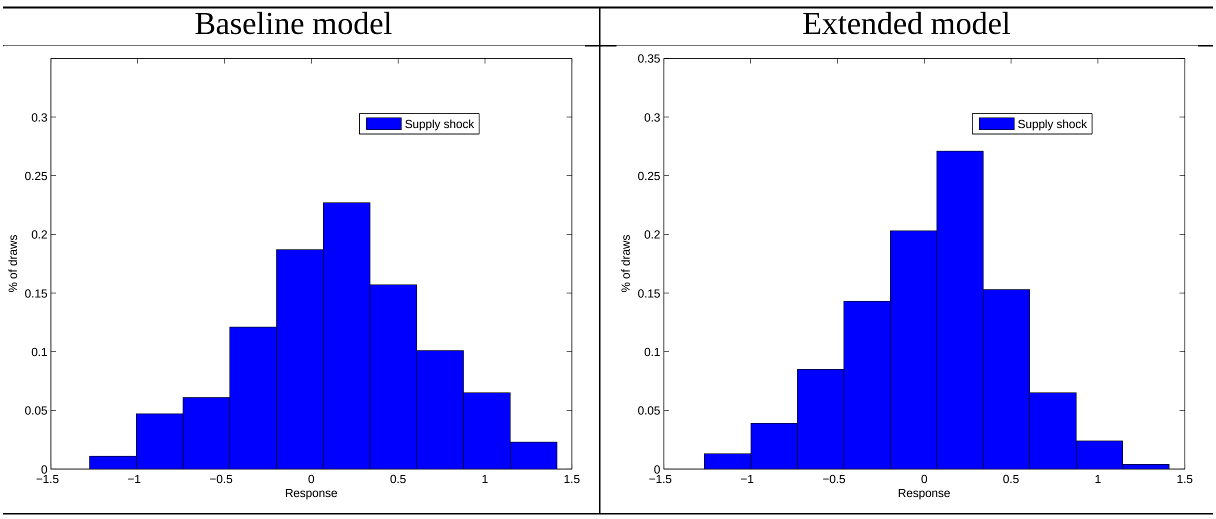
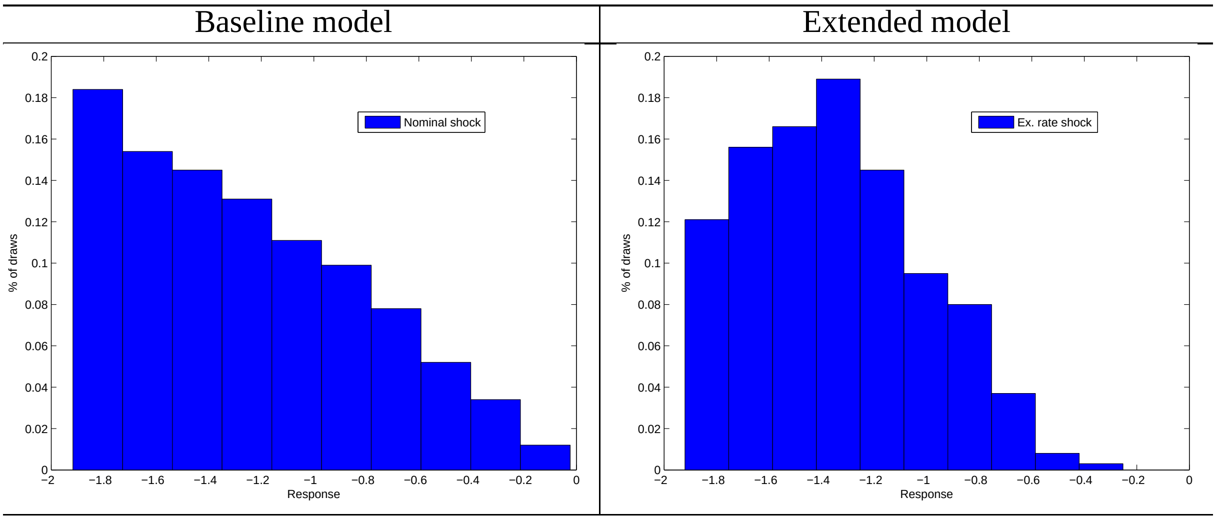


Figure 5.5 shows the effect of adding monetary policy to the model. It can be seen that the initial response distribution is slightly shifted toward deprecation after the inclusion of monetary policy in the model. The increase in the skewness of the distribution of the initial response of the exchange rate to the relative supply shock suggests that the uncertainty surrounding the responses of the variables decreases slightly. This suggests that the inclusion of the relative

monetary policy shock delivers additional features that are left unidentified in the parsimonious specification. This increase also suggests that the richer model and sign restriction identification improves the recovery of the true impulse responses, as the responses are not contaminated by the features of the monetary policy response.

The shift of distribution towards right (less appreciation) in the initial period suggests that the response to future easying of monetary policy does not need to be outweighed in the initial response of the exchange rate. This finding suggests that the likelihood of recovering the correct sign of the exchange rate was improved with the inclusion of the additional shock.

Figure 5.6: Initial Distributions of Real Exchange Rate



In Figure 5.6, the distributions of initial responses of the exchange rate to the nominal and exchange rate shocks are presented. From this comparison it can be seen how the distribution of the initial responses moves from the zero response. This means that the response of the real exchange rate to a pure exchange shock moves toward appreciation (the case of the extended model). When the nominal shock is considered (the case of the baseline model), the range of the responses is wider due to contamination by the inclusion of monetary policy.

5.3 Monetary Policy and the Exchange Rate

The last model explores the response of the exchange rate to monetary policy shocks. As Rogers (1999) and Artis and Ehrmann (2006) suggest, there are reasons to care about the nature of shocks that drive exchange rate volatility. Firstly, Rogers (1999) shows that knowledge about the nature of shocks is relevant for the decisions of monetary policy makers. Rogers (1999) also asserts that evidence on the nature of exchange rate volatility is relevant for the literature on dynamic stochastic general equilibrium models that include the exchange rate. This knowledge helps to replicate the observed real exchange rate patterns that follow monetary shocks. Furthermore, Artis and Ehrmann (2006) discuss the link between monetary policy and the nominal exchange rate. They analyze the situation in which asymmetric shocks, as opposed to symmetric shocks, were found to have the dominant influence on the exchange rate. This would inform policy makers that there are potential drawbacks associated with maintaining a system of fixed exchange rates. In this case, a flexible exchange rate system may be preferable to fixed rates.

The following analysis has its roots in the work of Clarida and Gali (1994), where the variables are specified as relative to the corresponding variables of the large neighbor. However, as Artis and Ehrmann (2006) and Peersman (2011) note, models formulated in relative terms are unable to disentangle the reactions of domestic and foreign variables themselves. The relative formulation can identify only asymmetric shocks and thus yields no information on the comparative frequency of symmetric and asymmetric shocks.

This does not allow one to identify which country has to bear the adjustment to a shock as when two-country models are considered. As the assumption of a small open economy is used, it is implicitly assumed that the small country is the one that bears the adjustment costs. In this case, if the exchange rate volatility is mainly generated by the response to asymmetric shocks (one-country shocks), we conclude that it can help stabilize the economy. Also, this part of the analysis helps us to assess what portion of exchange rate volatility is bred by its own shocks, and whether these shocks turn out to be destabilizing to the rest of the economy. To explore the response of monetary policy to symmetric and asymmetric shocks and the relation to the exchange rate, we employ the approach presented by Peersman (2011).

The approach used includes the implicit assumption that fiscal policy is too rigid to be an effective tool for stabilizing exchange rate shocks. Therefore, the policy response is fully assigned to monetary policy in the framework used.

Following the studies by Artis and Ehrmann (2006) and Peersman (2011), we estimate the following VAR $\Delta x_t = \{\Delta y_t,\ \Delta p_t,\ i_t,\ i_t^*\ \Delta q_t\}$. In the model, Δy_t denotes domestic output growth, Δp_t is domestic inflation, i_t is the domestic short-term interest rate, and i_t^* is the foreign interest rate. Also as in the previous models, Δq_t denotes changes in the real exchange rate, where positive values signal domestic currency depreciation. Here, all variables except the interest rates are in logs and the linear trend is removed before the differences are computed. As we focus on the effects of the exchange rate and symmetric and asymmetric monetary policy shocks, the corresponding vector of shocks is defined as $\varepsilon_t = \{\varepsilon_t^{\Delta y},\ \varepsilon_t^{\Delta p},\ \varepsilon_t^{i^A},\ \varepsilon_t^{i^S},\ \varepsilon_t^{\Delta q}\}$.

With the focus on the interaction of symmetric and asymmetric monetary policy shocks and the exchange rate, the identification scheme is an alternative to the agnostic identification scheme originally applied by Uhlig (2005) and used in recent studies such as Scholl and Uhlig (2008) and Rafiq and Mallick (2008). The intention of this analysis is to follow the minimalist approach of those studies. Our goal is to identify the response to symmetric and asymmetric policy shocks $\varepsilon_t^{i^A}$ and $\varepsilon_t^{i^S}$, respectively, and to analyze the contribution of exchange rate shocks $\varepsilon_t^{\Delta q}$. The sign restrictions imposed to identify these shocks are summarized in Table 5.4.

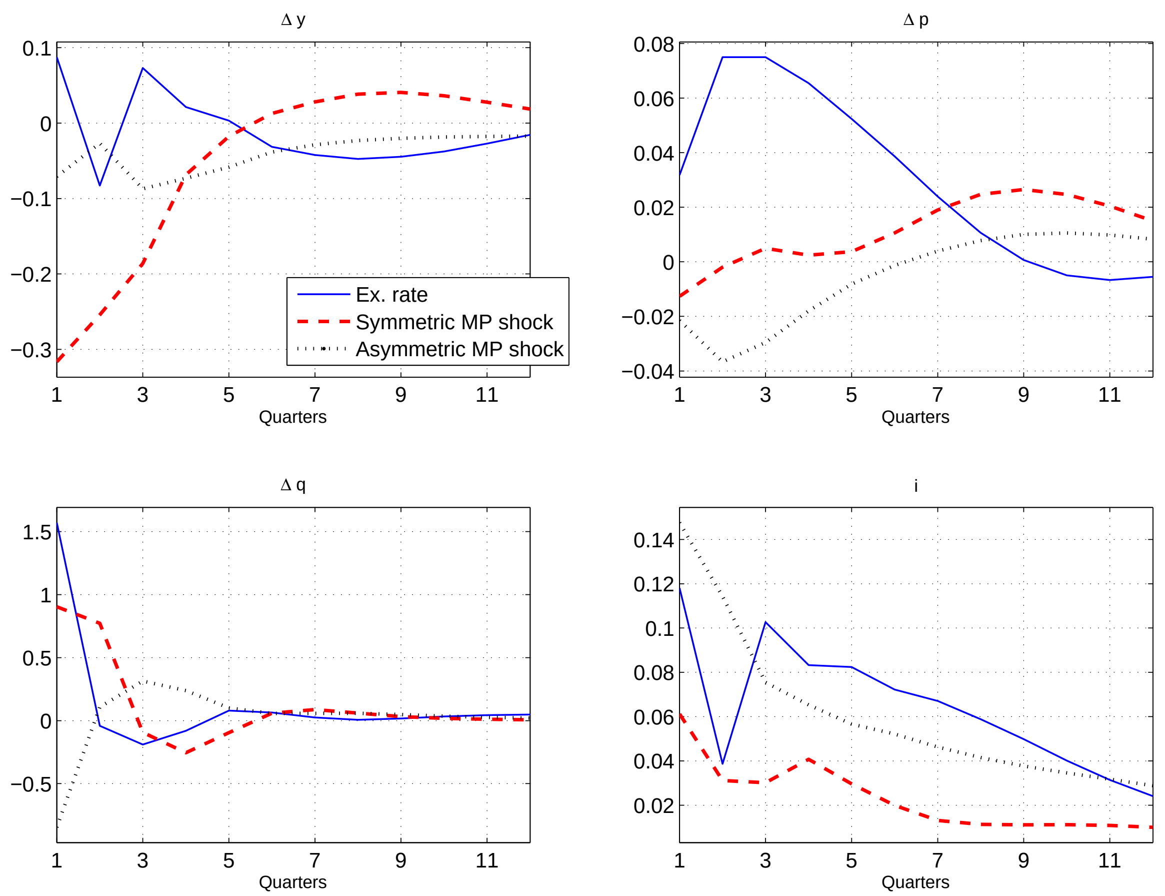
Table 5.4: Sign Restrictions for Impulse Responses – Agnostic Scheme

	Output	Prices	Int. rate	F. int. rate	Ex. rate
Symmetric policy shock	< 0	< 0	> 0	> 0	
Asymmetric policy shock	< 0	< 0	> 0	< 0	< 0
Exchange rate shock	> 0	> 0	> 0	< 0	> 0

To identify the symmetric monetary policy shocks, we impose the restrictions that domestic inflation and output growth slow down after a monetary tightening. As the shock is symmetric the foreign monetary authority also increases its policy rate. The response of the exchange rate is left unrestricted. However, in the case of the asymmetric policy shock, the foreign monetary authority eases its policy in response to the shock and in this case the exchange rate appreciates in response to the interest rate differential. Finally, in the case of the exchange rate depreciation shock, the domestic policy authority has to increase interest rates as domestic inflation and output growth increase in response to the sudden demand from abroad. As in Peersman (2011), in response to the domestic currency depreciation the foreign monetary policy authority eases its policy to reestablish competitiveness on international markets.

The response to the rest of the shocks ($\varepsilon_t^{\Delta y}$, and $\varepsilon_t^{\Delta p}$) is left unrestricted. As in the previous cases, we generate one thousand successful model draws. The closest-to-median impulse responses that result from imposing the restrictions listed in Table 5.4 are shown in Figure 5.7. In this figure, each chart shows the response of the variables to the three identified shocks.

Figure 5.7: Impulse Response Functions – Agnostic Scheme



According to the responses of the model closest-to-median responses, shown in Figure 5.7, the responses to the symmetric monetary policy shock (the red dashed line) show that output growth and inflation decrease and it takes approximately 2 years to return to the steady state. In the case of the symmetric policy shock the real exchange rate depreciates sharply. The size of the responses suggests that there is a permanent effect on prices, as the response of inflation is positive in the medium term. The profile of the real exchange rate change response suggests that there may be a permanent shift in the nominal exchange rate. However, the effect on real output growth seems to be only temporary. When one compares the deviations from the steady state, the responses of $\varepsilon^{\Delta y}$ and $\varepsilon_t^{\Delta p}$ are less persistent than the response of the interest rate.

The inflation-targeting nature of the monetary policy regime is also responsible for the responses (marked by the blue solid line) to the shock to the exchange rate $\varepsilon_t^{\Delta q}$. The positive shock delivers depreciation and leads to an increase in inflation. However, the monetary authority recognizes this shock and reacts strongly by increasing the interest rate, so some decrease in output is observed as some competitiveness is lost due to the subsequent appreciation. The strong response of monetary policy and the peak response of inflation after three periods suggests that rigidities are present. Due to these rigidities, the policy rate only slowly returns to the steady state. The identified response of the exchange rate suggests that the domestic economy experiences real exchange rate depreciation as the initial response to a symmetric shock.

In the case of the asymmetric shock the domestic authority reacts by tightening policy and the foreign authority by easing policy. In this case, output growth reacts negatively to the worsened competitiveness and the shape of the response suggests some permanent effects. Also, a negative response of inflation can be observed, and the peak in the second period suggests the presence of rigidities. The main results here are that domestic monetary policy reacts strongly and immediately to asymmetric shocks. This is further reflected in the variance decomposition. Also, the rest of the shocks considered show responses similar to the structural shocks in the previous model.

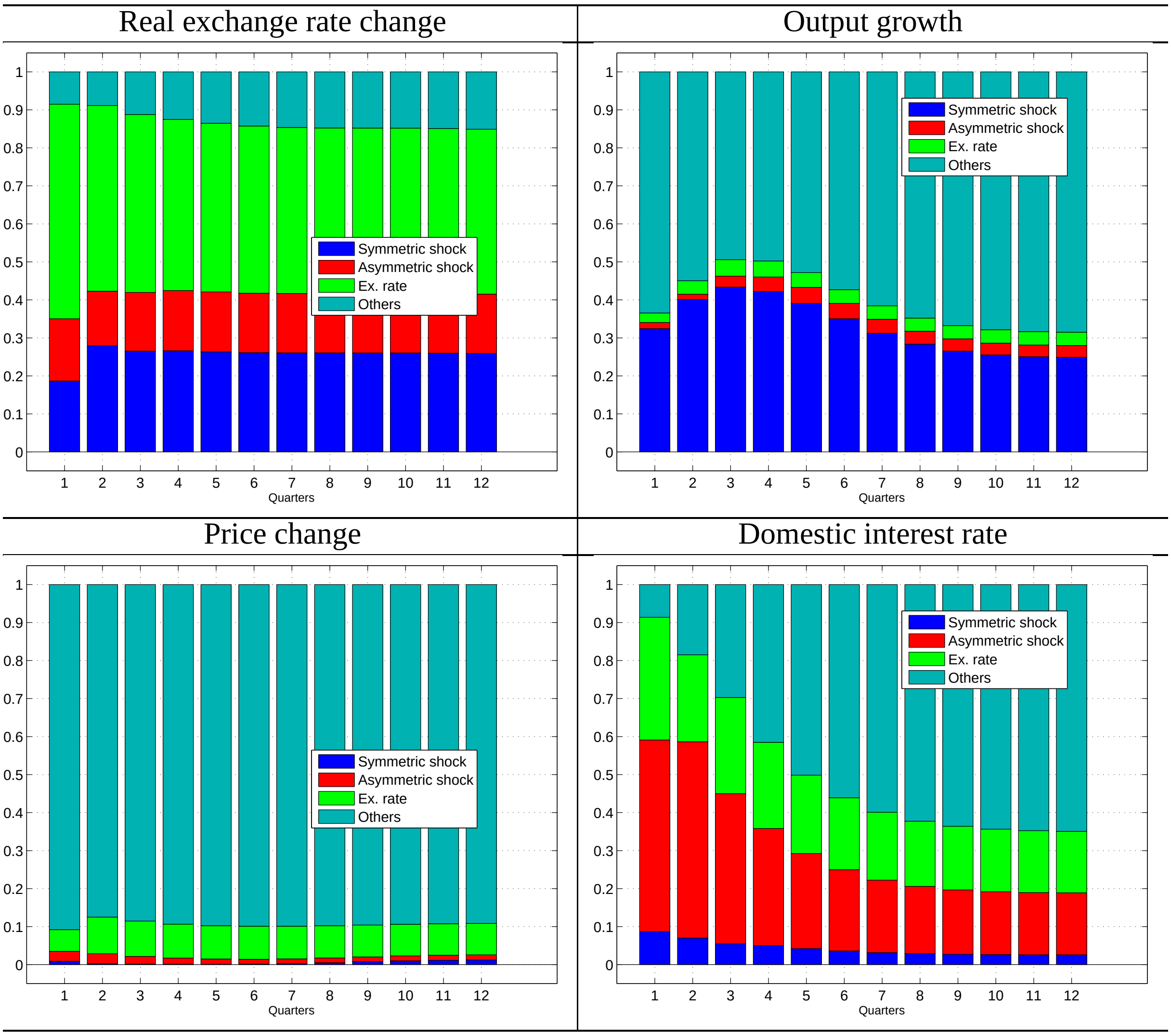
A central question of this analysis is the relative importance of symmetric and asymmetric monetary shocks for business cycle fluctuations. The forecast error variance decompositions of the variables of interest are shown in Figure 5.8.

The analysis of the forecast error variance shows that the volatility of output growth and inflation is mostly generated by the rest of the shocks. In the case of output growth, the symmetric monetary policy shock explains approximately 30% of the volatility. This suggest that there is quite a strong link between the countries considered, and this is consistent with the nature of the Czech economy. In the case of inflation, unidentified shocks are the main drivers of its volatility.

The main contributor to the exchange rate volatility is its idiosyncratic shock, which accounts for 50% of the volatility. The asymmetric and symmetric monetary policy shocks account for approximately 40% of the real exchange rate volatility. This is in line with the results from both relative models. Here, the contribution of the symmetric shock is almost twice as large as the contribution of the asymmetric shock. This suggests relatively lower importance of the exchange rate in handling asymmetric shocks. The evidence presented in Figure 5.8 indicates that policy and idiosyncratic shocks are important for exchange rate movements. This conclusion resembles that of Rogers (1999) and Clarida and Gali (1994) for the US and the UK, Japan, and Germany, where monetary shocks were found to account for approximately half of the forecast error variance of the real exchange rate over short horizons. Taking into account that the asymmetric and symmetric shocks represent the influence of monetary policy, these results are also similar to those of Scholl and Uhlig (2008) (comparing the sum of the contributions of foreign and domestic policy shocks), who analyze the influence of monetary policy on the exchange rate in a two-country model for pairs of developed economies.

From the decomposition of the interest rate volatility presented in Figure 5.8, it turns out that the symmetric monetary policy shock accounts only for a small fraction of the forecast error variance. The domestic interest rate responds to asymmetric shocks mostly in the short term. The fact that in the long term the volatility of domestic policy is explained by the response to non-policy shocks supports the view that the Czech National Bank's policy is predictable.

Figure 5.8: Variance Decomposition – Agnostic Scheme



According to Uhlig (2005), predictiveness is a property of good policy, so we can conclude that over the time span analyzed the monetary policy of the CNB was generally successful in not generating extra volatility.

Based on the variance decompositions, policy shocks and exchange rate shocks are the main contributors to variance of the relative exchange and interest rate in the short term. Also, variance decomposition identifies a significant contribution of the idiosyncratic shock to exchange rate volatility and this contribution is stable. However, for the remaining variables, the contribution of exchange rate shock and asymmetric policy shock is decreasing over the horizon of responses. This means that exchange rate as the shock absorber does not change over the horizon. As the contribution of exchange rate shocks is minor for output growth and the price change, this exchange rate is not considered as shock generator. This is consistent with the structure of domestic interest rate variance sources, where exchange rate shock is responsible for 20–30% of volatility. So, domestic interest rate responds to exchange rate shocks.

As the sign restriction method produces a lot of alternative parameterizations, we can also check how representative is the parameterization of the model closest to all the median responses (robustness of results). The distribution of the variance decomposition shows that the chosen model puts higher weight on the idiosyncratic exchange rate shock than the median response in favor of the rest of the shocks (see Figure Appendix A.1 in the Appendix). However, the results are still within a reasonable band and the ratio of symmetric to asymmetric shocks also seems to be stable.

6. Conclusions

The aim of this paper is to shed light on the role of the exchange rate as either stabilizing or distorting the economy. At first, the contributions of the shocks to variance of variables describing the economy of Czech Republic is analyzed in relative terms as described Clarida and Gali (1994). The initial analysis is based on estimation of VAR models in the relative terms using the sign restriction method. The motivation for use of the relative terms originates from nature of the exchange rate, as the exchange rate itself is a relative variable. Also, this the relative formulation maintains the parsimony of the models used. For robustness check of results, the original model is extended with the monetary policy shock. We find that the inclusion of this additional shock improves shock identification, thus delivering stronger inference on the unrestricted variables.

In this analysis, we focus on the Czech koruna-euro exchange rate and find that it tends to be more a shock absorber than a shock generator for the rest of the economic variables. Similarly to other studies for various developed economies, we find that exchange rate shocks account for a significantly drives the real exchange rate volatility. However, in contrast to these studies, we find that almost half of its variance is driven by relative supply and demand shocks. We find that exchange rate shocks are not very harmful, as they account for a minor share of the variance of other variables – it explains about 15% of the relative price change and output growth variance. Our results also suggest a significant role of real shocks in driving exchange rate volatility.

In contrast to the models in relative terms, we focus on the relation between monetary policy and the exchange rate in an additional model that is not formulated in the relative terms. The non-relative specification has the advantage to distinguish, whether the shocks are mainly symmetric or idiosyncratic in their nature. In case of predominantly asymmetric shocks, the exchange rate may reveal its shock absorbing nature.

The results from the third model imply that exchange rate behavior responds to monetary policy actions. Further, the moderate response of output growth to monetary policy shocks is identified. The third model shows that there is possibility that the exchange rate can be considered as a shock absorber. Exchange rate responds to asymmetric policy shocks, but its volatility is mostly generated by idiosyncratic shocks. However, the exchange rate shock is not the main source of output growth and price change volatility.

Our results may be biased toward a stronger role of the shock-absorbing nature of the exchange rate for the Czech Republic. This bias may originate from the choice of identification scheme and due to the short data sample. Because of the relatively short history of the Czech koruna and the monetary regime change in 1998 (the launch of inflation targeting), the model was estimated with limited data sample. This motivates us to use the sign restriction method as it belongs to class of Bayesian estimation methods that are able to handle this limitation.

Nonetheless, we believe that this study is a useful exercise to assess the functioning of the stabilizing role of the exchange rate under the inflation targeting regime. In this respect, this work provides useful guidance even though its results are dependent on various aspects of the estimation and identification procedures. However, our sensitivity analysis varying different assumptions supports the robustness of the results obtained.

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Appendix A. Additional Figures

Table Appendix A.1: Initial Response Distribution

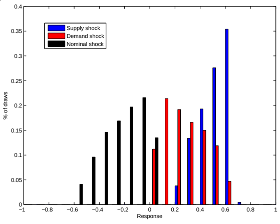
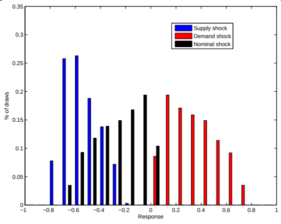
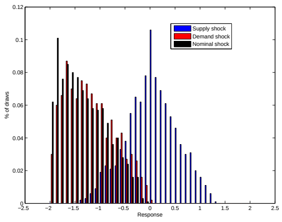
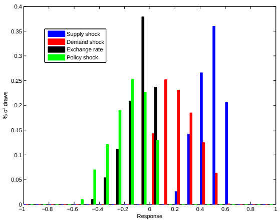
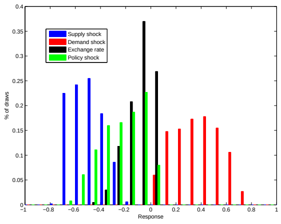
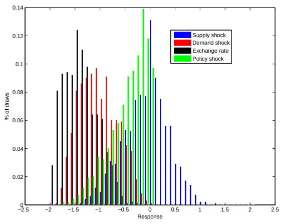
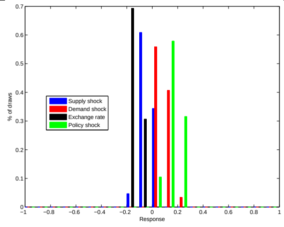
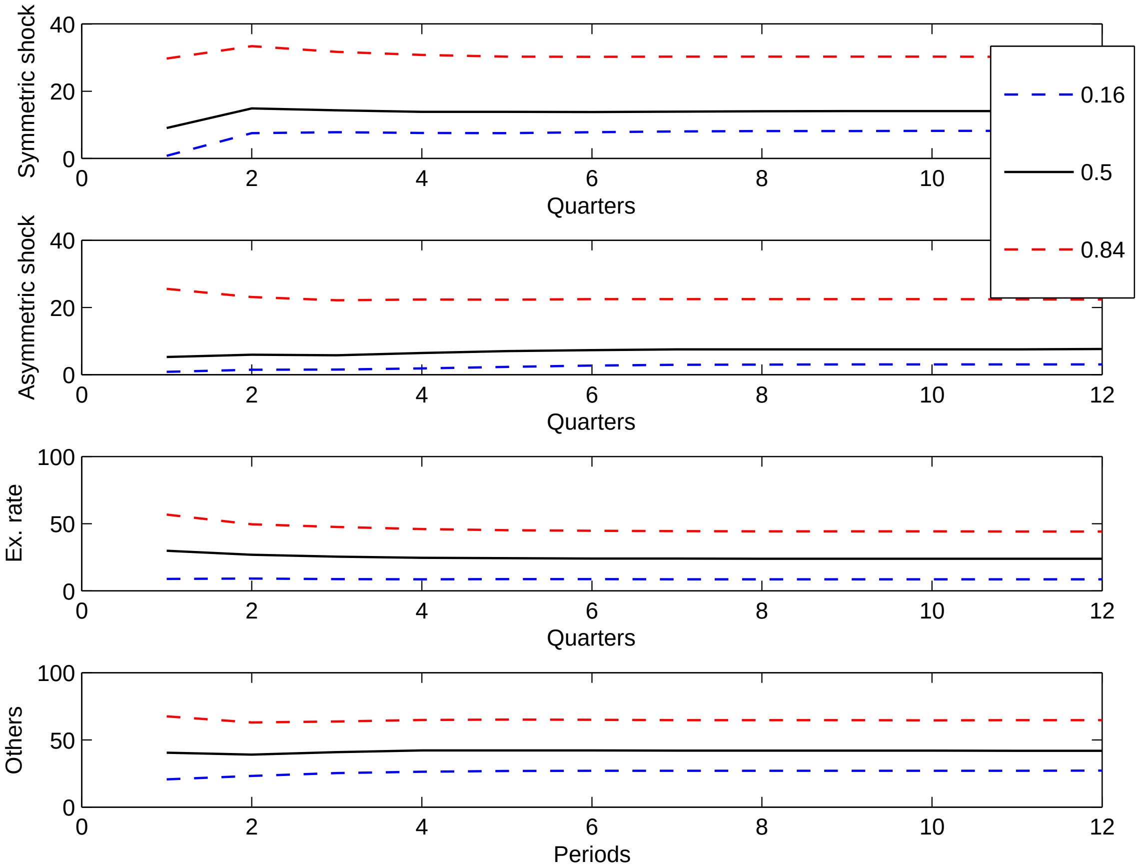
Δy_t	Δp_t	Δq_t	i_t
Baseline model			
			
Extended model			
			

Figure Appendix A.1: Distribution of Variance Decomposition - Exchange rate



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