Sources of Exchange Rate Fluctuations: Empirical Evidence from Croatia

RESEARCH PAPER

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Abstract

This paper investigates the sources of real exchange rate fluctuations in Croatia, distinguishing between real and nominal sources, for the sample period ranging from January 1998 to March 2011. The results obtained using a structural vector autoregression (SVAR) model indicate that the volatility of the Croatian real exchange rate is mainly influenced by demand shocks, both in the short run and in the long run. The impact of supply shocks proved to be insignificant. Therefore, the exchange rate seems to be a shock absorber in Croatian economy.

Keywords: macroeconomic shocks, real exchange rate, SVAR, Blanchard-Quah decomposition, impulse response function, Croatia
JEL classification: C32, E52, F41

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1 Introduction

The paper tries to distinguish between the real and nominal sources of real exchange rate movements and analyzes the role of the real exchange rate in the Croatian economy. In other words, the key question is whether the real exchange rate is driven by real or nominal shocks. In the former case the real exchange rate acts as a shock absorber, while in the latter case the real exchange rate is considered to be a source of shocks that destabilizes the economy.

There are many different approaches to addressing this question. According to MacDonald (1998), the four main ones are as follows. The *first* approach is based on the relationship between real exchange rates and real interest rate differentials. The *second* one decomposes fluctuations in the real exchange rate into a permanent and a transitory component using the Beveridge and Nelson (1981) decomposition method. The *third* approach is based on the Balassa-Samuelson theorem according to which fluctuations in the real exchange rate are decomposed into the changes in the relative price of traded to non-traded goods within countries and changes in the relative price of traded goods across countries. The *fourth* approach is based on estimating a structural vector autoregression model (SVAR), where structural shocks are identified using the Blanchard-Quah (1989) long-run restrictions technique and real exchange rate fluctuations are decomposed into parts due to various structural shocks.

The common practice in a large number of empirical studies is to use a structural vector autoregression (SVAR) model and Blanchard and Quah (1989) identification scheme to assess the relative importance of various shocks in explaining fluctuations in the real exchange rate.[1] One of the first such studies was performed by Lastrapes (1992) who employed a bivariate VAR model with the growth rates of the real and nominal exchange rate as the variables. Lastrapes identified two structural shocks: real shock, which can influence both variables in the long run, and nominal shock which can influence the nominal exchange rate but has no long-run influence on

[1] *For an overview of SVAR methodology see Gottschalk (2001).*

the real exchange rate. Clarida and Gali (1994) analyze the structural VAR model with three endogenous variables: the growth rates of real output, real exchange rate and price level. The authors identify three shocks – demand, supply and monetary – by using long-run zero restrictions which are based on an open economy macro model of Dornbusch (1976) and Obstfeld (1985). In particular, Clarida and Gali (1994) use the theoretical basis of the Mundell-Fleming-Dornbusch model to define the effects of the demand, supply and monetary shocks on the variables and question whether the real exchange rate movements in response to the analyzed shocks stabilize (act as a shock absorber) or destabilize the economy (act as a source of shocks). Most of the empirical analyses employ a trivariate SVAR similar to Clarida and Gali (1994) (Chadha and Prasad, 1997; Funke, 2000; Soto, 2003; Mumtaz and Sunder-Plassmann, 2010; Inoue and Hamori, 2009; Stazka, 2006; Stazka-Gawrysiak, 2009) and bivariate model of Lastrapes (1992) (Enders and Lee, 1997; Chowdhury, 2004). However, there are also studies that extend the SVAR model with more variables so that the model can identify additional shocks. In order to identify more shocks, Weber (1997), Rogers (1999) and Goo and Siregar (2009) specify a five-variable VAR model. Tien (2009) analyzes a set of eight variables to identify eight shocks.

Several authors apply the same methodology to study the sources of exchange rate fluctuations for the countries of Central and Eastern Europe (CEE). Dibooglu and Kutan (2001) employ bivariate SVAR for the period from 1990 to 1999. The results indicate that real shocks are the main source of the exchange rate fluctuations in Hungary, while the opposite holds for Poland. Borghijs and Kuijs (2004) study the sources of real exchange rate fluctuations in the Czech Republic, Poland, Slovakia, Hungary and Slovenia from 1993 to 2003. Both bivariate and trivariate VARs are estimated. The results indicate a destabilizing role of flexible exchange rate regimes as the nominal shocks are the main source of real exchange rate fluctuations. Kontolemis and Ross (2005) estimate a two-, three- and four-variable VAR for a set of CEE countries over the period from 1986 to 2003. While nominal shocks prove to be significant only in the short run, real demand shocks are a dominant source of fluctuations in the real exchange rate for all CEE economies. On the other hand, interest rate shocks have a negligible effect on the real exchange rates. Morales-Zumaquero (2006) estimates a structural VAR in order to analyze the sources of fluctuations in the real exchange rate for a set of advanced economies and CEE transition economies (Czech Republic, Hungary, Poland, Slovenia and Romania) by means of variance decomposition and impulse response functions for the period from 1991 to 2000. The author finds that real shocks are the main source of fluctuations in the real exchange rate for the Czech Republic, Slovenia and Hungary, while nominal shocks mostly explain movements in the real exchange rate for Poland and Romania. The author attributes the mixed results to the different initial conditions in the countries included in the study. Rodríguez-López and Torres Chacón (2006) examine the role of the exchange rate as a shock absorber in the Czech Republic, Hungary and Poland from 1993 to 2004. They estimate a two- and a three-variable structural VAR. Again, the results differ depending on the strategy used. In the two-variable SVAR, the exchange rate seems to be a destabilizing factor in the Czech Republic and Hungary, while in Poland it acts as a shock absorber. The results of the three-variable SVAR are the same for Hungary and Poland, while for the Czech Republic the exchange rate acts as a shock absorber (contrary to the findings for a bivariate VAR). Stazka (2006) investigates empirically the sources of real exchange rate fluctuations in eight CEE new European Union (EU) member states. The author analyzes the countries' decisions to join the Exchange Rate Mechanism (ERM) II for the period from 1995 to 2005. Contrary to her expectations, the author finds that real shocks are a dominant source of fluctuations in the ERM II participants, while the opposite holds for countries that are not ERM II participants. In a more recent study (Stazka-Gawrysiak, 2009), the same author analyzes the role of the flexible exchange rate in Poland relative to the euro area from 2000 to 2009. The author applies the same methodology as in the previous paper with an additional endogenous variable that enables the identification of a financial market shock. The additional variable accounts for the financial crisis in the analysis. The results suggest a stabilizing role of the exchange rate and a growing importance of financial market shocks in the context of the recent global financial crisis.

The results of the referred studies do not point to an unambiguous answer to the question whether the real exchange rate acts as a shock absorber or as a source of shocks. All studies for the CEE countries are based on monthly data, but differ regarding the analyzed period, the number of variables used (which also dictates the number of shocks that can be identified) and model specification. Consequently, different results could be obtained for the same country. This leads to the conclusion that the results of the studies are specification sensitive and one has to be very cautious with their interpretation.

The econometric technique employed in this paper is similar to Clarida and Gali (1994): a structural VAR model is defined and long-run zero restrictions are applied in order to identify three structural shocks (supply, demand and monetary). Our findings show that the Croatian real exchange rate is mainly influenced by demand shocks both in the short and in the long run. The role of supply shocks is marginal, while nominal shocks play virtually no role in explaining the real exchange rate fluctuations. Therefore, the exchange rate seems to be a shock absorber in Croatian economy. To our knowledge, there are no similar empirical analyses for the case of Croatia. Thus, this paper is the first attempt to address the role of the Croatian exchange rate and the sources of its fluctuations. Furthermore, we compare the obtained results with the results for the CEE countries, especially with CEE countries that, at least in part of the studied period, have the same exchange rate regime (managed float) as Croatia, such as the Czech Republic, Slovenia and Slovakia.

The rest of the paper is structured as follows. In Section 2 we describe the theoretical model of Clarida and Gali (1994). Section 3 contains a brief description of the data sets used in the study and applied methodology. Section 4 presents the main empirical results and, finally, Section 5 concludes.

2 Theoretical Framework

Our study is based on a structural vector autoregression (SVAR) model proposed by Clarida and Gali (1994) which uses a long-run triangular identification scheme suggested in Blanchard and Quah (1989). The starting point is a three-variable VAR model with the growth rates of real output, real exchange rate and price level as the variables. We are interested in fluctuations in these variables due to three types of structural disturbances which are labelled as real aggregate demand shocks (ε_{dt}), real aggregate supply shocks (ε_{st}) and nominal shocks (ε_{nt}).

Within the SVAR model the structural shocks are defined according to their impact on the variables in the VAR and do not necessarily coincide with the true demand, supply and nominal shocks as they are defined by the economic theory. We assume that nominal shocks are only short-run phenomena and for that reason they are identified by assuming that such shocks do not affect the real exchange rate and the relative output in the long run. On the other hand, demand shocks are supposed to have no long-run impact on the relative output, while supply shocks are defined as shocks which can affect all three variables in the long run.

Our trivariate VAR model in its simplest form (without deterministic components for notation simplicity) can be written as structural moving average model:

$$\Delta x_t = A_0\varepsilon_t + A_1\varepsilon_{t-1} + A_2\varepsilon_{t-2} + \ldots = A(L)\varepsilon_t \ , \tag{1}$$

where Δ denotes the difference operator, $x_t = [y_t, q_t, p_t]'$, $\varepsilon_t = [\varepsilon_{st}, \varepsilon_{dt}, \varepsilon_{nt}]'$ and $A(L) = A_0 + A_1 L + A_2 L^2 + \ldots$ is a matrix polynomial in the lag operator L.[2] It is assumed that structural shocks (ε_t) are serially uncorrelated and mutually orthogonal and $E[\varepsilon_t\varepsilon_t']$ is normalized to the identity matrix, i.e.,

$$E[\varepsilon_t] = 0 \ , \quad E[\varepsilon_t\varepsilon_t'] = \Sigma_\varepsilon = I \quad \text{and} \quad E[\varepsilon_s\varepsilon_t'] = [0], \quad \forall s \neq t \ . \tag{2}$$

[2] *The lag polynomials are assumed to have absolutely summable coefficients.*

On the other hand, the vector moving average (VMA) representation of the standard VAR model is given by

$$\Delta x_t = u_t + C_1 u_{t-1} + C_2 u_{t-2} + \ldots = C(L) u_t \ , \tag{3}$$

where $C(L) = I + C_1 L + C_2 L^2 + \ldots$, and $u_t = [u_{st}, u_{dt}, u_{nt}]'$ is a vector of reduced form disturbances that are serially uncorrelated but can be contemporaneously correlated with each other, i.e.,

$$E(u_t) = 0 \ , \quad E[u_t u_t'] = \Omega \quad \text{and} \quad E[u_s u_t] = [0], \quad \forall s \neq t \ . \tag{4}$$

Suppose that there exists a nonsingular matrix S such that $u_t = S\varepsilon_t$. Comparing Equations (1) and (3) reveals that

$$u_t = A_0 \varepsilon_t \ , \tag{5}$$

with variance-covariance matrix of the reduced form disturbances

$$\Omega = E[u_t u_t'] = A_0 A_0' \ . \tag{6}$$

As model (3) is underidentified, we need additional restrictions to obtain estimates of A_0 (and thus structural shocks ε_t) from the estimated model (3). Since A_0 is a 3x3 matrix, we need nine parameters to recover the structural residuals ε_t (original shocks that drive the behavior of the endogenous variables) from the reduced form residuals u_t. Of nine parameters, six are given by the elements of $\hat{\Omega}$ (three estimated variances and three estimated covariances of the VAR residuals) and three additional restrictions are needed for the system to be just-identified. These additional restrictions are made by making further assumptions about the structural shocks. According to Clarida and Gali (1994), three constraints are imposed on the long-run multipliers while the short-run dynamics are left unconstrained. These three restrictions are as follows: only supply shocks (ε_{st}) are expected to influence economic growth in the long run, while both the supply shocks (ε_{st}) and demand shocks (ε_{dt}) are expected to influence the real exchange rate in the long run. Nominal shocks (ε_{nt}) are expected to have no long-run impact on either economic growth or the real exchange rate.

Specifically, letting $A(1) = A_0 + A_1 + A_2 + \ldots$, the long-run representation of our structural moving average model (1) can be written as follows:

$$\begin{pmatrix} \Delta y_t \\ \Delta q_t \\ \Delta p_t \end{pmatrix} = \begin{pmatrix} A_{11}(1) & A_{12}(1) & A_{13}(1) \\ A_{21}(1) & A_{22}(1) & A_{23}(1) \\ A_{31}(1) & A_{32}(1) & A_{33}(1) \end{pmatrix} \begin{pmatrix} \varepsilon_{st} \\ \varepsilon_{dt} \\ \varepsilon_{nt} \end{pmatrix}, \tag{7}$$

where $A(1)$ is a matrix of the long-run effects of ε_t on Δx_t.

The restrictions that neither nominal nor demand shocks (ε_{nt} and ε_{dt}) influence economic growth in the long run are:

$$A_{12}(1) = A_{13}(1) = 0 \ . \tag{8}$$

Similarly, the restriction that nominal shocks (ε_{nt}) do not influence the real exchange rate in the long run requires that:

$$A_{23}(1) = 0 \ . \tag{9}$$

These three restrictions make the $A(1)$ matrix triangular and the system is exactly identified.

3 Econometric Methodology and Data Description

We estimate a three-variable VAR model for Croatia. The vector of endogenous variables is specified as $\Delta x_t = \left[\Delta y_t \quad \Delta q_t \quad \Delta p_t\right]'$ where Δ denotes the difference operator. The variables employed in the study are: real output (y_t), real effective exchange rate (q_t) and price level (p_t). All variables are in logarithms and multiplied by 100 so that their differences can be interpreted as the percentage change in the underlying variable. We use monthly data starting from January 1998 to March 2011 as quarterly data would make available time series rather short. Data for GDP are reported only on quarterly basis so monthly data on industrial production indices were employed as a proxy for the real income. The price level is measured by the Harmonized Index of Consumer Prices (HICP) which is also used as a deflator in turning nominal variables into real terms. All data are seasonally adjusted. The sources of the data are as follows: data on HICP and industrial production indices for Croatia are obtained from Eurostat and the source for real effective exchange rate (REER) is the Croatian National Bank.[3] Additionally, a dummy variable is included in the model to account for changes in the methodology for calculating the exchange rate. Namely, it reflects the new Croatian National Bank Act that came into force in April 2001 and according to which the Croatian National Bank may not extend credit to the Republic of Croatia (Croatian National Bank, 2011). We also experimented with several dummy variables to account for possible structural breaks, such as changes in the economic and financial structure of the Croatian economy or the impact of financial and economic crisis. Even though the visual inspection of the REER series (Figure 1) suggests the relevance of the financial and economic crisis dummy variable, eventually, the variable turned out to be statistically insignificant and hence was not included in the final specification of the model.[4]

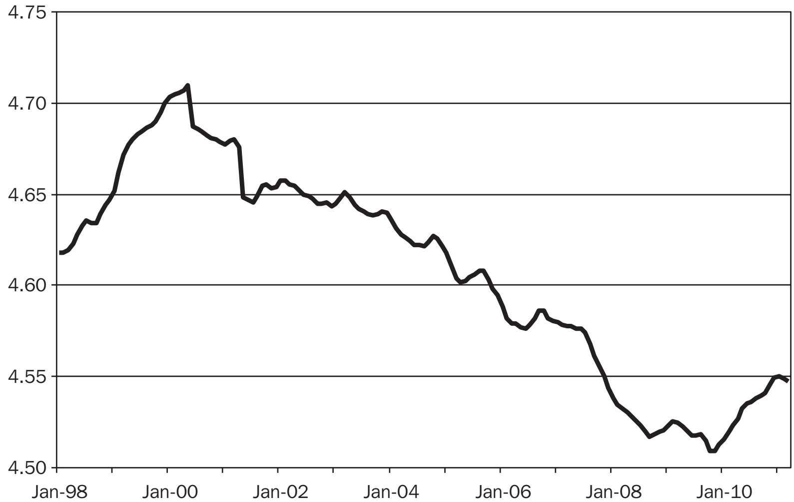
4 Empirical Results

The Clarida and Gali (1994) theoretical model requires that variables are nonstationary in levels but stationary in the first differences. Therefore, prior to model estimation and imposing the Blanchard and Quah (1989) identification scheme, we assess the order of integration of analyzed time series data and test for a possible cointegration. Visual inspection of the REER series (in levels) suggests the possibility of a linear trend (Figure 1).

[3] *Real effective exchange rate series deflated by consumer price index (2005=100) is employed in the study.*

[4] *A possible reason why the financial and economic crisis dummy variable is not statistically significant is the relatively short span of data following the crisis that our analysis covers. Namely, all effects of the crisis have not fed into the real economy yet.*

Figure 1 **Real Effective Exchange Rate**



Note: Real effective exchange rate deflated by consumer price index (2005=100).
Source: Croatian National Bank.

Hence, a constant and a trend are included in the unit root test for the REER series in levels, while unit root tests for the levels of other variables and the first differences of all variables contain a constant only. The results of the augmented Dickey-Fuller (ADF) tests (Table 1) applied to the levels and differences of the variables indicate that all variables have a unit root in levels and are stationary in the first differences, i.e., all variables are integrated of order one.

Table 1 **ADF Unit Root Tests**

Variable	No. of lags*	Deterministic components	ADF	*p*-value**
y	1	c	-1.3269	0.6163
q	1	c, t	-3.2591	0.0771
p	0	c	-1.3044	0.6269
Δy	0	c	-19.1690	0.0000
Δq	0	c	-7.5884	0.0000
Δp	0	c	-12.1488	0.0000

*Notes: * Number of lags is determined by Schwarz information criteria. Component* c *is a constant and* t *is a deterministic trend.*
*** p-values are based on MacKinnon (1996).*
Source: Authors' calculations.

Johansen cointegration tests (Table 2) show that there are no cointegrating relationships among the variables, i.e., variables follow different stochastic trends in the long run. Lag length of the VAR model in first differences k=2 is determined by the Akaike information criterion (AIC) and sequential modified LR test statistic (each test at 5 percent level).

The model includes a constant. The VAR model used in the empirical analysis is stable, i.e., all its roots are within the unit circle. Hence, the formal requirements for the use of the Blanchard and Quah (1989) identification scheme are satisfied.

Table 2 **Johansen Test for the Number of Cointegrating Vectors**

	Null	Alternative	Test statistics	5% critical value**
Trace	$r=0$*	$r>0$	29.32830	29.79707
	$r\leq1$	$r>1$	9.436615	15.49471
	$r\leq2$	$r>2$	3.363923	3.841466
Maximum eigenvalue	$r=0$*	$r=1$	19.89169	21.13162
	$r=1$	$r=2$	6.072692	14.26460
	$r=2$	$r=3$	3.363923	3.841466

*Notes: * Denotes that the null hypothesis cannot be rejected at the 0.05 level.*
*** Critical values are based on MacKinnon, Haug and Michelis (1999).*
Source: Authors' calculations.

Assessment of the sources of real exchange rate fluctuations in Croatia can be made by analyzing variance decomposition which measures the relative contributions of each structural shock to the real exchange rate. In Table 3 we report the variance decomposition for the real exchange rate in logarithmic first differences at selected horizons.

Table 3 **Variance Decomposition of the Real Exchange Growth Rate**

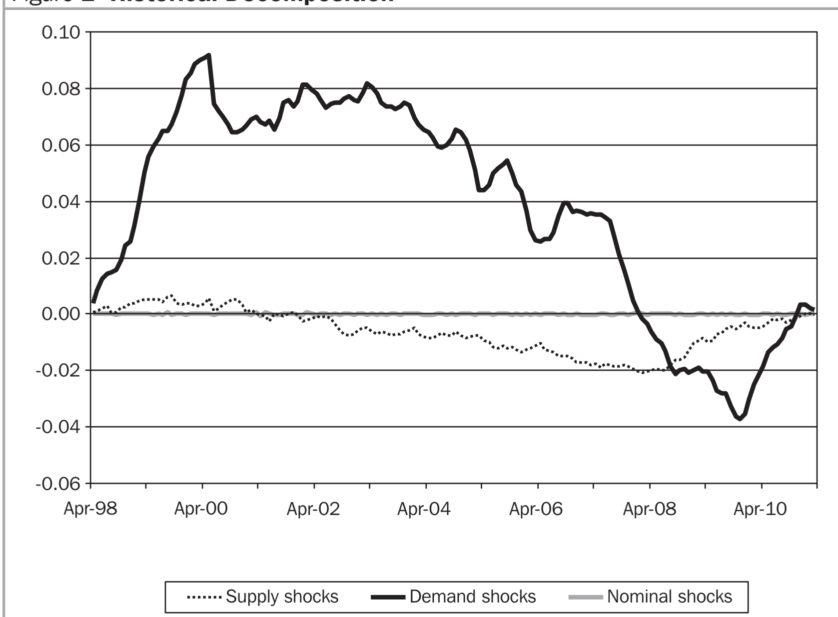
	1 month	1 year	2 years
Supply shock	14.605	9.770	9.770
Demand shock	85.275	89.084	89.084
Nominal shock	0.119	1.146	1.146

Source: Authors' calculations.

The results of variance decomposition reveal the dominant role of the demand shocks in explaining real exchange rate fluctuations. According to our structural VAR model, after the first year the major part (89 percent) of the volatility of the real exchange rate growth rate is attributed to demand shocks. A much smaller proportion (about 9.7 percent) is due to the supply shocks, while the role of the nominal shocks in explaining the variability of the real exchange rate is marginal. Due to the fact that the real exchange rate volatility is mainly driven by real shocks, the exchange rate seems to be a shock absorber and as such stabilizes the Croatian economy.

Historical decomposition of the real exchange rate is also conducted and the results are depicted in Figure 2. The obtained results confirm the findings of the variance decomposition that the demand shocks make a substantial contribution to real exchange rate fluctuations. The effect of nominal shocks is negligible while supply shocks explain a small proportion of variance in most of the observed period.

Figure 2 **Historical Decomposition**

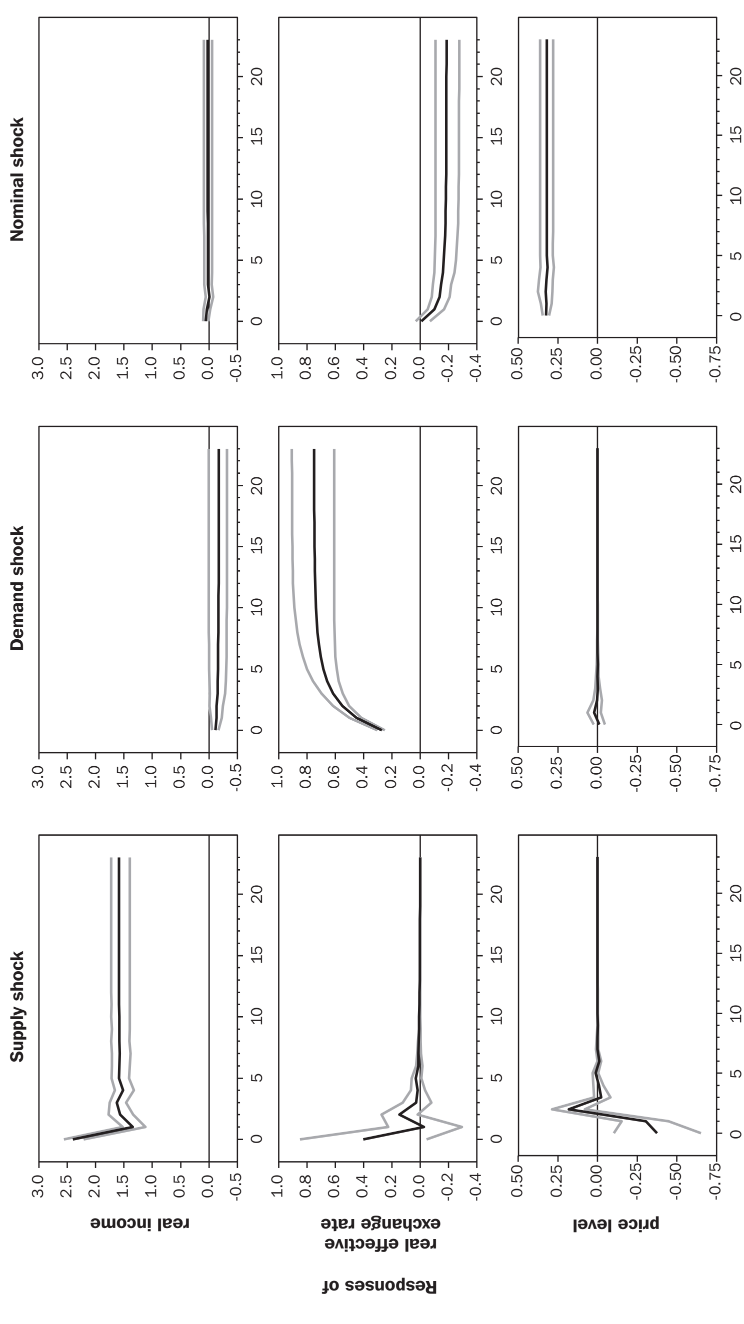


Source: Authors' calculations.

The results of our study are now compared with the findings of similar studies performed for other CEE economies. The shock absorbing role of the real exchange rate is also observed for Estonia, Slovenia, Lithuania and Slovakia (Stazka, 2006), Poland (Stazka-Gawrysiak, 2009), Hungary (Dibooglu and Kutan, 2001), Czech Republic and Poland (Rodríguez-López and Torres Chacón, 2006), Slovenia, Hungary, Latvia and Cyprus (Kontolemis and Ross, 2005), Czech Republic, Hungary and Slovenia (Morales-Zumaquero, 2006). The dominant role of demand shocks is in line with the findings of Stazka (2006) for Estonia, Slovakia and Slovenia where the real demand shocks account for between 56 and 84 percent of fluctuations in the real exchange rate. Depending on the model specification, Stazka-Gawrysiak (2009) finds that demand shocks account for 57 to 70 percent of the fluctuations in the real exchange rate, while the influence of the supply shocks is about 9 percent, similar to Croatia.

While the variance decomposition measures the relative importance of the different types of shocks to the real exchange rate, the impulse response function is used to measure the effects of one-time structural shock. Therefore, we proceed with the analysis of impulse response functions. We also look at the impulse response functions to match the results of our estimated model with the predictions of the Mundell-Fleming-Dornbusch model on which Clarida and Gali (1994) base their analysis and try to interpret the impact of the various shock types on the exchange rate. The impulse dynamics in response to the three structural shocks (demand, supply and nominal shocks) are analyzed. According to the Mundell-Fleming-Dornbusch model, a positive aggregate demand shock should create additional demand for home goods in Croatia, which should result in permanent appreciation of the real exchange rate. A positive nominal shock has a temporary effect on the real exchange rate. After a short-run depreciation of the real exchange rate in response to the nominal shock, the real exchange rate eventually returns to the initial level. On the other hand, the effects of a positive supply shock on the real exchange rate are ambiguous both in the short and in the long run (Buiter, 1995).

Figure 3 **Impulse Response Functions (Responses to One Standard Deviation Shock)**



Source: Authors' calculations.

The dynamic effects of demand, supply and nominal shocks on fluctuations in the Croatian real exchange rate are reported in Figure 3. The figure shows accumulated impulse responses of the differenced variables to a given shock which correspond to the responses of variables in levels, together with one standard deviation bands.

The results of the impulse response analysis show that a positive real aggregate demand shock leads to a permanent depreciation of the real exchange rate. Initially, the exchange rate depreciates to almost 0.7 percent within a month, after which the effect becomes permanent. Although the finding is contrary to the theoretical priors of the Mundell-Fleming-Dornbusch model, the results are in line with the results obtained for other CEE countries. Stazka (2006) obtained the same results for the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia, and offers two possible explanations. One possible reason for such unexpected results could be that the industrial production is a poor proxy for the economic activity as it does not reflect the growing importance of the service sector. Another explanation is that in order to give a better description of the system, one has to employ more than three shocks. Furthermore, Borghijs and Kuijs (2004) consider the real exchange rate depreciation in Hungary consistent with the implemented exchange rate regime. Namely, the depreciation of the exchange rate reflects the monetary authorities' attempts to offset the rise in the relative prices and its negative impact on competitiveness. Although Stazka's (2006) explanations seem more plausible for the case of Croatia, the inclusion of more shocks requires additional variables in the model which is not a feasible solution due to the relatively short time series available. Furthermore, the depreciation could be caused by the structure of the Croatian economy, as the majority of the demand shock is likely to be absorbed into increase of imports. Therefore, due to the lack of competitiveness of Croatian exports combined with limited capital mobility, the weakening of currency dominates the effects that should have led to appreciation of currency according to the Mundell-Fleming-Dornbusch model.

The same explanation could be applied to the pattern of the response to a nominal shock. Due to a positive nominal shock, the real exchange rate appreciates within two months after the shock, which is again not consistent with the theoretical predictions of the Mundell-Fleming-Dornbusch model. As for the supply shocks, the predictions of the theoretical model are ambiguous. For that reason, we turn to the results of empirical studies for other CEE economies to find similarities in the pattern of response of the real exchange rate to supply shocks. Depreciation of the real exchange rate in response to a positive aggregate supply shock is also observed by Stazka (2006) for Hungary and Poland. The same outcome was obtained by Borghijs and Kuijs (2004) for the Czech Republic, Poland and Slovenia as well as by Rodríguez-López and Torres Chacón (2006) for Hungary and Poland. The results of our study are mostly in line with the results obtained for other CEE economies, whether the countries have the same exchange rate regime as Croatia (Czech Republic) or different (Hungary and Poland) and whether the observed period is the pre-accession period or the period after joining the EU. Therefore, the explanation of the similarities in the response pattern cannot be attributed solely to the exchange rate regime or the position the country is in (pre-accession period), but is primarily dependent on the structure of the economy.

5 Conclusion

The paper analyzes the changes in the real exchange rate due to three structural shocks: supply, demand and monetary. The most important finding of the analysis is that the Croatian real exchange rate acts as a shock absorber. Namely, the results of the empirical analysis indicate that the fluctuations in the real exchange rate are mostly due to real demand shocks (more than 80 percent). Another finding of our research is that supply shocks explain a small proportion of the variance in real exchange rates. The results are in line with findings for other CEE countries, indicating that a similar response pattern exists for other countries in the region. However, the explanation of the similarities in the response pattern cannot be attributed solely to the exchange rate regime or the position the country is in (pre-accession period), but is primarily dependent on the structure of the economy.

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