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What Drives Inflation in a Small European Economy: The Case of Croatia

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What Drives Inflation in a Small European Economy: The Case of Croatia

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Abstract

We provide fresh evidence regarding the relative importance of domestic and foreign drivers of inflation in Croatia. Our results suggest that the majority of variation in domestic prices can be attributed to foreign shocks. We also provide evidence that the muted inflation in Croatia since the mid - 2013 has been mainly driven by external factors - primarily by foreign commodity prices. This is a conclusion that easily survives all the specifications we tested. Finally, we focus on the exchange rate pass-through to domestic prices. We contribute to related literature and identify the exchange rate shock for a small European country with a stable exchange rate against the euro using sign restrictions. Our approach builds on An (2006) and seems to be a theoretically more coherent way to identify the exchange rate shock compared to the usual strategy which employs Cholesky identification. Our method can be directly applied to other countries with a similar exchange rate regime.

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1 Introduction

Maintaining price stability is the main goal of many central banks including the Croatian National Bank (CNB). In order to achieve this goal it is important to identify the main drivers underlying inflation, as well as to quantify the impact they have on domestic prices. This is particularly relevant in the context of prolonged recession in Croatia coupled with inflation rates well below historical average. In that context this paper seeks to reexamine the relative importance of foreign and domestic shocks for inflation in Croatia. We pay special attention to identify the main shocks that characterize the current period of muted inflation rates in Croatia. Assessing the relative importance of individual shocks affecting inflation during that period is of special interest to policy makers - different sources of low inflation may call for different solutions to bring inflation back to normal rates.

Our analysis builds on a series of papers on domestic inflation that emphasizes the importance of external shocks for inflation dynamics, assessing the impacts of domestic real developments on inflation as relatively insignificant¹. We start by investigating the role of domestic real activity and import prices using a small open economy Phillips curve model. The main message of this part of the analysis is that both import prices and domestic real activity matter for domestic inflation dynamics. Although single-equation models like the Phillips curve convey some information about the drivers of inflation, they are in general of limited use for identifying underlying shocks and their propagation mechanisms. For example, in a small open economy real demand is likely to be influenced by both domestic and foreign demand shocks. At the same time import prices are driven by several different shocks (exchange rate, foreign prices etc.). Unfortunately, an answer to the question which of these shocks are more important for inflation dynamics cannot be provided within a Phillips curve framework. Hence, in order to disentangle the relative importance of foreign and domestic shocks for Croatian inflation we turn to a multivariate framework and estimate a BVAR with an exogenous foreign block. Our specification is similar to the model of pricing along the distribution chain presented in McCarthy (2007), adjusted to account for small open economy features². We identify the underlying shocks using a Cholesky decomposition in which the ordering reflects an idea that global commodity prices can influence European prices and output gap contemporaneously, but not the other way around. Our results suggest that the variability of domestic inflation has largely been driven by foreign commodity and oil price shocks. Although real developments in EU and Croatia, as well as exchange rate shocks have also contributed to inflation dynamics, they seem to be of secondary importance. Overall, the variance decomposition suggests that the majority of variation in domestic prices can be attributed to foreign shocks - 50% for import deflator

¹Pufnik and Gattin Turkalj (2002), Billmeier and Bonato (2002), Maoduš (2006), Jankov *et al.* (2008), Krznar and Kunovac (2010), and Krznar (2011).

²Jankov *et al.* (2008) and Krznar and Kunovac (2010) estimate a similar model. Our specification differs in that it uses a richer specification modelled within a Bayesian framework. For example, Jankov *et al.* do not control for a measure of foreign output.

and 68% for consumer inflation.

Regarding the sources of muted inflation since mid - 2013, results from the BVAR analysis clearly demonstrate that low inflation has predominantly been caused by external shocks. Strong negative shocks to foreign commodity prices, and to lesser extent to euro area producer prices, have been identified as the primary causes of low inflation rates during the period of interest. For example, shocks to foreign commodity prices and producer price inflation were lowering annual inflation rates below historical values (baseline projections) by an average of 1.8 percentage points during 2014. Exchange rate and demand variations also had deflationary effects on prices, but the intensity of these effects was relatively weak.

In order to examine the robustness of the model, alternative specifications were tested. Most notably, we checked the results against several alternative orderings of the benchmark model. Overall, the main message from the variance decomposition and historical decomposition exercises is that commodity prices remain the main drivers of domestic inflation, regardless of the chosen Cholesky ordering. Common conclusion is that foreign variables can explain more than half of the variance of domestic inflation. However, the effects of the foreign and domestic output gaps and exchange rates on prices do change for various orderings. In general, we find it quite challenging to clearly disentangle their effects on prices.

In the last part of the paper we focus on the issue of exchange rate pass-through - a potentially important driver of domestic inflation. The USD/EUR exchange rate seems to have the leading role for the mechanics of transmission of the exchange rate to domestic prices (see Jankov *et al.*, 2008). This is particularly interesting considering the fact that the Croatian foreign trade in US dollars is several times smaller compared to the trade in euro. We argue that the importance of the US dollar for domestic prices is the result of its significantly greater volatility as opposed to the relatively stable EUR/HRK exchange rate. In addition, the importance of the US dollar for domestic prices can also be explained by its special position in international trade as the most important invoicing and pricing currency. Of course, pronounced variations in the HRK/EUR exchange rate would undoubtedly have a significant impact on domestic prices; however, as such variations have not occurred thus far they have not had significant material impact on prices ³ - the transmission to prices is by and large materialized through the HRK/USD exchange rate. When estimating ERPT for Croatia we take the advantage of the importance that USD/EUR has for domestic consumer prices and identify the exchange rate shock by modelling the pass-through of this rate to euro area prices. To cope with problems related to Cholesky identification, we build on An (2006) who identifies the exchange rate shock using sign restrictions. We extend her model to make it suitable for measuring ERPT in a small open economy and we apply

³The exchange rate volatility has been too low to give a statistically significant result, or pegging the exchange rate to euro reduced inflation expectations to the point that existing volatility was lower than the costs of changing prices

the methodology to several inflation measures at various stages of the pricing chain. As expected, our results suggest that the exchange rate shock has a large impact on prices along the pricing chain for both the euro area and Croatia. Most notably, ERPT declines along the chain and reduces roughly to about a half at each stage. Following a one percent depreciation of euro against US, after a one year period, import prices in the euro area rise 0.6%, producer prices rise by about 0.3% and consumer prices rise less than 0.1%. Similarly in Croatia PPI inflation rises slightly less than 0.4% and CPI inflation by about 0.2%. Finally, our results suggest that exchange rate shocks were of relatively limited importance to consumer prices and of more importance to producer and energy prices. In the context of muted inflation rates since 2013, we argue that deflationary pressures coming from the effective exchange rate identified by the Cholesky identification can be attributed to the variability of the exogenous USD/EUR exchange rate.

We offer several contributions with this paper. First, we provide fresh evidence on relative importance of various domestic and foreign drivers of inflation in Croatia. We confirm the findings from the previous literature on the importance of foreign factors for domestic inflation dynamics. We build on these contributions and estimate a series of Bayesian VARs with a broader set of explanatory variables. Second, we provide evidence that muted inflation in Croatia since the mid - 2013 has been mainly driven by external factors - primarily by low commodity prices. This is a conclusion which easily survives all specifications we test. Finally, we suggest a way to estimate exchange rate pass-through for a small European economy with a stable exchange rate against the euro. Our approach builds on An (2006) and seems to be a theoretically more coherent way to identify the exchange rate shock compared to the usual strategy which employs Cholesky identification. Our method can be directly applied to other countries with a similar exchange rate regime.

2 Evidence from the Phillips curve

2.1 Preliminaries

In this part of the paper we use a small open economy Phillips curve framework to analyze consumer inflation in Croatia. Besides economic slack and inflation expectations, import prices are therefore allowed to influence domestic prices. We start with a specification which introduces import prices in a rather simple way - through an identity that defines consumer prices as a weighted average of domestic and import prices. However, this approach gives a rather limited role to import prices. For this reason we extend the basic specification by allowing the import prices to influence the markup of domestic producers. This results in what we call an *extended* Phillips curve model where lagged deviation of consumer prices from its target level (given by a weighted average of unit labor costs and import prices) enters the specification along with the output gap.

2.2 Small open economy Phillips curve

We start by estimating the small open economy Phillips curve of the following form

$$\Delta p_t = a_1 + a_2 \Delta p_{t-1} + a_3 \tilde{y}_t + a_4 \Delta p_t^{im} \quad (1)$$

where lowercase letters denote variables in logs, Δp_t is the inflation rate, \tilde{y}_t is the output gap, and Δp_t^{im} is the change in import prices. Equation (1) can be rationalized in two different ways. First, it can be interpreted as a traditional open economy Phillips curve that can be derived from reduced form price and wage equations, expectations formation based on the AR(1) process for inflation, and a definition of consumer prices as a weighted average of prices charged by domestic producers and import prices (this is illustrated in Appendix A1). On the other hand, it can also be regarded as a reduced form of the New Keynesian Phillips curve model (see for example Milani, 2005).⁴

Our estimation sample starts in 2000Q1 and ends in 2014Q4. As a measure of domestic inflation we use core CPI inflation - an aggregate consumer inflation which excludes administrative prices and prices of agricultural products whereas import prices are represented by the total import deflator from national accounts. In order to check the robustness of our results we use three different output gap measures⁵. To make the output gap predetermined, we include it in the model with a lag. The estimation results are shown in Table 1⁶. The results suggest that both output gap and changes in import prices drive consumer inflation in Croatia⁷. Overall, it appears the small open economy Phillips curve with output gap as a measure of economic slack fits Croatian inflation reasonably well over the last fifteen years. Moreover, this result is robust across different measures of output gap. Interestingly, Krznar (2011) estimates a similar specification for the period from 1998Q1 to 2010Q1 and fails to find a significant relationship between domestic activity (measured by the HP-filter based output gap) and consumer inflation. This discrepancy between his and our findings

⁴Krznar (2011) finds a hybrid version of the New Keynesian Phillips Curve (NKPC) developed by Gali and Gertler (1999) to be a good description of Croatian inflation dynamics. By using GMM to estimate the NKPC he assumes that agents form rational expectations. Here we choose a less structural approach and abstract from the rationality assumption. As shown later, our specifications explain inflation dynamics quite well.

⁵The first measure (HP) is obtained by applying a HP-filter with $\lambda = 1600$ to seasonally adjusted GDP series. The second measure (PF) is a standard production function based output gap, linearly interpolated from annual to quarterly frequency. Finally, the third measure (MF) is obtained from the estimation of a small macro model similar to the one presented in Bokan and Ravnik (2012).

⁶p-values in brackets below the estimated coefficients are based on Newey-West (HAC) standard errors. Residual autocorrelation is tested using Breusch-Godfrey LM Test (4 lags), and normality with Jarque-Bera test. Stability test is Quandt-Andrews break-point test. We report p-values. For QA test these are calculated according to Hansen (1997) and are associated with max. LR F-statistics.

⁷The estimated equations pass all usual diagnostic tests. As a robustness check we also have included additional lags of inflation in the specification and found them to be redundant. In addition, we have also tested for the significance of two dummy variables related to changes in VAT in 2009Q3 and 2012Q2, but surprisingly we found them to be insignificant. Finally, we have replaced core CPI with the headline CPI and the results turned out to be quite similar.

Table 1: OLS estimates of the Phillips Curve

Variable	Gap (PF)	Gap (HP)	Gap (MF)
ΔP_{t-1}	0.40 (0.001)	0.39 (0.002)	0.45 (0.000)
ΔP_t^{IM}	0.13 (0.009)	0.11 (0.020)	0.10 (0.035)
\tilde{y}_{t-1}	0.06 (0.004)	0.08 (0.003)	0.05 (0.003)
Constant	0.22 (0.010)	0.27 (0.002)	0.17 (0.020)
Observations	58	58	58
Adjusted R^2	0.49	0.44	0.47
Autocorrelation	0.82	0.44	0.35
Normality	0.92	0.91	0.99
Stability	0.12	0.53	0.59

probably reflects the characteristics of the different data sample we use for estimation, which includes the prolonged recessionary period and does not include first two years of Krznar's sample⁸. To illustrate that, in Figure 1 we show impulse responses of core inflation to an output gap shock for the period before and after the crisis⁹.

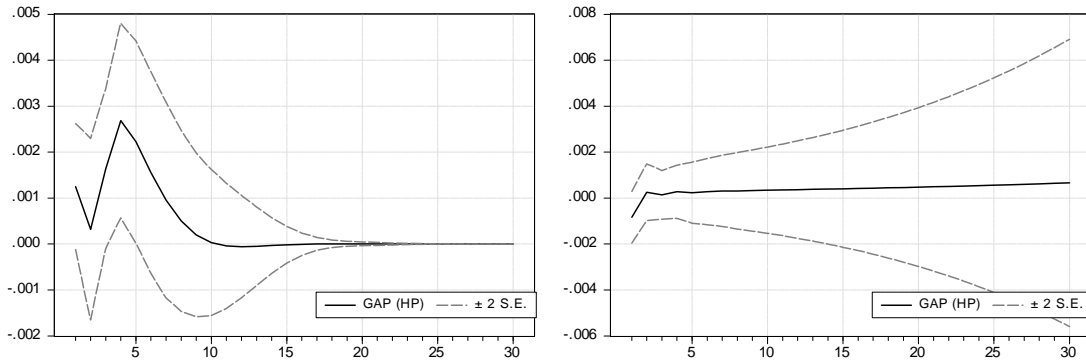


Figure 1: Response of core CPI to output gap shock for the pre-crisis period (right) and during the crisis (left).

The figure illustrates that a statistically significant impact of the output gap on inflation appears only when we include the crisis period in the estimation. On the other hand, during

⁸Beside that, GDP data were in the mean time revised several times.

⁹Impulse responses are produced from a VAR model including changes in import prices, output gap and core inflation. We included two lags of each variable and used recursive ordering to identify the output gap shock.

the pre-crisis period cyclical output variations did not matter much for inflation dynamics.

2.3 Extended small open economy Phillips curve

The basic Phillips curve model gives a rather limited role to import prices in shaping domestic prices - they enter only through the identity defining consumer prices. One way to make import prices more important for domestic inflation is to assume that prices of domestic goods and services depend on the price foreign competitors charge on the domestic market. This is a reasonable assumption given that the majority of goods produced at home and abroad are to some extent substitutes in consumption. By allowing import prices to affect the markup of domestic producers and introducing costly price adjustment one can obtain the following equation for consumer inflation (see for example Bjornstad and Nymo en, 2008):

$$\Delta p_t = \tilde{a}_1 + \tilde{a}_2 \Delta p_{t-1} + \tilde{a}_3 \tilde{y}_t + \tilde{a}_4 \Delta p_t^{im} + \tilde{a}_5 (p_{t-1} - p_{t-1}^*) \quad (2)$$

with

$$p_t^* = \gamma_0 + \gamma_1 (w_t - a_t) + (1 - \gamma_1) p_t^{im} \quad (3)$$

where p_t^* is a static price target, w_t are wages and a_t is labor productivity. $(1 - \gamma_1)$ can be seen as a measure of long-run pass-through of import prices into domestic consumer prices. Equation (2) says that besides output gap, transitory deviations of actual prices from the corresponding target should also matter for inflation¹⁰. Note that Equation (3) implies that consumer prices, unit labor costs, and import prices should be cointegrated. Hence, before proceeding with the estimation of Equation (2)¹¹ we have to test whether this is actually true in the data¹². We estimate γ_1 to be around 0.5 which implies that 1% increase in import prices raises domestic consumer prices by about 0.5% in the long run¹³.

In order to check the sensitivity of our results to different specifications we estimate

¹⁰As discussed by Bowdler and Jansen (2004), in the context of New Keynesian Phillips Curve literature these two are seen as alternative driving variables of inflation (see in particular Gali and Gertler, 1999). However, since they do not have the same cyclical dynamics they could simultaneously play a role in the inflation process.

¹¹Which we loosely refer to as the *extended* Phillips curve

¹²In Figure 2 (Appendix A2) we show core CPI, total import deflator, and unit labor costs in the non-government sector. Looking at the figure (both levels and growth rates) it is obvious that core CPI series is much smoother than import prices and ULC implying that shocks to latter variables only gradually feed into core consumer prices. Also, it appears that a drift in core CPI is balancing drifts in import prices and unit labor costs. Hence, visually it seems there is long run co-movement between these variables. We formally test for cointegration and find evidence in favour of there being one cointegrating relation between the analyzed variables. We interpret this as a long-run price equation (for details see Appendix A2).

¹³This seem reasonable and is in line with existing literature. For example, Petursson (2002) obtains $\gamma_1 = 0.6$ for Iceland, while Marques (2008) obtains $\gamma_1 = 0.51$ for Portugal.

several versions of the *extended* Phillips curve. Results can be found in the Table 2¹⁴:

Table 2: OLS estimates of the extended Phillips curve

Variable	(1)	(2)	(3)	(4)
ΔP_{t-1}	0.48 (0.000)	0.41 (0.000)	0.28 (0.005)	—
$(p - p^*)_{t-1}$	-0.13 (0.008)	-0.17 (0.002)	-0.14 (0.003)	-0.09 (0.010)
\tilde{y}_{t-1}	—	—	0.05 (0.011)	0.07 (0.000)
ΔP_t^{IM}	—	0.15 (0.003)	0.15 (0.000)	0.09 (0.011)
ΔP_{t-1}^{IM}	—	—	—	0.07 (0.009)
ΔP_{t-2}^{IM}	—	—	—	0.08 (0.003)
ΔP_{t-3}^{IM}	—	—	—	0.12 (0.000)
Constant	0.34 (0.000)	0.34 (0.000)	0.37 (0.000)	0.35 (0.000)
Observations	58	58	58	58
Adjusted R^2	0.39	0.51	0.55	0.64
Autocorrelation	0.32	0.52	0.87	0.40
Normality	0.03	0.88	0.72	0.16
Stability	0.70	0.68	0.53	0.17

Model (1) includes lagged deviations of consumer prices from a static price target as a substitute for the output gap and omits contemporaneous change in import prices. Model (2) reintroduces contemporaneous change in import prices into specification. Model (3) is the *extended* Phillips curve in which we allow both cyclical demand pressures and the deviation of consumer from their long-run target to affect inflation. Finally, in Model (4) we start from a specification that includes 4 lags of consumer, import and unit labor costs inflation. Here we use a general-to-specific approach to pin down the most parsimonious specification. Interestingly, lagged inflation drops out of the specification while three lags of changes in import prices appear to be significant. In short, both output gap and deviations of consumer prices from their target level seem to matter for domestic inflation. The latter confirms our prior expectations that import prices matter more for domestic prices than was suggested by the simple Phillips curve.

Overall, the analysis of Croatian inflation in the context of a small open economy Phillips curve framework points towards a significant influence of import prices in shaping consumer inflation. This result is in accordance with the previous literature dealing with

¹⁴p-values in brackets below the estimated coefficients are based on Newey-West (HAC) standard errors. Residual autocorrelation is tested using Breusch-Godfrey LM Test (4 lags), and normality with Jarque-Bera test. Stability test is Quandt-Andrews break-point test. We report p-values. For QA test these are calculated according to Hansen (1997) and are associated with max. LR F-statistics. We use production function based measure of output gap.

price dynamics in Croatia (Krznar, 2011; Krznar and Kunovac, 2010). However, unlike the previous literature, we find that real activity also matters for domestic inflation. The findings presented here provide some information about the drivers of domestic inflation. However, given its partial equilibrium nature, the Phillips curve is only of limited help in explaining inflation dynamics. First, it neglects possible feedback reactions between inflation and explanatory variables. Second, it is rather uninformative about actual sources of the shocks driving Croatian consumer prices. For example, in a small open economy real demand is likely to be influenced by both domestic and foreign demand shocks. At the same time import prices are driven by several different shocks (exchange rate, foreign prices etc.). An answer to the question which of these shocks are more important for inflation dynamics cannot be provided using a Phillips curve framework. To disentangle the relative importance of different shocks for domestic inflation we have to resort to a multivariate analysis.

3 Evidence from a small open economy BVAR

3.1 Preliminaries

This section seeks to identify the main determinants of domestic CPI inflation in the last 15 years by using a multivariate setup. As shown in the previous section both domestic and foreign variables need to be included in the model. In order to identify the main forces governing inflation in Croatia, we estimate a structural Bayesian VAR with block exogeneity restrictions. Hence, in our model the propagation of economic shocks is asymmetric in a sense that it takes into account that Croatia is a small open economy. Based on the evidence from the impulse response functions, historical decomposition and variance decomposition we discuss the relative importance of different forces underlying inflation. The estimated specifications include different measures of domestic and foreign real variables, exchange rates and also several indicators that measure inflation at various stages of the pricing chain. A similar model of pricing along a distribution chain is developed in McCarthy (2007), but our model differs in that it is suitable to model the propagation of economic shocks between a small and a big country. In view of the current low inflation it is of particular interest to decompose inflation into domestic and external factors. Results of the analysis indicate that the subdued inflation primarily reflects the spillover of foreign oil and food prices onto domestic consumer prices. In addition, shocks to producer prices in the EA also played a significant role. Unfavourable real developments, both in Croatia and the EA, and exchange rate shocks also contributed to deflationary pressures, although to a much smaller extent than food and oil prices.

3.2 Model - Bayesian VAR with block exogeneity restrictions

Let us consider a structural vector autoregression (SVAR) model

$$A_0 y_t = \mu + A_1 y_{t-1} + \dots + A_k y_{t-k} + \varepsilon_t, \quad t = 1, \dots, T. \quad (4)$$

where y_t is an $n \times 1$ vector of observed variables, the A_j are fixed $n \times n$ coefficient matrices with invertible A_0 , μ is $n \times 1$ fixed vector and ε_t are economic shocks with zero mean and covariance matrix I_n . The reduced form VAR model obtained from (4) is

$$y_t = c + B_1 y_{t-1} + \dots + B_k y_{t-k} + u_t, \quad t = 1, \dots, T, \quad (5)$$

where $B_j = A_0^{-1} A_j$, $c = A_0^{-1} \mu$ and $u_t = A_0^{-1} \varepsilon_t$. It is easy to see that $E(u_t) = 0$ and $E(u_t u_t') = \Omega = (A_0' A_0)^{-1}$ (see Lutkepohl (2005) for more details about VARs). Model (5) can be written in a form more convenient for Bayesian simulation of reduced form parameters

$$y_t = X_t' \beta + u_t. \quad (6)$$

where

$$X_t' = I_n \otimes [1, y_{t-1}', \dots, y_{t-k}'] \quad (n \times (kn^2 + n)), \quad \beta = \text{vec}([cB_1 \dots B_k]') \quad ((kn^2 + n) \times 1). \quad (7)$$

Block exogeneity is a common assumption when modelling transmission of economic shocks between a big and a small economy using VARs. It refers to a certain type of restrictions where shocks originating in the big economy (or foreign block from a small country point of view) can influence the small economy, but not the other way around. Now let y_{1t} be a n_1 dimensional vector of external variables and y_{2t} an $n_2 = n - n_1$ dimensional vector of domestic variables so y_t can be decomposed as $y_t' = [y_{1t}', y_{2t}']$. Matrices A_j from (4) now must have block lower triangular form

$$A_j = \begin{bmatrix} A_{11}^j & 0 \\ A_{21}^j & A_{22}^j \end{bmatrix}, \quad j = 0, \dots, k,$$

and it can be shown that coefficient matrices B_j inherit this block exogeneity form so that

$$B_j = \begin{bmatrix} B_{11}^j & 0 \\ B_{21}^j & B_{22}^j \end{bmatrix}, \quad j = 1, \dots, k. \quad (8)$$

In order to implement block exogeneity both matrix A_0 and some VAR coefficients need to be restricted. In order to restrict A_0 , for example, standard Cholesky-based identification is a valid choice, but other structural schemes are also feasible. The second part of block exogeneity implementation is to shut down the impact of domestic (small economy) shocks

on the foreign variables beyond the impact ($h = 1, 2, \dots$). Within the Bayesian framework this can be achieved by assuming appropriate prior distribution for restricted parameters. The natural conjugate (i.e. normal inverse Wishart) prior is not suitable for this purpose because it assumes that the prior covariance of coefficients in any two equations are proportional to each other (see Koop and Korobilis, 2009). However, the Independent normal inverse Wishart will be appropriate. Under this prior reduced form coefficients and error covariance matrix are independent:

$$\beta \sim N(\underline{\beta}, \underline{V}_\beta), \quad \Omega \sim IW(\underline{M}, \underline{\gamma})$$

Conditional posterior distributions $p(\beta|y, \Omega)$ and $p(\Omega|y, \beta)$ now have the following form

$$\beta|y, \Omega \sim N(\bar{\beta}, \bar{V}_\beta), \quad \Omega|y, \beta \sim IW(\bar{M}, \bar{\gamma}),$$

where

$$\bar{V}_\beta = \left(\underline{V}_\beta^{-1} + \sum_{t=1}^T X_t \Omega^{-1} X_t' \right)^{-1}, \quad \bar{\beta} = \bar{V}_\beta \left(\underline{V}_\beta^{-1} \underline{\beta} + \sum_{t=1}^T X_t \Omega^{-1} y_t \right)$$

and

$$\bar{\gamma} = T + \underline{\gamma}, \quad \bar{M} = \underline{M} + \sum_{t=1}^T (y_t - X_t' \beta) (y_t - X_t' \beta)'$$

To implement block exogeneity we can assume zero mean priors with extremely small variance for all the small country parameters in every equation of the big country block, i.e. if we want to restrict j -th element of β we can set $(\underline{\beta})_j = 0$ and $(\underline{V}_\beta)_{jj} = \varepsilon$ where ε is some small positive number. That puts a dominant weight to the (zero mean) prior parameters when calculating the posterior. In this way sample information is largely ignored as the posteriors of these coefficients will be predominantly influenced by the prior.

Sample from the posterior of the reduced form parameters and residual covariance matrix is drawn by using a Gibbs sampler (see for example Koop and Korobilis, 2009). For each posterior draw a structural matrix is calculated from the Cholesky decomposition of the reduced form residuals covariance matrix $\Omega = (A_0' A_0)^{-1}$. Indirect sampling of structural parameters we employ is correct as long as the system is just-identified (Sims and Zha, 1998).

3.3 Data and identification

The output gap and different measures of domestic inflation are included in the domestic block of variables, while euro area output gap, measures of inflation in the euro area (EA) and the global prices of oil and food constitute the foreign block. Block exogeneity of foreign variables is used for modelling shock transmission from a large economy, in our case the

EA, or, in more general terms, the global economy, to a small open economy - Croatia. Within this framework, the impact of external shocks on the small economy is allowed, but the channel going the other way around is shut down, i.e. the small open economy cannot influence a big country. Structural shocks are identified via recursive ordering with the following benchmark ordering: commodity prices -> EA output gap -> EA PPI inflation -> exchange rate-> domestic output gap -> domestic import inflation -> domestic consumer inflation. The adopted ordering reflects the idea that global commodity prices can affect European variables contemporaneously but not the other way around. However, EA shocks can influence world commodity prices, but only with a lag. On the other hand, the imposed block exogeneity ensures that Croatian variables cannot influence the euro area or world commodity variables.

The choice of the variables used in the VAR is standard. The domestic real variable is the GDP gap calculated based on the standard production function approach, whereas domestic inflation at various stages is measured by PPI, CPI inflation and import deflator. External real activity is represented by the output gap of the euro area real GDP calculated by the Hodrick Prescott filter. Prices of crude oil are represented by the Brent oil index in US dollars, while prices of food are represented by the HWWI index¹⁵. Exchange rate is represented by the index of effective nominal rate (INEER) which is calculated as the weighted average of bilateral exchange rates of the kuna against the currencies of the main trade partners of Croatia¹⁶. All variables are in logs.

3.4 Results

As a benchmark we estimate a VAR with imposed block exogeneity consisting of a domestic and foreign block. The domestic block includes the output gap, import and CPI inflation and nominal effective exchange rate whereas the foreign block includes the output gap in the euro area, the PPI in the euro area and food and oil prices. The model is estimated in first differences with two lags on the period from 2000 - 2014. Impulse responses, historical decomposition and variance decomposition are all based on the Cholesky decomposition of the residual covariance matrix.

Regarding the impulse response function, domestic consumer inflation generally react to both domestic and foreign shocks with the expected signs (Figure 2). For example, both foreign and domestic output gap shocks have a positive impact on domestic inflation, foreign commodity prices have strong impact on prices while exchange rate depreciation propagates

¹⁵Instead of the HWWI food, consumer food price index may be used as foreign food prices. In that case, they incorporate the channels of transmission of foreign raw material prices and consumer prices on domestic consumer prices. Still, we do not have a clear and unique answer of which indicator of foreign food prices should be included in our specification. Difficulties in measuring the pass-through of food prices to consumer inflation are well documented in the literature and include problems with choosing appropriate measure of foreign food inflation or failing to account for possible non-linearities in the pass-through.

¹⁶The euro has the largest share in the INEER of more than 70% followed by the dollar share of around 20% during the last decade.

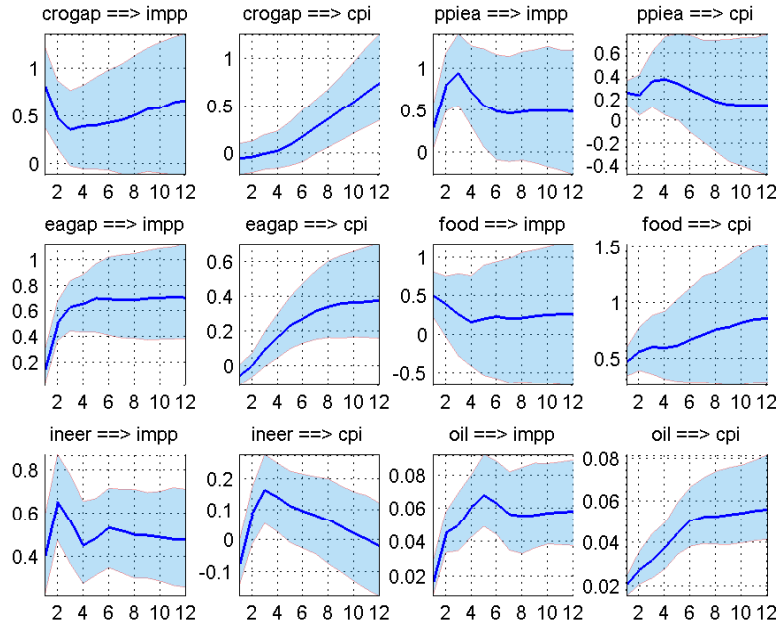


Figure 2: Median impulse response function together with 68% probability band. Impulse responses are cumulative responses calculated from a VAR in first differences.

to both import and consumer prices. The chosen ordering therefore produces a reasonable summary of the propagation of shocks to domestic prices.

Historical decomposition and (forecast error) variance decomposition can shed some light on the relative importance of domestic and foreign shocks for domestic inflation. Variance decomposition results shown in Table 3 suggest that foreign variables have a large impact on variability of domestic prices. With a two year horizon oil and food prices account for more than 30% of import and even 50% of consumer inflation. After accounting for commodity price shocks, an orthogonal shock to foreign PPI inflation matters less for domestic prices and accounts for around 2% of import and 7% of consumer inflation. Foreign demand shock isolated from the EA GDP gap also matters for domestic prices and accounts for 11% of import and 9% of consumer inflation. The variance decomposition thus suggests that majority of variation in domestic prices can be attributed to foreign shocks - 50% for import deflator and 68% for consumer inflation. Regarding domestic variables, after accounting for external shocks, domestic output gap has only a minor impact on domestic prices and accounts for only 4% of import and 2% of consumer inflation. Finally, exchange rate has stronger impact on prices and accounts for 8% of import and 5% of consumer inflation.

Historical decomposition offers a suitable methodological framework for the analysis of specific economic episodes because it enables the identification of shocks which predominate

Table 3: Variance decomposition

Variable	Time	CPI	PIMP	HR GAP	INET	EA PPI	EA GAP	FOOD	OIL	FOREIGN
CPI	1	31.3	2.0	1.1	4.9	5.4	3.3	18.3	33.7	60.8
	4	25.4	2.2	1.2	5.2	6.4	7.8	16.4	35.4	66.0
	8	23.3	2.1	1.8	5.0	7.2	8.9	16.3	35.4	67.8
PIMP	1	2.9	41.4	4.7	8.3	6.4	11.0	6.8	18.5	42.8
	4	3.5	35.3	4.3	8.1	7.9	11.4	8.3	21.3	48.9
	8	3.4	34.1	4.2	8.0	8.0	11.4	8.5	22.3	50.3
HRGAP	1	0.4	1.6	63.3	5.1	3.1	14.3	3.9	8.2	29.6
	4	1.1	1.3	44.2	10.4	3.9	11.1	5.8	22.2	43.0
	8	1.9	1.3	41.3	12.4	5.9	9.7	8.1	19.5	43.2
INET	1	1.0	0.8	1.0	41.4	9.1	8.4	8.0	30.3	55.7
	4	1.8	1.2	2.1	31.9	9.9	8.4	9.5	35.2	63.0
	8	1.8	1.2	2.7	30.3	9.9	8.6	9.9	35.7	64.0
EAPPI	1	0.0	0.0	0.0	0.0	20.0	4.7	2.8	72.5	100.0
	4	0.0	0.0	0.0	0.0	19.2	5.6	5.2	69.9	100.0
	8	0.0	0.0	0.0	0.0	19.1	6.0	5.6	69.3	100.0
EAGAP	1	0.0	0.0	0.0	0.0	1.0	45.1	5.5	48.5	100.0
	4	0.0	0.0	0.0	0.0	7.2	36.2	9.1	47.5	100.0
	8	0.0	0.0	0.0	0.0	8.1	35.1	10.4	46.4	100.0
FOOD	1	0.0	0.0	0.0	0.0	1.3	1.9	83.4	13.4	100.0
	4	0.0	0.0	0.0	0.0	2.9	5.3	68.8	23.0	100.0
	8	0.0	0.0	0.0	0.0	3.7	6.0	67.0	23.3	100.0
OIL	1	0.0	0.0	0.0	0.0	2.0	0.9	1.7	95.4	100.0
	4	0.0	0.0	0.0	0.0	3.1	2.2	3.2	91.6	100.0
	8	0.0	0.0	0.0	0.0	3.3	2.3	3.4	91.1	100.0

antly characterize a particular period. In terms of methodology, a historical decomposition breaks down a time series into two components. The first component represents a baseline projection, i.e. a scenario which does not take economic shocks (whether domestic or external) into account, while the other component includes only economic shocks that occurred in the past. In the context of the low domestic inflation since mid - 2013, a hypothetical inflation rate can be constructed under the assumption that there had been no negative external shocks of energy and food prices and that these variables moved within the range of their expected values. Figure 3 shows the breakdown of CPI inflation into the baseline projection and historical shocks. The results clearly demonstrate that, after mid-2013, low inflation was predominantly caused by external shocks. Strong negative external shocks of foreign commodity prices were primary cause of low inflation rates during the period of interest. In addition, shocks to PPI in euro area have significantly contributed to these developments. Moreover, unfavourable trends in the external real sector were influencing domestic inflation indirectly through their impact on foreign, euro area prices. In 2014 for example, shocks of foreign commodity prices and PPI inflation have been lowering the annual inflation rate below historical values (baseline projections) by an average of 1.8 per-

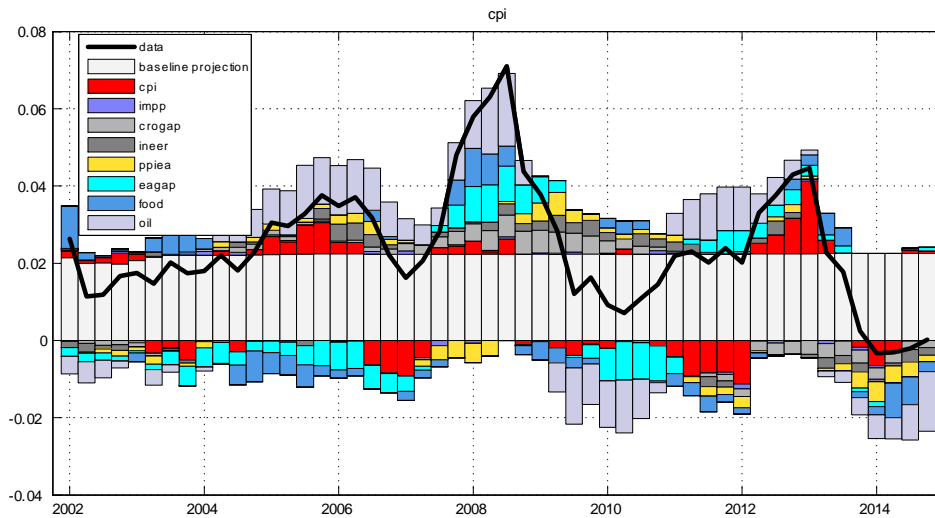


Figure 3: CPI inflation historical decomposition based on Cholesky recursive identification.

centage points. At the same time, real shocks had an average negative impact on the annual inflation rate of 0.3 percentage points. Exchange rate variations also had deflationary effects to prices, but the intensity of that effect was not very strong. Similarly, as shown in Figure 4 low import prices were driven strongly by the foreign commodity prices.

In order to gain an insight into the relative importance of real variables as against that of foreign commodity and producer prices over time, Figure 5 shows the pertaining contributions of these groups to domestic inflation. The inflation rate decomposition performed points to the same conclusion that foreign prices of raw material prices were a dominant factor contributing to recent domestic inflation. Foreign and domestic real activity also had a negative impact on consumer inflation, although the intensity of such an impact has thus far been low compared to the effect of foreign prices.

In addition to the aforementioned real shocks and prices of raw materials in the global market, tax changes and changes in administratively regulated prices also affected inflation in the same period; however, their impact was quite weak compared to the external shocks mentioned above. Still, even though administrative prices and tax changes had only a minor impact on inflation during the period of muted inflation since 2013, this had not always been the case in the past. Such conclusion may be drawn from the historical decomposition in Figure 3 as well as from Table 3 showing the inflation variance decomposition. Approximately 34% of import inflation and 23% of consumer inflation left unexplained by our model. This can be attributable to tax changes, administrative prices and other shocks to inflation omitted in the model.

In order to examine the robustness of the model, alternative specifications were tested.

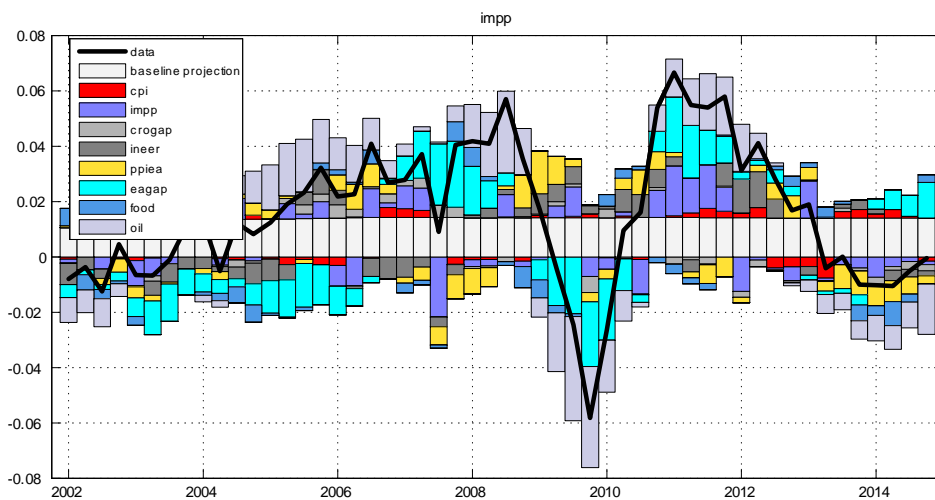


Figure 4: Import price inflation historical decomposition based on Cholesky recursive identification.

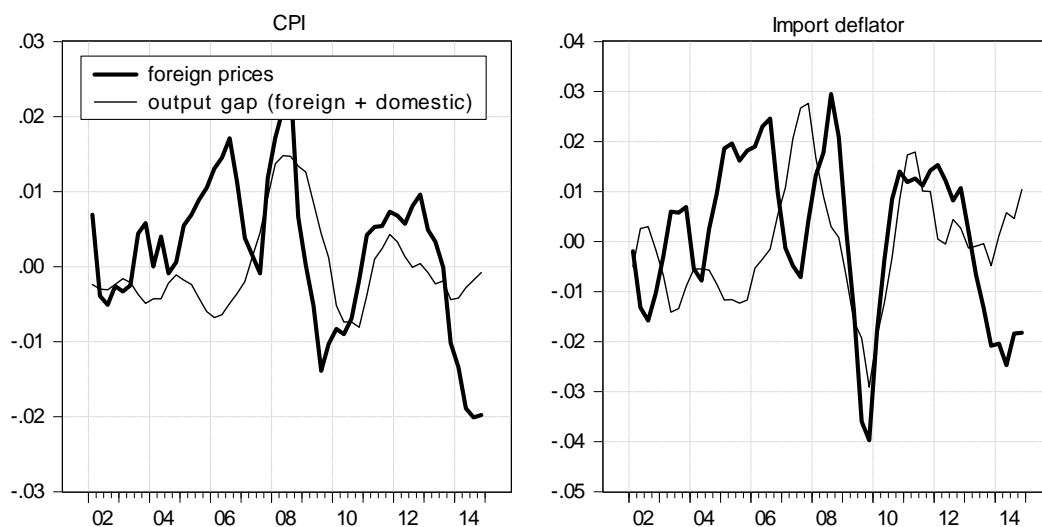


Figure 5: Contribution of foreign price shocks and output gap shocks to domestic CPI and import price inflation.

Most notably, we estimated several alternative orderings of the benchmark model. Furthermore, as a robustness check, the assumption that EA variables can influence world oil and food variables was also relaxed by introducing a third separate block - consisting of world commodity prices only. The variables within that block are mutually endogenous but cannot be influenced by other variables. Overall, the main message from the variance decomposition and historical decomposition exercise is that commodity prices remain the main drivers of domestic inflation, regardless of the chosen Cholesky orderings or placing of foreign variables within one or two blocks. Common conclusion is that foreign variables can explain more than half the variance of domestic prices. The effects of the output gaps and exchange rates on prices however do change for various orderings. For example we find it quite challenging to disentangle demand and exchange rate effects to prices clearly when altering the orderings. Apart from the ordering, it is not clear whether the exchange rate should be included in the domestic or foreign block. For example, if exchange rate is included in the exogenous block, domestic prices react to depreciation with the wrong sign. Instead of the nominal effective rate we also estimated specifications with the HRK/EUR exchange rate. In this specification the exchange rate had no impact on domestic prices which is the expected result. Most probably, either the exchange rate volatility has been too low to give statistically significant result, or pegging the exchange rate to euro reduced inflation expectations to the point that existing volatility was lower than the costs of changing prices.

4 Exchange rate pass-through in a small open economy - BVAR with sign restrictions and block exogeneity

4.1 Importance of the USD/EUR for prices in Croatia

Exchange rate pass-through (ERPT) refers to the transmission of exchange rate shocks to inflation at various stages along *the pricing chain* - to import inflation, producer inflation and finally consumer inflation. Within a multivariate framework, ERPT is typically estimated using Cholesky identification (see for example Hahn, 2003; and McCarthy, 2007). This approach however has an important disadvantage of imposing strong restrictions onto relations between variables at impact. Beside that, the estimated ERPT may be affected by the choice of the ordering of variables in a model. Moreover, it is not quite clear whether the exchange rate should be modelled as a domestic or foreign variable in case of a small open economy. Indeed, in the case of Croatia, the US dollar seems to have the leading role for the mechanics of transmission of the exchange rate to domestic prices (see Jankov *et al.*, 2008). This is particularly interesting considering the fact that the Croatian foreign trade in US dollar is several times smaller compared to the trade in euro. So what makes the dollar so important for our prices? The importance of the US dollar for domestic prices is the result

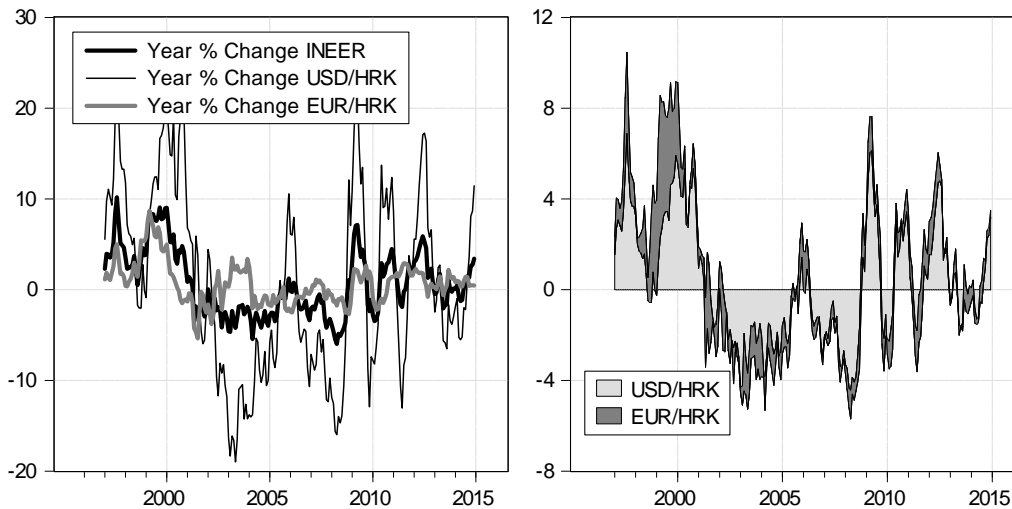


Figure 6: Index on nominal effective exchange rate and bilateral rates USD/HRK and EUR/HRK (on the left). Contributions to kuna effective exchange rate.

of its significantly greater volatility as opposed to the relatively stable EUR/HRK exchange rate¹⁷. To illustrate that, Figure 6 shows individual contributions of the two exchange rates to INEER. In the past 15 years the nominal effective exchange rate has been driven mainly by the variability of the dollar.

An important consequence of the figure above is that it is the exogenous USD/EUR exchange rate that may be of key interest when calculating the exchange rate pass-through in Croatia. This is a simple consequence of the stability of the HRK/EUR and the identity $HRK/USD = (HRK/EUR)/(USD/EUR)$ - the importance of the variation of the HRK/USD exchange rate for consumer prices in comparison with the HRK/EUR exchange rate depends exclusively on the stability of the latter¹⁸. Pronounced variations in the HRK/EUR exchange rate would undoubtedly have a significant impact on domestic prices; however, as such variations have not occurred thus far they have not had significant impact on prices¹⁹ - the transmission to prices is by and large materialized through the HRK/USD exchange rate. To support the above arguments, it is instructive to consult the firm survey on the manner in which the prices of their main products are formed. Almost all export/import

¹⁷Monetary policy in Croatia uses the exchange rate against euro to anchor import prices and inflation expectations. In addition to stabilizing inflation, this policy helps to ensure the stability of highly euroized financial system.

¹⁸The exchange rate however is not fixed - central bank intervenes to prevent large oscillation in exchange rate. As the result, the exchange rate against euro has been very stable with small oscillations from long term average.

¹⁹The exchange rate volatility has been too low to give statistically significant result, or pegging the exchange rate to euro reduced inflation expectations to the point that existing volatility was lower than the costs of changing prices

companies participating in the survey claimed they would alter the prices of their products as a result of a change in the exchange rate above 3%. For survey details see Kunovac and Pufnik (2012).

The importance of the US dollar for domestic prices can also be found in its special position in international trade as the most important invoicing currency. For example, many countries, especially in Asia, use the US dollars as their dominant invoicing currency. Yet, the share of the dollar as the invoicing currency is much higher compared to the actual exports to the United states (see Goldberg and Tille, 2006). Let us note however that the invoicing and the exchange rate pass-through need not be related - but in practice they are. Goldberg and Tille (2006) for example report that the currency of invoicing is also the currency in which prices are held steady (i.e. unadjusted following the exchange rate shock). As a result, exchange rate fluctuations pass through to import prices. Despite the low share the dollar has for domestic import its large fluctuation thus may have a prominent impact on domestic prices through its dominance as a invoicing (and pricing) currency.

In the case of Croatia we argued that it is the USD/EUR exchange rate that really drives the ERPT. Dynamics of this rate originates externally, on the world market, which makes it hard to isolate exchange rate shocks from the correlated commodity prices and demand shocks²⁰. This task becomes even more difficult after adopting the Cholesky identification for a VAR in which case the ERPT estimates proved to be quite sensitive to different orderings. To cope with the problem related to Cholesky identification, An (2006) successfully identifies the exchange rate shock using the sign restrictions. We extend that model to make it suitable for measuring ERPT in a small country and finally apply the methodology to several inflation measures at various stages along the pricing chain.

The sign restrictions we use are motivated by the relation between foreign export prices and domestic import prices in a two country model:

$$P^m = ER \times P^x$$

where P^m denotes import prices, ER is the exchange rate expressed in domestic currency per unit of foreign currency and P^x denotes the foreign export prices. Taking the logarithm yields:

$$p^m = er + p^x = er + markup^x + mc^x.$$

The expression above reflects the fact that exporter prices are essentially a mark-up over marginal costs. While the related literature includes import prices in their specifications when estimating the ERPT, export prices are generally ignored. However, exchange rate can also influence export prices by affecting the mark-up and marginal costs. For example, in the presence of short run price rigidity exporting firms's mark-up will fall with exporting

²⁰The negative correlation between USD/EUR exchange rate and oil prices has been documented in the recent literature (see for example Fratzscher *et al.*, 2014).

firms' currency appreciation (Kim, 1990). Similarly, marginal costs will probably also fall due to cheaper imported inputs (Devereux and Genberg, 2010).

4.2 Identification with sign restrictions

As already argued when calculating ERPT for Croatia our main concern is how variations in the USD/EUR exchange rate influence domestic inflation. Therefore the model needs to capture the main features of the trade mechanism between the euro zone and the United States. Croatian price variables are then included in the model as a separate block that cannot influence the rest of the world. To do so let us first note that the equation above naturally suggests how euro area import prices and the US export prices react to the USD/EUR exchange rate shocks. The signs of reaction then offer a possible identification strategy of exchange rate shock with sign restrictions. Regarding implementation, our model includes a similar set of variables as the VAR in previous chapter. However with an important difference that the sign restricted VAR includes US export prices - a series necessary to identify the exchange shock. Expanding the basic specification in An (2006) our VAR includes:

- EA output gap. Identification assumes that the exchange rate shock (depreciation of euro) will decrease US export prices and increase EA import prices. Thus the effect of the exchange rate shock to output gap in euro area is positive.
- Exchange rate defined as EUR/USD will increase following the exchange rate shock.
- EA prices (import, PPI and HICP) will increase following the exchange rate depreciation.
- US export prices will decrease following the exchange rate shock.
- Domestic, Croatian prices (import, PPI and CPI) increase following the depreciation.
- The impact of the exchange rate shock to oil prices is left unrestricted. The oil prices have a role to account for supply shock in the model.

Parameters of the VAR are estimated as described in the previous chapter. The structural exchange rate shock is identified by imposing listed sign restrictions onto the impulse response function as suggested by Rubio-Ramirez *et al.* (2010). In short, for each posterior draw of reduced form parameters β and Ω , we first draw an orthogonal matrix Q that can be shown to have a uniform distribution with respect to the Haar measure. After that we multiply orthogonal matrix Q by the matrix A_0 obtained from Cholesky factorization of Ω and we calculate the IRFs. If impulse responses satisfy the sign restrictions the posterior draw is accepted. Otherwise we repeat the procedure with a new posterior draw of reduced form parameters β and Ω .

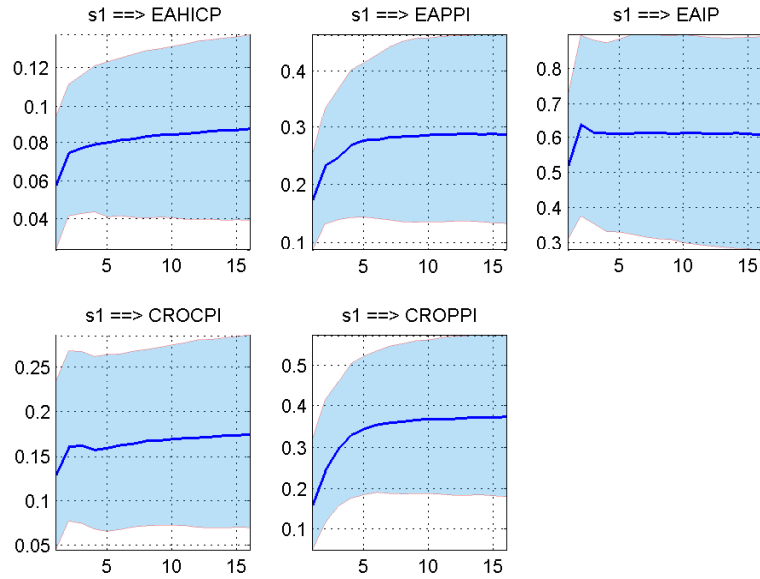


Figure 7: EUR/USD exchange rate pass-through along the pricing chain in the euro area (upper row) and Croatia (bottom row).

4.3 Results

In order to identify the exchange rate shock with sign restrictions we first estimate a (first order differenced) VAR with 7 foreign variables - EA output gap, EA import inflation, producer inflation and consumer inflation, the US export prices, EUR/USD rate and oil prices. We also include producer and consumer inflation for Croatia. Reduced form parameters are estimated by MCMC techniques, as shown in the previous section, whereas structural shocks are identified by the algorithm proposed by Rubio-Ramirez *et al.* (2010) with sign restrictions imposed at impact and one period after the impact only. The ERPT is calculated as the cumulated response of inflation at various stages to an exchange rate shock. In order to make results comparable over different samples and models, impulse responses are normalised and reported with respect to a one percent exchange rate shock.

Figure 7 reports the estimated ERPT to EA inflation and Croatian inflation in form of median impulse responses together with 68% error bands. The reported results suggest that the exchange rate shock has largely expected impact onto prices along the pricing chain for both the euro area and Croatia. Most notably, ERPT is declining along the chain and reduces roughly to about a half at each stage of the distribution chain. Following a one percent depreciation of euro against US dollar, after a one year period, import prices in the euro area rise 0.6%, producer prices rise around 0.3% and consumer prices rise less than 0.1%. Similarly in Croatia PPI inflation rises slightly less than 0.4% and CPI inflation 0.18%.

The result that ERPT declines along the distribution chain is well documented in related literature (e.g. Hahn, 2003; McCarthy, 2007). Common explanation of the phenomenon includes large transportation, wholesaling and retailing costs that come at later stages of the distribution chain. Campa and Goldberg (2005) report that expenditure on local distribution services are 32 to 50 percent of the total cost of goods across OECD countries. Also, price indexes at later stages include a smaller portion of tradable goods compared to import prices and therefore automatically their reaction to an exchange rate shock is weaker.

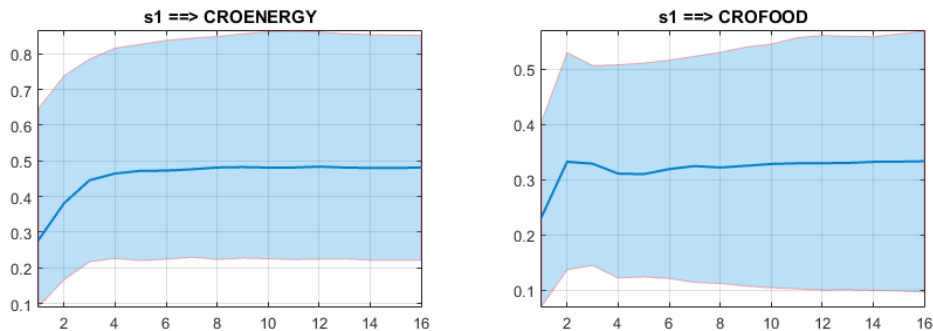


Figure 8: EUR/USD exchange rate pass-through to energy and food prices in Croatia.

We also estimate two similar models in order to measure the ERPT to some of the key CPI subcomponents, namely to food and energy prices to test for consistency of the estimated exchange rate shock. The importance of the food for domestic prices is reflected in its large share of more than 30% in consumer price inflation and thus it is of great interest to measure how strongly they are influenced by an exogenous exchange rate shock. On the other hand energy prices largely originate in the world market and are traditionally priced in the dollar. Therefore the pass-through to energy prices is expected to be large. Figure 8 confirms that. The variability of the EUR/USD rate feeds into domestic energy prices strongly - the estimated pass through is 0.5% is much stronger compared to the impact on the overall consumer price index. On the other hand the pass through to food prices is weaker, although still quite strong - 0.35%.

So how important has the USD/EUR exchange rate shock has been to inflation in Croatia? This question can be addressed by disregarding the impact of the exchange rate shock, i.e. by looking at the hypothetical scenarios - counterfactuals that ignore the identified shock. Figure 9 compares consumer, producer, energy and food inflation with pertaining counterfactuals suggests that the exchange rate shock was of a limited importance to consumer prices and of more importance to producer and energy prices - a conclusion that is consistent with the estimated ERPT effects. In the context of the muted inflation rates since the 2013 the figure suggests that deflationary pressure from the effective rate identified for that period in the previous chapter represent the variability of the exogenous USD/EUR exchange rate.

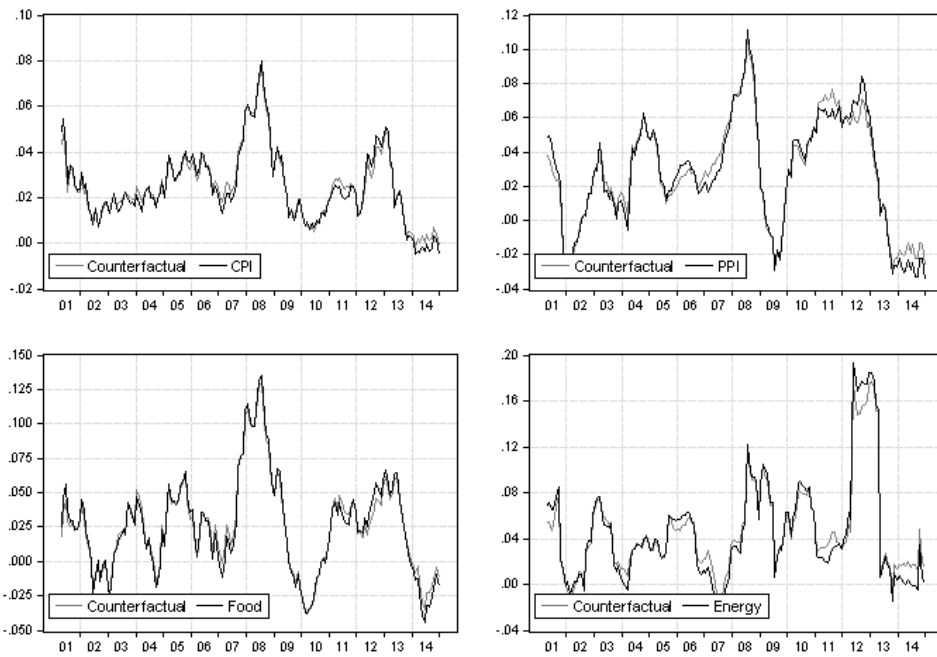


Figure 9: Inflation and counterfactuals - killing off the exchange rate shock

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A 1

The traditional Phillips curve in the open economy context implies that consumer inflation rate is determined by lagged inflation, foreign prices, and the degree of economic slack. As shown for example by Mehra (2004) and Bardsen *et al.* (2005) relationship of this kind can be derived from the following system of equations

$$\Delta q_t = (\Delta w + \Delta a)_t + b_1 \tilde{y}_t + b_2 sp_t \quad (9)$$

$$(\Delta w + \Delta a)_t = c_1 E_{t-1} \Delta p_t + c_2 \tilde{y}_t + c_3 sw_t \quad (10)$$

$$\Delta p_t = \varphi \Delta q_t + (1 - \varphi) \Delta p_t^{im} \quad (11)$$

$$E_{t-1} \Delta p_t = (1 - \phi) \Delta p_t + \phi \Delta p_{t-1} \quad (12)$$

where all variables are expressed in logs and where Δ is a first difference operator; E is the expectations operator; q denotes prices charged by domestic firms; w is a wage rate; a is labor productivity, \tilde{y} denotes output gap; p stand for consumer price index while p^{im} is an import price index. Finally, sp_t and sw_t are random exogenous shocks to prices and wages, respectively.

Equation (9) can be seen as a price equation of profit maximizing domestic producers derived by assuming monopolistic competition in goods market, Cobb-Douglas production technology, and isoelastic demand curves for firms' products. Additionally, markup is allowed to fluctuate with cyclical demand condition and random shocks to price equation. Equation (10) relates wages to productivity, expected consumer inflation, demand pressures and exogenous shocks affecting the wage setting process. Equation (11) gives consumer price inflation as a weighted average of domestic and imported prices. Finally, Equation (12) says that agents use a simple AR(1) process to forecast inflation. By substituting (12) into (10) and then the resulting expression with (9) and (11) we arrive to the Equation (1) in the main text where the coefficients $a_i, i = 1, \dots, 4$, are functions of the parameters from the system above.

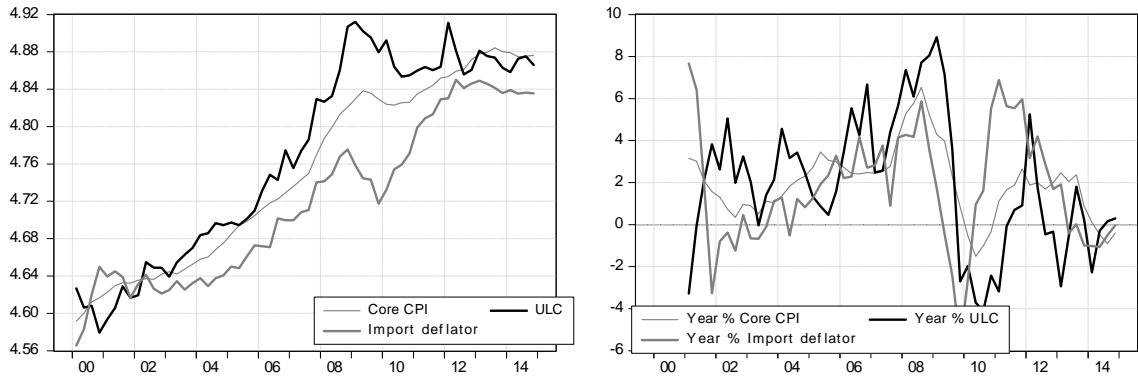


Figure 10: Core CPI, ULC and import prices (2000Q1 - 2014Q4)

A 2

To formally test for cointegration between core CPI, total import deflator and unit labour costs we use Johansen eigenvalue based test and Engle-Granger residual based test. We present our results in Table 3

Table 4: Cointegration Analysis

<i>Johansen rank analysis</i>				
Rank order	Eigenvalues	λ_{max}	critical value (95%)	RA-adjustment
$r = 0$	0.34	24.43	21.13	21.90
$r \leq 0$	0.06	3.43	14.26	3.08
<i>Engle-Granger test</i>				
z-statistics	p-value			
-26.3	0.025			
Standardised cointegrating vector				
	p_t	$w_t - a_t$	p_t^{im}	constant
Johansen	1.00	0.51	0.49	0.63
FM-OLS	1.00	0.48	0.56	- 0.19

Note: MacKinnon-Haug-Michelis (1999) p-values for the max-eigenvalue test, and MacKinnon (1996) p-values for Engle-Granger z-test. RA-adjustment denotes small sample correction of max-eigenvalue test statistics as suggested by Reinsel and Ahn (1992).