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April 10, 2017

Abstract

In this paper we estimate and identify a small open economy Bayesian VAR model in order to disentangle the contribution of individual domestic, euro area-specific and global shocks to domestic macroeconomic developments. Our identification suggests that foreign (global and euro area - specific) shocks have a large impact on the variability of domestic variables - they account for approximately 40% of variation in GDP growth and around 50% of variation in inflation. Looking at the contribution of individual structural shocks our results emphasize two particular findings. First, low oil prices have played an important role for muted inflation in Croatia during the last two years while, at the same time, domestic real activity has not benefited much. We show how this finding depends crucially on the specific mix of economic shocks underlying the movements in oil prices (demand vs supply shocks). Second, our results suggest that the large-scale asset purchase programme launched by the ECB at the beginning of 2015 resulted in favourable, albeit limited, spillover effects on domestic economy.

Keywords: Small open economy, BVAR with sign and zero restrictions, Oil prices, ECB monetary policy
JEL Classification: E30, E10, E50, Q43

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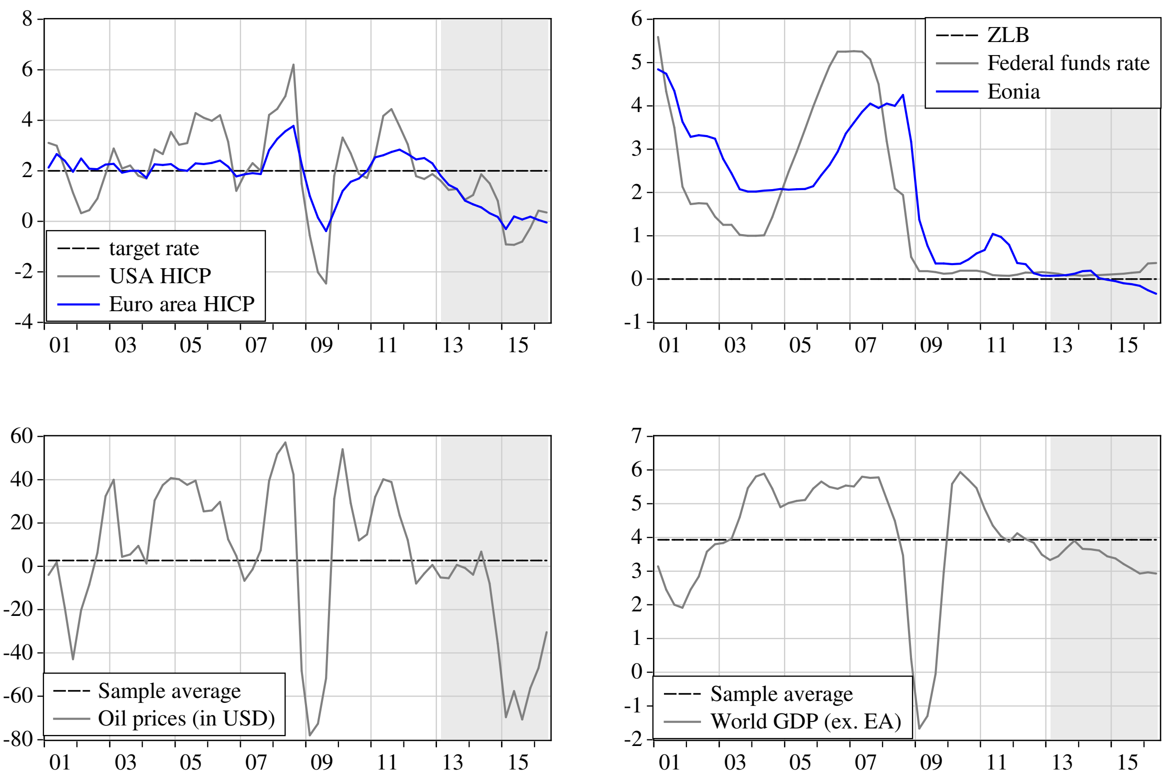
1 Introduction

After continuously falling from the beginning of 2013, the headline inflation rate in Croatia turned negative in 2015. During the same period domestic GDP growth had gradually been picking up and finally turned positive in 2015. These developments have, to a large extent, coincided with falling inflation rates in the euro area and most other advanced economies, a sharp decline in world oil prices, and a slowdown in global real activity growth (Figure 1). With nominal policy rates already hovering around the zero lower bound (ZLB), major central banks around the world continued to use unconventional monetary policy actions in order to foster GDP growth and bring inflation rates back to their official targets. For example, in the beginning of 2015, the European Central Bank (ECB) announced a new asset purchase programme that was planned to be carried out until at least September 2016, and in which ECB expanded purchases to include bonds issued by euro area central governments, agencies and European institutions.

Figure 1: Foreign macroeconomic developments from 2001Q1 to 2016Q2

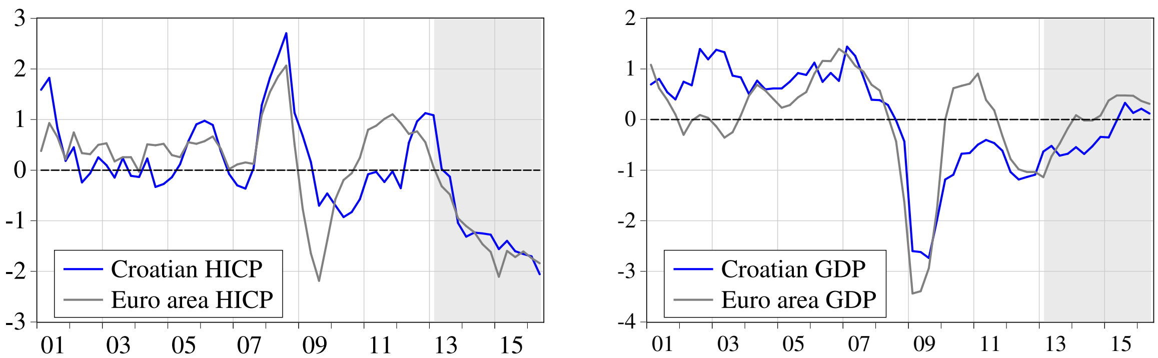


Notes: HICP, oil prices and World GDP are in annual growth rates and interest rates in levels.
Sources: FRED data base, Eurostat, ECB.

In this paper we study how these external developments affected the Croatian economy. From a theoretical point of view, foreign macroeconomic developments and monetary policy actions, especially those in the euro area, are expected to have a significant impact on the Croatian economy. This is mainly because Croatia is a small open economy, characterised by free capital flows and the Croatian National

Bank's (CNB) monetary policy framework is based on maintaining the stability of the nominal exchange rate of the kuna against the euro.[1] Figure 2 compares consumer price inflation (HICP) and GDP growth in Croatia and the euro area and points to a strong correlation between pertaining indicators, both historically and during the more recent period. In order to identify economic shocks generating these obvious strong co-movements between domestic, euro area and global variables we need to resort to *structural* analysis. Hence, we assess the relative importance of individual domestic, euro area-specific and global factors in shaping domestic macroeconomic developments using an estimated Bayesian structural VAR model. In order to take into account that Croatia is a small open economy we impose block exogeneity restrictions onto VAR parameters.

Figure 2: Inflation and real activity in Croatia and euro area



Notes: Standardized annual growth rates.
Sources: Eurostat, ECB, Croatian Bureau of Statistics (CBS).

Our work is related to Jankov *et al.* (2008), Krznar and Kunovac (2010), Jovančević *et al.* (2012) and Dumičić *et al.* (2013). These papers all use structural small open economy VARs in order to assess the relative importance of foreign and domestic shocks for the Croatian economy and strongly point to a common conclusion - foreign shocks are relevant drivers of the domestic economy. Our paper builds on this literature and offers several important contributions. First, we move away from a recursive identification of economic shocks and use a combination of zero and sign restriction on the impulse response functions in order to identify structural shocks (see Arias *et al.* 2014 for details). One of the main disadvantages of the recursive identification of VAR models is that it generally lacks theoretical foundations and, therefore, the estimated shocks do not have a clear structural interpretation. On the other hand, our identification scheme allows us not only to separate shocks into global, euro area specific and domestic ones, but also to identify a full set of individual structural shocks with clear interpretation. The identified shocks are labelled *oil supply, global real activity, euro area aggregate demand and supply, euro area monetary policy* and *domestic aggregate demand and supply shocks*. Second, we distinguish

[1]"The Croatian National Bank chose the stability of the exchange rate of the kuna against the euro as the nominal anchor of the monetary policy. By maintaining the stability of the exchange rate of the kuna against the euro, the CNB indirectly pursues its primary objective, price stability. Against the backdrop of the high euroisation of the Croatian banking system, exchange rate stability is a tool by which the CNB maintains financial stability as well, which, in turn, ensures the macroeconomic stability of the country and the preservation of the real value of funds in all economic sectors" (CNB web page - https://www.hnb.hr/en/core-functions/monetary-policy/monetary-policy-framework).

different underlying shocks driving the world oil prices (oil supply vs. global demand) when evaluating their impact on domestic variables. We find this important since both the intensity and the sign of correlation between world oil prices and domestic variables are likely to depend on the origin of structural shocks driving the oil price dynamics (Killian, 2009; Peersman and Van Robays, 2012). Third, we use Wu and Xia (2016) shadow interest rate as a measure of the ECB monetary policy stance in order to avoid modelling difficulties associated with the ZLB constraint. As a consequence, the identified monetary policy shocks include both conventional and unconventional policy actions. Finally, in contrast to the related literature we estimate our model using Bayesian techniques. Bayesian estimation reduces the problem of over-parameterization present in traditional VAR models, especially if the data set is short. Moreover, parameters of the model are more precisely estimated and inference is in general more transparent than in the traditional VAR analysis (exact posterior distributions of parameters and related functions of parameters like impulse responses are readily available).

Our results suggest that falling inflation rates observed since the beginning of 2013 were to a large extent driven by global factors - in particular negative real activity shocks. Although these unfavourable global demand conditions were also dragging down the domestic real activity throughout the analysed period, euro area specific and domestic developments led to a gradual recovery in the GDP growth rate. There are two interesting findings regarding the contributions of individual structural shocks worth pointing out. First, oil supply shocks played only a limited role in the aforementioned domestic macroeconomic developments. Namely, it appears that much of the large drop in world oil prices during the last two years can be attributed to lower global demand for oil, and less so to favourable supply conditions. Second, our results suggest that euro area monetary policy might not have been accommodative enough before 2015 and that the subsequent large-scale asset purchase programme brought the needed loosening of the ECB policy stance with favourable, but limited spillover effects on the domestic economy.

2 Model and identification with sign and zero restrictions

In this section we first present the model and we discuss the Bayesian estimation of a structural VAR with block exogeneity restrictions with shocks identified by imposing both sign and zero restrictions on the impulse response functions. After that we describe the data we use for estimation purposes and discuss the pattern of *sign and zero* restrictions employed to identify the structural shocks of our model. In the light of the recent sharp drop in oil prices and unconventional monetary policy measures implemented by central banks around the world, we next discuss in more details how we model the pass-through of oil prices on domestic real activity and inflation. After that we also look at how monetary policy shocks of the ECB may affect the domestic economy, taking into account both conventional and unconventional monetary policy measures.

2.1 Structural BVAR with block exogeneity

The model we use is a structural vector autoregression (SVAR) model:[2]

$$A_0 y_t = \mu + A_1 y_{t-1} + \ldots + A_k y_{t-k} + \varepsilon_t, \qquad t = 1, \ldots, T. \tag{1}$$

[2]The description of the methodology is taken from Comunale and Kunovac (2017).

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 an $n \times 1$ fixed vector and ε_t are economic shocks with zero mean and covariance matrix I_n. The reduced form VAR model obtained from (1) is

$$y_t = c + B_1 y_{t-1} + \ldots + B_k y_{t-k} + u_t, \qquad t = 1, \ldots, T, \tag{2}$$

where $B_j = A_0^{-1} A_j$, $c = A_0^{-1}\mu$ and $u_t = A_0^{-1}\varepsilon_t$ and thus $E(u_t u_t') = \Omega = (A_0' A_0)^{-1}$. The model (2) can be written in a compact form more convenient for Bayesian simulation of reduced form parameters:

$$y_t = X_t'\beta + u_t. \tag{3}$$

where

$$X_t' = I_n \otimes [1, y_{t-1}', \ldots, y_{t-k}'] \ (n \times (kn^2 + n)), \qquad \beta = vec([cB_1 \ldots B_k]') \ ((kn^2 + n) \times 1). \tag{4}$$

Block exogeneity is a common assumption when modelling the transmission of economic shocks between large and small economies 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. To illustrate that let y_{1t} be an n_1 dimensional vector of foreign variables and y_{2t} an $n_2 = n - n_1$ dimensional vector of domestic variables so y_t can be decomposed as $y_t' = [y_{1t}', y_{2t}']$. In order to account for block exogeneity matrices A_j from (1) need to be lower triangular:

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

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

$$B_j = \begin{bmatrix} B_{11}^j & 0 \\ B_{21}^j & B_{22}^j \end{bmatrix}, \qquad j = 1, \ldots, k. \tag{5}$$

In order to implement the block exogeneity assumption, both impact matrix A_0 and VAR coefficients need to be restricted. The impact matrix is restricted by placing zeros so that a small country cannot affect a big country at $t = 0$. In order to prevent the propagation of the domestic (small) economy through the foreign block beyond the impact ($h = 1, 2, \ldots$), some parameters of the VAR need to be restricted as well. Within the Bayesian framework this can be achieved by assuming the appropriate prior distribution for parameters to be restricted. The natural conjugate (i.e. normal inverse Wishart) prior is not suitable for this purpose since it assumes that the prior covariance of coefficients in any two equations are proportional to each other (see Koop and Korobilis, 2010). However, the Independent normal inverse Wishart serves the purpose. Under this prior, reduced form coefficients and error covariance matrix are independent:

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

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

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

where

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

and

$$\overline{\gamma} = T + \underline{\gamma}, \qquad \overline{M} = \underline{M} + \sum_{t=1}^{T} \left(y_t - X_t'\beta\right)\left(y_t - X_t'\beta\right)'.$$

To restrict the VAR parameters needed for block exogeneity we assume zero mean priors with extremely small variance for all the small country parameters in every equation of the big country block. In other words, if we want to restrict the j-th element of β we can set $\left(\underline{\beta}\right)_j = 0$ and $\left(\underline{V}_\beta\right)_{jj} = \varepsilon$ where ε is some small positive number. By doing so we attach the 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. The 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, 2010).

In this paper structural shocks are identified by imposing both sign and zero restrictions on the impulse response functions (IRFs). Sign restrictions alone are efficiently implemented by iterating the steps suggested in Rubio-Ramirez, Waggoner and Zha (2010). In a nutshell, for each posterior draw of reduced form parameters (regression parameters and covariance matrix) they first calculate a uniformly distributed orthogonal matrix Q. After that they multiply the Cholesky based impact matrix A_0 by orthogonal matrix Q and construct the resulting IRFs. If impulse responses satisfy the sign restrictions the posterior draw is accepted. Otherwise they repeat the procedure with a new posterior draw of reduced form parameters. If a model has both sign and zero restrictions imposed the algorithm outlined above cannot be applied in that case - the impulse responses based on QA_0 almost surely do not satisfy zero restrictions. To cope with that problem Arias, Rubio-Ramirez, and Waggoner (2014) propose an algorithm that produces an orthogonal Q such that QA_0 do satisfy the zero restrictions at various horizons of the IRF. Sign restrictions are checked in similar fashion as before. It is important to say that, beside the details of the algorithm, Arias, Rubio-Ramirez and Waggoner also provide a rigorous proof of validity of their algorithm from the Bayesian perspective. They show that their algorithm really draws from the posterior distribution of structural parameters conditional on the sign and zero restrictions which is a property that other identification strategies of the problem fail to provide.

Data Our preferred VAR model includes seven variables: oil prices (in US dollars), rest-of-the-world GDP (excluding euro area), euro area GDP and consumer price inflation, ECB shadow interest rate as calculated by Wu and Xia (2016), and domestic GDP and inflation. Data sources are listed in the Appendix. All variables except the interest rate enter the VAR in log differences and seasonally adjusted data were used where needed. The model is estimated for the sample period 2001Q1 - 2016Q2 with two lags. As already mentioned, we impose block exogeneity restrictions for domestic variables and we identify the structural model by using a combination of sign and zero restrictions on the impulse response functions. All restrictions on the impulse response functions are placed at impact period only.

2.2 Identification

We divide the structural shocks into three blocks: the global, the euro area, and the domestic block. Domestic block is separated from foreign blocks by assuming that domestic shocks do not influence foreign variables contemporaneously (in addition to block exogeneity restrictions placed on the parameters of a reduced form model). In order to separate global and euro area specific shocks we rely on timing (zero) restrictions - euro area specific shocks can affect oil prices and rest of the world GDP only with a delay of one period. In contrast, global shocks are allowed to influence all variables in the model immediately. We identify two global shocks labelled (negative) *oil supply* and (positive) *real activity* shocks.[3] The oil supply shock is the one that generates a negative co-movement between oil prices and real activity both in the euro area and the rest of the world. In addition, we assume that the oil supply shock raises consumer prices in the euro area. In contrast, the global real activity shock implies a positive correlation between oil prices and real activity in the euro area and the rest of the world. When it comes to the euro area block we identify three shocks: the (positive) *aggregate supply*, the (positive) *aggregate demand* and the (contractionary) *monetary policy shock*. Supply and demand shocks are identified by using a conventional approach. A positive supply shock raises real GDP and lowers inflation, while a positive demand shock raises both real GDP, inflation, and interest rate in the euro area (through the ECBs reaction function). The ECB's monetary policy shock is defined as the one that raises the shadow interest rate and lowers euro area GDP and inflation. Finally, within the domestic block we identify the domestic (positive) *aggregate supply* and (positive) *aggregate demand* shock in the same way as in the euro area. Responses of domestic inflation and GDP growth to foreign shocks are left unrestricted - after identifying foreign shocks from their impact onto foreign variables we only study how they propagate through the domestic economy without imposing any restrictions on domestic variables following these shocks. We summarise our identification scheme in Table 1.

[3] In contrast to other identified supply shocks, oil supply is normalised to represent *negative* supply. In this way, both oil supply and world real activity shocks are normalised to *increase* oil prices which may make the analysis of the pass-through of oil prices easier to follow.

Table 1.: Identification restrictions

shock/variable	P_{oil}	GDP_{ROW}	GDP_{EA}	$HICP_{EA}$	INT_{EA}	GDP_{HR}	$HICP_{HR}$
Global shocks							
Oil supply	+	-	-	+	?	?	?
Activity (RoW)	+	+	+	?	?	?	?
Euro area shocks							
Demand	0	0	+	+	+	?	?
Supply	0	0	+	-	?	?	?
Monetary policy	0	0	-	-	+	?	?
Domestic shocks							
Demand	0	0	0	0	0	+	+
Supply	0	0	0	0	0	+	-

Notes: (+) = positive sign, (-) = negative sign, and (?) = unrestricted.

The set of imposed restrictions we use to identify structural shocks is rather uncontroversial; it is largely based on the mainstream New Keynesian macroeconomic theory (see for example Forbes *et al.*, 2015 and Bobeica and Jarocinski, 2017). We also take into account small open economy properties of Croatia - the domestic economy can be affected by foreign shocks but not the other way around. There is, however, one important caveat to our imposed pattern of sign and zero restrictions. One could imagine euro area specific shocks having contemporaneous effect on global variables. If this is indeed the case then our identification scheme would label part of the euro area shocks as global ones. Nevertheless, it seems reasonable to assume that most of the identified global shocks would indeed be global. Other possible identifications schemes suffer from the same problem (see Bobeica and Jarocinski, 2017).

In the light of the recent sharp drop in oil prices and unconventional monetary policy measures implemented by central banks worldwide, we next discuss in more details how we model the pass-through of oil prices on domestic real activity and inflation. After that we also look at how monetary policy shocks of the ECB may affect the domestic economy.

Oil prices and macro economy - supply vs demand shocks Since mid-2014, the price of crude oil in the world market fell by almost USD 80 per barrel. In isolation, this drop in oil prices should have dampened consumer prices and boosted real activity in oil importing countries. For example, lower oil prices feed directly into the CPI through lower prices of petrol and other oil-intensive items. In addition, a decrease in oil prices leads to lower costs of production and higher profit margins, allowing firms to cut prices. Consequently, a fall in oil prices should lead to higher real aggregate income, and hence domestic demand (the main channel works through personal consumption). In addition, it may also boost potential supply by raising productivity growth. In general, in an oil-importing country a positive oil supply shock normally results in lower inflation and increase in real activity.

However, when trying to evaluate the effects of oil price changes on inflation and real activity one should take into account that changes in oil prices are driven by both demand and supply shocks (Killian, 2009; Peersman and Van Robays, 2012). While the fall in world oil prices caused by the supply shock (e.g. by the introduction of new production techniques like *fracking* or strategic OPEC decisions about oil production) should work in a way described above, the same will probably not hold true in case when the decrease in oil prices is mainly driven by weaker global aggregate demand. A negative shock to global real activity results in a fall both in demand for oil and in demand for other goods and services in the world market. This leads to a more pronounced fall in consumer prices compared to the one following an oil supply shock. However, in contrast to the case in which oil prices are driven by supply shocks, now oil prices and real activity may be *positively* correlated - they both decrease following an adverse global demand shock. Although a demand driven decrease in oil prices may have beneficial effects on an oil importing economy as real income rises, these effects may not be sufficient to compensate for adverse effects of weaker global demand (ECB 2016). In short, both the intensity and the sign of correlation between world oil prices and domestic macro-variables may crucially depend on the origin of structural shocks driving the oil price dynamics.

The discussion above implies that it is necessary to distinguish between oil supply and oil demand shocks when evaluating the effects of oil prices on domestic economy. Consequently, the question of how oil prices affect domestic inflation and real activity is *ex ante* ill-posed. Failing to account for different sources of oil price changes (supply vs demand) is likely to result in an incomplete assessment of the relation between world oil prices and domestic economic developments. Moreover, it may also result in unwarranted monetary policy actions since the optimal policy response should vary depending on the source of the oil price shock (Bodenstein, 2012).

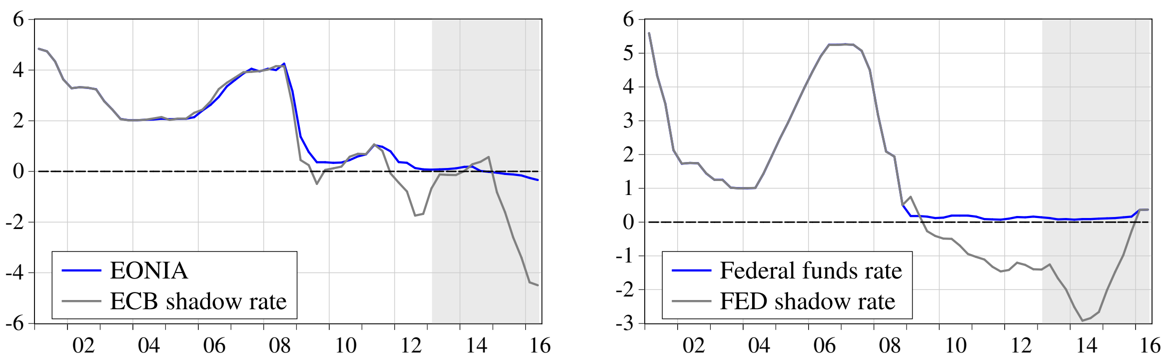
Monetary policy shocks in the euro area under the ZLB Many central banks in the world, including the ECB, use some form of an interest rate rule (reaction function) in order to dampen cyclical fluctuations in inflation and real activity. Central banks achieve these objectives by appropriately adjusting their policy rates in response to developments in the economy. Conventional monetary policy therefore relies on raising policy interest rates in booms and lowering them in economic busts. Following the Great Recession, major central banks around the world brought their policy rates down, close to zero and thus conventional policy became ineffective. Constrained by the zero lower bound, the central banks started using unconventional policy measures in order to boost economic activity and anchor long-term inflation expectations. From a modelling perspective, policy rate being at the ZLB poses a problem if one needs to identify a monetary policy shock. In this case it is not clear how to represent monetary policy actions - they are no longer reflected by policy rate dynamics.

As pointed out by Francis et al. (2014), with the ZLB binding for an extended period of time empirical monetary models cannot be estimated, nor can monetary policy shocks be identified using conventional approach described earlier. There are two main remedies for this problem. First, one can split the sample into periods before and after the ZLB became binding and include additional variables to identify (unconventional) monetary policy shocks. Second, one can use a proxy for the conventional monetary policy stance that is allowed to violate the ZLB constraint, and thus capture both conventional and unconventional policy shocks using a single indicator. Here we follow the latter approach since the first one involves estimating a larger set of parameters on a very short sample.

As a proxy for the monetary policy stance of the ECB we use Wu and Xia (2016) shadow interest rate.

Their approach uses information from the term structure of interest rates in an unobserved components model to design the measure of the shadow interest rate. In the periods when the ZLB is not binding, the estimated shadow rate is almost identical to the EONIA rate, but it turns negative in several periods when the observed interest rate is very close to zero. Using the shadow interest rate as a measure of the ECB monetary policy stance allows us to use the entire available sample for estimation and to preserve the linearity of our VAR model. Figure 3 compares the shadow rates of the ECB and FED with EONIA and Federal funds rate.

Figure 3: ECB nad FED shadow interest rates



Sources: FRED data base, ECB, Cynthia Wu web page (https://sites.google.com/site/jingcynthiawu/).

3 Results

In this section we present and discuss the results of our structural VAR - impulse responses to the identified shocks and their contribution to the forecast error variance and historical evolution of inflation and real GDP growth. The results are based on 10000 MCMC draws from the posterior distribution of structural parameters of the estimated BVAR.[4]

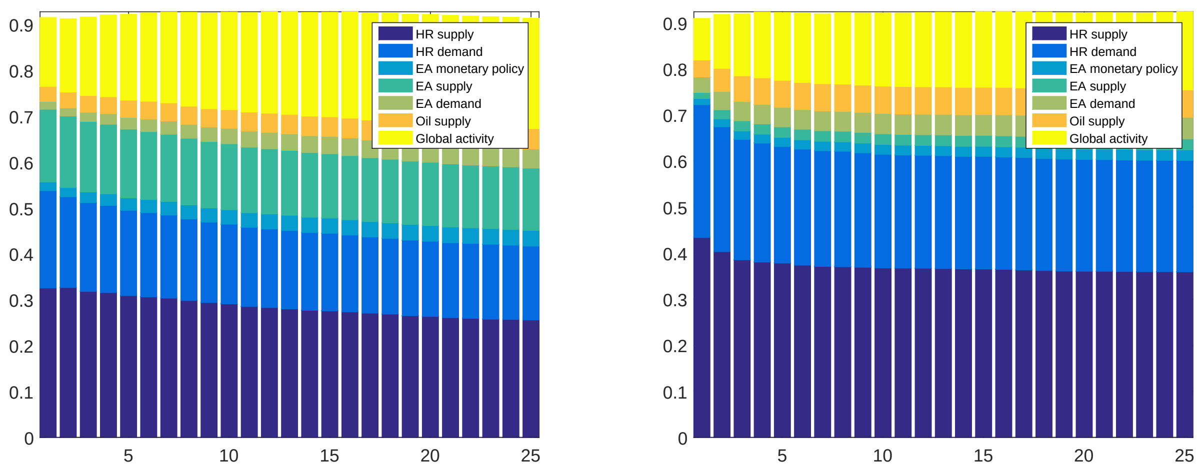
3.1 Impulse responses and variance decomposition

In the first step we calculate the accumulated pointwise median impulse responses (together with 68% error bands) of domestic inflation and GDP to identified domestic and foreign shocks (see Appendix). Results suggest that both variables, in general, react to identified global and euro area specific shocks with the expected signs. The domestic inflation increases following a negative oil supply shock while, at the same time, real activity decreases. This is an expected result for an oil importing country. Similarly, shocks to global real activity raise both prices and GDP, which is consistent with the notion that real activity is mostly driven by demand shocks. On the other hand, our methodology was not able to identify a significant reaction of domestic inflation to a contractionary ECB monetary policy shock.

[4]Identification based on sign and zero restrictions is implemented using a MATLAB Toolbox by Kunovac and Kotarac (2015). The Toolbox and the code used in this paper are available upon request.

While impulse response analysis is useful for studying the transmission of identified structural shocks, it is not really informative regarding their relative economic significance. In that context, (forecast error) variance decomposition may be of more help to assess the relative importance of various shocks for domestic inflation and real activity.[5] Figure 4 shows the variance decomposition of inflation and GDP growth for a horizon up to 24 quarters.

Figure 4: Variance decomposition of domestic inflation and GDP growth



(a) HICP

(b) GDP

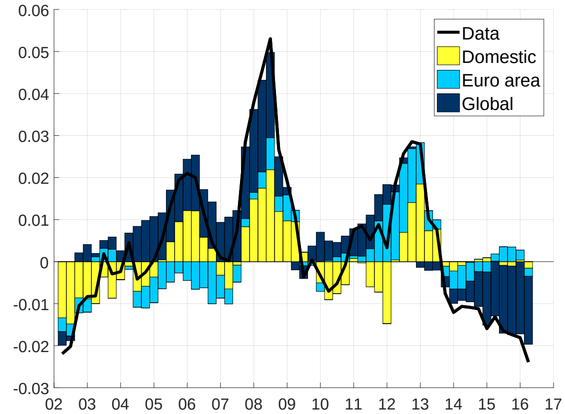
The variance decomposition exercise suggests that foreign (global and euro area specific) shocks have had a large impact on the variability of domestic variables. Over a three year horizon foreign shocks account for around 40% of variation in GDP growth and around 50% variation in inflation. This is in line with the results from previous studies like Krznar and Kunovac (2011) and Globan *et al.* (2015). For example, Krznar and Kunovac found that external shocks explain above 50% of variation in GDP growth and around 40% variation in inflation. When it comes to specific shocks, global shocks, in particular global real activity shocks, appear to be very important for the dynamics of domestic variables. It is also interesting to note that our model suggests that domestic supply shocks explain relatively more variation in inflation and real activity growth than domestic demand shocks.

3.2 Drivers of domestic inflation and real activity

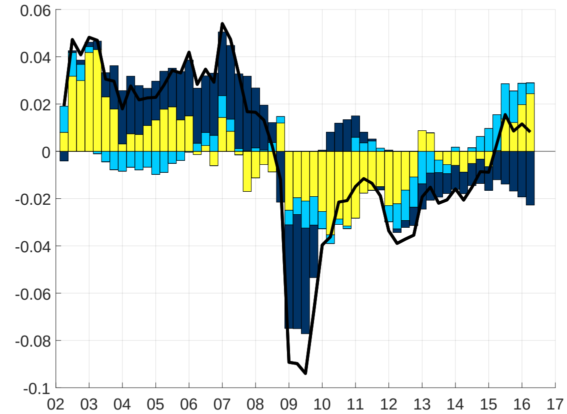
Compared to the variance decomposition exercise described above, historical decomposition offers a suitable methodological framework for the analysis of specific economic episodes because it enables the identification of those shocks which predominantly characterize a particular period. In terms of methodology, a historical decomposition breaks down a time series into two components. The first component represents a baseline projection, i.e. a scenario which assumes there were no shocks during the whole period, while the other component consists of the identified structural shocks that have occurred in the past. In other words, historical decomposition enables us to decompose domestic GDP

[5]The variance decomposition shown in the graph is calculated as an average of variance decompositions calculated for each draw from the posterior distribution.

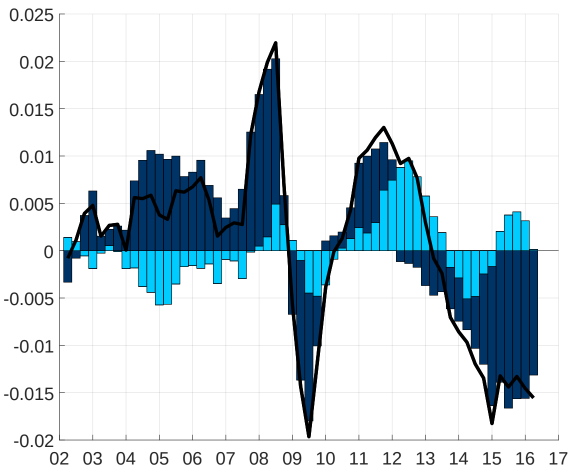
Figure 5: Historical decomposition of inflation and GDP growth



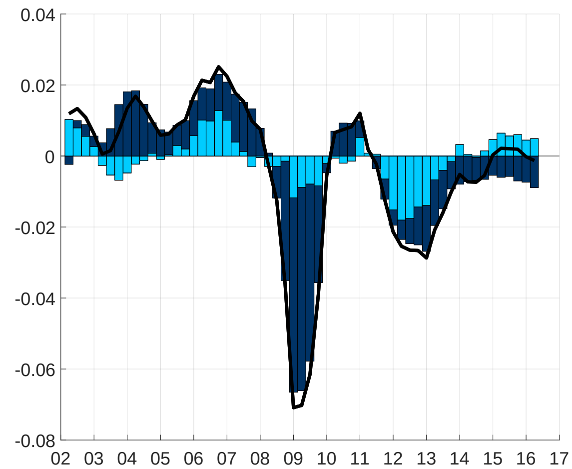
(a) Domestic HICP y-o-y growth



(b) Domestic GDP y-o-y growth



(c) EA HICP y-o-y growth



(d) EA GDP y-o-y growth

and inflation in each quarter into contributions of the identified structural shocks. Figure 5 reports the historical decomposition of year on year growth rates of domestic variables into domestic, euro area specific and global shocks. The black line is the difference between the unconditional forecast from the VAR (baseline projection) and the actual series.

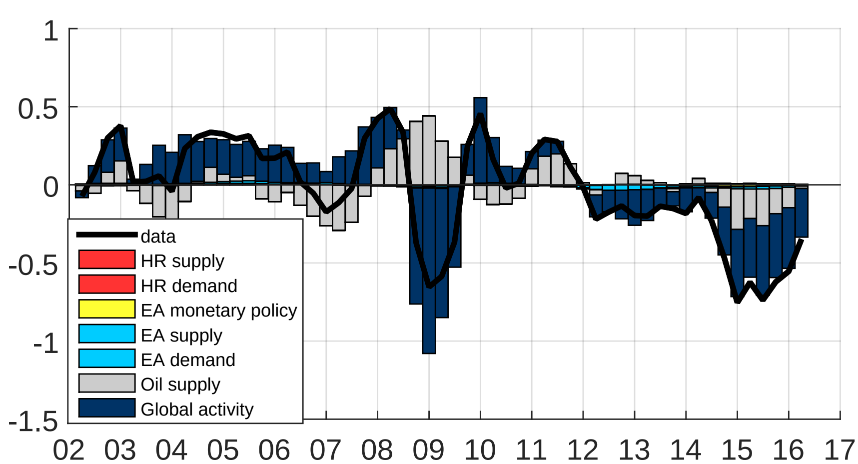
Focusing on the recent period, it appears that muted inflation dynamics since mid - 2013 have been driven mostly by global factors (real activity and oil supply shocks). Although unfavourable global demand conditions were also dragging down the domestic real activity throughout the analyzed period, euro area specific and domestic developments led to a gradual recovery of the domestic GDP growth rate. It is interesting to note that our results suggests that global factors were also largely responsible for the low inflation environment in the euro area and that adverse global activity shocks were dragging euro area GDP growth down. This is, at least partially, in contrast with the results presented by Bobeica and Jarocinsky (2016), who emphasize the role of domestic factors in explaining the low inflation environment in the euro zone.

As we have discussed previously, within the monetary policy framework that rests on the stability of the kuna/euro exchange rate, the domestic economy will experience adverse consequences of negative real activity developments in the euro area. Moreover, the policy of keeping the kuna/euro exchange rate relatively stable essentially anchors domestic inflation and inflation expectations to those in the euro area. Consequently, deflationary pressures in the euro area are expected to be transmitted to domestic inflation developments.

3.3 The role of oil supply shocks and ECB monetary policy

Falling inflation and the gradual recovery of domestic real activity growth coincided with an unfavourable foreign environment characterized by a sharp decline in world oil prices and effective ZLB constraint on the ECB policy rate. Faced with falling inflation rates and still fragile GDP growth developments in the euro area, the ECB launched an extensive new asset purchase programme at the beginning of 2015. With this programme, the ECB expanded asset purchases to include bonds issued by euro area central governments, agencies and European institutions. Since falling oil prices and unconventional policy measures taken by the the ECB have received a lot of attention, it is interesting to look at the role of oil prices and ECB monetary policy shocks in shaping the dynamics of both domestic and euro area variables. As we have discussed previously, our identification strategy is able to distinguish between oil supply and oil demand shocks which is important for evaluating the effects of oil prices on the economy. At the same time, by using the shadow interest rate we are able to account for unconventional monetary policy shocks.

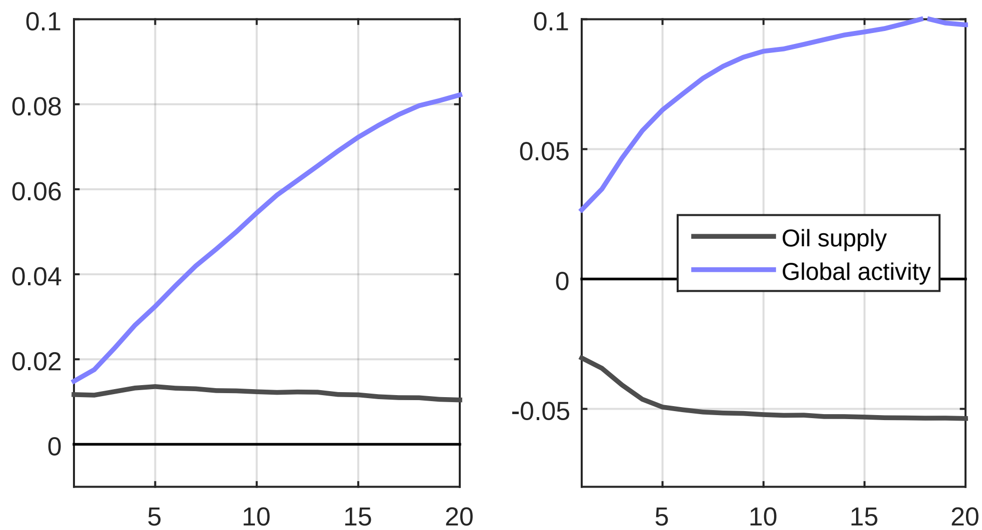
Figure 6: Oil prices: historical decomposition (annual growth rates)



Regarding the impact of oil prices on the economy we have argued that it is important to identify the specific mix of oil supply and demand shocks governing the movement in oil prices. Overall, our identification scheme suggests that both oil supply shocks and demand shocks have played important roles in shaping the dynamics of world oil prices during the last two years. However, it appears that the sharp decline in oil prices can be attributed somewhat more to the lower global demand for oil than to favourable supply conditions (Figure 6).

Hence, instead of identifying an exogenous movement in oil prices, we study how correlation between oil prices and domestic variables changes conditional on different structural shocks triggering the movement in oil prices. Figure 7 reports the median of accumulated impulse response functions of inflation and GDP divided by the response of world oil prices conditional on the oil supply and global real activity shocks. These *impulse response ratios* can be interpreted as *pass-through* coefficients of a permanent 1% increase in oil prices (see Forbes, 2015). Our results illustrate how both the intensity and the sign of correlation between oil prices and domestic variables depends on the underlying shock governing the movement in oil prices (supply vs. demand).

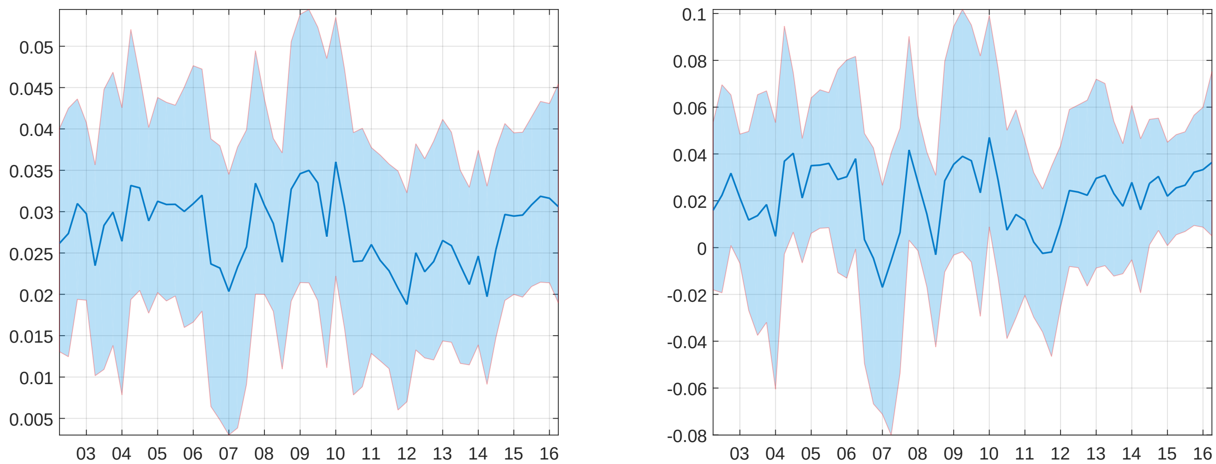
Figure 7: Ratios of impulse responses conditional on the underlying shock



In other words, the pass-through of nominal oil prices on the domestic economy is naturally time-varying. In order to effectively estimate the time-varying pass-through coefficient of oil prices on the domestic economy we follow Comunale and Kunovac (2017). By weighting the estimated shock dependent ratios (Figure 7) by the relative importance of supply and demand shocks in the historical decomposition of oil prices (Figure 6) we construct the time-varying pass-through indicator (Figure 8).

The estimated time-varying coefficients for inflation are always positive reflecting the fact that pass-through ratios conditional on both shocks are positive as well. On the other hand, the correlation between oil prices and domestic real GDP growth is less clear - the sign is changing throughout the sample under analysis, but mainly stays on the positive side. This finding may somewhat be in contrast to the conventional idea that decreasing oil prices are accompanied with increasing real activity. As already mentioned, the beneficial effects of low oil prices need not be sufficient to compensate for adverse effects of weaker global demand when demand shocks dominate among oil price drivers. As a consequence of the composition of shocks and estimated pass-through coefficients, it turns out that the impact of oil supply shocks on the domestic and the euro area economy during the last two years was rather limited (Figure 9).

Figure 8: Time-varying pass-through of oil prices to domestic inflation and real activity using pass-through ratios after 4 quarters (median with 68% error bands)



(a) Domestic HICP y-o-y growth

(b) Domestic GDP y-o-y growth

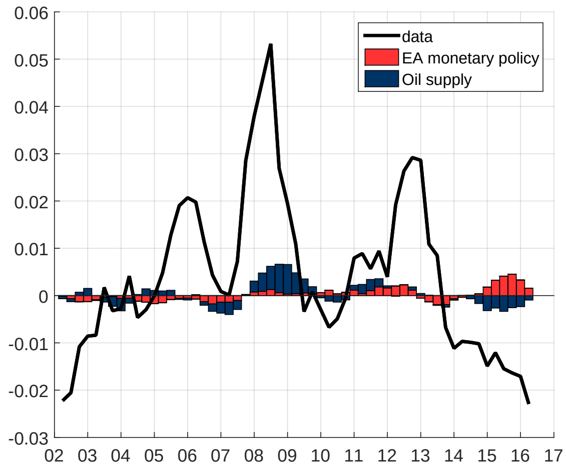
When it comes to ECB monetary policy the same figure also suggests that it may not have been accommodative enough prior to 2015. During the period from 2013 to 2014 monetary policy shocks had a negative contribution to both GDP and inflation dynamics. The subsequent large-scale asset purchase programme launched by the ECB brought the much needed loosening of the policy stance with a favourable impact on the EA economy. At the same time spillovers on domestic variables were limited, especially on inflation [6] (Figure 9).

3.4 Robustness checks

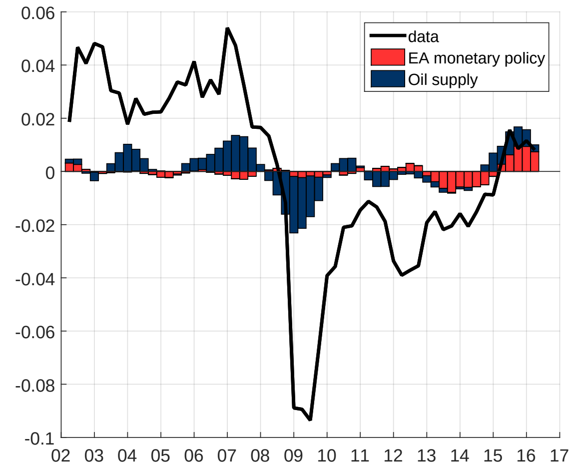
We estimated several alternative specifications in order to test the robustness of our results. First, we have extended our baseline VAR by including the kuna/euro and euro/dollar exchange rates. It appears that exogenous exchange rate shocks are not particularly important for domestic inflation and real activity once we have other structural shock identified in our model. For that reason the results in that case are very similar to those from the baseline specification. We have also tested the specification in which we have included the production of crude oil and identified the oil demand and oil supply shocks as in Peersman and Van Robays (2009). In this way we are able to distinguish between global demand and oil-specific demand shocks. Again, since latter shocks do not appear to be important drivers of oil prices, the results do not change much. Finally, increasing the number of lags does not change the results significantly.

[6] This of course comes from the fact that the response of domestic inflation. to the ECB policy shock is muted.

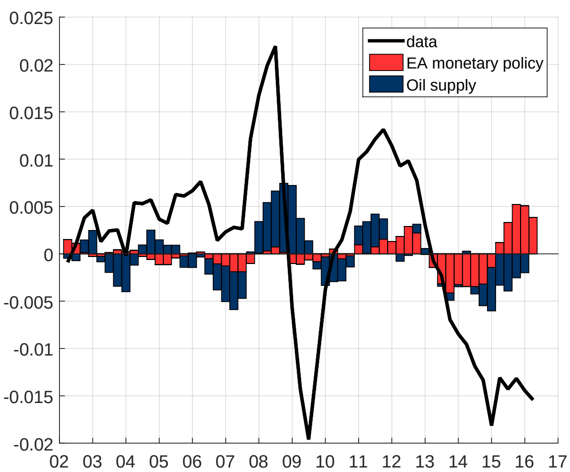
Figure 9: Contributions of oil supply and EA monetary policy shocks



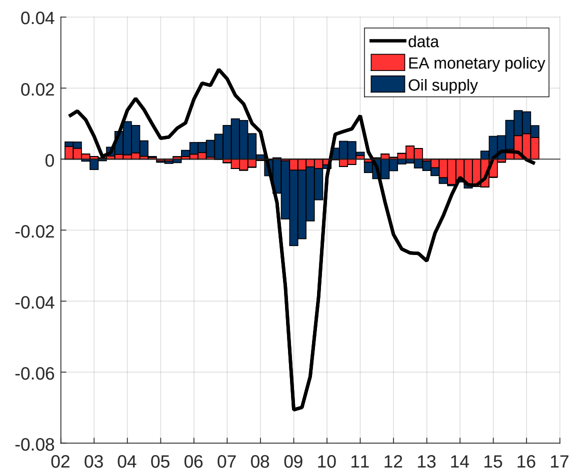
(a) Domestic HICP y-o-y growth



(b) Domestic GDP y-o-y growth



(c) EA HICP y-o-y growth



(d) EA GDP y-o-y growth

4 Conclusion

In this paper we have used a Bayesian VAR model identified with sign and zero restrictions in order to disentangle the impact of various domestic and foreign economic shocks on domestic inflation and real activity. We find that falling inflation rates observed since the beginning 2013 were to a large extent driven by global factors - in particular negative real activity shocks. Although these unfavourable global demand condition were also dragging down real activity, positive euro area specific and domestic conditions led to gradual recovery of the domestic GDP growth. Looking at the contributions of individual structural shocks we find that world oil-supply and ECB monetary policy shocks, which have received a lot of attention among economists and the media, had a relatively modest contribution to domestic macroeconomic developments during the same period. Although our empirical approach is fairly standard, presented results should be interpreted cautiously. Namely, our analysis was performed on a relatively small sample and under the assumption of fixed parameters of the model and therefore it may not be advisable to extrapolate automatically the reported results outside the sample we use for estimation. Moreover, in a structural VAR analysis the identifying assumptions and the assumption of linearity can always be questioned.

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5 Appendix

Table 1: Data description and sources

Variable	Block	Description	Source
HICP_HR	domestic	HICP, all items, index 2010=100	Eurostat
GDP_HR	domestic	GDP, chain linked volumes, index 2010=100	Eurostat
INT_EA	euro area	Wu and Xia shadow interest rate	Cynthia Wu web page
HICP_EA	euro area	HICP, all items, index 2010=100	ECB data warehouse
GDP_EA	euro area	GDP, chain linked volumes, index 2010=100	Eurostat
GDP_ROW	global	World GDP excluding EA, index 2010=100	ECB
POIL	global	BRENT Europe, US dollars	FRED

Figure 10: Impulse responses of domestic inflation and GDP to identified shocks

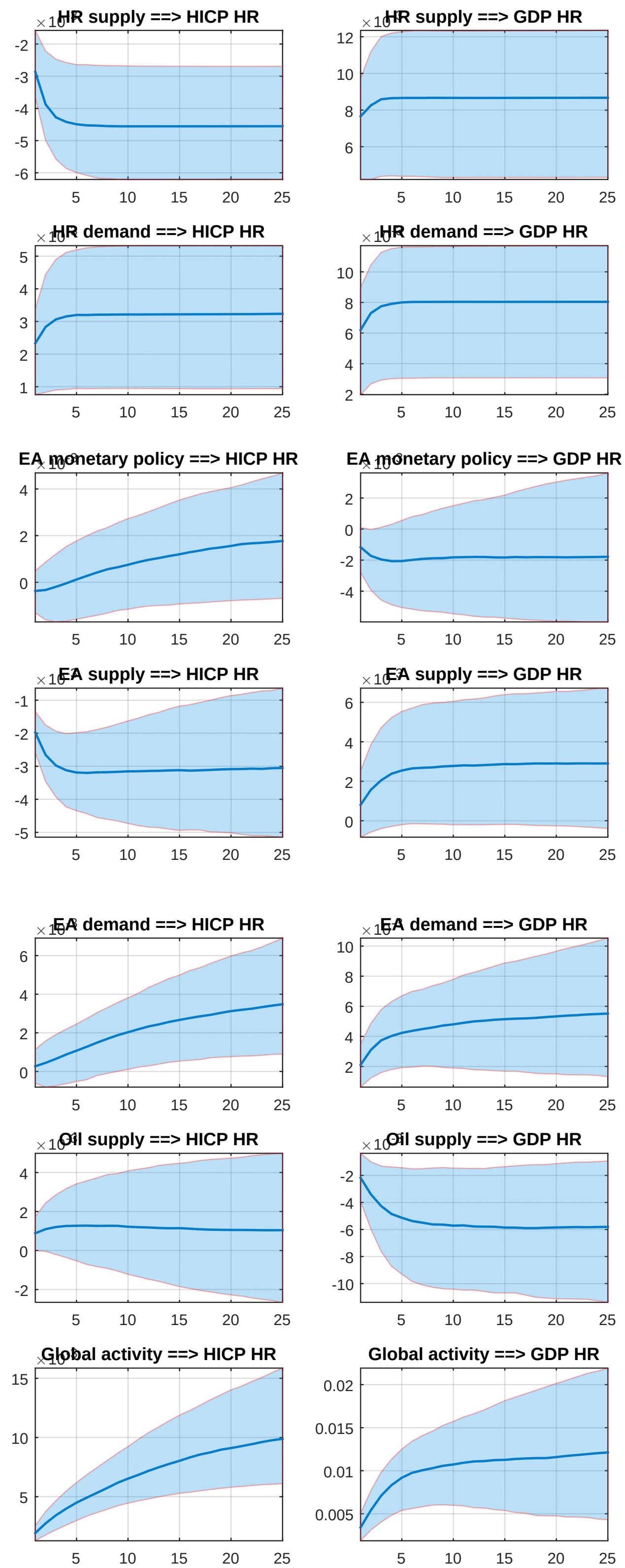
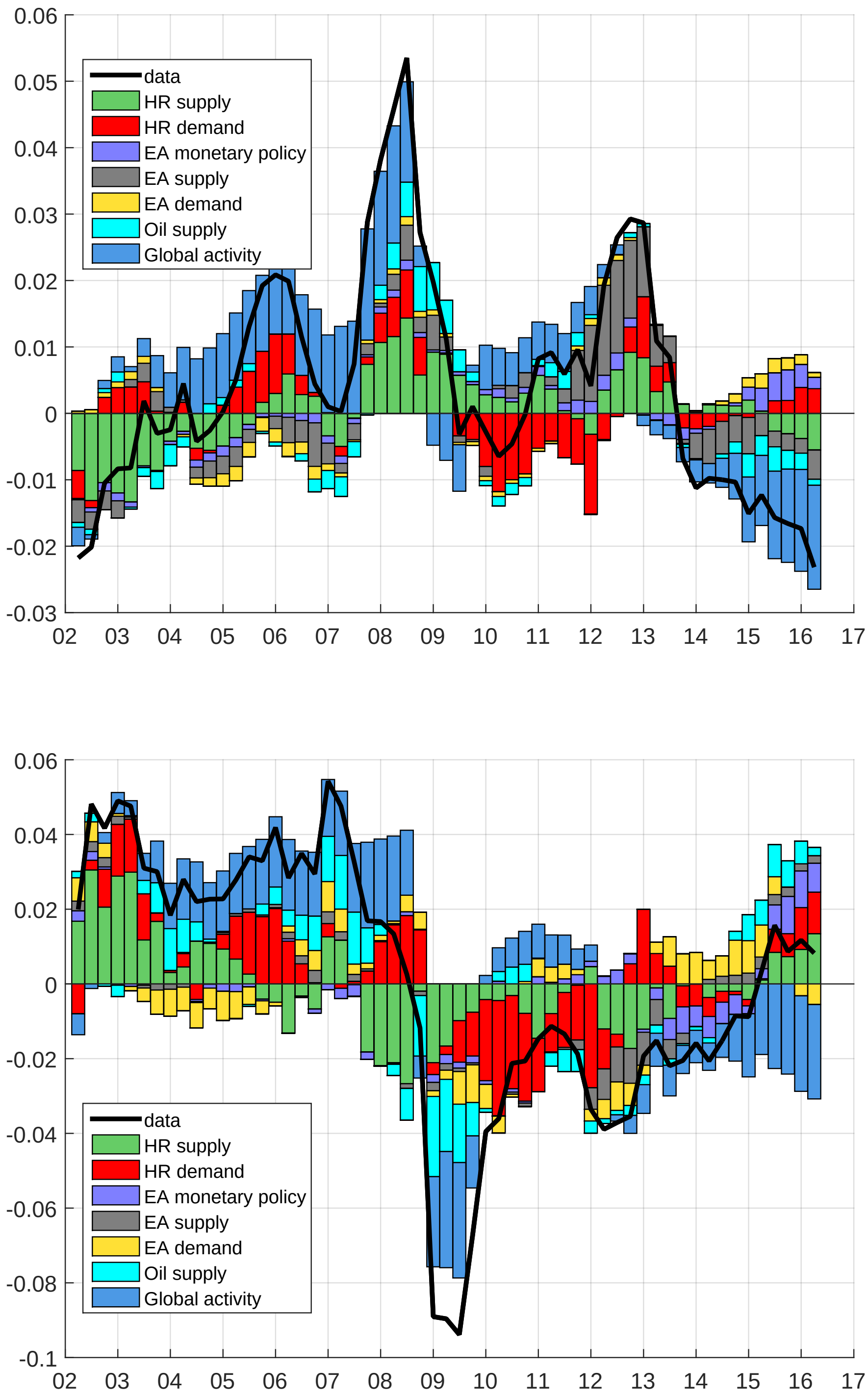


Figure 11: Historical decomposition of domestic inflation (upper figure) and GDP (lower figure)



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