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Abstract

The paper analyses the coherence of business cycles and supply and demand shocks between Croatia and euro area core countries. The results obtained point to several basic conclusions. Firstly, the coherence of business cycles and the correlation of supply and demand shocks between Croatia and euro area core countries are relatively high. Secondly, symmetric (common) shocks are dominant for explaining the dynamics in domestic GDP, while the contributions of asymmetric shocks are significantly smaller. Thirdly, the results point to the convergence of supply and demand shocks and business cycles between Croatia and euro area core countries. Based on all of the above, we may conclude that the introduction of the euro and the related adoption of the common countercyclical monetary policy should not result in significant costs for the Croatian economy.

Keywords:
cycle coherence, aggregate supply and demand shocks, symmetric and asymmetric shocks

JEL:
F33, F44, E42, C32

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The views expressed in the paper do not necessarily reflect the views of the Croatian National Bank.

Contents

1 Introduction

The formation of the Economic and Monetary Union (EMU) in the 1990s sparked renewed interest among economists in the *optimum currency area theory* developed by Mundell (1961), McKinnon (1963) and Kenen (1969). By joining the European Union, Croatia committed to adopt the euro as the official currency, bringing the optimum currency area theory into the recent focus of the domestic economic and political public sphere. In a nutshell, the OCA theory provides a detailed elaboration of the idea that, if a country's costs of adjustment to macroeconomic shocks through the adjustment of wages, prices and labour and capital mobility are lower than the costs of adjustment through the exchange rate channel, there is probably no need for the country to have its own currency.

The costs of joining the monetary union for new member states are primarily reflected in the adoption of a common countercyclical monetary policy. The basic OCA theory postulates that these costs are negligible if the business cycles of countries within the monetary union are coherent – in that case, the countercyclical effects of the common monetary policy will be well-suited for all member states (the "one-size-fits-all" monetary policy). For example, by joining the monetary union, Croatia would knowingly abandon the possibility of reacting to asymmetric shocks by using standard monetary policy and exchange rate measures. On the other hand, common monetary policy reacts only to shocks relevant for the entire union. Hence, the level of coherence between the Croatian business cycle (and shocks) and euro area business cycles (and shocks) is directly linked to the potential costs of Croatia's participation in the monetary union. In case of a high level of synchronicity between the business cycles of Croatia and the euro area, the countercyclical monetary policy of the European Central Bank (ECB) would successfully smooth out the Croatian business cycle. In that case, the loss of an independent monetary policy would not cause any significant costs for the domestic economy.

The OCA theory also analyses the justification of maintaining a country's own currency from the aspect of the influence of shocks on the economic activity of potential monetary union member states. The theory posits that a country benefits from maintaining its own currency if its GDP is under the dominant influence of *asymmetric shocks*. In other words, if economic shocks have a different effect on the analysed domestic economy than on the economies of monetary union member states, an adjustment of the bilateral exchange rate is needed in order to absorb the shocks. For instance, if the Croatian GDP is under the dominant influence of shocks that affect the domestic GDP in the opposite direction than the euro area GDP, the exchange rate of the kuna against the euro needs to be adjusted in order for the domestic economy to absorb such shocks adequately. If, on the other hand, the domestic economy's GDP is under the dominant influence of *symmetric shocks*, i.e. if economic shocks affect the domestic economy and the monetary union economy in a similar way, the necessary adjustment of the exchange rate due to economic shocks would be equal for all countries. In other words, in that case, the adjustment through the exchange rate channel would operate only through the adjustment of the exchange rate against the currencies of third countries that are not members of the monetary union. Therefore, in that case, a country's own currency would not be a comparative advantage in terms of shock absorption and the cost related to the loss of its own currency would thus be negligible.

The main objective of the paper is to provide a detailed analysis of the extent to which supply and demand shocks and business cycles in Croatia are synchronised with those in the euro area. Moreover, in order to analyse the costs associated with the adoption of the common European currency in more detail, we explore the extent to which the Croatian GDP is under the influence of *symmetric* (common) and *asymmetric* shocks. Therefore, it is *not* the purpose of this paper to analyse all costs and benefits associated with the adoption of the euro as the official currency,[1] but rather to focus on potential costs related to the adoption of the common countercyclical monetary policy.

The analysis was performed in two steps. In the first step, we examine the degree of coherence between the *business cycles* of Croatia and euro area core countries. In order to put the results obtained for Croatia in a wider context, the coherence between Croatia's and core euro area countries' business cycles is compared with the corresponding results for other EU peripheral member states. Besides correlations, the analysis of cycle coherence is based on two additional measures: *phase synchronicity* and *cycle similarity*, where phase synchronicity measures the synchronicity of cycle signs, while similarity measures the synchronicity of cycle amplitudes (see Mink et al., 2012). A significant finding of that part of the analysis shows that the degree of coherence between the business cycles of Croatia and euro area core countries is relatively high and generally higher than that of other peripheral EU countries.

The second step analyses the extent to which the *shocks in aggregate supply and demand* generating the Croatian business cycle are similar to those in euro area core countries. As in the preceding step, the results for Croatia are compared with those of peripheral EU countries. In line with the relevant literature, we identify the aforementioned shocks for each country on the basis of simple bivariate VAR model shocks (Bayoumi and Eichengreen, 1992, 1993 and 1994). The synchronicity of the obtained supply and demand shocks of Croatia and euro area core countries is then analysed using correlation coefficients. Having identified shocks using a simplified bivariate VAR model, we move away from this standard model and construct a more complex VAR model, which we use to identify six shocks. This enables us to analyse in more detail the mechanisms that generate the domestic and the foreign cycle and thus directly answer the key question regarding the benefits of abandoning an independent monetary policy in the context of joining the monetary union – to what extent is the Croatian GDP under the influence of symmetric and asymmetric shocks? The contribution of all symmetric shocks calculated from the historical GDP decomposition was used as the measure of relative significance of symmetric shocks for the domestic economy. The results suggest the following main conclusions. First, the coherence of demand shocks between Croatia and euro area countries is relatively high and somewhat higher than in other peripheral EU countries. On the other hand, the correlation of supply shocks in Croatia and the euro area core countries is slightly lower. Second, symmetric supply and demand shocks are exceptionally important for Croatia's GDP, while the contributions of asymmetric shocks are significantly smaller. Third, the significance of symmetric shocks for Croatia's GDP has grown in the period following 2006. In that regard, it is important to note that the OCA endogeneity theory (Frankel and Rose, 1998) postulates that the aforementioned shock and cycle synchronisation process could gain additional momentum if the monetary union were joined. Based on all of the above, we may conclude that the introduction of the euro would not imply significant costs for the Croatian economy from the aspect of countercyclical monetary policy.

The coherence of cycles and supply and demand shocks between Croatia and the euro area has already been the subject of earlier research. The authors of the first relevant research papers, which explored the synchronicity of the unemployment cycles of Croatia and other countries of Southeast Europe with the

1 In addition to the costs associated with the loss of autonomous countercyclical monetary policy, there are other potential costs related to the adoption of the euro, such as the accumulation of macroeconomic imbalances due to excessive capital inflow, price increase due to currency conversion, one-off conversion costs and one-off costs arising from the CNB's participation in the Eurosystem as well as the costs of participation in the provision of financial assistance to other member states. As for the benefits of the adoption of the euro as the official currency, we may emphasize the elimination of the currency risk from the economy, reduction of the borrowing costs of domestic sectors and the reduction of the risk of a banking and currency crisis. Furthermore, euro adoption leads to lower transaction costs and may stimulate foreign trade. Finally, by becoming a member of the monetary union, Croatia gains access to euro area financial assistance mechanisms, and the CNB participates in the allocation of Eurosystem monetary income.

unemployment cycle of Germany, are Šonje and Vrbanc (2000) and Belullo, Šonje and Vrbanc (2000). The authors found a strong connection between the Croatian and the German cycle in the period from 1992 to 1999. Furthermore, Arčabić (2011) calculated simple coefficients of the correlation between Croatia's and selected EMU countries' cyclical GDP component. The results suggest that cycle coherence after 2002 was relatively high and that the Croatian cycle does not lag behind the EMU countries' cycle. Similar results were obtained in Obradović and Mihajlović (2013) and Hildebrandt and Moder (2015) as well. The authors of the first paper analysing the correlation between the aggregate supply and demand shocks in Croatia and the EMU countries using the standard identification from Eichenbaum and Bayoumi (1992) were Fidrmuc and Korhonen (2002). The results suggest that the demand shocks in Croatia in the 1990s did not correlate with the demand shocks in the EMU countries, while supply shocks exhibited a moderate correlation compared with other post-transition countries. Broz (2010) uses a similar methodology on a sample from 1995 to 2006, confirming the results described above. Velickovski (2013) finds similar correlation for supply shocks, but a significantly stronger correlation for demand shocks. This paper is also closely linked to the literature that uses VAR models to point to the importance of external shocks for the dynamics of key variables in the domestic economy, such as Jankov et al. (2008), Krznar and Kunovac (2010), Jovančević et al. (2012), Dumičić et al. (2015) and Jovičić and Kunovac (2017).

The present paper offers several original contributions to the literature – both to that focusing on the coherence between Croatia's cycle and foreign cycles and to the more general literature on optimal currency areas. First of all, the paper improves the existing methodology for the quantification of contributions of symmetric and asymmetric shocks to the GDP dynamics of existing and potential monetary union member states (Bayoumi and Eichengreen (1992), Peersman (2011) and similar research). Moreover, in the context of the empirical literature focusing on Croatia, this is, to the best of our knowledge, the first paper to analyse other measures of cycle coherence – synchronicity and similarity – in addition to the analysis of the correlation of Croatia's cycle with that of the EMU countries. Finally, the sample used in this paper encompasses the recent period following Croatia's accession to the European Union, which included significant structural and institutional changes that could be reflected in cycle coherence. Following the introductory part of the paper, the second section analyses business cycle coherence between the euro area and Croatia, as well as between other EU peripheral countries, while the third section focuses on the analysis of the synchronicity of their shocks. The conclusion is provided in the last section.

2 Business cycle coherence

The existing empirical literature on the coherence of business cycles heavily relies on the calculation of correlations among the cycles of individual countries. Still, it is necessary to note that, based on such correlation indicators, it is sometimes difficult to assess the coherence between countries in a manner useful to the monetary policy maker in a monetary union (Mink et al., 2012, Belke at al., 2017). For instance, business cycles of two countries can be in the same phase in the observed period – both experiencing recessions and expansions – but, at the same time, have a very low correlation coefficient. On the other hand, the cycles of these two countries can correlate perfectly, with their amplitudes exhibiting no similarities at all. Therefore, in this paper, we analyse the cycle coherence between Croatia and euro area countries using not only correlations, but also two additional measures – *phase synchronicity* and *cycle similarity*. Phase synchronicity measures the coherence of the signs of two cycles, while similarity measures cycle amplitude coherence. All three measures mentioned above were calculated for Croatia relative to euro area core countries, after which the results for Croatia were compared with the results for other EU peripheral countries. In order to facilitate analysis and visualisation, the cycle coherence of all analysed countries is shown in two-dimensional space by applying the method of multidimensional scaling. The aforementioned method enables the consistent representation of all bilateral cycle coherences in one graph. Measures of cycle coherence (according to Mink et al., 2012) used in the analysis and the multidimensional scaling method are briefly described below.

2.1 Methodology

Let us assume that we want to compare a country's cycle with the cycles of all countries belonging to a set of reference countries. The analysed country is denoted as i, while reference countries are indexed by $r = 1, ..., n$.

Cycle phase synchronicity. For country i and each reference country r, we calculate the measure of synchronicity $\varphi_{ir}(t)$ indicating whether, at moment t, the sign of the cycle of country i, $c_i(t)$ equals the sign of the cycle of reference country $c_r(t)$:

$$\varphi_{ir}(t) = \frac{c_i(t)c_r(t)}{|c_i(t)c_r(t)|} = \begin{cases} 1, & \text{if the cycle of country } i \text{ has the same sign as cycle of country } r \\ -1, & \text{if the cycle of country } i \text{ has a different sign from the cycle of country } r \end{cases} \tag{1}$$

We then calculate total phase synchronicity of the analysed country's cycle with the cycle of a group of n countries for each period t:

$$\varphi_i(t) = \sum_{r=1}^{n} w_r \cdot \varphi_{ir}(t). \tag{2}$$

The aforementioned measure represents the weighted average of n bilateral phase synchronicities of the reference countries' cycles with the cycle of the analysed country calculated by the expression (1). If, at a given moment, the cycles of all n countries have the same sign as the cycle of analysed country i, $\varphi_i(t)$ will equal one. The weights w_r have to be non-negative, and their sum needs to be one.

Cycle similarity. Cycle similarity measures the synchronicity of the amplitudes of two cycles. For selected country i and any country from the set of reference countries (indexed with $r = 1,...,n$), we calculate the measure of cycle similarity for each moment t:

$$\gamma_{ir}(t) = 1 - \frac{|c_i(t) - c_r(t)|}{\sum_{r=1}^{n} |c_r(t)|/n}. \tag{3}$$

For the shown measure, $\gamma_{ir}(t) \leq 1$ applies, and if at a given moment t both countries have identical cycles, $\gamma_{ir}(t)$ will equal one. Total similarity of the analysed country's cycle with the cycles of the group of n countries was calculated, like the phase synchronicity measure, as follows:

$$\gamma_i(t) = \sum_{r=1}^{n} w_r \cdot \gamma_{ir}(t). \tag{4}$$

In this paper, the analysed countries are Croatia and other peripheral EU countries, while the reference group of n countries includes euro area core countries. The weights w_r in expressions (2) and (4) are shares of GDP of each of the core countries in euro area GDP. Total phase synchronicity for each analysed country is interpreted as the synchronicity of the country's cycle with the euro area cycle. Total cycle similarity is interpreted in a similar way for each analysed country.

The **multidimensional scaling method** enables the representation of objects in, most frequently, a two-dimensional coordinate system (see Torgerson, 1952) based on available bilateral distance measures of n objects. More precisely, the method requires a square matrix D that has to be symmetrical ($d_{ij} = d_{ji}$) and have non-negative elements ($d_{ij} \geq 0$) and zeros on the main diagonal ($d_{ii} = 0$). Element d_{ij} of this matrix represents the distance between the i-th and the j-th object. The aim of the method is to use matrix D to find points x_1, x_2, ..., x_n in a q-dimensional real space $\mathbb{R}^q$ (usually $\mathbb{R}^2$) for which d_{ij} is approximately equal to the Euclidean distance between point x_i and x_j. Under the additional assumption that $\sum_{k=1}^{n} x_k = 0$ applies, the solution to this problem is unique (see Wickelmeier, 2003) and obtained as follows:

1 Matrix $B=-\frac{1}{2}JD^{(2)}J$ is calculated, where $D^{(2)}=[d_{ij}^2]$ and $J=I_n-\frac{1}{n}\mathbf{1}_n$. Here, I_n is the unit matrix, and $\mathbf{1}_n$ is the square matrix of size n where all elements equal 1.
2 The decomposition of the symmetric matrix B into eigenvalues $\lambda_1,\ldots\lambda_n$ (where $\lambda_1\geq\lambda_2\geq\cdots\geq\lambda_n$) and respective orthogonal eigenvectors $v_1,\ldots,v_n$ is performed.
3 The required $X=[x_1x_2\ldots x_n]'$ for the selected dimension q is obtained according to the formula

$$X=[v_1\ldots v_q]\cdot diag(\sqrt{\lambda_1},\ldots,\sqrt{\lambda_q})\,. \quad (5)$$

If $q=2$, then vectors $x_1, x_2, \ldots, x_n$ are usually represented in a coordinate plane graph. The distances between individual objects in the graph should, to the greatest extent possible, be in line with the distances in matrix D. It is important to note that the arbitrary rotation of all points around the origin represents the same configuration, i.e. that the values on the axes do not provide any information – the only information relevant is the relative position of points in the graph. In our analysis, the objects to which we will apply the multidimensional scaling method are the business cycles of a particular country. In the first step, we construct matrix A, which can contain data on cycle phase synchronicity, cycle similarity or represent a correlation matrix. In each of these cases, matrix A is symmetric, and $a_{ij}\leq 1$ applies to its elements. It also has the property that higher values of element a_{ij} imply greater similarity between country i and country j. In the second step, we define matrix D with the elements $d_{ij}=1-a_{ij}$ and then apply the aforementioned procedure.

2.2 Data

Cycles of economic activity have been extracted from the series of real GDP in 24 EU countries[2] by applying a simple univariate HP filter, using the coefficient λ of 1600. The seasonally adjusted chain-linked real GDP in domestic currency (reference year 2010) from Eurostat was used. The length of the sample varies across countries depending on data availability, but the shortest sample included in the analysis refers to the period from the first quarter of 1998 to the third quarter of 2016.[3] As the HP filter belongs to a group of two-sided univariate filters, the reliability of trend estimates is reduced towards the end of the analysed sample as the filtered trend is biased towards realizations in the several last periods (the so-called *endpoint problem*). In order to address the issue adequately, actual GDP time series were extended with forecasts for the period from the fourth quarter of 2016 to the fourth quarter of 2018. Depending on availability, Consensus Economic Forecast and European Commission forecasts were used for the purpose. For the countries for which forecasts were not available on a quarterly level, annual rates have been interpolated at a quarterly frequency.

The aforementioned 24 EU member states were divided into two groups. The first group comprised seven *euro area core* countries: Germany, France, Italy, Spain, the Netherlands, Belgium and Austria, accounting for approximately 90% of euro area GDP. The second group of countries consisted of *EU peripheral member states*, for which the measures of phase synchronicity and similarity described above were calculated by using shares of the GDP of each of the core countries in the euro area GDP as weights in expressions (2) and (4).[4] The definition of euro area core was chosen according to the criterion of relevance for the common monetary policy. More precisely, as the ECB's monetary policy, among other things, responds to the dynamics in the business cycle of the entire euro area, the cycles of countries constituting around 90% of euro area GDP can be considered a relevant representative of the entire monetary union cycle.

2 All EU countries have been included except Malta, Luxembourg, Ireland and Cyprus, for which adequate real GDP time series were not available.

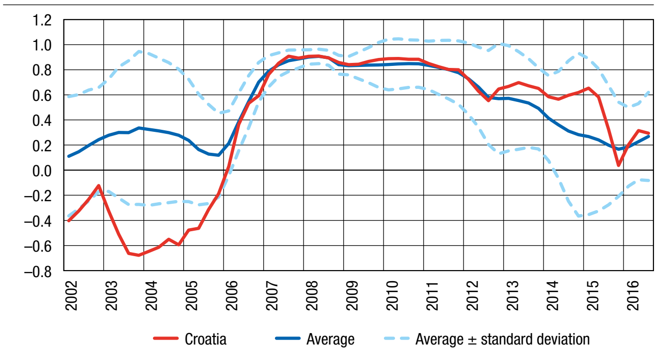
3 Available GDP series for Croatia, Poland and Bulgaria have been back-casted (for Croatia and Bulgaria for the period from the first quarter of 1998 to the fourth quarter of 1999 and for Poland for the period from the first quarter of 1998 to the fourth quarter of 2001) using the quarterly dynamics of seasonally adjusted GDP series in line with the ESA 95 methodology. The series were taken from the database of the European Central Bank.

4 Alternatively, we could have taken only euro area peripheral countries as the other group of countries, but in order to perform a comprehensive analysis, we observed a wider set of countries, which includes other EU countries as well (those which are not a part of the euro area). The results were almost identical for both data versions mentioned above. All the results, according to individual countries, are provided in the Appendix.

2.3 Results

Figure 1 shows moving correlations between the cycles in Croatia and the euro area core (red line) and average moving correlations between the cycles of the group of EU peripheral member states and the euro area (full blue line) along with the interval of one standard deviation (dashed blue line).[5] The figure suggests that Croatia's cycle in the period until 2006 correlated negatively with the euro area cycle, while immediately before the global financial crisis, the correlation began to increase substantially. Due to the common contraction of economic activity, correlation remained at levels above 80%. In the period from 2011 onwards, the correlation declined gradually. If we compare the results obtained for Croatia with other peripheral countries, we may conclude that the observed correlations in the period until 2006 are in line with the average correlation of those countries.[6] It is also necessary to point to an interesting finding regarding dispersion among countries, i.e. among observed standard deviations. The figure suggests that the dispersion was rather wide during periods of expansion, i.e. from 2002 to 2007 and 2014 to 2016, while during recessions, the cycles of all European countries correlated strongly, thereby reflecting the fact that their economic cycles were to a large extent driven by the same economic shocks during recessions.

Figure 1 Cycle moving correlations



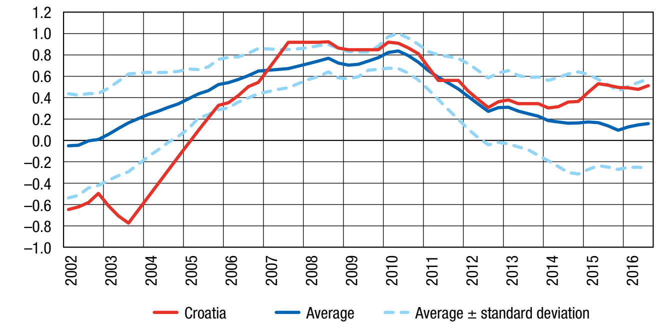
Note: The red line shows the weighted average of the correlation coefficient between the Croatian cycle and the cycles of seven euro area core countries, where weights constitute the share of GDP of each of the countries in euro area GDP. A similar measure was calculated for the set of other peripheral countries and the average correlation for these countries is shown as a full blue line together with the interval of one standard deviation (dashed blue line). The calculated correlation coefficient is shown as the four-year moving average.
Source: CNB.

Figure 2 shows the average phase synchronicity of the Croatian cycle and the cycle of EU peripheral member states with the euro area core countries' cycle. The results for the period until 2006 is in line with the results on the correlation of the cycles – during the aforementioned period, the synchronicity of the Croatian cycle was lower than the average of other countries. However, the synchronicity of the Croatian business cycle with the cycles of euro area core countries increased considerably in the period that followed and synchronised almost fully immediately before the onset of the financial crisis. Due to common global shocks in the 2008-2009 period, the synchronicity of Croatia and the euro area remained high, and was higher than the average synchronicity of peripheral countries throughout the entire remaining period. The synchronicity of the Croatian cycle with that of the euro area declined only in the 2011-2013 period, i.e. during the sovereign debt crisis in the euro area. The figure also clearly shows that, towards the very end of the sample, the Croatian cycle is

5 The moving correlation between the cycles of all analysed peripheral countries and core country cycles is individually shown in the Appendix. Figure 11 provides a comparison of results for Croatia and euro area peripheral countries, while Figure 12 provides a comparison for Croatia and other EU peripheral countries that are not members of the euro area. Table 3 shows bilateral coefficients of correlation for all pairs of countries throughout the entire period.

6 The obtained results are confirmed by the calculated alternative measure of correlation described in the Appendix and shown in Figure 17. The figure shows the transformed correlation index for Croatia and the average index along with the interval of one standard deviation for other EU peripheral countries. It also suggests that the correlation index for Croatia towards the end of the sample is significantly higher than at the beginning. In addition, as of 2009, the upward trend of the correlation index for Croatia is similar to the average of the correlation index for other EU countries.

Figure 2 Cycle phase synchronicity

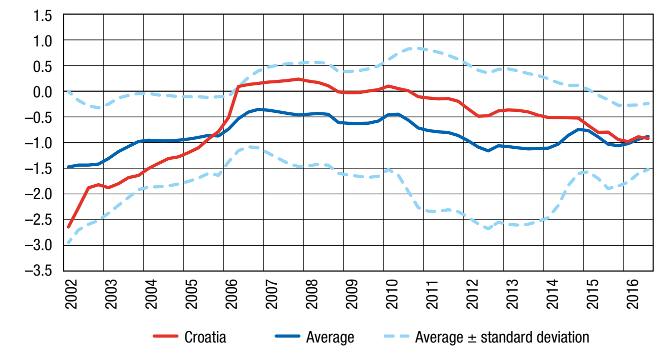


Note: The red line shows the weighted average of the phase synchronicity of the Croatian cycle with the cycles of seven euro area core countries, where weights constitute the share of GDP of each of the countries in euro area GDP. A similar measure was calculated for the set of other peripheral countries and the average synchronicity for these countries is shown as a full blue line together with the interval of one standard deviation (dashed blue line). The calculated measure of phase synchronicity is shown as the four-year moving average. Phase synchronicity includes the range from –1 (maximum non-synchronicity) to 1 (maximum synchronicity).
Source: CNB.

significantly more synchronised than the average of EU peripheral member states, whose synchronicity continues to decrease. Moreover, a detailed analysis suggests that the synchronicity of the Croatian cycle with the cycle of core countries at the very end of the sample is higher than the equivalent synchronicity measure of any other euro area peripheral country (Figure 13 in the Appendix). The aforementioned finding is related to the end of the sample, which confirms earlier arguments according to which phase synchronicity and the correlation coefficient can, in certain periods, point to the opposite conclusion.

Figure 3 shows the results for cycle similarity in an equivalent manner.[7] The measure for the period before 2010 additionally confirms earlier findings. The similarity between the Croatian cycle and that of euro area core countries increased immediately before and during the global recession, but declined slightly afterwards. In the period from 2006 to the end of 2015, the cycle similarity was greater for Croatia than for the average of peripheral member states, while in the last several quarters it hovered around the peripheral countries' average.

Figure 3 Cycle similarity

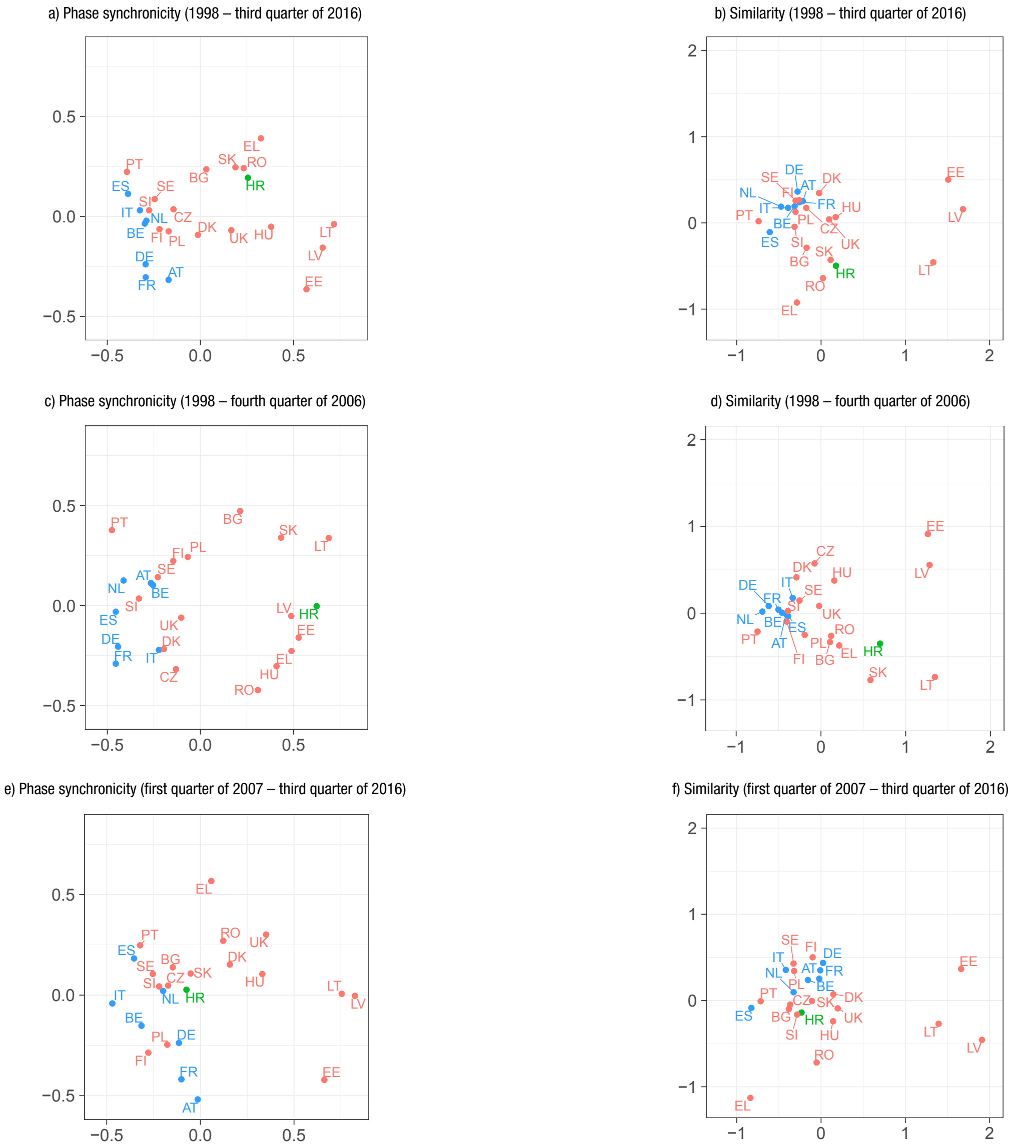


Note: The red line shows the weighted average of the similarity of the Croatian cycle with the cycles of seven euro area core countries, where weights constitute the share of GDP of each of the countries in euro area GDP. A similar measure was calculated for the set of other peripheral countries and the average similarity for these countries is shown as a full blue line together with the interval of one standard deviation (dashed blue line).The calculated measure of similarity is shown as the four-year moving average. Similarity covers the range from –∞ to 1 (equal cycle amplitudes).
Source: CNB.

7 The similarities of the cycles of all analysed peripheral countries and those of EU core countries are individually shown in the Appendix. Figure 15 provides a comparison of results for Croatia and euro area peripheral countries, while Figure 16 provides a comparison for Croatia and other EU peripheral countries that are not members of the euro area. Table 5 shows bilateral similarities for all country pairs.

Figure 4 illustrates the distance of countries using cycle synchronicity and similarity measures for all pairs of countries based on the results of multidimensional scaling. In order to explore the extent to which the results change over time, maps for three sub-samples are shown – on the total sample (Figures (a) and (b)), the first (Figures (c) and (d)) and the second half of the sample (Figures (e) and (f)). Generally, the distance between two countries on the map should decrease as the synchronicity/similarity between respective cycles increases. All six figures show both groups of countries by rendering peripheral countries in red, euro area core countries in blue and Croatia in green. Results based on the total sample for both measures indicate that the coherence of the Croatian cycle with euro area core cycles was relatively low (relatively large distances). However, Figures 4(e) and (f) clearly show that in the second half of the sample (after 2006), the Croatian cycle converged with the cycles of almost all of the euro area core countries, which confirms the findings described earlier. In the aforementioned period, the Croatian cycle was synchronised, for the most part, with the cycles of the Netherlands, Belgium, Germany and Italy. As regards peripheral countries, the Croatian cycle is in line with the Czech, Slovenian, Slovakian, Bulgarian and Swedish cycles. Figure 4(f) suggests that the results for

Figure 4 Multidimensional scaling results based on phase synchronicity and cycle similarity



Source: CNB.

cycle similarity are mostly in line with the results for synchronicity, with a slightly larger relative distance from Germany and Italy.

Based on the results shown above, we may conclude that the coherence between the business cycles of Croatia and those of euro area core countries is relatively high. According to the estimates of all three measures, the level of coherence for Croatia is slightly higher than that of other peripheral EU countries. Moreover, the results suggest that the cycle coherence between Croatia and the euro area increased immediately before the global financial crisis and that, depending on the observed measure, it remained relatively high. In order to perform an additional verification of the findings described in this chapter, in the following chapter we analyse the synchronicity of shocks, i.e. the transmission of symmetric and asymmetric shocks to domestic GDP.

3 Coherence of shocks

The preceding chapter analyses the coherence of business cycles as an important criterion for the successful countercyclical action of common monetary policy. However, the key effect of joining the monetary union is the loss of the ability to absorb asymmetric shocks by using standard measures of domestic monetary and exchange rate policy. The extent to which such limitations truly affect monetary union member states depends primarily on the type and the degree of synchronicity of shocks as well as the dynamics of adjustment of the economy to such shocks. In order to examine this in more detail, in this chapter, we first analyse the coherence of shocks in Croatia and the euro area core. In addition, taking into account shock propagation, we analyse the reaction of domestic economic activity to symmetric and asymmetric shocks. In the first subsection we use standard bivariate VAR models to identify structural shocks for each country and measure their synchronicity using standard correlation coefficients. In the second subsection, we use a larger-scale VAR model containing six variables to analyse the importance of the contributions of symmetric (common) and asymmetric shocks in explaining the dynamics of real activity in Croatia.

3.1 Correlation of aggregate supply and demand shocks

In this part, we analyse the synchronicity of aggregate supply and demand shocks between Croatia and the group of euro area core countries. As in the preceding chapter, we compare results for Croatia with the results of other peripheral countries.

3.1.1 Methodology

Aggregate supply and demand shocks are identified by imposing restrictions on impulse response functions in the bivariate Bayesian VAR model. Previous research on aggregate supply and demand shock synchronicity have usually followed the methodology proposed by Bayoumi and Eichengreen (1992). Explained briefly, according to this approach, identification is based on the assumption that only supply shocks can affect the GDP level in the long-run, which was implemented in line with Blanchard and Quah (1989). However, this identification strategy does not provide the usual correlation between GDP and inflation – due to demand shocks, it should be positive, and after supply shocks, it should be negative. In contrast to the standard method applied by Bayoumi and Eichengreen (1992), in this paper, structural shocks described above will be identified by a combination of long-run zero restrictions and short-run sign restrictions applied to impulse response functions, as performed earlier in Comunale and Kunovac (2017). For that purpose, we used the algorithm proposed in Arias et al. (2014) and implemented in the toolbox by Kotarac and Kunovac (2015).[8]

8 The MATLAB code and toolbox are available upon request.

3.1.2 Data

Economic activity and price variables are the minimum set of variables needed to identify supply and demand shocks. In this paper, we use real quarterly GDP growth and quarterly inflation rates as endogenous variables in the model described above. Both variables have been calculated as the quarterly change of the natural algorithm. The time series of GDP described in the previous section is also used in this VAR model. Prices are measured by the seasonally adjusted harmonised consumer price index. Consumer price series are taken from the European Central Bank Statistical Data Warehouse. The length of the sample for all VAR models covers the period from the first quarter of 1998 to the second quarter of 2016. Individual bivariate VAR models are estimated for each country from the group of 24 EU member states listed above.

3.1.3 Identification

The restrictions necessary for the identification of aggregate supply and demand shocks are provided in Table 1. Columns refer to the reaction of endogenous variables, while rows refer to shocks. We distinguish two types of restrictions: long-run and short-run restrictions, depending on the horizon of individual shock effects. *Short-run restrictions* have been applied to impulse responses only at the moment of the impact of a particular shock on endogenous variables. The restrictions are shown in the upper part of Table 1 ($t = 0$). The usual identification that a positive demand shock drives GDP and prices up in the short run and a positive supply shock drives GDP up and prices down is assumed. Supply shocks are generally considered productivity shocks, while demand shocks usually refer to various preference, consumer confidence or economic policy shocks. In contrast to short-run restrictions, *long-run restrictions* have been imposed on the cumulative effect of a particular shock on the appropriate variable. This VAR model includes a restriction by which we assume that demand shocks cannot affect GDP in the long run, which means that demand shocks are transitory. On the other hand, no restrictions have been placed on supply shocks, enabling their permanent effect on economic activity. Such long-run restrictions are in line with the existing literature on the synchronicity of supply and demand shocks based on the identification proposed in Bayoumi and Eichengreen (1992), while a combination of such long-run sign restrictions with short-run sign restrictions represents a contribution to the existing literature on shock synchronicity analysis.

Table 1 Restrictions for shock identification

	GDP	Inflation
	short run (t = 0)	
Aggregate demand	+	+
Aggregate supply	+	–
	long run	
Aggregate demand	0	?
Aggregate supply	?	?

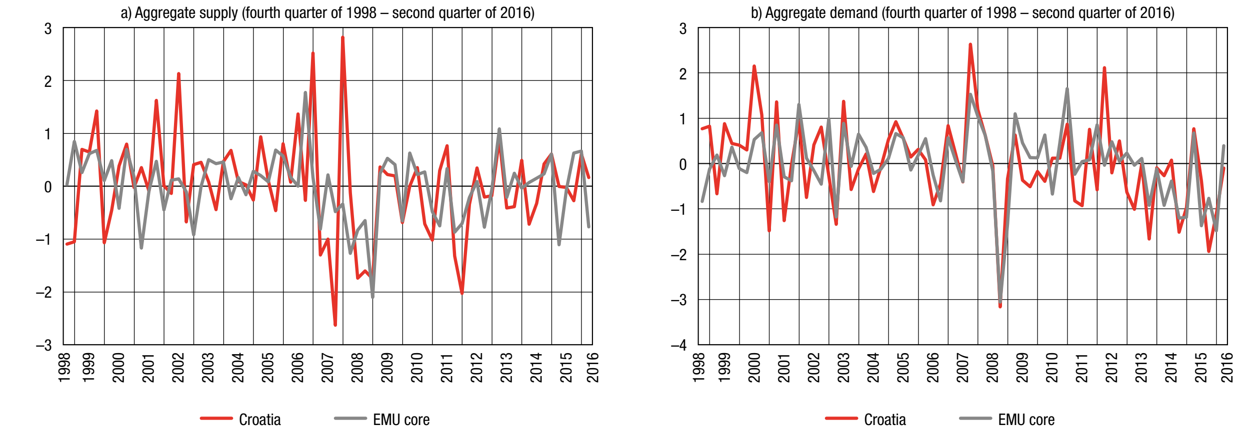
Note: The positive reaction of the endogenous variable to structural shock is indicated by +, negative reaction is indicated by –, while ? means that the reaction of the respective variable remains unrestricted.

3.1.4 Results

Figures 5(a) and (b) show identified aggregate supply and demand shocks for Croatia and the average of the same shocks for euro area core countries, estimated by VAR models described above.[9] Figure 5(b) suggests that demand shocks in Croatia correlate highly with demand shocks in euro area core countries. Strong synchronicity was particularly pronounced immediately before and during the common crisis in 2008 and at the beginning of 2009, while divergent shock dynamics were recorded only in the 1998-2001 period. On the other hand, supply shocks seen in Figure 5(a) show a somewhat lower correlation throughout the entire period. Lower correlation of aggregate supply shocks is not surprising as the Croatian economy went through a period

9 Two lags of endogenous variables are assumed for all countries.

Figure 5 Structural shocks identified by the bivariate BVAR model

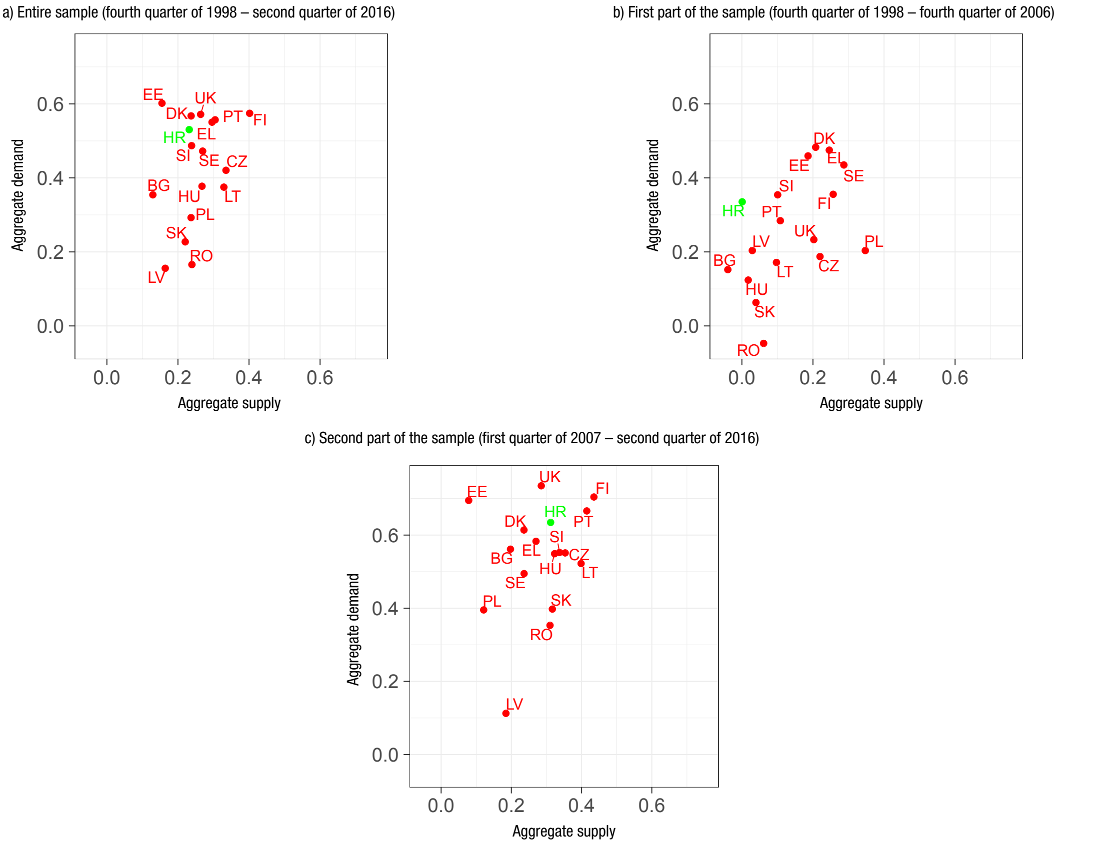


Note: Euro area core shocks have been calculated as the average of individual shocks of seven euro area core countries.
Source: CNB.

of significant structural changes during the transition process. Such changes should primarily be reflected in supply shocks, i.e. productivity shocks related to long-run changes in the structure of the economy.

In order to compare the results regarding the synchronicity of supply and demand shocks for Croatia with the corresponding results for other peripheral countries, Figure 6 provides a representation of average coefficients

Figure 6 Correlations of supply and demand shocks with euro area countries

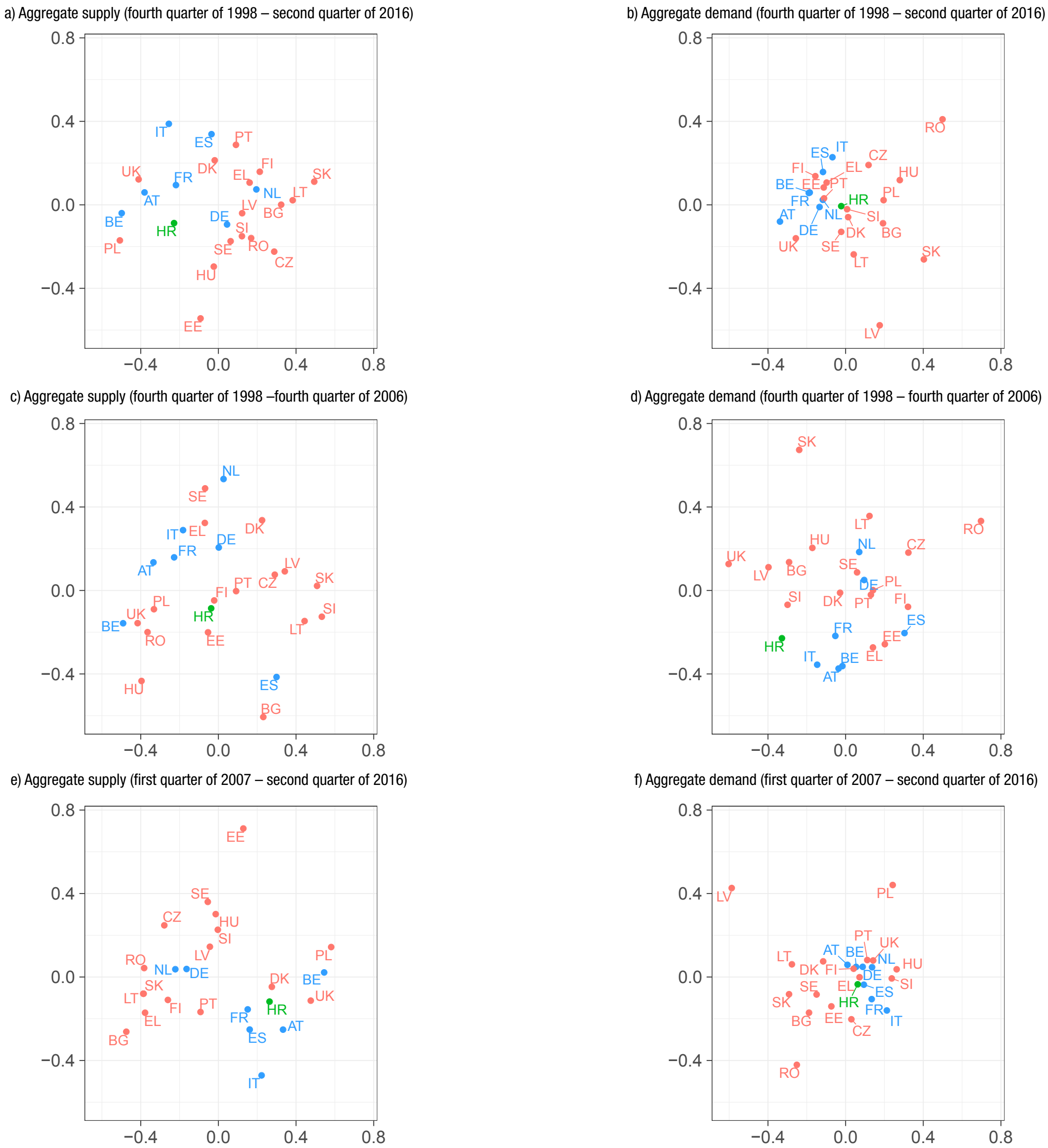


Note: Correlations with core countries have been calculated as the weighted average of the correlation of the analysed peripheral country with seven core countries, where weights refer to the share of each of the seven countries in euro area GDP.
Source: CNB.

of correlation of individual countries' shocks with the shocks of euro area core countries. Figure 6(a) refers to the entire sample, Figure 6(b) to the first half, and Figure 6(c) to the second half of the sample. In all figures, the correlation of supply shocks is shown on the x-axis, while the correlation of demand shocks is shown on the y-axis. The results confirm the preliminary findings according to which Croatian demand shocks are highly synchronised with euro area core demand shocks. Indeed, Croatia belongs to a group of countries with the highest correlation coefficient for demand shocks. However, results related to supply shocks suggest that the Croatian economy is somewhat less synchronised with the euro area economy. Namely, the coefficient of correlation between supply shocks in Croatia and euro area core countries is below the average of the analysed sample. Furthermore, as in the preceding section, the results point to the convergence of economic shocks in Croatia and euro area core countries. In the second half of the sample (Figure 6(c)), Croatia is located in the upper right corner (*northeast*), meaning that Croatian supply and demand shocks have a somewhat higher correlation with the supply and demand shocks in euro area core countries.

As in the previous chapter, multidimensional scaling was performed based on the correlation of supply and

Figure 7 Multidimensional scaling results based on the correlation of supply and demand shocks



Source: CNB.

demand shocks for all pairs of countries included in the analysis for the entire sample as well as for the two sub-samples. The proximity of countries on the map points to a high correlation of shocks. All bilateral correlations of supply and demand shocks are provided in Tables 6 and 7 in the Appendix. Figures 7(b), (d) and (f) suggest that Croatian demand shocks were very similar to the shocks of the majority of euro area member states and that the aforementioned relative synchronicity of shocks grew over time. On the other hand, Figures 7(a), (c) and (e) generally show a somewhat greater dispersion of countries based on correlations of supply shocks. According to the results, in the 2007-2016 period, Croatia was in the vicinity of some euro area core countries, such as Spain, Austria and France, while some countries, whose cycles are highly synchronised with the Croatian cycle according to the results presented in the second section, were slightly more distant. This primarily refers to the Netherlands and Germany and some peripheral countries such as Bulgaria, Hungary and Slovakia. It is therefore important to note that the similarity of two economies regarding shocks need not necessarily be reflected in the similarity of cycles of the two countries. The differences in the relative ranking of countries between the current and the preceding section suggest that one needs to be cautious when drawing conclusions regarding the expected costs of the common monetary policy and that it is therefore important to analyse this issue using a variety of methodological tools and conceptual approaches.

3.2 Importance of symmetric and asymmetric shocks for domestic GDP

In the analysis so far, we have, to a large extent, followed the existing empirical literature and measured shock synchronicity by using correlation coefficients. However, this approach of focusing exclusively on the coherence between shocks has an obvious disadvantage, as it completely ignores endogenous transmission mechanisms or reactions of economic variables to structural shocks. It is necessary to note that the common cycle, i.e. the cycle to which the common monetary policy reacts, is, eventually, determined by a *combination of shocks and transmission mechanisms* of individual economies. The related literature (for instance, Bayoumi and Eichengreen, 1992), unfortunately, mostly focuses on the synchronicity of shocks and disregards the propagation of shocks, thus ignoring a key problem - the overall effect of shocks on macroeconomic variables. The analysis of shock correlation is therefore insufficient for drawing firm conclusions on the adequacy of common monetary policy if the transmission mechanisms in the observed economies differ considerably. In that regard, Peersman (2011) proposes the classification into *symmetric* and *asymmetric* shocks according to their influence on the variables of a small domestic economy (United Kingdom) and a large foreign economy (euro area). In this way, his analysis directly answers the question of the importance of symmetric and asymmetric shocks for a small open economy and thus analyses the fulfilment of one of the OCA criteria. For that purpose, he estimates a more complex VAR model in which he simultaneously models the domestic and the foreign economy (two-country model), which enables a more detailed analysis of the nature of shocks that generate the cycle of the domestic economy. Peersman (2011) defines symmetric shocks as shocks affecting domestic and foreign variables with the *same sign*, while asymmetric shocks are those having the opposite impact on domestic variables relative to foreign variables. We consider the aforementioned identification not fully relevant for the group of countries analysed here. Specifically, we find the assumption about the opposite reactions of economic variables to the same type of shock in EU countries too strong, considering that they share common institutions and participate in the common market. For example, Peersman assumes that an asymmetric aggregate supply shock (productivity/technology) drives domestic GDP down and domestic prices up, while at the same time, it drives foreign GDP up and foreign prices down. This implies not only the absence of technology spillover, but also that the increase in technology in one country would lead to a decrease in technology in the other. In this paper, we build upon the identification described in Peersman (2011) and add *domestic, idiosyncratic* shocks to the model. The results show that such shocks are the main source of asymmetry for a small economy such as Croatia.[10]

10 This was confirmed empirically by comparing the identification that includes domestic shocks with the identification in Peersman (2011), using the identical sample and the same reduced form of VAR model for Croatia. For that purpose, we compared the share of accepted iterations in the applied algorithm for two alternative identifications. In case the share is high, the model suggests that the imposed restrictions are more plausible. According to the results of the analysis, the aforementioned share of accepted iterations was approximately 40 times higher for the identification proposed here than for the identification in Peersman (2011).

3.2.1 Methodology and shock identification

As in the previous subsection, shocks were identified by combining short-run sign restrictions and long-run zero restrictions, using the Bayesian two-country VAR model. The main difference from the previously estimated VAR model is that, in addition to the domestic variables, euro area variables were added as well. This extension of the VAR model by including foreign variables enables the separate identification of symmetric and asymmetric shocks. Therefore, the VAR model used here includes the following six variables: domestic GDP growth and domestic inflation, rate of change of the real exchange rate, inflation and GDP growth for the euro area aggregate and short-term euro area reference interest rate. As in the previous section, we assume two lags for endogenous variables. Most peripheral countries are small economies whose GDP does not exceed 1% of euro area GDP, which is why we include block exogenous restrictions in VAR models. In that way, we assume that a small domestic economy cannot affect the large foreign economy, i.e. the euro area. A detailed description of the implementation of the block exogenous restrictions in a similar VAR model is provided in Jovičić and Kunovac (2017).

Table 2 shows restrictions used to identify structural shocks in the VAR model. As in Table 1, the upper part shows short-run restrictions for each analysed shock, while the lower part shows long-run restrictions. As emphasized earlier, short-run restrictions were placed on impulse responses only at the moment of the impact of shock on endogenous variables (impact response), while long-run restrictions were imposed on the long-run effect of shock on the appropriate variable. In contrast to the usual division of shocks into domestic and foreign shocks, we propose a division into symmetric and asymmetric shocks, which means that the emphasis is on foreign shocks that lead to a symmetric reaction of GDP in the domestic and the foreign economy.

Table 2 Restrictions for the identification of symmetric and asymmetric shocks

	GDP	Inflation	Exchange rate	EA GDP	EA inflation	EA interest rate
			short run (t = 0)			
Symmetric shocks						
Aggregate demand	+	+	?	+	+	+
Aggregate supply	+	–	?	+	–	–
Asymmetric shocks						
Idiosyncratic aggregate demand	+	+	?	0	0	0
Idiosyncratic aggregate supply	+	–	?	0	0	0
Asymmetric real activity	+	?	?	–	?	?
Other shocks						
ECB monetary policy	?	?	?	+	+	–
			long run			
Symmetric shocks						
Aggregate demand	0	?	?	0	?	?
Aggregate supply	?	?	?	?	?	?
Asymmetric shocks						
Idiosyncratic aggregate demand	0	?	?	?	?	?
Idiosyncratic aggregate supply	?	?	?	?	?	?
Asymmetric real activity	?	?	?	?	?	?
Other shocks						
ECB monetary policy	?	?	?	0	?	?

Positive symmetric aggregate demand shocks initially increase GDP and prices in both economies and raise the euro area interest rate due to the monetary policy reaction function. The real exchange rate remains unrestricted, reflecting the idea that it is not a priori clear whether the shock will affect domestic or euro area prices more. We also assume that, in the long run, as in the smaller VAR model described earlier, demand shocks cannot affect GDP. Therefore, long-run zero restrictions are imposed on GDP responses in both countries. Expansionary symmetric aggregate supply shocks have the same effect on GDP and prices in both countries: GDP increases and prices decline in the short run, while long-run restrictions were not imposed. We also introduced a restriction on the euro area interest rate, for which we assume that it decreases as a response to a positive symmetric supply shock due to the monetary policy reaction function driven by the drop in prices and an increase in potential GDP which is stronger than the increase in actual GDP (drop in GDP cyclical component).

Besides the two symmetric shocks mentioned above, we identified three asymmetric shocks and the ECB monetary policy shock. Asymmetric shocks include an idiosyncratic domestic demand shock, an idiosyncratic domestic supply shock and an asymmetric real activity shock. A positive asymmetric (idiosyncratic) shock of aggregate demand results in a rise in domestic GDP and prices in the short run, while foreign variables remain unchanged. In addition, due to block exogeneity restrictions, further endogenous transmission mechanisms cannot lead to changes in euro area variables. Again, we assume that the shock is temporary, i.e. that the response of domestic GDP converges to zero in the long run. A positive asymmetric (idiosyncratic) aggregate supply shock drives domestic GDP up and domestic prices down, while foreign variables do not react to the shock. The asymmetric real activity shock is defined as the shock leading to the opposite reaction of domestic GDP relative to the reaction of euro area GDP. In contrast to Peersman (2011), in this paper, we do not impose restrictions on other variables. Therefore, the aforementioned shock unites asymmetric shocks of aggregate supply, demand and monetary policy. Such identification is necessary bearing in mind the maximum number of shocks we can identify and, at the same time, it reflects the disadvantages of the identification of asymmetric shocks proposed in Peersman (2011), described above. The last shock identified in this model is the ECB monetary policy shock. This shock implies the usual set of restrictions for monetary VAR models, which assume that the exogenous decrease of the reference interest rate has an expansionary effect on euro area GDP and increases prices, while restrictions on domestic variables were not set. In line with the standard monetary theory, the aforementioned shock does not have long-run effects on GDP.

In order to compare the importance of asymmetric shocks defined above with that of symmetric shocks, we calculate the share of symmetric and asymmetric shocks in the historical GDP decomposition based on the estimated VAR model for each country.

3.2.2 Data

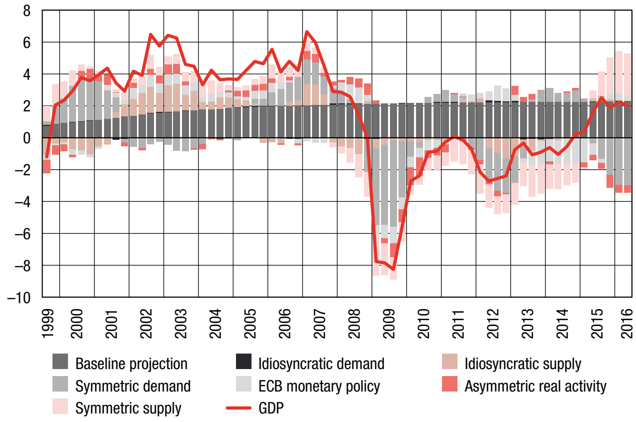
Time series for GDP and inflation for 17 peripheral countries described above have been used for the domestic block. The measure used for the real exchange rate is the real effective exchange rate of the domestic economy vis-a-vis euro area countries, taken from Eurostat. As stated earlier, the foreign block includes euro area GDP, euro area inflation measured by HICP and the euro area short-term reference interest rate. The euro area interest rate used is the shadow rate (Wu, Xia, 2016), i.e. the interest rate corrected for non-standard ECB monetary policy measures. For VAR models where the domestic economy is represented by one of the euro area peripheral member states, GDP and inflation in the foreign block were adjusted for the GDP and inflation of the respective domestic economy. More precisely, in such VAR models, foreign GDP refers to the sum of GDPs of all euro area countries besides the GDP of the analysed country. Similarly, based on Eurostat weights, euro area HICP was calculated for the models in which one of euro area peripheral countries is the domestic economy. All variables except interest rates have been included into the model as log differences.

3.2.3 Results

Figure 8 shows the historical decomposition of the annual growth rate of the Croatian GDP into identified structural shocks[11]. The figure shows that, before the global financial crisis, asymmetric supply shocks and symmetric demand shocks were the main drivers of GDP growth. The results are in line with the results showing a slightly lower correlation of aggregate supply shocks in the period prior to 2006, presented in the previous section. As already mentioned, such findings are not surprising considering the transition process that the Croatian economy was going through, during which various domestic shocks affecting productivity in the long run had a dominant role. However, in the 2007-2016 period, domestic GDP was under the dominant influence of symmetric shocks, which also confirms most of the results previously presented.

11 Figure 23 in the Appendix shows impulse response functions for variables included in the VAR model for Croatia.

Figure 8 Historical decomposition of Croatian GDP

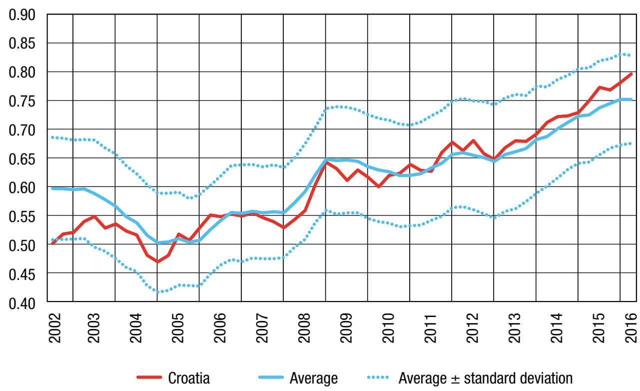


Note: The figure shows the contributions of individual shocks to the annual GDP growth rate estimated by the BVAR model of a small open economy.
Source: CNB.

Figure 9 shows the relative importance of symmetric shocks for the dynamics of domestic GDP. To be more precise, the absolute values of the contributions of symmetric shocks were added for each period and then divided by the sum of absolute values of the contributions of all structural shocks. Similarly to the figures included in the previous section, the red line indicates the contributions of symmetric shocks for Croatia, while the blue line shows the average contribution of symmetric shocks for all other EU peripheral countries along with the interval of one standard deviation. It is important to note that the contributions of the ECB monetary policy shock have been added to symmetric shocks, as it would become symmetric in the event that Croatia joins the common monetary union.

Figure 9 points to strong growth in the contributions of symmetric shocks for the Croatian GDP, as confirmed by the preliminary findings in Figure 8. Figure 9 also demonstrates that the aforementioned growth in the contributions of symmetric shocks is largely in line with the average results of other countries.[12] This leads to the conclusion that the costs associated with the loss of autonomous monetary policy should not be significant for Croatia.

Figure 9 Contributions of symmetric shocks to GDP

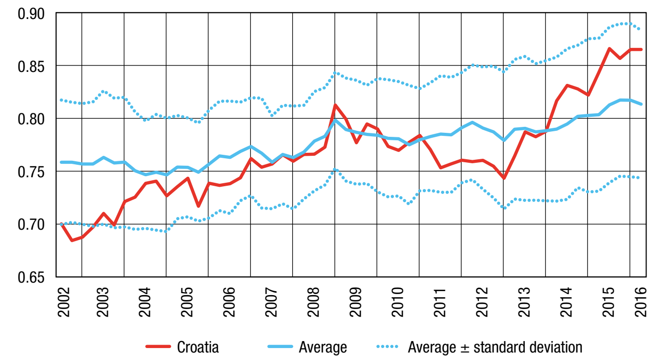


Notes: Contributions of symmetric shocks have been calculated as the percentage share of symmetric shocks (and monetary policy shocks) in the historical decomposition of the quarterly rate of growth of domestic GDP. The figure shows four-year moving averages.
Source: CNB.

12 The Appendix shows the contributions of symmetric shocks for all analysed peripheral countries individually. Figure 18 provides a comparison of results for Croatia and euro area peripheral countries, while Figure 19 provides a comparison for Croatia and other EU peripheral countries that are not members of the euro area.

It is necessary to note that a part of asymmetric shocks can also lead to a symmetric reaction in economic variables. In other words, a shock identified as asymmetric, i.e. an idiosyncratic shock, can, at certain moments, affect domestic GDP in the same direction as a symmetric shock. We provide two potential explanations for such a symmetric reaction below. First, a symmetric reaction can, potentially, be entirely coincidental – economic developments can be aligned for completely unrelated reasons. Alternatively, it is possible that, at certain moments, domestic shocks, although exogenous by definition, can be motivated by economic developments or euro area economic policy actions/announcements. It is necessary to emphasize that the exogeneity refers to the information set included in the VAR model, while the information set of agents in the economy is much wider. It is therefore possible that, at certain moments, domestic asymmetric shocks, which, by definition, do not affect euro area variables, are caused by euro area information not included in the VAR model. An example of such shocks is domestic fiscal consolidations motivated by similar consolidations in the euro area. Another example is the initiation of investment projects in the tourism sector in response to a change in euro area economic activity – particularly if such a reaction is stronger than the predictable endogenous reaction of domestic GDP to external shocks. Finally, domestic consumer confidence shocks motivated by the economic developments in the euro area can also serve as an example of such shocks. Irrespective of the actual source of the shock, in Figure 10, we add the contributions of such asymmetric shocks to the contributions of symmetric shocks shown earlier. According to the results shown, asymmetric shocks leading to a symmetric reaction in domestic GDP, depending on the period observed, account for 10% to 30% of Croatian GDP dynamics. The figure shows that the common contribution of the above-mentioned asymmetric and symmetric shocks accounted for more than 70% of Croatian GDP dynamics over almost the entire sample. Figure 10 also suggests that, towards the end of the sample, these contributions exceed 85% and are significantly higher than the average of other peripheral countries.[13] Based on the aforementioned results, we may conclude that symmetric shocks, along with asymmetric shocks that result in a symmetric reaction of Croatian GDP, are indeed dominant in explaining the dynamics of Croatian GDP.

Figure 10 Contributions of shocks leading to a symmetric reaction in GDP



Notes: Contributions of symmetric shocks have been calculated as the percentage share of symmetric shocks (and monetary policy shocks) in the historical decomposition of the quarterly rate of growth of domestic GDP. Contributions of asymmetric shocks were added to the contributions of symmetric shocks if they had the same sign at a given moment. The figure shows four-year moving averages.
Source: CNB.

13 The Appendix shows the contributions of the broadly defined symmetric shocks for all analysed peripheral countries individually. Figure 20 provides a comparison of results for Croatia and euro area peripheral countries, while Figure 21 provides a comparison for Croatia and other EU peripheral countries that are not members of the euro area.

4 Conclusion

The paper analyses the coherence between business cycles and economic shocks in Croatia and euro area core countries. Additionally, we explored the extent to which Croatian GDP is under the influence of symmetric (common) and asymmetric shocks. The results were compared with the results for other peripheral EU countries. The results discussed here should contribute to public debate regarding the expected costs associated with the adoption of common monetary policy once Croatia joins the euro area. It is generally accepted that joining the monetary union is associated with potential costs and benefits for new member states, with costs primarily being reflected in the loss of autonomous countercyclical monetary policy. The basic OCA theory assumes that all monetary union member states will benefit from the common monetary policy provided that their cycles and economic shocks are synchronised.

The analysis conducted in this paper points to several conclusions. Firstly, the coherence of business cycles and the correlation of economic shocks between Croatia and euro area core countries is relatively high. The measures of similarity and phase synchronicity of the Croatian cycle with the cycles of euro area core countries included in this paper are high compared with the same measures for other EU peripheral countries. A similar conclusion applies to the correlation of demand shocks, while the correlation of supply shocks between Croatia and euro area core countries is somewhat lower. Secondly, symmetric (common) shocks are dominant for describing the dynamics of Croatian GDP, while the contributions of asymmetric shocks are significantly smaller. Thirdly, the results point to the convergence of supply and demand shocks and business cycles between Croatia and euro area core. More precisely, in the period following 2006, cycle coherence between Croatia and the euro area is significantly higher than in the period before 2006. Moreover, the results show that, in the last several years, the significance of symmetric shocks for Croatian GDP has increased: in the recent period, symmetric shocks have accounted for between 75% and 85% of Croatian GDP dynamics, depending on the measure used.

Based on all of the above, we may conclude that the introduction of the euro and the related adoption of the common monetary policy should not result in significant costs for the Croatian economy from the viewpoint of countercyclical monetary policy action.

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A Appendix

A1 Alternative measure of moving cycle correlation

The correlation index proposed in Cerqueira and Martins (2009) was used to test the robustness of the results obtained from moving correlations. The index is defined as follows for the two x_i and x_j series:

$$\rho_{ij}(t)=1-\frac{1}{2}\left(\frac{x_i(t)-\bar{x}_i}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(x_i(t)-\bar{x}_i)^2}}-\frac{x_j(t)-\bar{x}_j}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(x_j(t)-\bar{x}_j)^2}}\right)^2.$$

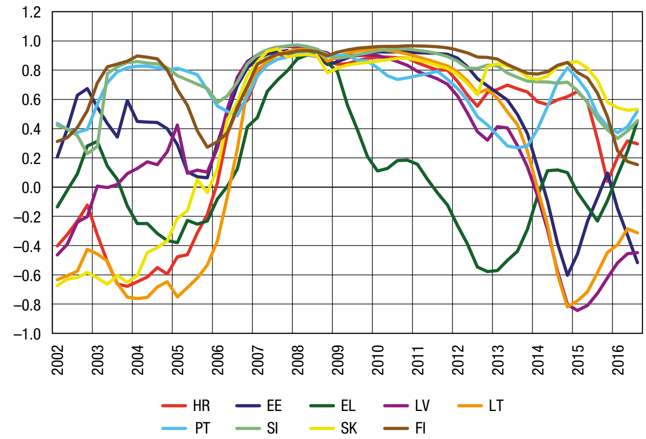
The index has several advantages over moving correlations. The main advantage of the index thus defined is its average value, which equals the correlation coefficient between x_i and x_j series in the entire sample. Furthermore, there are no losses of observations and no need to determine the size of the moving window. The values of the index are non-symmetric, ranging from $3-2T$ to 1. We constructed a transformed index in line with Cerqueira (2013):

$$\bar{\rho}_{ij}(t)=\tanh\left(\frac{1}{2}\ln\left(\frac{1+\frac{\rho_{ij}(t)}{2T-3}}{1-\rho_{ij}(t)}\right)\right),$$

with values ranging from –1 to 1.

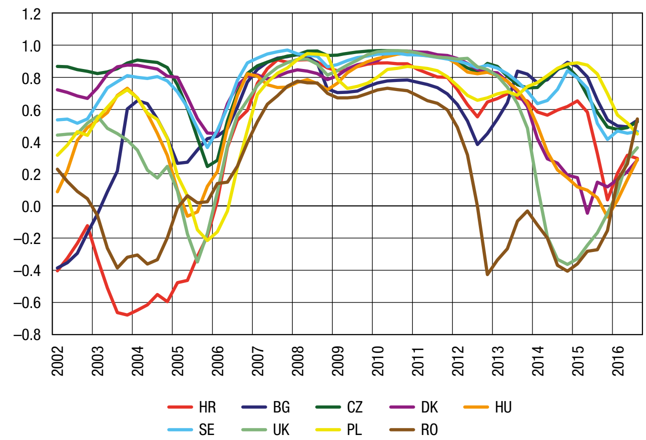
A2 Figures and tables

Figure 11 Correlations of cycles of euro area peripheral countries (and Croatia) with cycles of euro area core countries



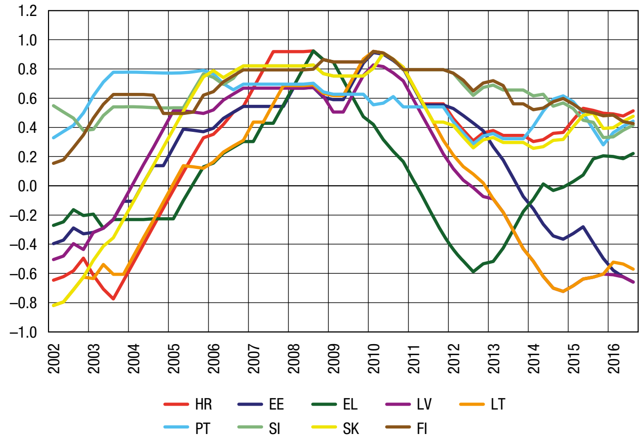
Source: CNB.

Figure 12 Correlations of cycles of other EU countries with cycles of euro area core countries



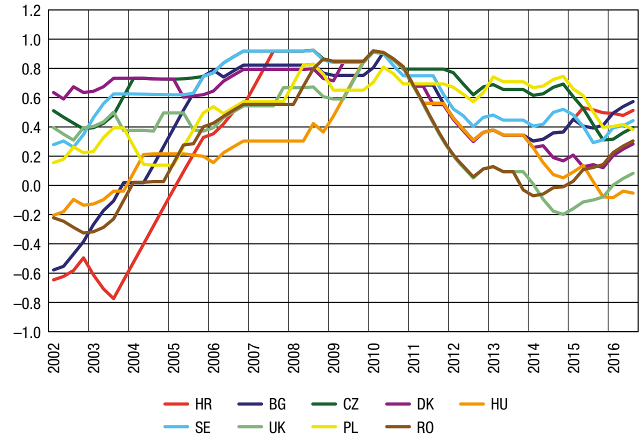
Source: CNB.

Figure 13 Phase synchronicity of cycles of euro area peripheral countries (and Croatia) with cycles of euro area core countries



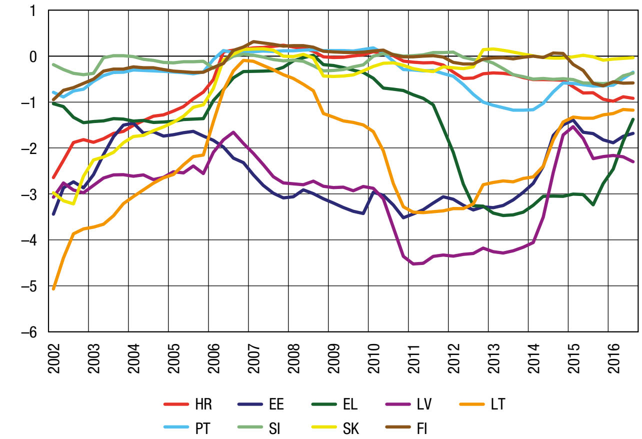
Source: CNB.

Figure 14 Phase synchronicity of cycles of other EU countries with cycles of euro area core countries



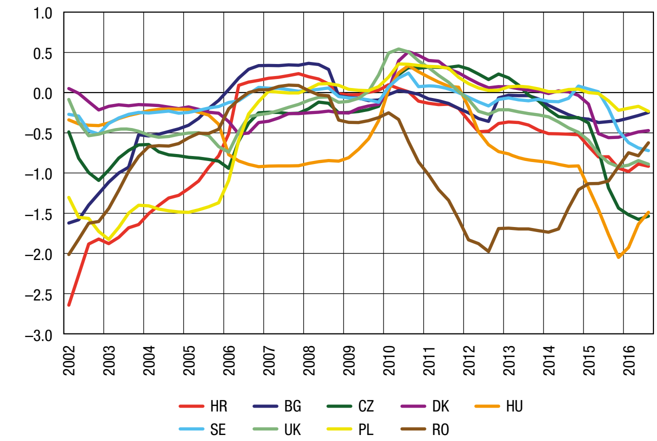
Source: CNB.

Figure 15 Similarity of cycles of euro area peripheral countries (and Croatia) with cycles of euro area core countries



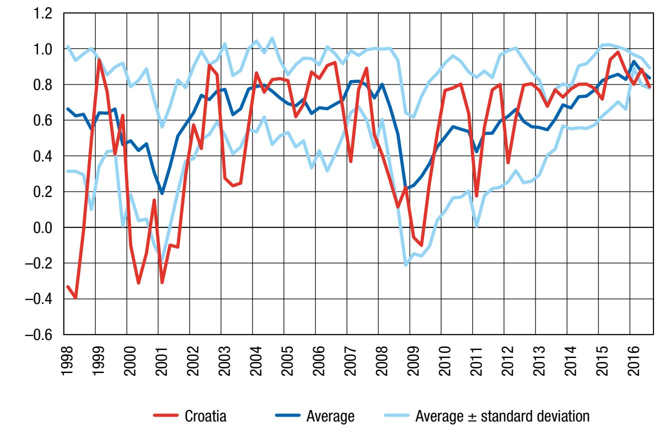
Source: CNB.

Figure 16 Similarity of cycles of other EU countries with cycles of euro area core countries



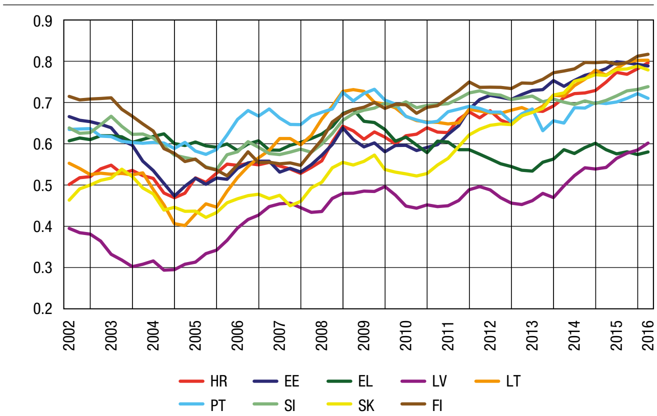
Source: CNB.

Figure 17 Correlation index between cycles of EU peripheral countries and cycles of euro area core countries according to Cerqueira and Martins (2009)



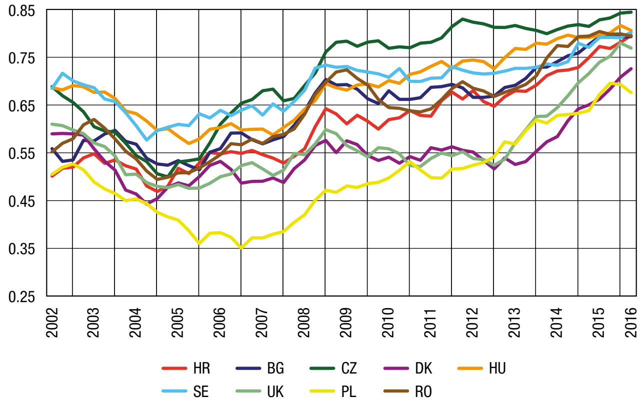
Source: CNB.

Figure 18 Contributions of symmetric shocks to GDP (euro area peripheral countries and Croatia)



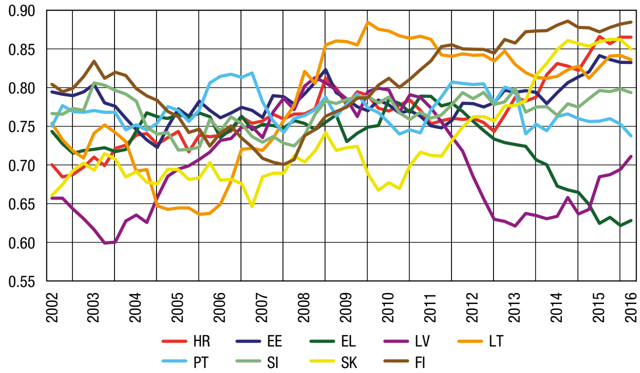
Notes: Contributions of symmetric shocks have been calculated as the percentage share of symmetric shocks (and monetary policy shocks) in the historical decomposition of the quarterly rate of growth of domestic GDP. The figure shows four-year moving averages.
Source: CNB.

Figure 19 Contributions of symmetric shocks to GDP (other EU countries)



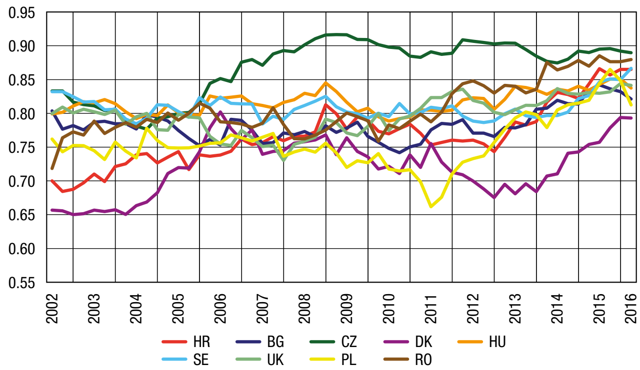
Notes: Contributions of symmetric shocks have been calculated as the percentage share of symmetric shocks (and monetary policy shocks) in the historical decomposition of the quarterly rate of growth of domestic GDP. The figure shows four-year moving averages.
Source: CNB.

Figure 20 Contributions of shocks leading to a symmetric reaction in GDP (euro area peripheral countries and Croatia)



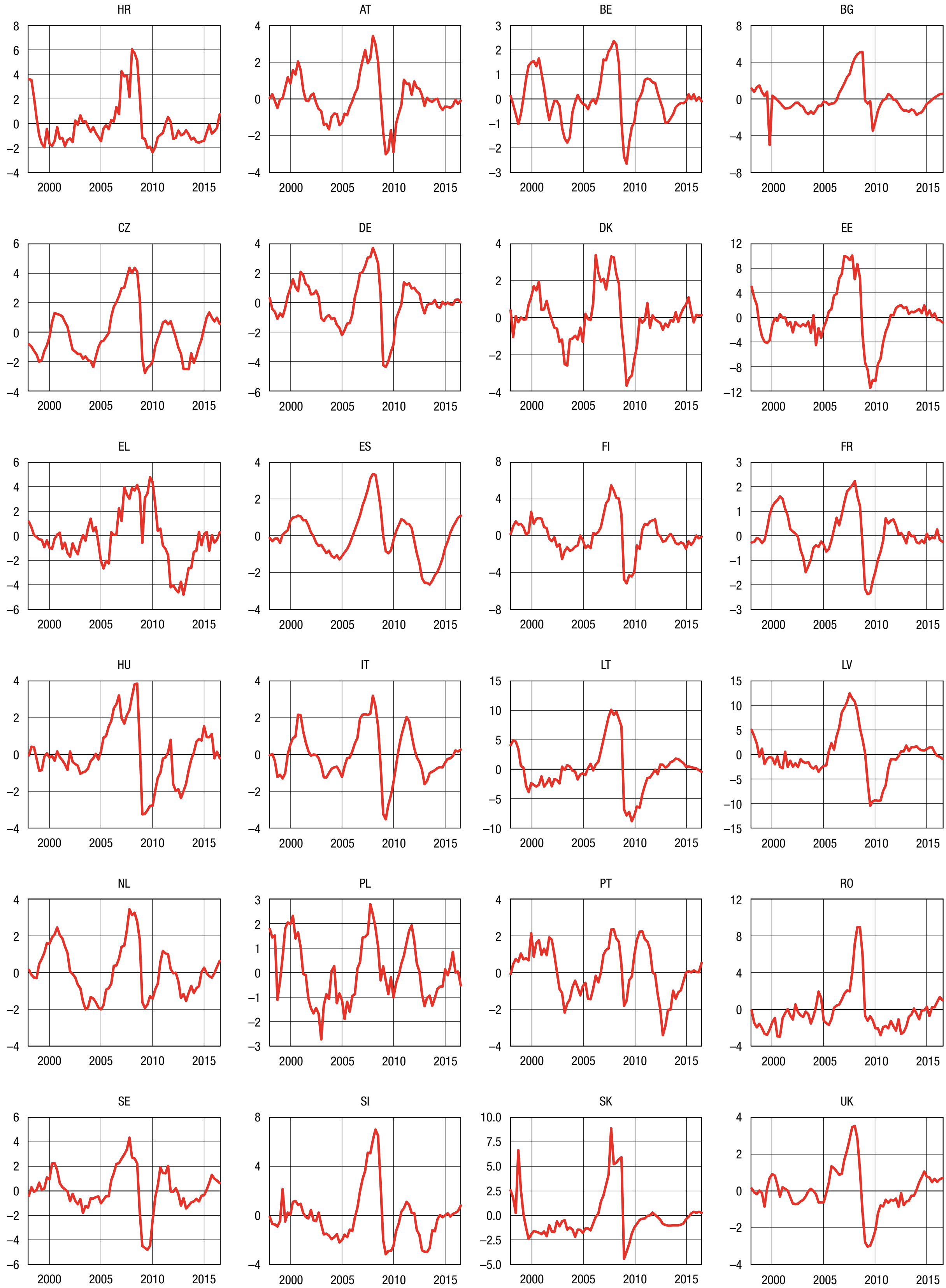
Notes: Contributions of symmetric shocks have been calculated as the percentage share of symmetric shocks (and monetary policy shocks) in the historical decomposition of the quarterly rate of growth of domestic GDP. Asymmetric shocks leading to a symmetric reaction in Croatian and euro area GDP have been added to symmetric shocks. The figure shows four-year moving averages.
Source: CNB.

Figure 21 Contributions of shocks leading to a symmetric reaction in GDP (other EU countries)



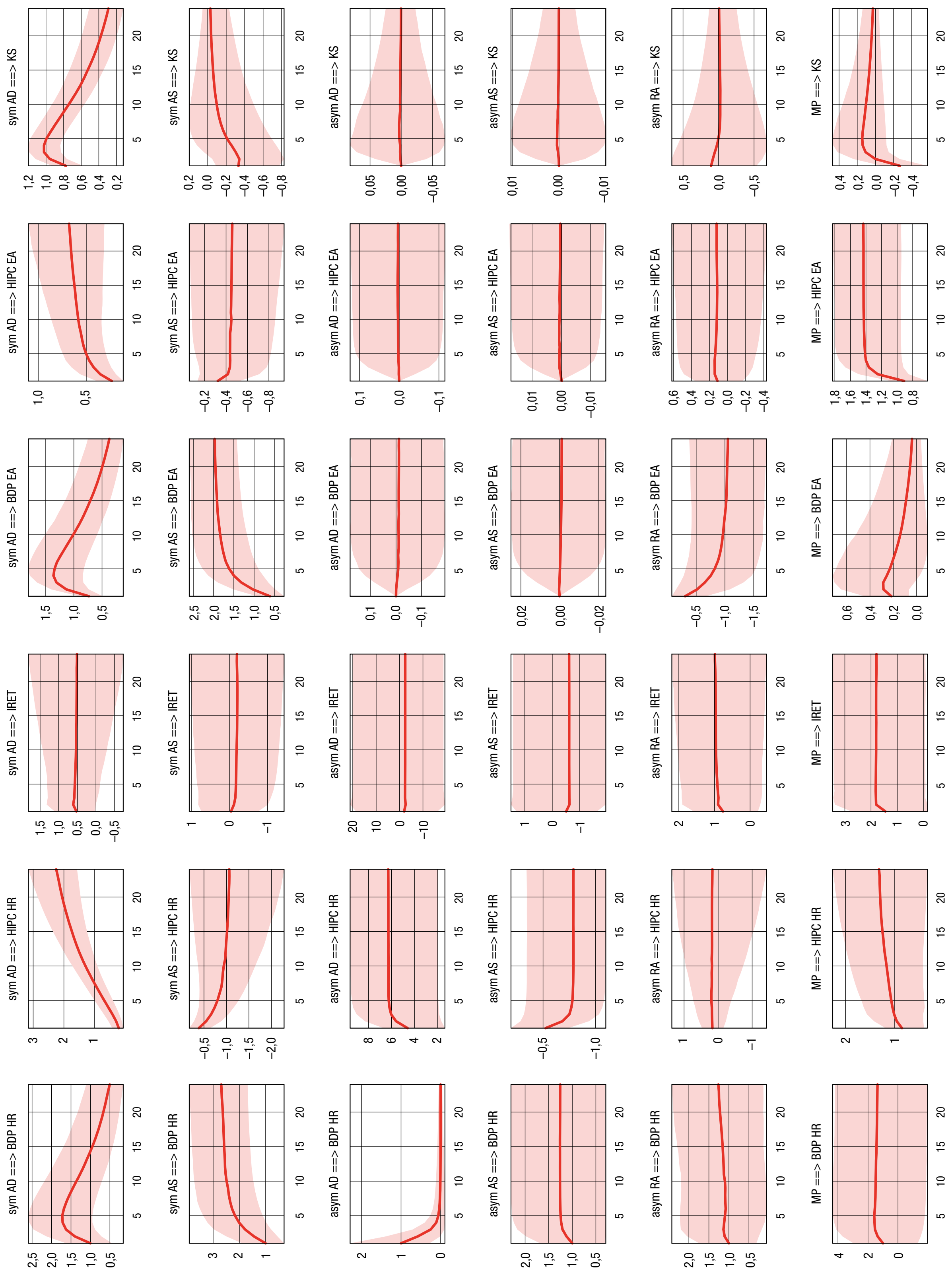
Notes: Contributions of symmetric shocks have been calculated as the percentage share of symmetric shocks (and monetary policy shocks) in the historical decomposition of the quarterly rate of growth of domestic GDP. Asymmetric shocks leading to a symmetric reaction in Croatian and euro area GDP have been added to symmetric shocks. The figure shows four-year moving averages.
Source: CNB.

Figure 22 Business cycles (GDP deviation from the HP trend)



Source: CNB.

Figure 23 Impulse response functions obtained from the VAR model for a small open economy – Croatia



Notes: Impulse response functions are shown in normalised form so that the reaction of domestic GDP at the moment of shock effect stands at 1%. Furthermore, the cumulative effect of individual shocks are shown for all variables except interest rates. Symmetric aggregate supply and aggregate demand shocks are indicated by *sym AD* and *sym AS*, while *asym AD* and *asym AS* denote idiosyncratic aggregate supply and aggregate demand shocks. The asymmetric real activity shock is indicated by *asym RA*, while the ECB monetary policy shock is represented by *MP*.
Source: CNB.

Table 3 Cycle correlations

	HR	AT	BE	BG	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IT	LT	LV	NL	PL	PT	RO	SE	SI	SK	UK
HR	1.00	0.59	0.45	0.76	0.64	0.54	0.49	0.70	0.44	0.59	0.61	0.46	0.65	0.56	0.80	0.74	0.49	0.42	0.27	0.71	0.50	0.72	0.75	0.60
AT	0.59	1.00	0.87	0.57	0.76	0.91	0.83	0.75	0.06	0.64	0.89	0.93	0.64	0.86	0.63	0.69	0.85	0.66	0.50	0.43	0.83	0.81	0.55	0.73
BE	0.45	0.87	1.00	0.47	0.75	0.81	0.79	0.60	0.16	0.68	0.82	0.90	0.64	0.87	0.45	0.49	0.81	0.72	0.63	0.36	0.86	0.77	0.45	0.71
BG	0.76	0.57	0.47	1.00	0.72	0.53	0.52	0.55	0.42	0.71	0.69	0.48	0.60	0.52	0.72	0.62	0.61	0.45	0.45	0.73	0.52	0.78	0.81	0.50
CZ	0.64	0.76	0.75	0.72	1.00	0.77	0.79	0.68	0.37	0.86	0.75	0.77	0.77	0.84	0.59	0.64	0.81	0.56	0.57	0.65	0.78	0.87	0.64	0.72
DE	0.54	0.91	0.81	0.53	0.77	1.00	0.81	0.75	0.04	0.63	0.87	0.91	0.64	0.90	0.62	0.64	0.83	0.55	0.52	0.46	0.84	0.80	0.57	0.74
DK	0.49	0.83	0.79	0.52	0.79	0.81	1.00	0.76	0.07	0.60	0.78	0.88	0.78	0.79	0.60	0.70	0.77	0.51	0.47	0.41	0.85	0.73	0.52	0.82
EE	0.70	0.75	0.60	0.55	0.68	0.75	0.76	1.00	0.00	0.38	0.72	0.72	0.77	0.67	0.85	0.90	0.50	0.36	0.09	0.50	0.72	0.63	0.60	0.83
EL	0.44	0.06	0.16	0.42	0.37	0.04	0.07	0.00	1.00	0.56	0.11	0.02	0.27	0.17	0.18	0.13	0.30	0.26	0.45	0.53	0.09	0.45	0.40	0.16
ES	0.59	0.64	0.68	0.71	0.86	0.63	0.60	0.38	0.56	1.00	0.65	0.62	0.55	0.75	0.37	0.41	0.84	0.64	0.79	0.55	0.67	0.86	0.58	0.53
FI	0.61	0.89	0.82	0.69	0.75	0.87	0.78	0.72	0.11	0.65	1.00	0.90	0.65	0.82	0.72	0.66	0.82	0.64	0.56	0.47	0.85	0.81	0.71	0.73
FR	0.46	0.93	0.90	0.48	0.77	0.91	0.88	0.72	0.02	0.62	0.90	1.00	0.66	0.89	0.56	0.62	0.84	0.62	0.55	0.36	0.88	0.74	0.48	0.77
HU	0.65	0.64	0.64	0.60	0.77	0.64	0.78	0.77	0.27	0.55	0.65	0.66	1.00	0.69	0.73	0.73	0.56	0.34	0.34	0.63	0.72	0.73	0.58	0.84
IT	0.56	0.86	0.87	0.52	0.84	0.90	0.79	0.67	0.17	0.75	0.82	0.89	0.69	1.00	0.50	0.51	0.81	0.59	0.64	0.40	0.88	0.79	0.49	0.71
LT	0.80	0.63	0.45	0.72	0.59	0.62	0.60	0.85	0.18	0.37	0.72	0.56	0.73	0.50	1.00	0.88	0.45	0.30	0.10	0.67	0.57	0.67	0.81	0.77
LV	0.74	0.69	0.49	0.62	0.64	0.64	0.70	0.90	0.13	0.41	0.66	0.62	0.73	0.51	0.88	1.00	0.50	0.38	0.06	0.58	0.59	0.65	0.65	0.79
NL	0.49	0.85	0.81	0.61	0.81	0.83	0.77	0.50	0.30	0.84	0.82	0.84	0.56	0.81	0.45	0.50	1.00	0.71	0.75	0.45	0.76	0.86	0.56	0.61
PL	0.42	0.66	0.72	0.45	0.56	0.55	0.51	0.36	0.26	0.64	0.64	0.62	0.34	0.59	0.30	0.38	0.71	1.00	0.57	0.20	0.58	0.61	0.38	0.42
PT	0.27	0.50	0.63	0.45	0.57	0.52	0.47	0.09	0.45	0.79	0.56	0.55	0.34	0.64	0.10	0.06	0.75	0.57	1.00	0.22	0.58	0.65	0.39	0.31
RO	0.71	0.43	0.36	0.73	0.65	0.46	0.41	0.50	0.53	0.55	0.47	0.36	0.63	0.40	0.67	0.58	0.45	0.20	0.22	1.00	0.33	0.70	0.65	0.53
SE	0.50	0.83	0.86	0.52	0.78	0.84	0.85	0.72	0.09	0.67	0.85	0.88	0.72	0.88	0.57	0.59	0.76	0.58	0.58	0.33	1.00	0.75	0.56	0.81
SI	0.72	0.81	0.77	0.78	0.87	0.80	0.73	0.63	0.45	0.86	0.81	0.74	0.73	0.79	0.67	0.65	0.86	0.61	0.65	0.70	0.75	1.00	0.73	0.71
SK	0.75	0.55	0.45	0.81	0.64	0.57	0.52	0.60	0.40	0.58	0.71	0.48	0.58	0.49	0.81	0.65	0.56	0.38	0.39	0.65	0.56	0.73	1.00	0.59
UK	0.60	0.73	0.71	0.50	0.72	0.74	0.82	0.83	0.16	0.53	0.73	0.77	0.84	0.71	0.77	0.79	0.61	0.42	0.31	0.53	0.81	0.71	0.59	1.00

Table 4 Cycle phase synchronicity

	HR	AT	BE	BG	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IT	LT	LV	NL	PL	PT	RO	SE	SI	SK	UK
HR	1.00	0.28	0.20	0.57	0.33	0.23	0.28	0.28	0.39	0.17	0.36	0.20	0.36	0.36	0.31	0.28	0.28	0.17	0.15	0.44	0.23	0.23	0.63	0.20
AT	0.28	1.00	0.60	0.39	0.36	0.57	0.25	0.25	−0.01	0.47	0.60	0.71	0.17	0.49	0.07	0.15	0.57	0.52	0.33	0.09	0.41	0.52	0.28	0.17
BE	0.20	0.60	1.00	0.47	0.55	0.49	0.39	0.12	0.17	0.60	0.57	0.52	0.20	0.63	−0.12	−0.04	0.60	0.65	0.47	0.17	0.65	0.71	0.36	0.31
BG	0.57	0.39	0.47	1.00	0.39	0.28	0.33	0.12	0.23	0.44	0.52	0.25	0.25	0.41	0.31	0.23	0.49	0.49	0.47	0.44	0.55	0.49	0.79	0.36
CZ	0.33	0.36	0.55	0.39	1.00	0.57	0.63	0.20	0.25	0.68	0.49	0.60	0.33	0.76	0.01	0.15	0.63	0.47	0.49	0.52	0.63	0.68	0.44	0.44
DE	0.23	0.57	0.49	0.28	0.57	1.00	0.57	0.09	−0.07	0.52	0.44	0.65	0.17	0.60	−0.09	−0.01	0.63	0.36	0.44	0.20	0.41	0.63	0.23	0.33
DK	0.28	0.25	0.39	0.33	0.63	0.57	1.00	0.25	0.20	0.47	0.39	0.49	0.44	0.60	0.12	0.25	0.57	0.36	0.33	0.36	0.47	0.47	0.33	0.65
EE	0.28	0.25	0.12	0.12	0.20	0.09	0.25	1.00	0.20	−0.12	0.12	0.17	0.55	0.07	0.60	0.73	−0.01	0.25	−0.20	0.20	0.04	0.04	0.28	0.28
EL	0.39	−0.01	0.17	0.23	0.25	−0.07	0.20	0.20	1.00	0.09	0.07	−0.04	0.28	0.17	0.12	0.20	0.09	0.15	0.07	0.36	0.15	0.15	0.28	0.17
ES	0.17	0.47	0.60	0.44	0.68	0.52	0.47	−0.12	0.09	1.00	0.49	0.55	0.17	0.71	−0.15	−0.07	0.73	0.52	0.71	0.31	0.68	0.68	0.33	0.33
FI	0.36	0.60	0.57	0.52	0.49	0.44	0.39	0.12	0.07	0.49	1.00	0.57	0.09	0.63	0.04	0.07	0.60	0.55	0.47	0.17	0.65	0.49	0.41	0.25
FR	0.20	0.71	0.52	0.25	0.60	0.65	0.49	0.17	−0.04	0.55	0.57	1.00	0.15	0.68	−0.12	0.01	0.60	0.49	0.36	0.28	0.49	0.49	0.15	0.31
HU	0.36	0.17	0.20	0.25	0.33	0.17	0.44	0.55	0.28	0.17	0.09	0.15	1.00	0.20	0.36	0.49	0.23	0.17	0.09	0.39	0.17	0.28	0.36	0.41
IT	0.36	0.49	0.63	0.41	0.76	0.60	0.60	0.07	0.17	0.71	0.63	0.68	0.20	1.00	−0.17	−0.04	0.65	0.49	0.52	0.33	0.71	0.65	0.36	0.36
LT	0.31	0.07	−0.12	0.31	0.01	−0.09	0.12	0.60	0.12	−0.15	0.04	−0.12	0.36	−0.17	1.00	0.76	−0.04	0.01	−0.12	0.23	0.01	−0.04	0.41	0.36
LV	0.28	0.15	−0.04	0.23	0.15	−0.01	0.25	0.73	0.20	−0.07	0.07	0.01	0.49	−0.04	0.76	1.00	0.04	0.04	−0.15	0.31	0.04	−0.01	0.33	0.39
NL	0.28	0.57	0.60	0.49	0.63	0.63	0.57	−0.01	0.09	0.73	0.60	0.60	0.23	0.65	−0.04	0.04	1.00	0.47	0.55	0.25	0.57	0.63	0.33	0.39
PL	0.17	0.52	0.65	0.49	0.47	0.36	0.36	0.25	0.15	0.52	0.55	0.49	0.17	0.49	0.01	0.04	0.47	1.00	0.39	0.20	0.52	0.52	0.44	0.23
PT	0.15	0.33	0.47	0.47	0.49	0.44	0.33	−0.20	0.07	0.71	0.47	0.36	0.09	0.52	−0.12	−0.15	0.55	0.39	1.00	0.12	0.65	0.55	0.36	0.20
RO	0.44	0.09	0.17	0.44	0.52	0.20	0.36	0.20	0.36	0.31	0.17	0.28	0.39	0.33	0.23	0.31	0.25	0.20	0.12	1.00	0.31	0.25	0.55	0.39
SE	0.23	0.41	0.65	0.55	0.63	0.41	0.47	0.04	0.15	0.68	0.65	0.49	0.17	0.71	0.01	0.04	0.57	0.52	0.65	0.31	1.00	0.57	0.39	0.49
SI	0.23	0.52	0.71	0.49	0.68	0.63	0.47	0.04	0.15	0.68	0.49	0.49	0.28	0.65	−0.04	−0.01	0.63	0.52	0.55	0.25	0.57	1.00	0.44	0.33
SK	0.63	0.28	0.36	0.79	0.44	0.23	0.33	0.28	0.28	0.33	0.41	0.15	0.36	0.36	0.41	0.33	0.33	0.44	0.36	0.55	0.39	0.44	1.00	0.31
UK	0.20	0.17	0.31	0.36	0.44	0.33	0.65	0.28	0.17	0.33	0.25	0.31	0.41	0.36	0.36	0.39	0.39	0.23	0.20	0.39	0.49	0.33	0.31	1.00

Table 5 Cycle similarity

	HR	AT	BE	BG	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IT	LT	LV	NL	PL	PT	RO	SE	SI	SK	UK
HR	1.00	–0.06	–0.12	0.17	–0.25	–0.27	–0.24	–0.86	–0.30	–0.08	–0.16	–0.12	–0.18	–0.02	–0.48	–0.89	–0.20	–0.22	–0.33	–0.18	–0.25	–0.16	0.10	–0.09
AT	–0.06	1.00	0.58	0.20	0.00	0.52	0.41	–0.86	–0.46	0.29	0.40	0.67	0.01	0.51	–0.81	–1.05	0.48	0.24	0.20	–0.27	0.32	0.26	–0.07	0.23
BE	–0.12	0.58	1.00	0.22	0.09	0.37	0.40	–0.93	–0.38	0.27	0.23	0.67	0.14	0.51	–0.89	–1.16	0.45	0.40	0.28	–0.20	0.35	0.27	–0.09	0.29
BG	0.17	0.20	0.22	1.00	0.07	–0.02	0.07	–1.01	–0.28	0.31	0.11	0.17	–0.05	0.18	–0.65	–1.08	0.23	0.07	0.12	–0.10	0.16	0.21	0.31	0.10
CZ	–0.25	0.00	0.09	0.07	1.00	0.00	0.18	–0.90	–0.52	0.30	–0.11	0.11	0.00	0.24	–1.03	–1.00	0.12	–0.08	–0.05	–0.22	0.24	0.23	–0.16	0.06
DE	–0.27	0.52	0.37	–0.02	0.00	1.00	0.29	–0.92	–0.59	0.16	0.25	0.48	–0.09	0.48	–0.93	–1.15	0.46	0.12	0.13	–0.32	0.17	0.30	–0.14	0.09
DK	–0.24	0.41	0.40	0.07	0.18	0.29	1.00	–0.75	–0.50	0.12	0.11	0.48	0.24	0.33	–0.74	–0.82	0.32	0.05	0.05	–0.33	0.32	0.13	–0.16	0.42
EE	–0.86	–0.86	–0.93	–1.01	–0.90	–0.92	–0.75	1.00	–1.43	–1.30	–1.01	–0.91	–0.65	–1.00	–0.34	–0.15	–1.16	–1.01	–1.44	–1.08	–0.99	–1.03	–0.94	–0.71
EL	–0.30	–0.46	–0.38	–0.28	–0.52	–0.59	–0.50	–1.43	1.00	–0.27	–0.58	–0.44	–0.38	–0.41	–1.07	–1.41	–0.45	–0.38	–0.36	–0.32	–0.53	–0.25	–0.39	–0.37
ES	–0.08	0.29	0.27	0.31	0.30	0.16	0.12	–1.30	–0.27	1.00	0.03	0.33	–0.09	0.39	–1.12	–1.41	0.37	0.07	0.32	–0.15	0.29	0.33	–0.10	0.12
FI	–0.16	0.40	0.23	0.11	–0.11	0.25	0.11	–1.01	–0.58	0.03	1.00	0.32	–0.29	0.26	–0.88	–1.14	0.28	0.18	0.06	–0.52	0.19	0.06	–0.10	–0.11
FR	–0.12	0.67	0.67	0.17	0.11	0.48	0.48	–0.91	–0.44	0.33	0.32	1.00	0.11	0.56	–0.79	–1.10	0.46	0.25	0.26	–0.21	0.34	0.21	–0.12	0.34
HU	–0.18	0.01	0.14	–0.05	0.00	–0.09	0.24	–0.65	–0.38	–0.09	–0.29	0.11	1.00	0.04	–0.71	–0.76	–0.14	–0.20	–0.22	–0.23	0.02	–0.05	–0.30	0.39
IT	–0.02	0.51	0.51	0.18	0.24	0.48	0.33	–1.00	–0.41	0.39	0.26	0.56	0.04	1.00	–0.97	–1.24	0.45	0.20	0.27	–0.22	0.42	0.28	–0.04	0.20
LT	–0.48	–0.81	–0.89	–0.65	–1.03	–0.93	–0.74	–0.34	–1.07	–1.12	–0.88	–0.79	–0.71	–0.97	1.00	–0.29	–1.05	–0.92	–1.22	–0.69	–0.92	–0.93	–0.38	–0.52
LV	–0.89	–1.05	–1.16	–1.08	–1.00	–1.15	–0.82	–0.15	–1.41	–1.41	–1.14	–1.10	–0.76	–1.24	–0.29	1.00	–1.22	–1.20	–1.52	–1.15	–1.16	–1.13	–0.90	–0.83
NL	–0.20	0.48	0.45	0.23	0.12	0.46	0.32	–1.16	–0.45	0.37	0.28	0.46	–0.14	0.45	–1.05	–1.22	1.00	0.25	0.40	–0.30	0.30	0.38	–0.04	0.09
PL	–0.22	0.24	0.40	0.07	–0.08	0.12	0.05	–1.01	–0.38	0.07	0.18	0.25	–0.20	0.20	–0.92	–1.20	0.25	1.00	0.14	–0.46	0.15	0.04	–0.06	–0.03
PT	–0.33	0.20	0.28	0.12	–0.05	0.13	0.05	–1.44	–0.36	0.32	0.06	0.26	–0.22	0.27	–1.22	–1.52	0.40	0.14	1.00	–0.42	0.17	0.22	–0.23	–0.12
RO	–0.18	–0.27	–0.20	–0.10	–0.22	–0.32	–0.33	–1.08	–0.32	–0.15	–0.52	–0.21	–0.23	–0.22	–0.69	–1.15	–0.30	–0.46	–0.42	1.00	–0.34	–0.14	–0.20	–0.10
SE	–0.25	0.32	0.35	0.16	0.24	0.17	0.32	–0.99	–0.53	0.29	0.19	0.34	0.02	0.42	–0.92	–1.16	0.30	0.15	0.17	–0.34	1.00	0.14	–0.09	0.28
SI	–0.16	0.26	0.27	0.21	0.23	0.30	0.13	–1.03	–0.25	0.33	0.06	0.21	–0.05	0.28	–0.93	–1.13	0.38	0.04	0.22	–0.14	0.14	1.00	0.03	0.04
SK	0.10	–0.07	–0.09	0.31	–0.16	–0.14	–0.16	–0.94	–0.39	–0.10	–0.10	–0.12	–0.30	–0.04	–0.38	–0.90	–0.04	–0.06	–0.23	–0.20	–0.09	0.03	1.00	–0.14
UK	–0.09	0.23	0.29	0.10	0.06	0.09	0.42	–0.71	–0.37	0.12	–0.11	0.34	0.39	0.20	–0.52	–0.83	0.09	–0.03	–0.12	–0.10	0.28	0.04	–0.14	1.00

Table 6 Supply shock correlations

	HR	AT	BE	BG	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IT	LT	LV	NL	PL	PT	RO	SE	SI	SK	UK
HR	1.00	0.28	0.20	0.05	0.19	0.24	0.13	0.14	0.16	0.18	0.07	0.30	0.34	0.21	0.21	0.11	0.10	0.21	0.14	0.25	0.07	0.21	0.03	0.17
AT	0.28	1.00	0.48	0.07	0.09	0.35	0.15	0.03	0.14	0.09	0.20	0.47	0.22	0.30	0.12	−0.05	0.24	0.39	0.14	0.17	0.10	0.22	0.03	0.24
BE	0.20	0.48	1.00	0.05	0.12	0.18	0.09	0.26	0.10	0.19	0.20	0.44	0.30	0.35	−0.02	−0.09	0.18	0.46	0.21	0.11	0.16	0.20	−0.10	0.29
BG	0.05	0.07	0.05	1.00	0.33	0.22	0.02	0.06	0.14	0.19	0.39	0.06	0.15	0.03	0.51	−0.01	0.23	0.02	0.26	0.40	0.05	0.22	0.39	−0.05
CZ	0.19	0.09	0.12	0.33	1.00	0.46	0.17	0.43	0.29	0.20	0.44	0.43	0.48	0.10	0.56	0.20	0.56	0.06	0.34	0.33	0.42	0.45	0.43	−0.04
DE	0.24	0.35	0.18	0.22	0.46	1.00	0.20	0.26	0.31	0.14	0.54	0.52	0.37	0.25	0.49	0.15	0.50	0.20	0.19	0.36	0.41	0.37	0.35	0.29
DK	0.13	0.15	0.09	0.02	0.17	0.20	1.00	0.02	−0.01	0.25	0.23	0.25	0.22	0.26	0.20	0.07	0.38	0.09	0.21	−0.01	0.31	0.15	0.30	0.07
EE	0.14	0.03	0.26	0.06	0.43	0.26	0.02	1.00	0.11	0.02	0.09	0.20	0.35	−0.02	0.14	0.20	0.21	0.27	0.07	0.22	0.50	0.26	0.02	0.12
EL	0.16	0.14	0.10	0.14	0.29	0.31	−0.01	0.11	1.00	0.13	0.34	0.31	0.17	0.39	0.42	0.17	0.38	−0.09	0.18	0.36	0.19	0.13	0.26	0.08
ES	0.18	0.09	0.19	0.19	0.20	0.14	0.25	0.02	0.13	1.00	0.30	0.30	0.22	0.34	0.28	0.20	0.32	0.11	0.49	0.09	0.14	0.26	0.24	0.33
FI	0.07	0.20	0.20	0.39	0.44	0.54	0.23	0.09	0.34	0.30	1.00	0.44	0.21	0.24	0.61	0.16	0.51	0.18	0.49	0.37	0.35	0.26	0.58	0.13
FR	0.30	0.47	0.44	0.06	0.43	0.52	0.25	0.20	0.31	0.30	0.44	1.00	0.32	0.50	0.38	0.20	0.33	0.38	0.30	0.24	0.20	0.17	0.19	0.32
HU	0.34	0.22	0.30	0.15	0.48	0.37	0.22	0.35	0.17	0.22	0.21	0.32	1.00	0.05	0.29	0.19	0.32	0.19	0.21	0.38	0.30	0.33	0.18	0.11
IT	0.21	0.30	0.35	0.03	0.10	0.25	0.26	−0.02	0.39	0.34	0.24	0.50	0.05	1.00	0.07	0.19	0.23	0.17	0.37	0.13	0.19	0.10	0.05	0.17
LT	0.21	0.12	−0.02	0.51	0.56	0.49	0.20	0.14	0.42	0.28	0.61	0.38	0.29	0.07	1.00	0.29	0.54	−0.02	0.24	0.35	0.21	0.29	0.59	0.09
LV	0.11	−0.05	−0.09	−0.01	0.20	0.15	0.07	0.20	0.17	0.20	0.16	0.20	0.19	0.19	0.29	1.00	0.22	0.02	0.07	0.07	0.23	0.08	0.17	0.01
NL	0.10	0.24	0.18	0.23	0.56	0.50	0.38	0.21	0.38	0.32	0.51	0.33	0.32	0.23	0.54	0.22	1.00	0.10	0.49	0.32	0.48	0.26	0.43	0.13
PL	0.21	0.39	0.46	0.02	0.06	0.20	0.09	0.27	−0.09	0.11	0.18	0.38	0.19	0.17	−0.02	0.02	0.10	1.00	0.01	0.04	0.18	0.04	−0.10	0.20
PT	0.14	0.14	0.21	0.26	0.34	0.19	0.21	0.07	0.18	0.49	0.49	0.30	0.21	0.37	0.24	0.07	0.49	0.01	1.00	0.15	0.34	0.23	0.27	0.10
RO	0.25	0.17	0.11	0.40	0.33	0.36	−0.01	0.22	0.36	0.09	0.37	0.24	0.38	0.13	0.35	0.07	0.32	0.04	0.15	1.00	0.25	0.02	0.32	0.04
SE	0.07	0.10	0.16	0.05	0.42	0.41	0.31	0.50	0.19	0.14	0.35	0.20	0.30	0.19	0.21	0.23	0.48	0.18	0.34	0.25	1.00	0.27	0.33	0.20
SI	0.21	0.22	0.20	0.22	0.45	0.37	0.15	0.26	0.13	0.26	0.26	0.17	0.33	0.10	0.29	0.08	0.26	0.04	0.23	0.02	0.27	1.00	0.31	−0.08
SK	0.03	0.03	−0.10	0.39	0.43	0.35	0.30	0.02	0.26	0.24	0.58	0.19	0.18	0.05	0.59	0.17	0.43	−0.10	0.27	0.32	0.33	0.31	1.00	−0.07
UK	0.17	0.24	0.29	−0.05	−0.04	0.29	0.07	0.12	0.08	0.33	0.13	0.32	0.11	0.17	0.09	0.01	0.13	0.20	0.10	0.04	0.20	−0.08	−0.07	1.00

Table 7 Demand shock correlations

	HR	AT	BE	BG	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IT	LT	LV	NL	PL	PT	RO	SE	SI	SK	UK
HR	1.00	0.48	0.53	0.48	0.28	0.48	0.52	0.48	0.44	0.56	0.39	0.58	0.47	0.58	0.25	0.26	0.45	0.35	0.40	0.15	0.41	0.61	0.19	0.50
AT	0.48	1.00	0.67	0.24	0.36	0.67	0.53	0.62	0.52	0.51	0.56	0.61	0.16	0.44	0.34	0.24	0.47	0.17	0.53	–0.01	0.40	0.39	0.13	0.60
BE	0.53	0.67	1.00	0.42	0.42	0.69	0.56	0.70	0.61	0.55	0.62	0.68	0.47	0.62	0.36	0.26	0.47	0.34	0.50	0.13	0.43	0.49	0.08	0.57
BG	0.48	0.24	0.42	1.00	0.34	0.33	0.43	0.39	0.38	0.35	0.34	0.40	0.40	0.43	0.30	0.22	0.15	0.12	0.26	0.11	0.24	0.44	0.39	0.34
CZ	0.28	0.36	0.42	0.34	1.00	0.49	0.46	0.46	0.29	0.30	0.52	0.44	0.36	0.40	0.38	0.06	0.32	0.32	0.36	0.27	0.27	0.36	0.15	0.22
DE	0.48	0.67	0.69	0.33	0.49	1.00	0.56	0.61	0.55	0.64	0.65	0.76	0.34	0.48	0.49	0.23	0.65	0.32	0.60	0.17	0.48	0.45	0.32	0.60
DK	0.52	0.53	0.56	0.43	0.46	0.56	1.00	0.57	0.47	0.60	0.64	0.64	0.45	0.52	0.51	0.30	0.45	0.37	0.60	0.19	0.62	0.46	0.37	0.51
EE	0.48	0.62	0.70	0.39	0.46	0.61	0.57	1.00	0.49	0.66	0.59	0.63	0.30	0.56	0.49	0.21	0.44	0.27	0.40	0.29	0.58	0.48	0.12	0.50
EL	0.44	0.52	0.61	0.38	0.29	0.55	0.47	0.49	1.00	0.53	0.52	0.64	0.39	0.52	0.29	0.13	0.33	0.25	0.43	0.16	0.46	0.42	0.16	0.34
ES	0.56	0.51	0.55	0.35	0.30	0.64	0.60	0.66	0.53	1.00	0.51	0.69	0.32	0.59	0.44	0.09	0.46	0.28	0.54	0.32	0.45	0.44	0.14	0.57
FI	0.39	0.56	0.62	0.34	0.52	0.65	0.64	0.59	0.52	0.51	1.00	0.62	0.35	0.46	0.43	0.10	0.50	0.26	0.55	0.18	0.57	0.31	0.10	0.42
FR	0.58	0.61	0.68	0.40	0.44	0.76	0.64	0.63	0.64	0.69	0.62	1.00	0.39	0.66	0.39	0.15	0.48	0.30	0.62	0.12	0.62	0.53	0.22	0.64
HU	0.47	0.16	0.47	0.40	0.36	0.34	0.45	0.30	0.39	0.32	0.35	0.39	1.00	0.50	0.17	0.17	0.32	0.47	0.36	0.25	0.29	0.47	0.26	0.30
IT	0.58	0.44	0.62	0.43	0.40	0.48	0.52	0.56	0.52	0.59	0.46	0.66	0.50	1.00	0.21	0.05	0.36	0.27	0.44	0.19	0.31	0.58	0.17	0.48
LT	0.25	0.34	0.36	0.30	0.38	0.49	0.51	0.49	0.29	0.44	0.43	0.39	0.17	0.21	1.00	0.36	0.20	0.16	0.35	0.11	0.46	0.19	0.24	0.35
LV	0.26	0.24	0.26	0.22	0.06	0.23	0.30	0.21	0.13	0.09	0.10	0.15	0.17	0.05	0.36	1.00	0.12	0.29	0.13	–0.11	0.28	0.21	0.17	0.21
NL	0.45	0.47	0.47	0.15	0.32	0.65	0.45	0.44	0.33	0.46	0.50	0.48	0.32	0.36	0.20	0.12	1.00	0.23	0.58	0.11	0.46	0.40	0.29	0.45
PL	0.35	0.17	0.34	0.12	0.32	0.32	0.37	0.27	0.25	0.28	0.26	0.30	0.47	0.27	0.16	0.29	0.23	1.00	0.30	0.12	0.16	0.43	0.02	0.19
PT	0.40	0.53	0.50	0.26	0.36	0.60	0.60	0.40	0.43	0.54	0.55	0.62	0.36	0.44	0.35	0.13	0.58	0.30	1.00	0.13	0.43	0.38	0.26	0.47
RO	0.15	–0.01	0.13	0.11	0.27	0.17	0.19	0.29	0.16	0.32	0.18	0.12	0.25	0.19	0.11	–0.11	0.11	0.12	0.13	1.00	0.14	0.05	0.17	–0.07
SE	0.41	0.40	0.43	0.24	0.27	0.48	0.62	0.58	0.46	0.45	0.57	0.62	0.29	0.31	0.46	0.28	0.46	0.16	0.43	0.14	1.00	0.42	0.34	0.34
SI	0.61	0.39	0.49	0.44	0.36	0.45	0.46	0.48	0.42	0.44	0.31	0.53	0.47	0.58	0.19	0.21	0.40	0.43	0.38	0.05	0.42	1.00	0.23	0.47
SK	0.19	0.13	0.08	0.39	0.15	0.32	0.37	0.12	0.16	0.14	0.10	0.22	0.26	0.17	0.24	0.17	0.29	0.02	0.26	0.17	0.34	0.23	1.00	0.25
UK	0.50	0.60	0.57	0.34	0.22	0.60	0.51	0.50	0.34	0.57	0.42	0.64	0.30	0.48	0.35	0.21	0.45	0.19	0.47	–0.07	0.34	0.47	0.25	1.00

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