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## Abstract

Business cycle synchronisation between the V4 countries and the euro area is important in regard to the costs of the common monetary policy. This paper addresses the issue of business cycle synchronisation by directly calculating cross correlations, by calculating cross correlations from primary impulses, and finally by calculating output gap component correlations from common and country-specific shocks. In regard to the output gap, the results of all three methods are approximately the same: before 2001, the business cycles of the V4 countries were not synchronised with the euro area (low or negative correlations); between 2001 and 2007, the correlations entered positive territory as the V4 countries joined the EU and trade between the V4 countries and the euro area increased; and during the economic crisis of 2008–2009, synchronisation increased still further.

JEL classification: E32, F02
Key words: optimum currency area, business cycle, autoregressive model, SVAR

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# INTRODUCTION

When joining the European Union, the V4 countries undertook to adopt the euro single currency. Slovakia fulfilled this commitment on 1 January 2009 and, in doing so, relinquished its independent monetary policy. In this light, the question arises whether the V4 countries will create an optimum currency area (OCA) with the euro area. To meet the criteria of an optimum currency area, a group of countries must have a wage level that is sufficiently flexible (mainly downwards) or there must be free movement of labour between the countries. The good functioning of an optimum currency area may be supported by the common budget, through which funds can be redistributed from one country to another. The euro area, when compared to the USA, fails to meet the criteria of an optimum currency area (wages are less flexible and the movement of labour between is lower due to language barriers) and the common budget is not large enough to be able to significantly eliminate temporary differences in economic performance caused by asymmetric shocks.

The economies of particular countries may change during the process of integration into the economic and monetary union. There are two established views on these changes: the OCA endogeneity hypothesis and the Krugman hypothesis. According to the OCA endogeneity hypothesis, formulated by Frankel and Rose (1998), the higher the level of integration, the smaller the differences between countries and the lower the likelihood of asymmetric shocks. According to Krugman (1993), individual countries will specialise after integration, therefore increasing the likelihood of asymmetric shocks.

The higher the openness of countries, the greater the effects on monetary union. As regards the cost-benefit analysis of the monetary union, the result depends on whether we expected amplified symmetric shocks (Frankel and Rose) or asymmetric shocks. Both theories assume that the benefits of monetary union are an increasing function of openness. According to the first theory, the costs of monetary union are a decreasing function of openness; therefore monetary union brings net benefits even for semi-open economies and these increase sharply as openness rises. According to the Krugman theory, the costs of monetary union are an increasing function of openness, but they rise more slowly than the benefits. In this case, the costs and benefit curves of monetary union intersect only for very open economies and the net benefits of monetary union, if positive, are relatively low.

This paper aims to examine in empirical terms business cycle synchronisation in the V4 countries, with the business cycle defined as the short-term variation in real output around potential output. The presence of asymmetric shocks indicates asynchronous business cycles, while synchronous cycles imply that the costs of the common monetary policy are relatively low. The net advantage of euro area membership for V4 countries depends on the relative size of such costs.

In this paper, we will begin with simpler methods and work towards more sophisticated ones. After reviewing the literature, we will make a simple analysis of output gap correlations, then continue by examining the correlations of business cycles' primary impulses, and, finally, analyse the contributions of common and country-specific shocks identified using VAR models.

# 1. LITERATURE REVIEW

Business cycle synchronisation has been the subject of research at least since the OCA theory was formulated. The number of studies in this field has been notably rising since the mid-1990s, when the issue of European monetary integration started coming to the fore. The relevant literature may be divided into three groups: the examination of business cycle synchronisation directly on a time series basis; the examination of causes and factors that affect business cycle synchronisation and OCA endogeneity; and the search for structural shocks that affect business cycle synchronisation.

## 1.1 STUDIES EXAMINING TIME SERIES PROPERTIES

The simplest way of examining synchronisation is by detrending an indicator of economic activity (GDP or industrial production; sometimes also GDP components) and by calculating pairwise correlations, cross correlations, or Spearman correlation coefficients. This approach is followed by Artis and Zhang (1995) for 12 countries in the European Exchange Rate Mechanism and non-European G7 countries, as well as by Fidrmuc and Korhonen (2003), Darvas and Szapáry (2005), Levasseur (2008), Kappler et al. (2008), Gouveia and Correia (2008) and Gogas and Kothroulas (2009). The majority of studies concur that the business cycle of European countries has synchronised, although Kappler et al. (2008) reach a less clear-cut result, while Gouveia and Correia (2008) and Gogas and Kothroulas (2009) point to the divergence between the EU core and periphery countries and to the fact that a common monetary policy may not necessarily be optimal for all countries involved. According to earlier studies on accession countries, the most synchronised countries were Hungary, Poland and Slovenia, while some later studies also include Slovakia in this bracket.

Aguiar-Conraria and Soares (2009) study business cycle synchronisation with the help of wavelets, specifically a continuous wavelet transform. They identified the EMU core and periphery, with the business cycles of periphery countries converging to the business cycles of core countries, albeit it at different speeds. Crowley and Lee (2005), using a similar mathematical apparatus, demonstrate that even though the cycle synchronisation in general (for all frequencies) has not changed, certain smaller countries as well as Denmark and the United Kingdom converged for frequencies corresponding to the business cycle.

Kappler et al. (2008) calculated coherence, phase shift, and dynamic correlations and found that the business cycles of Greece and Finland, following their adoption of the euro, lagged the euro area business cycle. They also examined nominal and fiscal convergence using dispersions of different variables. The adoption of the euro led to low and stable dispersion of output and inflation, but not of general government budget deficits and real interest rates. On the basis of a cluster analysis, they defined the following groups of countries: 1. Austria, Germany and the Netherlands; 2. France, Belgium, Italy and Spain; and 3. Greece and Portugal. Ireland, Luxembourg, and Finland were not associated. Savva, Neanidis and Osborn (2007) use monthly industrial production (an HP filter cycle) to examine the synchronisation of old and new EU member countries and candidate countries and they use a VAR-GARCH model for two-variable vectors (the euro area and individual country) with time-variable correlation. Since the beginning of the 1990s, accession countries have at least doubled the correlation or changed the correlation from negative to positive, which shows an increased level of business cycle synchronisation.

Darvas and Szapáry construct a common factor (by using a Kalman filter) and a VAR model for the common factor and for the GDP of the euro area and a given country. They evaluate correlations, lead-lag, cycle volatility, inertia (serial correlation) and the response to shocks simulated by the VAR model (a common shock to individual countries). They divide accession countries into synchronised (Slovenia, Hungary, Poland), less synchronised (the Czech Republic and Slovakia), and unsynchronised (the rest).

The results of particular studies are summarised in Table 1.

## 1.2 STUDIES EXAMINING FACTORS IN BUSINESS CYCLE SYNCHRONISATION AND IN THE ENDOGENEITY OF AN OPTIMUM CURRENCY AREA.

The easiest way to describe factors related to business cycle synchronisation is by computing the correlation of GDP components and interpreting them. Levasseur (2008) calculates GDP components and their contributions to the change in GDP co-movements. Internal factors make the greatest contribution, while the contribution of external trade is mostly positive, but less significant. In contrast, the high correlation of accession countries' exports and the euro area's imports shows a strong interconnection. A similar analysis for consumption is carried out by Darvas and Szapáry (2005).

Panel regressions are frequently used for the analysis of business cycle synchronisation. These involve the observation of country pairs over a specific period of time, where the dependent variable is either a correlation coefficient or its transformation and the explanatory variables are external trade, financial links, and indicators of labour market rigidity in the particular countries. A dummy variable representing monetary union membership may also be used. According to Fidrmuc (2004), the correlations of the V4 countries' business cycle are caused by the intensity of mutual trade and by the intra-industry trade index. He establishes that such correlations lose their connection with overall mutual trade if other variables are also included in the regression. Nevertheless, intra-industry trade is always significant. The OCA endogeneity hypothesis is therefore confirmed in regard to intra-industry trade. The most synchronised of the accession countries are Hungary, Slovenia and Poland. Darvas et al. (2004) examine the relationship between the business cycle correlations of country pairs and the differences in the countries' deficit-to-GDP ratios. They conclude that synchronised fiscal policy leads to greater synchronisation of business cycles. They also examine a panel of 21 OECD countries and 40 annual observations of deviations from the trend output and fiscal position. They find that higher deficits lead to higher output volatility. Complying with the Maastricht criterion for the general government deficit (below 3 percent of GDP) will lead to a decrease in business cycle volatility. Traistaru (2005) explains the correlation coefficients by dummy variables for monetary union and accession countries or, alternatively, by specialisation and trade. Variables that take into account both specialisation and trade are significant. Despite indications of the endogeneity of the monetary union, the author emphasises the low correlations between the accession countries and the euro area. Kappler et al. (2008) model correlation coefficients as functions of various variables: fiscal similarity, trade union membership, co-ordination and centralisation of negotiations, the benefit compensation rate and wage tax rate, the level of employment protection, the centralisation of negotiations, and the long-term interest rate (absolute difference). The dummy variable was also insignificant for monetary union, and so the impact of the euro adoption on business cycle synchronisation was not proven. As explanatory variables in the regression for OECD countries, Artis, Fidrmuc and Scharler (2008) use the intensity of mutual trade, intra-industry trade, foreign direct investment intensity, the sum of labour market rigidity indicators, the sum of government deficit-to–GDP ratios, and a dummy variable for monetary union (this variable is statistically important) . Their preferred specification enables the identification of business cycle synchronisation factors in accession countries. The integration effects provide support for business cycle synchronisation; the effect of labour market rigidity on such synchronisation is negative, since it promotes the acquisition of specific skills that reduce mobility between industries, and support specialisation, thus making asymmetric shocks more likely to occur. Fiscal policy also represents a source of idiosyncratic shocks and adversely affects business cycle synchronisation. According to this study, the most synchronised countries are Hungary, Poland and Slovenia. The correlation of Slovakia is close to zero and negative factors have a significant weight.

Rose (2008) carries out a meta-analysis of market sensitivity to monetary union and of the sensitivity of business cycle synchronisation indicators (correlations) to mutual trade. By evaluating twenty-six and twenty studies using, respectively, fixed and random-effect methods, he obtains values for the sensitivity of business cycle synchronisation to reciprocal trade and monetary union, which were positive and varied significantly from zero. The author confirms his findings from 1998 that there is a positive virtuous cycle where monetary union supports mutual trade, thus increasing business cycle synchronisation.

Fidrmuc and Korhonen (2010) examine the influence of the world economic crisis on China and India. Before the outbreak of the crisis, the business cycle of these countries was unsynchronised – thus supporting the theory of decoupling.[2] During the crisis, however, the business cycle became more synchronised due to the decrease in international trade. A positive influence on international trade could be seen in the dynamic correlations for business cycle frequencies and long-term frequencies.

This theory does not make clear how financial integration affects business cycle synchronisation. On one hand, its synchronising effect may be similar to that of mutual trade; on the other hand, it may support specialisation and susceptibility to asymmetric shocks (as proven by Kalemli-Ozcan et al., 2001). Maurel (2004) examines the effects of financial integration on decisions about joining the monetary union. He examines the correlation of the investment-to-GDP ratio to the savings-to-GDP ratio and its interaction with openness, using observations for fifteen original EU member countries and seven accession EU member countries. The results support the hypothesis of financial interconnectedness. He also models the flexibility of cross exchange rates of country pairs as a function of financial integration, and the asymmetry of supply and demand shocks. While the first two variables shift the exchange rate regime towards a fixed exchange rate, the

[2] Decoupling represents the separation of the business cycle of Asian countries from the business cycle of advanced America and Europe.

asymmetry of demand shocks shifts the regime towards a floating exchange rate. The paper concludes by stating that in European conditions of financial interconnectedness, the exchange rate is not effective in eliminating asymmetric shocks, and also that the advantages of early entry into the monetary union are greater than the costs of the exchange rate being fixed at an incorrect level.

## 1.3 STUDIES IDENTIFYING STRUCTURAL SHOCKS

The most common way of identifying structural shocks is by calculating supply, demand and, if need be, monetary shocks by means of a structural VAR model identified by long-term multipliers, as carried out by Bayoumi and Eichengreen (1993) using the calculation of Blanchard and Quah (1989). This method involves estimating models and calculating structural shocks for particular countries, and then calculating the structural shock correlations. Levasseur (2008) applies it to EU accession countries and the euro area, finding that supply shock correlations are lower and that demand shock correlations are higher, mainly in Slovenia and Latvia. Fidrmuc and Korhonen (2003) show that supply shocks are more correlated than demand shocks. Supply shocks are also more significant, since the economic policy that causes demand shocks will converge. The correlation of supply shocks is highest in Poland and is also high in Hungary, the Czech Republic and Latvia. Slovakia has a negative correlation of supply shocks. The authors highlight the relationship between business cycle synchronisation and mutual trade, mainly within industries. Therefore, in their view, the increase in business cycle synchronisation is a consequence of growing trade. They also warn, however, that accession countries have a deficit fiscal policy and will need to move towards a balanced budget as part of the process of meeting the Maastricht criteria. In their study, the correlation of shocks for Slovakia could be affected by the choice of period under review, since Slovakia experienced a boom caused by an expansive fiscal policy and then stagnation caused by fiscal consolidation. Fidrmuc and Korhonen (2006) carry out a review and meta-analysis of further such studies and also of several studies that use correlations. They establish that the cycle of Hungary, Poland and Slovenia is sufficiently synchronised with the EU cycle so as not to prevent monetary union, but they also point out necessity of convergence of economic policies and that studies using quarterly data offer higher correlations than those using monthly data. Furthermore, correlations calculated in a simple way were higher than those based on more complex models.

Babetskii (2004) uses a Kalman filter to estimate time-variable correlation coefficients: they are cumulative processes that depend on differences in shocks between, on one hand, the accession countries and Germany or the EU-15, and, on the other hand, between Germany and the EU-15. For country convergence, such time-variable correlation coefficients should l decrease over time, as confirmed for demand shocks. Their correlation with the intensity of reciprocal trade is also calculated. A positive correlation coefficient supports the Krugman hypothesis and a negative correlation coefficient is evidence for the hypothesis formulated by Frankel and Rose (1998). Demand shock coefficients always come out negative (in favour of this hypothesis) and supply shock coefficients are mainly positive. The author also presents the panel regression of the correlation index in relation to trading intensity and exchange rate volatility. Regarding trade intensity, the result remains unchanged. In the case of Germany, the reduction of exchange rate volatility leads to demand shock convergence, while supply shocks are not affected. Thus, the fixed exchange rate of accession countries will lead to the synchronisation of demand shocks.

Structural shocks may also be calculated using a vector auto-regression for the GDP growth rate or output gap of different countries, and with subsequent identification. This model enables the calculation of both common (symmetric) shocks that affect all countries and country-specific shocks affecting only a single country, as well as the contributions that these shocks make to the development of the business cycle. Perez et al. (2003) construct three-component VAR models for the GDP growth rate of the United States, EU-15, and one other G7 country, so that the structural shocks have a diagonal covariance matrix, rather than an identity matrix. According to them, the results show a decrease in business cycle volatility. Given the lower standard deviation, economic growth is more stable in the EU-15 than in the United States, but this is not the case with individual countries. Although the European business cycle decoupled from the US cycle after 1980, the US shocks started to have an effect again after 1993. Stock and Watson (2005) construct a factor SVAR (FSVAR) model for all the countries and use it to identify the influence of two common shocks, spillovers, and the effect of idiosyncratic shocks. After 1983, the contribution of common shocks increased and reached around 90 percent in Canada and France. The reduced business cycle volatility was caused mainly by lower shock volatility. In Canada, France, the United Kingdom and the United States, the volatility of impulse-response functions increased. To calculate the counterfactual correlations that determine correlations for a common or country-specific shock, Kappler et al. (2008) use VAR models for the output gap, GDP growth and inflation (the vector of endogenous variables comprises a variable for the euro area and one specific country). For the output gap, these correlations are positive and high, indicating similar responses to shocks. They also construct a factor SVAR model identified by long-run multipliers for the output gap, real interest rate, and inflation in G7 countries. The structural shocks (supply, demand and nominal) for each country are a function of common factors and idiosyncratic shocks. They calculate counterfactual correlations, as if the system as a whole was subject to only one type of shock, and also calculate the historical decomposition for determining the importance of shocks. The counterfactual correlations show high similarity in responses to shocks for the output gap. Giannone and Reichlin (2006) construct an SVAR model for the GDP level in the euro area and individual countries, with structural shocks interpreted as common and country-specific shocks. They conclude that the growth gap – the difference in business cycles – between the euro area and individual countries is largely attributable to shocks specific to a particular country, but that output is not (except in Greece, Finland and Ireland). They calculate counterfactual correlations for output as if the countries were subject only to a common or country-specific shock. According to their calculations, asymmetries are caused by idiosyncratic shocks, not by different responses to common shocks.

Inagaki (2005) examines the effect of euro adoption using correlations of residuals. He uses a monthly time series of the industrial production growth rate for a majority of euro area countries between 1994 and 2003. For each country, he first estimates an autoregressive model and examines correlations between the residuals of these models and the residuals for Germany, while also examining the lead/lag for particular country pairs. For the period between 1994 and 1998, there are 11 country pairs with significant contemporaneous correlations, and between 1999 and 2003 there are 23 country pairs. Taking Germany as the basis for comparison, the contemporaneous correlation of residuals between 1994 and 1998 is mostly not significant; nevertheless, the cycles of most countries are dependent on the German cycle, with lags/leads ranging from -10 months (lead) to +7 months (lag). Therefore, the business cycles are dependent but not synchronised. For the period between

1999 and 2003, the contemporaneous correlation of the majority of countries is significant; the lag/lead no more than 3 months, which can be considered a short period of time. The author thus infers empirical support for the OCA endogeneity hypothesis.

The cited literature deals with the business cycle synchronisation of either G7 countries or various combinations of European countries. Overall, it may be said that business cycles are synchronised to a great extent and that synchronisation increases over time, with the possible exception of some small countries in western Europe. For countries in central and eastern Europe, the results differ for different periods under review, but some more recent studies indicate that the business cycle in Slovakia is relatively synchronised. The majority of studies also recognise the endogeneity of the optimum currency area, but also that it may be negated by unsuitable economic policy. The main findings of individual studies are summarised in Table 1.

**Table 1 Summary of literature and main findings**

| Author | Year | Area under review | Presence of synchronisation | OCA endogeneity hypothesis/ Krugman hypothesis |
|---|---|---|---|---|
| Artis and Zhang | 1995 | ERM countries and G7 countries outside of Europe | Before the ERM was established, the cycle of European countries is synchronised with the US cycle; afterwards, the cycle of European countries (except for the UK and Ireland) is synchronised with Germany. | Not mentioned. |
| Artis Fidrmuc and Scharler | 2008 | OECD countries | The most synchronised accession countries, are Hungary, Poland and Slovenia. | Optimum currency area is endogenous. |
| Fidrmuc and Korhonen | 2003 | EU countries and access countries | Hungary, the Czech Republic and Latvia have a high correlation with the EU; Slovakia has a negative correlation of supply shocks. | Authors incline in favour of OCA endogeneity. |
| Fidrmuc | 2004 | OECD countries | Among accession countries, Hungary, Poland and Slovenia have high synchronisation with Germany. | OCA endogeneity hypothesis is confirmed for intra-industry trade. When preparing for EMU, the countries were |

| | | | | |
|---|---|---|---|---|
| | | | | synchronised. |
| Fidrmuc and Korhonen | 2006 | Accession countries | Hungary, Poland and Slovenia have a high rate of synchronisation. | Not mentioned. |
| Babetskii | 2004 | EU and accession countries, United States | In the period 1999–2002, demand shocks of accession countries correlated positively with Germany and the euro area; supply shocks correlated too, but to a lesser extent. | Study results tend to favour OCA endogeneity. |
| Darvas et al. | 2005 | 21 OECD countries | Not mentioned | Fiscal convergence supports business cycle convergence and the beneficial effect of monetary union. |
| Darvas and Szapáry | 2008 | Euro area and accession countries, other major economies | Slovenia, Hungary and Poland are synchronised; the Czech Republic and Slovakia are less synchronised; other accession countries are unsynchronised. | Authors are slightly in favour of OCA endogeneity, and claim that a global cycle is emerging. |
| Traistaru | 2005 | Euro area and accession countries | Bilateral correlations between the business cycles of the euro area countries and the new EU member countries are low. | Estimates confirmed the endogeneity of optimum currency area. |
| Savva, Neanidis and Osborn | 2007 | Old and new EU countries | Correlations either increased (positive) or changed from negative to positive. | Slightly in favour of OCA endogeneity. |
| Levasseur | 2008 | Euro area and accession countries | Slovenia and Poland are still synchronised; Hungary is no longer synchronised and Slovakia is synchronised. | Internal components contribute to synchronisation; external components do not. |
| Perez et al. | 2003 | G7 countries | After 1980, the European business cycle decoupled | Not mentioned |

| | | | | |
|---|---|---|---|---|
| | | | from the US cycle; after 1993, the US shocks started to have an effect again. | |
| Stock and Watson | 2005 | G7 countries | Two blocs emerged after 1983: the euro area and English speaking countries. Correlations within the blocs increased, but those between them decreased. | Not mentioned |
| Conraria and Soares | 2009 | Euro area | The core countries/regions comprise Germany, France, Austria, Spain and Benelux; the periphery countries are Portugal, Italy, Greece and Finland. | Business cycles of countries sharing a common currency will converge, albeit unevenly. |
| Kappler et al. | 2008 | Euro area | Italy, Belgium, Germany and the Netherlands have very high coherence and minimum phase shift. | Confirmation of OCA endogeneity depending on method used. |
| Maurel | 2004 | Old EU countries and accession countries | Not mentioned | OCA endogeneity is assumed. Even in the case of asymmetric shocks, risk-sharing is beneficial for monetary union. |
| Rose | 2008 | Euro area | Not mentioned. | In favour of OCA endogeneity. |
| Gouveia and Correia | 2008 | Nine euro area countries with the whole euro area | Synchronisation of large countries (except Spain) was still increasing; synchronisation of small countries increased at first, but then decreased. | Monetary union could cause convergence of large countries and divergence of small countries. |

| | | | | |
|---|---|---|---|---|
| Crowley and Lee | 2005 | Euro area and the UK | Majority of countries correlated with the euro area aggregate; Greece not correlated for higher frequencies; Denmark, Sweden, UK not correlated for higher frequencies. | When taking into account business cycle frequencies after 1999, there was convergence of Ireland, Germany, Finland and the Netherlands, as well as the UK and Denmark. |
| Inagaki | 2005 | Euro area countries | Between 1994 and 1998, the business cycle of most countries leads or lags the German cycle by up to one year.<br><br>Between 1999 and 2003 the majority of countries have a significant contemporaneous correlation, with a lag/lead of no more than 3 months. | The author regards the OCA endogeneity hypothesis as empirically supported, but points out that certain costs remain. |
| Gogas and Kothroulas | 2009 | ERM I countries | Belgium, Germany, Denmark, Italy, Spain, Ireland and Luxembourg have a higher correlation with the aggregate cycle; the Netherlands, Finland, the UK, Austria, France and Greece have a lower correlation. | In general, the correlation coefficients indicate lower synchronisation after 2002. According to another method, however, some countries recorded a higher synchronisation. OCA endogeneity not valid for all euro area countries. |
| Giannone and Reichlin | 2006 | Euro area | Cyclical asymmetries measured by output level are small. | Not mentioned. |

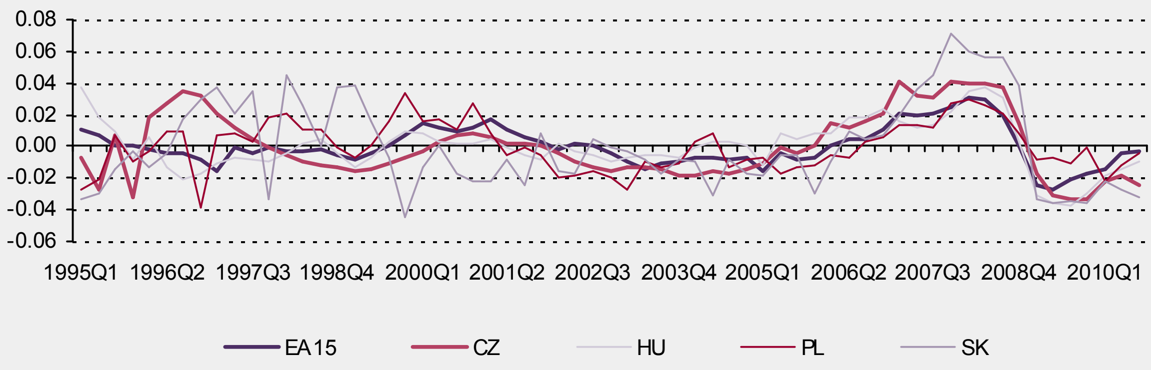
*Source: Literature*

# 2. EMPIRICAL EXAMINATION OF BUSINESS CYCLE SYNCHRONISATION

## 2.1 BUSINESS CYCLE SYNCHRONISATION MEASURED BY THE OUTPUT GAP.

Output gap correlations are a basic measure of business cycle synchronisation. The business cycle may be measured by several indicators. In this part, we selected the output gap derived from quarterly GDP series. The time series were first seasonally-adjusted and set as logarithms. We calculated potential output using an HP filter (smoothing parameter $\lambda = 1600$) and deducted it from seasonally-adjusted real GDP. Since the logarithm of GDP values was set before filtering, the resulting output gap is relative. We used Eurostat data for the V4 countries and the euro area countries (fixed composition of 15 countries), from the first quarter of 1995 to the third quarter of 2010. Due to possible leads/lags, it is appropriate to calculate the cross correlations that take such shifts into account. We divided the calculations into three periods: 1995 to 2000, 2001 to 2007, and 2001 to 2010. In order to take account of the potential effect of the economic slump in 2008 and 2009, we chose two overlapping periods. For better comparability, all calculations are made with data for the 15 euro area countries.

**Chart 1: Output gaps of the euro area and V4 countries**




*Source: Own calculations*

**Table 2: Output gap correlations of the V4 and euro area countries**

| Period: 1995Q1 2000Q4 | CZ-EA15 | | HU-EA15 | | PL-EA15 | | SK-EA15 | |
|---|---|---|---|---|---|---|---|---|
| i | lag | lead | lag | lead | lag | lead | lag | lead |
| 0 | -0.25 | -0.25 | **0.67** | **0.67** | 0.23 | 0.23 | **-0.72** | **-0.72** |
| 1 | -0.15 | -0.30 | **0.44** | **0.55** | 0.12 | **0.41** | **-0.48** | **-0.55** |
| 2 | -0.01 | -0.31 | 0.24 | 0.35 | 0.10 | 0.20 | **-0.42** | -0.30 |
| 3 | 0.02 | -0.33 | 0.12 | 0.13 | -0.11 | 0.16 | -0.12 | -0.13 |
| 4 | 0.23 | -0.26 | 0.04 | -0.06 | -0.21 | 0.12 | -0.17 | 0.07 |
| **Period: 2001Q1 2010Q4** | CZ-EA15 | | HU-EA15 | | PL-EA15 | | SK-EA15 | |
| | lag | lead | lag | lead | lag | lead | lag | lead |
| 0 | **0.91** | **0.91** | **0.85** | **0.85** | **0.75** | **0.75** | **0.81** | **0.81** |
| 1 | **0.86** | **0.79** | **0.75** | **0.74** | **0.70** | **0.63** | **0.84** | **0.63** |
| 2 | **0.72** | **0.60** | **0.53** | **0.52** | **0.60** | **0.44** | **0.72** | **0.41** |
| 3 | **0.50** | **0.42** | 0.25 | 0.30 | **0.46** | 0.20 | **0.58** | 0.20 |
| 4 | 0.24 | 0.25 | 0.00 | 0.14 | **0.33** | 0.02 | **0.35** | -0.04 |
| **Period: 2001Q1 2007Q4** | CZ-EA15 | | HU-EA15 | | PL-EA15 | | SK-EA15 | |
| i | lag | lead | lag | lead | lag | lead | lag | lead |
| 0 | **0.88** | **0.88** | **0.65** | **0.65** | **0.74** | **0.74** | **0.69** | **0.69** |
| 1 | **0.68** | **0.80** | **0.39** | **0.64** | **0.56** | **0.61** | **0.63** | **0.46** |
| 2 | **0.54** | **0.75** | 0.24 | **0.71** | **0.41** | **0.54** | **0.51** | **0.36** |
| 3 | **0.39** | **0.68** | 0.09 | **0.72** | 0.24 | **0.39** | **0.49** | 0.29 |
| 4 | 0.16 | **0.53** | -0.06 | **0.66** | 0.02 | 0.28 | 0.26 | 0.15 |

*Source: Own calculations.*
*Note: Statistically significant values in bold*

Between 1995 and 2000, the output gap in the Czech Republic did not correlate significantly with the output gap in the euro area. For Hungary, the contemporaneous correlation, first lead and first lag were significant. For Poland, only the second lead was significant. Technically, this means that the Polish business cycle leads the euro area cycle by six months, but given the shortness of the periods used, this may be only a coincidence. Owing to the relative size of the V4 countries and euro area, significant demand impulses may be transmitted only from the euro area to the accession countries. So if the business cycle of Poland, an accession country, leads that of the euro area, it should rather be viewed as a coincidence, considering that the business cycle is also affected by several domestic factors. In this period, Slovakia's contemporaneous correlation is significant, as is its first lead and first lag as well as its second lag. The correlation is, however, negative. Such a distribution of cross correlations reflects a situation in which the business cycle in Slovakia was mainly determined by domestic factors (fiscal loosening and subsequent consolidation). According to the results, the shocks that these factors brought into the economic process could be characterised as asymmetric.

After 2000, the V4 countries prepared intensively for EU accession and eventually became EU Member States. The integration of their economies with the euro area economy continued, and that is why the cross correlation for all V4 countries increased. For all the countries, the contemporaneous correlations are highly statistically significant, as are many of the leads/lags. Strangely, between 2001 and 2007, leads are more significant than lags in all countries except for Slovakia, meaning that the business cycles of these countries are slightly leading the euro area. This may be related to the fact that after 2000, the output gap of the V4 countries was entering negative territory at a faster rate than the output gap of the euro area.

Looking at the period between 2001 and 2010, however, the situation changes slightly, as there are more statistically significant cross correlations for lags. In the case of Slovakia, the highest correlation is a one-quarter lag instead of the contemporaneous correlation between 2001 and 2007. These facts show that the spillover of negative demand shocks from the euro area affected the V4 countries to some extent during the crisis years of 2008 and 2009. The basic fact that the business cycles of the V4 countries became synchronised with the euro area after 2000 was also confirmed for this longer period.

## 2.2 SYNCHRONISATION OF BUSINESS CYCLES' PRIMARY IMPULSES

In this part, the business cycle is understood as the aggregate result of initial shocks and a mechanism that projects these shocks into the actual business cycle. Business cycles may be uncorrelated if the primary impulses are uncorrelated and the responses of particular economies are similar, or if the primary impulses are correlated, but the responses of economies are diametrically different. For overall synchronisation, however, we assume that the synchronisation of primary impulses will be more important than the nature of the propagation mechanisms, since the structural differences between the V4 countries and western Europe should diminish during the convergence process.

We will use the same methodology as Inagaki (2005), except that it will not be based on time series of industrial production. Industrial production is an indicator that takes into account not only the business cycle, but also supply shocks (meaning changes in potential output) and it features relatively high short-term variations. Furthermore, these are monthly time series, and while the data are more plentiful, they also contain considerable noise, which leads to results that may be difficult to interpret.

We will use the previously-derived quarterly data for the output gap of the V4 countries and the euro area. The data will neither be tested for stationarity, nor differentiated, since we assume that real output must, in the long run, be equal to potential output, and that the output gap captures only short-term variations and is stationary (it may, though, be serially correlated to a high degree).

For the calculation, we will proceed as follows:

1. For each rate of growth, we will estimate a one-dimensional autoregressive model (starting with four lags and gradually omitting non-significant variables). The initial model for each country is as follows:

$$lygap_{jt} = \beta_0 + \sum_{i=1}^{4} \beta_i lygap_{jt-i} \tag{1}$$

where $lygap_{jt}$ is the output gap in country *j* (the Czech Republic, euro area, Hungary, Poland, Slovakia) at time *t* calculated in Section 2.1. at time *t*. Non-significant parameters are eliminated. The intercept, despite its non-significance, is retained in the models, since several observations from the beginning of the period will be eliminated in the estimation process and therefore the time series will not have a null mean. If we left the intercept out, it could distort parameters for output gap lags. The parameters of particular estimates clearly show the diversity of mechanisms determining the development of the output gap. However, the determination coefficients are lower for some countries, and so these mechanisms correspond to only a particular part of the variability. The not insignificant remainder corresponds to the primary impulses.

2. We retain the residuals, considering them to be the primary impulses for the development of the business cycle (the parameters of the autoregressive models estimations are given in the Annex).

3. We will calculate cross correlations for the V4 countries' residuals with the euro area's residuals for four leads and lags. The correlations are calculated for the periods between 1995 and 2000, 2001 and 2007 (to separate the impact of the crisis), and 2001 -2010.[3]

From the primary impulses (residuals), we calculated the following cross correlations.

[3] We also carried out calculations for industrial production, after first setting logarithms for this indicator and differentiating it in order to obtain a stationary time series. The results, however, were affected by a high level of noise in these data and therefore we do not show them.

**Table 3 :Cross correlations of output gap residuals**

| Period: 1995Q1 2000Q4 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CZ-EA15 | | HU-EA15 | | PL-EA15 | | SK-EA15 | |
| i | lag | lead | lag | lead | lag | lead | lag | lead |
| 0 | 0.01 | 0.01 | 0.10 | 0.10 | 0.17 | 0.17 | **-0.51** | **-0.51** |
| 1 | 0.12 | -0.10 | -0.02 | 0.10 | 0.04 | **0.53** | 0.31 | -0.03 |
| 2 | 0.09 | 0.03 | -0.11 | 0.42 | 0.09 | **-0.65** | **-0.53** | 0.05 |
| 3 | 0.03 | **-0.52** | 0.12 | -0.29 | 0.00 | 0.13 | **0.44** | 0.04 |
| 4 | 0.03 | 0.18 | 0.10 | **-0.46** | -0.11 | -0.21 | -0.05 | 0.05 |
| Period: 2001Q1 2010Q4 | | | | | | | | |
| | CZ-EA15 | | HU-EA15 | | PL-EA15 | | SK-EA15 | |
| | lag | lead | lag | lead | lag | lead | lag | lead |
| 0 | **0.66** | **0.66** | **0.66** | **0.66** | **0.37** | **0.37** | **0.42** | **0.42** |
| 1 | 0.27 | 0.16 | 0.16 | 0.17 | **0.39** | 0.17 | **0.50** | -0.01 |
| 2 | 0.07 | -0.17 | 0.14 | -0.04 | 0.15 | 0.10 | 0.16 | -0.07 |
| 3 | 0.15 | 0.04 | -0.03 | -0.09 | 0.07 | -0.19 | 0.34 | 0.18 |
| 4 | -0.23 | 0.20 | -0.06 | -0.11 | 0.06 | 0.03 | -0.02 | -0.07 |
| Period: 2001Q1 2007Q4 | | | | | | | | |
| | CZ-EA15 | | HU-EA15 | | PL-EA15 | | SK-EA15 | |
| i | lag | lead | lag | lead | lag | lead | lag | lead |
| 0 | **0.55** | **0.55** | **0.53** | **0.53** | 0.22 | 0.22 | 0.33 | 0.33 |
| 1 | 0.01 | 0.06 | -0.18 | -0.07 | 0.23 | 0.22 | **0.43** | 0.02 |
| 2 | -0.07 | 0.09 | 0.06 | 0.19 | 0.04 | 0.25 | -0.13 | 0.13 |
| 3 | **0.46** | **0.38** | 0.11 | 0.21 | 0.24 | -0.02 | **0.48** | **0.38** |
| 4 | 0.07 | 0.35 | 0.12 | 0.08 | -0.07 | 0.21 | 0.17 | -0.09 |

*Source: Own calculations*
*Note: Statistically significant values in bold*

In the period up to 2000, there was at least one significant negative correlation for each country. In the case of Poland and Slovakia, significant positive correlations were also recorded, but the primary impulses of the business cycle impulses tend overall to be unsynchronised. In Slovakia, the domestic factors of, first, an overheating economy and, second, a decline in demand and consolidation played an important part during this period, with the result that the contemporaneous correlation was significantly negative.

In the period between 2001 and 2007, the situation changed as all significant negative correlations were eliminated. For the Czech Republic and Poland, the contemporaneous correlations are significant. For Poland, there are no significant correlations. For Slovakia, the first and third lag and third lead are significant. Overall, the primary impulses directing the business cycles of the Czech Republic, Hungary and Slovakia can be said to have been synchronised in this period, although in the case of Slovakia there remained certain moderate leads/lags.

If we add the period 2008 to 2010, the contemporaneous correlations are significant for all the countries. For Poland and Slovakia, the first lag is also significant. The impact of the economic crisis between 2008 and 2010 on the business cycle of all countries was confirmed again. The optimistic conclusion of this method is weakened by the fact that parameters of one-dimensional models imply different mechanisms for the propagation of initial shocks in the euro area and in individual V4 countries.

## 2.3 APPLICATION OF VAR MODELS TO THE CALCULATION OF COMMON AND COUNTRY-SPECIFIC SHOCK CORRELATIONS

In this part, we will apply the methodology used in the works of Giannone and Reichlin (2006) and Kappler et al. (2008). The economic interpretation of this approach is based on the hypothesis that euro area countries are subject to only a common shock (we will ignore the effect of individual V4 countries on the euro area as it is too minor in comparison), while the V4 countries are subject to two types of shocks – common and country-specific. Thus, the output gap of the V4 countries may be disaggregated into one part corresponding to common shocks and another part corresponding to country-specific shocks. From these two parts, correlations can be calculated. In addition, structural impulse-response functions can be used to determine the impact of shocks on the output gap difference, which is an indicator of susceptibility to an uneven business cycle.

For the estimation, we use the previously derived output gaps for the euro area and individual V4 countries from the first quarter of 1995 to the third quarter of 2010. We estimate the two-variable VAR with five lags in such a way that the LM serial correlation test for residuals does not, for any of the countries, reject the null hypotheses at the five-percent significance level. The estimated model for the country *x* is therefore as follows:

$$\begin{bmatrix} lygap_{EA} \\ lygap_X \end{bmatrix}_t = \begin{bmatrix} \mu_{EA} \\ \mu_X \end{bmatrix} + \sum_{i=1}^{5} A_i \begin{bmatrix} lygap_{EA} \\ lygap_X \end{bmatrix}_{t-i} + \begin{bmatrix} \varepsilon_{EA} \\ \varepsilon_X \end{bmatrix}_t, \qquad (2)$$

where $lygap_{EA}$ is the output gap in the euro area, $lygap_X$ is the output gap in one of the V4 countries, $\mu_{EA}$ *a* $\mu_X$ are intercepts, $A_i$ are 2x2 parameter matrices, and the residuals ε have a general variance-covariance matrix. The results of the estimates are stated in the Annex.

Identification of the VAR model (transformation to a structural VAR) consists of the introduction of so-called structural shocks with an identity variance-covariance matrix, such that reduced-form residuals are their functions. In our case, we defined the following in accordance with economic assumptions

$$\begin{bmatrix} \varepsilon_{EA} \\ \varepsilon_X \end{bmatrix}_t = \begin{bmatrix} f_{11} & 0 \\ f_{21} & f_{22} \end{bmatrix} \begin{bmatrix} u_C \\ u_S \end{bmatrix}_t, \qquad (3)$$

where $u_C$ indicates a common shock and $u_S$ country-specific shock. Calculations were carried out in the Eviews 7.0 software, which provided a transformation matrix for the calculation of structural shocks and structural impulse-response functions (for details, see the Eviews 7 User's Guide II.). We inserted the reduced-form residuals into matrix $R_e$ (58 x2) and calculated a similar matrix $R_u$ with structural shocks as $R_u` = T^{-1} R_e`$, where $T$ is the transformation matrix from equation 3 (the R matrices were transposed). Then, from the structural MA representation, we calculated

$$\begin{bmatrix} lygap_{EA} \\ lygap_X \end{bmatrix}_t = \sum_{1=0}^{\infty} \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix}_i \begin{bmatrix} u_C \\ u_S \end{bmatrix}_{t-i}, \qquad (4)$$

In doing so, we used structural impulse-response functions and we approximated the sum using the available observations of structural shocks. The correlations of time series of the V4 countries with their counterparts for the euro area, obtained according to equation 4, are stated in the second column of Table 4. The parts corresponding to common and country-specific shocks for country *x* were calculated as

$$\begin{bmatrix} lygap_{EA}^{com} \\ lygap_{X}^{com} \end{bmatrix}_t = \sum_{1=0}^{\infty} \begin{bmatrix} c_{11} \\ c_{21} \end{bmatrix}_i u_{C,t-i} \qquad (5a)$$

and

$$\begin{bmatrix} lygap_{EA}^{spec} \\ lygap_{X}^{spec} \end{bmatrix}_t = \sum_{1=0}^{\infty} \begin{bmatrix} c_{12} \\ c_{22} \end{bmatrix}_i u_{S,t-i} \qquad (5b)$$

From these parts, we calculated the correlations of particular V4 countries with the euro area for specific periods, as in the previous calculations. These correlations correspond to the counterfactual correlations calculated by Giannone and Reichlin (2006). The results are summarised in Table 4:

**Table 4 Correlations of the output gap and its components for the V4 countries and the euro area**

| | Real output gap | Simulated output gap | Simulated common shocks | Simulated country-specific shocks |
|---|---|---|---|---|
| Period 1996 -2000 | | | | |
| CZ | -0.18 | 0.76 | 0.96 | 0.39 |
| HU | 0.71 | 0.81 | 0.97 | 0.41 |
| PL | 0.57 | 0.56 | 0.98 | 0.32 |
| SK | -0.70 | -0.70 | 0.74 | 0.20 |
| Period 2001-2010 | | | | |
| CZ | 0.91 | 0.91 | 0.94 | 0.84 |
| HU | 0.85 | 0.85 | 0.96 | 0.62 |
| PL | 0.75 | 0.75 | 0.98 | -0.04 |
| SK | 0.81 | 0.81 | 0.85 | 0.25 |
| Period 2001 -2007 | | | | |
| CZ | 0.88 | 0.88 | 0.97 | 0.89 |
| HU | 0.65 | 0.65 | 0.95 | 0.42 |
| PL | 0.74 | 0.74 | 0.98 | -0.04 |
| SK | 0.69 | 0.70 | 0.86 | 0.15 |

*Source: Own calculations*

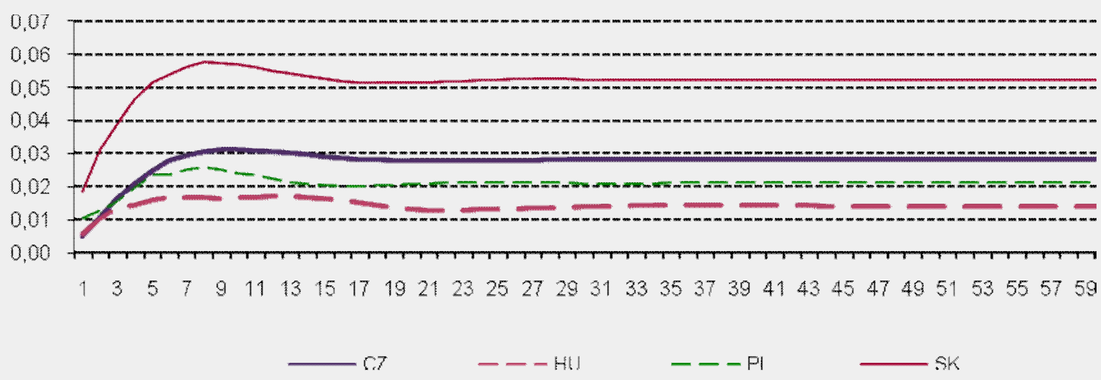
Due to the structure of the simulated time series, the worst approximation is at the beginning of the period under review. This is manifested by the wide disparities between the correlations of real and simulated output gaps for some country pairs. In the period between 1996 and 2000, the most synchronised business cycle is in Hungary, where there is also the highest synchronisation of components calculated from country-specific shocks. It is worth mentioning that correlations of calculated output gaps may be lower than correlations of components from country-specific shocks, since the calculated output gaps are a mixture of common and country-specific shocks of varying weights. This is the case with Slovakia, which for the period in question has the lowest correlation of a component calculated from country-specific shocks.

In the period between 2001 and 2007, the correlations entered positive territory in line with the previous analysis. Similar results are obtained for the period between 2001 and 2010, although with slightly higher correlations. Poland had the lowest correlation, evidently affected by the negative correlation of components calculated from country-specific shocks. In the case of Slovakia there was an increase in the correlation of components from country-specific shocks as well as in the correlation of simulated time series of the output gap.

Overall, it is possible to say that the results of this methodology confirm the previous findings derived from single-equation models for the output gap, in the sense that before 2001 business cycles (mainly in the case of Slovakia) were uncorrelated and their correlation in time increases.

The sources of differences in business cycles are clearly country-specific shocks in particular countries. It is instructive to know how they affect these differences. Like Giannone and Reichlin (2006), we are going to analyse structural impulse-response functions. In this regard, our focus is on the impact of the country-specific shock on output gap differences of particular V4 countries and the euro area ($c_{22X}$-$c_{12X}$). When compiling Chart 2, we used cumulated impulse-response functions. The impulse-response functions themselves are presented in the Annex.

**hart 2: Differences in impulse-response functions for V4 countries and the euro area**




*Source: Own calculations*
*Note: Horizontal axis shows quarters.*

The Chart shows that for all V4 countries, the country-specific shock has a higher impact on the given country than on the euro area. For Slovakia, moreover, it is clear that the impact of the country-specific shock on the difference in output gaps is higher than for other V4 countries. This explains why, on one hand, Slovakia up to 2001 had a positive correlation of country-specific shock components and a negative correlation of output gap simulated time series, and, on the other hand, Poland after 2001 had a negative correlation of country-specific shock components and a positive correlation of output gap simulated time series.

# CONCLUSION

By entering the European Union, the V4 countries undertook also to join the euro area. Since the euro area does not meet the criteria of an optimum currency area, the synchronisation of business cycles is important in regard to costs of the common monetary policy. This paper addresses the issue of business cycle synchronisation by directly calculating cross correlations, by calculating cross correlations from primary impulses, and finally by calculating output gap component correlations from common and country-specific shocks.

For the output gap, the results of all three methods are approximately the same: before 2001, the business cycles of the V4 countries were not synchronised with the euro area (low or negative correlations); between 2001 and 2007, correlations entered positive territory as the V4 countries joined the EU and trade between the V4 countries and the euro area increased; and during the economic crisis of 2008–2009, synchronisation increased still further, indicating that the spillover of demand shocks from the euro area into the V4 countries was an important channel for the spread of the crisis and represented a symmetric shock for the V4 countries. It is clear from the single-equation model parameters for primary impulse calculations that primary impulse propagation mechanisms vary from one country to another. The calculation of the impact of country-specific shocks on output gap differences showed that, as a consequence of country-specific shocks, the deviation from the euro area business cycle is far greater in Slovakia than in the other V4 countries. This represents a risk. In general, however, it can be said that the costs of the (potential) common monetary policy will decrease, as the synchronisation of business cycles increases. The varying impact of different factors on synchronisation should, though, be acknowledged. While integration – mainly intra-industry trade – has the potential to synchronise the business cycle in the long run, to achieve fast convergence requires a convergence of economic policies (alignment of fiscal policy; reduction in labour market rigidities).

Across most of the literature cited there is a consensus that the business cycle in Europe is relatively synchronised and that it is becoming even further synchronised due to the endogeneity of the optimum currency area. This study confirms that conclusion, while the requirement for economic policy convergence remains valid.

A weakness of this study is that periods under review were short, and in some cases do not cover even two business cycles. Another problem is that it does not take into account additional factors that could in some way interact with the business cycle and thus complicate the situation. These problems represent challenges for further research.

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# ANNEX 1: OUTPUT GAP MODELS

**Table 5: Output gap models for the V4 countries and the euro area**

| Parameter (lag) | Czech Republic | Euro area | Hungary | Poland | Slovakia |
|---|---|---|---|---|---|
| C | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 0.849 | 1.120 | 1.018 | 0.535 | 0.672 |
| 2 | 0.369 | -0.232 | | | |
| 3 | -0.425 | | -0.434 | 0.179 | |
| 4 | | -0.139 | 0.196 | | |
| RSQ | 0.775 | 0.795 | 0.741 | 0.404 | 0.453 |
| DW | 1.637 | 2.008 | 1.651 | 1.950 | 2.173 |

*Source: own calculations*

*Note: C is the ntercept, RSQ is the determination index, DW is the Durbitn-Watson test*

The estimates were made using quarterly data from 1995 to the third quarter of 2010. Since the estimate excluded certain observations from the beginning of the period, the output gap did not have a null mean. Therefore, we left the intercept in the specifications despite its negligible values and non-significance.

# ANNEX 3 VAR MODELS FOR OUTPUT GAPS

**Table 6 Parameters of reduced-form VAR models**

| Model | Czech Republic | | Hungary | | Poland | | Slovakia | |
|---|---|---|---|---|---|---|---|---|
| Variable | EA | CZ | EA | HU | EA | PL | EA | SK |
| EA(-1) | **1.069** | 0.168 | **0.991** | **0.316** | **1.063** | **0.604** | **1.094** | **1.494** |
| EA(-2) | -0.167 | 0.045 | -0.033 | 0.120 | -0.139 | -0.363 | -0.144 | **-2.056** |
| EA(-3) | -0.057 | -0.022 | 0.113 | -0.110 | 0.037 | -0.312 | -0.115 | **2.208** |
| EA(-4) | -0.139 | **-0.400** | -0.103 | -0.044 | -0.192 | 0.279 | -0.115 | **-1.996** |
| EA(-5) | -0.018 | 0.231 | **-0.318** | **-0.352** | -0.028 | -0.066 | 0.040 | **0.814** |
| X(-1) | 0.070 | **1.157** | 0.067 | **0.876** | **0.180** | **0.387** | -0.021 | **0.661** |
| X(-2) | -0.100 | **-0.260** | -0.086 | -0.276 | **-0.214** | 0.038 | 0.011 | -0.046 |
| X(-3) | 0.034 | -0.016 | -0.173 | -0.240 | -0.001 | **0.321** | 0.052 | **0.225** |
| X(-4) | 0.089 | 0.050 | 0.004 | **0.317** | -0.044 | 0.105 | -0.030 | -0.162 |
| X(-5) | -0.053 | -0.095 | **0.280** | 0.035 | **0.116** | **-0.300** | -0.046 | -0.021 |
| C | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| RSQ | 0.801 | 0.911 | 0.834 | 0.813 | 0.837 | 0.517 | 0.808 | 0.647 |

*Source: Own calculations*
*Note: Statistically significant values in bold*

Models were estimated for the period between Q2 of 1996 and Q3 of 2010 (after omitting observations for lagged variables). The values in bold had an absolute t-test value of more than 1.4. All models were estimated in such a way that their roots are in unit circle and the LM serial correlation is not rejected at the five-percent significance level. In the left column of the Table, X represents the respective country for the given model. Intercepts were retained in the model for the same reasons that they were in the single-dimension models.

The VAR models were identified by condition (4) in part 2.4. (In Eviews notation, we used the identification Ae=Bu, where *A* and *B* are 2x2 matrices, *e* are the reduced-form residuals and *u* are structural shocks. In this case, *A* is always an identity matrix and *B* is a transformation matrix with $f_{ij}$ elements and zero restriction for $f_{12}$.). Table 7 shows the transformation matrix elements:

**Table 7 Parameters of VAR model structural forms (transformation matrices of shocks)**

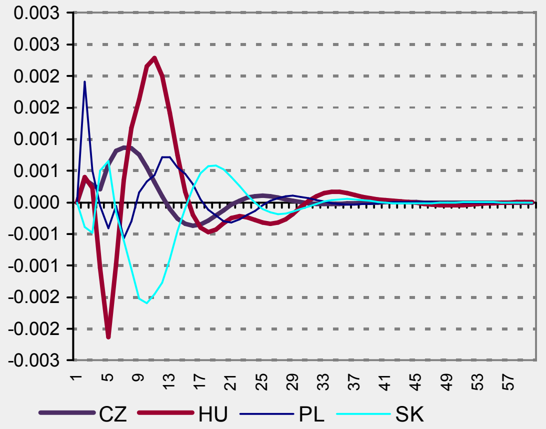
| Matrix | Czech Republic | | Hungary | | Poland | | Slovakia | |
|---|---|---|---|---|---|---|---|---|
| i \ j | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| 1 | 0.006271 | 0.000000 | 0.005728 | 0.000000 | 0.005678 | 0.000000 | 0.006153 | 0.000000 |
| 2 | 0.004080 | 0.005228 | 0.004327 | 0.005896 | 0.004914 | 0.010605 | 0.000667 | 0.018687 |

*Source: Own calculations*

All parameters are significant at the one-percent significance level, except for $f_{21}$ for Slovakia, which is non-significant.

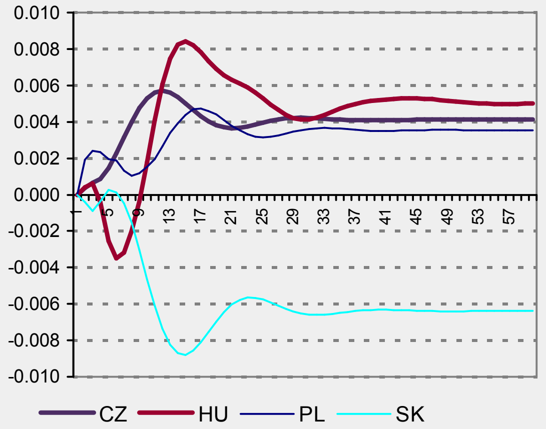
# ANNEX 4 SELECTED STRUCTURAL IMPULSE-RESPONSE FUNCTIONS OF VAR MODELS

**Chart 3: Structural IRFs of the euro area for a country-specific shock**



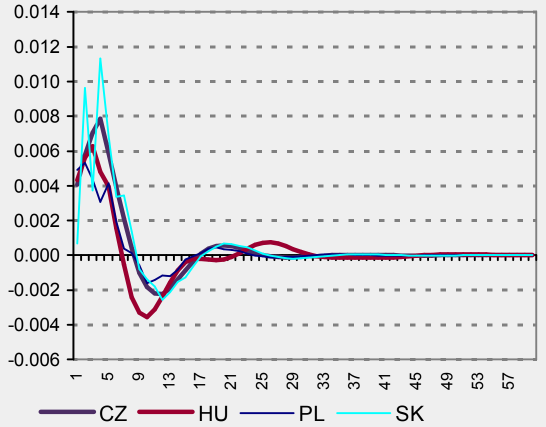

*Source: Own calculations.*
*Note: Horizontal axis shows quarters.*

**Chart 4: Cumulated structural IRFs of the euro area for a country-specific shock**



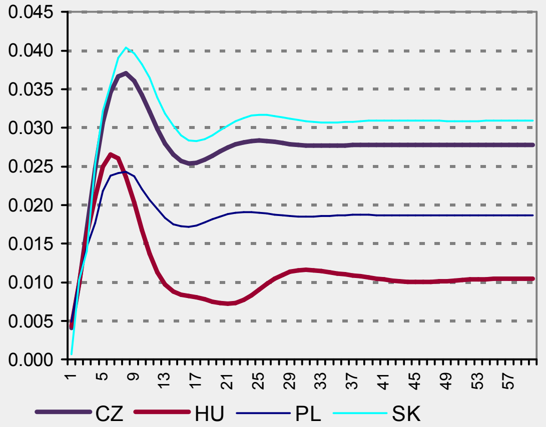

*Source: Own calculations.*
*Note: Horizontal axis shows quarters.*

**Chart 5 Structural IRFs of individual countries for a common shock**



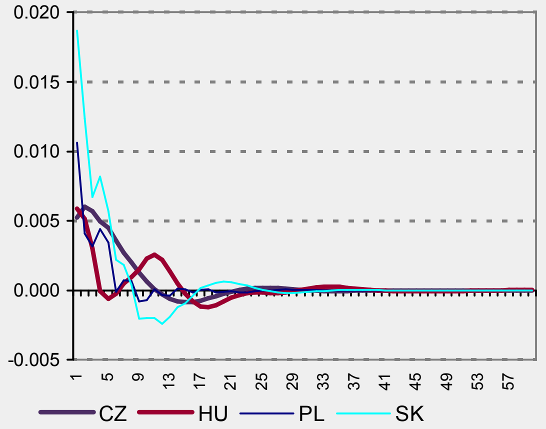

*Source: Own calculations.*
*Note: Horizontal axis shows quarters.*

**Chart 6: Cumulated structural IRFs of individual countries for a common shock**



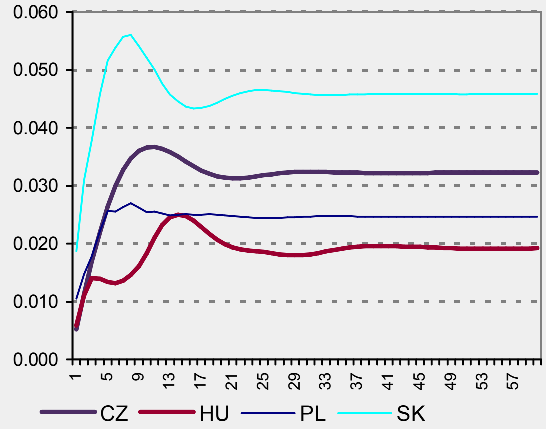

*Source: Own calculations.*
*Note: Horizontal axis shows quarters.*

**Picture 7: Structural IRFs of individual countries for a country-specific shock**




*Source: Own calculations.*
*Note: Horizontal axis shows quarters.*

**Picture 8 Cumulated structural IRFs of individual countries for a country-specific shock**




*Source: Own calculations.*
*Note: Horizontal axis shows quarters.*