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SPURIOUS SYNCHRONIZATION OF BUSINESS CYCLES: DYNAMIC CORRELATION ANALYSIS OF V4 COUNTRIES

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Abstract

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The purpose of our paper is to define rules for decision of existence spurious synchronization of countries within the currency area. We devote this new methodological approach from an empirical research based on the variability of a dynamic correlation (correlation in frequency domain). We analyze the dynamic correlation in full range and in the business cycle frequencies as well. We also consider lags in economic activity co-movements. Contrary to the standard approach we show its insufficiency especially in case of time domain instruments. For this goal GDP values in quarters of the four Visegrad countries and the Eurozone in the period 1997/Q1–2011/Q1 are used.

OCA theory, monetary policy efficiency, co-movements, Hamming window

The process of European integration, especially the issue of business cycle synchronization is at the forefront of economists' minds over the past twenty years. The theoretical arguments are founded in the theory of optimal currency areas (OCA theory) which was pioneered by Mundell (1961) and contributed by McKinnon (1963) and Kenen (1969). The traditional version of OCA theory was supplemented by Corden (1972), who argues that joining a currency area is related with loss of autonomous monetary policy and exchange rate control. These arguments followed by new theoretical development of OCA which focuses more on the benefits and costs of adopting a common currency. On the basis of the theoretical principles, the costs are minimized and benefits maximized with high degree of cyclical and structural synchronization.

There are several methods for measuring the synchronization of business cycles. The most common methods are the unconditional correlation between the two countries in different time periods, the identification of delays various phases of business cycles, volatility of cyclical fluctuations in economic activity, stability and similarity of unexpected fluctuations in economic activity or shock response (Darvas and Szapáry, 2008). Croux *et al.* (2001) applied dynamic correlation, Koopman and Azevedo (2008) focus on phase correlation, Hardin and Pagan (2006) applied index of cyclical conformity (Concordance Index). Fidrmuc and Korhonen (2006) point out, that the different empirical studies of business cycles synchronization in the Eurozone provide significantly different results. These differences are caused by various types of methodological approaches to identify business cycles and its synchronization.

The most of recent empirical analysis are based on the stochastic approach with the frequency uncertainty. These analyses are based on the correlation and similar methods which do not provide any information about the causality. *The intuition is that if the incidence of supply and demand shocks and the speed with which the economy adjusts – taking into consideration also the policy responses to shocks – are similar across partner countries, then the need for policy autonomy is reduced and the net benefits from adopting a single currency might be higher* (Mongelli, 2002). However, Mundell's basic idea deals with the impact of shocks on the aggregate demand and supply within the currency region. Assume that two different macroeconomic shocks affect aggregate demand and supply in two regions identically. The same change in real output and aggregate prices appears but its causes are different. Can be this situation considered as the symmetric shock? The answer is No. These are two different local shocks with the same or similar effects in selected countries. The conclusion about business cycles synchronization could be biased.

The main objective of this paper is to provide methodological approach to identify possibility of spurious synchronization. Finally, the authors specify decision criteria based on the dynamic correlation and its variability in different frequencies. They suppose that co-movements in different frequencies show different correlation. Subsequently, they conclude that variability of co-movements in different frequencies increases costs of losing autonomous monetary policy because shocks affect these countries differently. The arguments are supported by empirical analysis of V4 countries.

Theoretical background

The authors suppose that variability of dynamic correlation in different frequencies appears with specialization and country-specific shocks. The question is, if we can assume the existence of pure local shock in the open economies. There is international trade as the important transmission channel for foreign shocks. And not only the trade but also consumptions, investments, house prices are transmitted through consumer sentiment. Kose *et al.* (1993) analyzed 60-country sample covering sever regions of the world. *The results indicate that a common world factor is an important source of volatility for aggregates in most countries, providing evidence for a world business cycle* (Kose *et al.*, 1993). They found that local factors play only a minor role in explaining fluctuations in economic activity. Aastveit *et al.* (2011) showed that foreign shocks explain a major share of business cycle fluctuations (50–70 percent) in Canada, New Zealand, Norway and UK. However, they conclude that local factors explain approximately 20 percent of the variance in domestic variables. Clark and Shin (2000) identified common and country-specific shocks in accounting for variation in industrial production in European countries. Consequently, we can assume that local shocks play important role in analysis of synchronization. And, simultaneously, there is probability of asymmetric shocks which reduces the monetary policy efficiency.

However, the detailed analyses of business cycle fluctuations are limited by data and econometric tools. The most empirical studies focus on aggregate economic activity. It consists of many components affected by exogenous and endogenous forces. Assume that two different macroeconomic shocks reversely affect different components in aggregate economic activity. The first has a global character and changes business cycle within the whole currency union. The second country-specific shock affected only one country. Subsequently, the business cycle as a consequence of these shocks will not change in this specific country. The business cycles synchronization in full range of spectrum is biased.

There is another example. Assume that macroeconomic global, regional and country-specific shocks affect countries within the currency union. The business cycles in the currency union are significantly co-moved and referred to be synchronized. However, identified co-movements are changing in different frequencies. Then the demand or supply shocks need policy autonomy and costs from adopting a single currency are high. In this case, the business cycle synchronization is spurious.

High variability of correlation in different frequencies could be caused by specialization and concentration as well. In that case, the common monetary policy is not efficient to stabilize output and unemployment. The explanation was already provided by Kenen (1969) and Krugman (1993) in traditional version of OCA theory. Kenen (1969) assumes that diversified economies with inter-industrial mobility are good candidates to join OCA, because diversification helps them to adjust rapidly to negative external shocks. Diversified economy with diversified export sector is more stable if those shocks are uncorrelated. Krugman (1993) points out that economic integration leads to regional concentration of industries (e.g. automobile plants in Michigan). Subsequently, regional concentration of industry could lead to asymmetric shocks within the currency region.

MATERIAL AND METHODS

Correlation coefficient calculated in time domain and denoted as classical correlation is very popular methods to identify business cycles synchronization. Unfortunately, it measures only direct or indirect linear relationship between time series. The dynamic correlation is alternative approach based on spectral analysis where time series are represented by sine and cosine waves. The results are represented in frequency domain. This methodological approach allows identify the different correlation at different frequencies. Thus, we can identify different types of waves represented by specific cycles (investment cycle, changes in stocks, innovations, policy cycles etc.) or/and cyclical movements in economic activity of specific sectors in the economy (it is found that characteristic frequencies of business indicators are remarkably stable.

Let's consider input time series which can be represented by the real values. The time series usually contain several components, such as long-term trend component, cyclical or seasonal component. Before analysis of co-movement it is suitable to remove seasonal and trend component. For this aim we can use additive decomposition of the time series x_t, $t = 1, \dots, n$

$$x_t = g_t + c_t + s_t + \varepsilon_t, t = 1, \ldots, n, \quad (1)$$

where g_t denotes long-term trend, c_t is the cyclical component, s_t is the seasonal component and ε_t is the irregular component.

Removing trend component can be done in several ways. You can apply filtering technique. The choice of corresponding filter depends of the aim of the work. Because we are working with the business cycles, the suitable is to can work with band-pass filters such as Baxter-King (Baxter and King, 1999), Christiano-Fitzgerald (Christiano and Fitzgerald, 1999) or Hamming Window filter (Iacobucci and Noullez, 2005).

The prior to the application of the Hamming Window filter (HW) is that the trend has to be removed similar to the Christiano and Fitzgerald filter. For this can be used for example high-pass Hodrick-Prescott algorithm (Hodrick and Prescott, 1980).

To make application of HW filter we are going to follow these steps. At first we calculate a discrete Fourier transform (DFT) X of the input time series x. This operation transforms the time series from the time domain to the frequency domain

$$X = DFT\{x\}. \quad (2)$$

After that we apply the Hamming windowed filter according to the formula

$$Y = (W \times H)X, \quad (3)$$

where H represents the frequency transfer function of the ideal filter, i.e. the filter that filters out all the frequency components outside the business cycle band, W corresponds to the selected window function (Iacobucci, 2003) and denotes for a convolution operation. At the end we calculate the filtered time series using the Inverse Discrete Fourier Transform (IDFT) of Y. The IDFT transforms the frequency domain time series Y into the time domain series y

$$y = IDFT\{Y\}. \quad (4)$$

For quantification of co-movements between time series we use the dynamic correlation according Croux, Forni and Reichlin (2001). The dynamic correlation measures the similarity of the frequency components of two time series y and z and can be defined as:

$$\rho_{yz}(\omega) = \frac{C_{yz}(\omega)}{\sqrt{S_z(\omega) S_y(\omega)}}, \quad (5)$$

where Cyz is a co-spectrum (the real part of the cross-spectrum) and Sy, Sz are the individual spectra of time series y and z for frequencies ω. The dynamic correlation values can lie in the interval from −1 to +1. Integrating in the frequency band from ω_1 to ω_2 a dynamic correlation coefficient arises:

$$\rho_{yz}(\omega_1, \omega_2) = \frac{\int_{\omega_1}^{\omega_2} C_{yz}(\omega) d\omega}{\sqrt{\int_{\omega_1}^{\omega_2} S_z(\omega) d\omega \int_{\omega_1}^{\omega_2} S_y(\omega) d\omega}}. \quad (6)$$

It evaluates the common behavior of the two time series in the given band of frequencies, e.g in the business cycle frequencies (6–32 quarters). For $\omega_1 = 0$, $\omega_2 = \pi$ the integration is done over the whole defined frequency range and thus the dynamic correlation coefficients corresponds to the classical correlation coefficient.

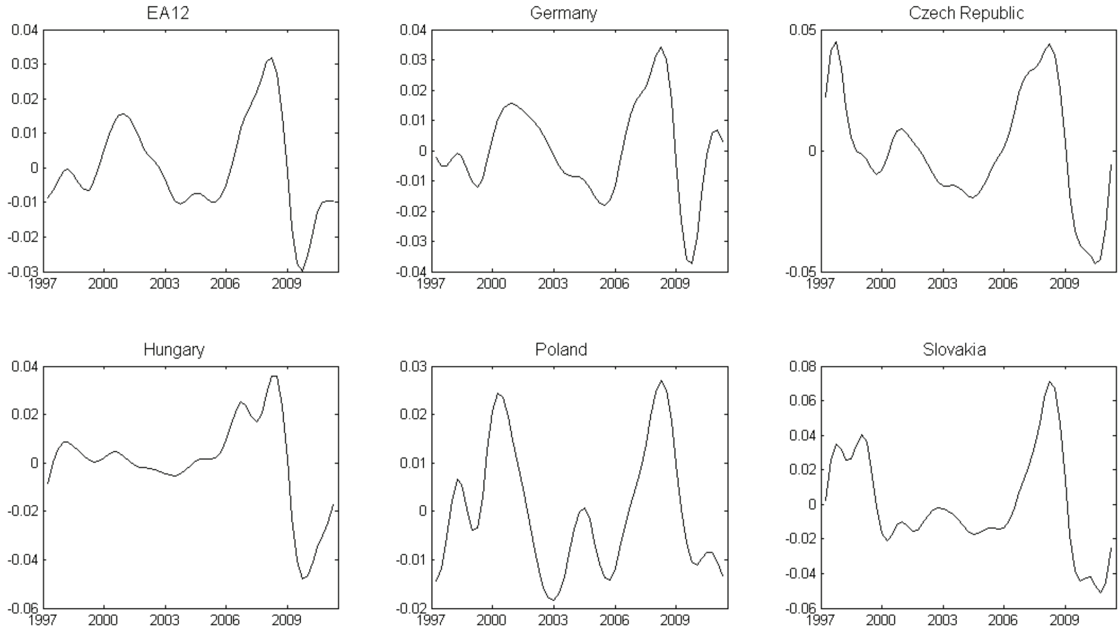
RESULTS

For empirical analysis we use data set containing seasonally adjusted quarterly values of gross domestic product in constant prices (reference year 2000), millions of national currency in the period 1997/Q1–2011/Q1. The business cycles co-movements is analyzed between V4 countries, Czech Republic (CZ), Hungary (HU), Poland (PL) and Slovakia (SK) and the Eurozone (EA12) and Germany (DE) as the reference currency regions. All data sets were sourced in National accounts system provided by Eurostat (Eurostat, 2011). The transformation of natural logarithms was applied on all time series.

The time domain representation of growth business cycles identified via detrending by application Hamming window filter is showed in the Figure 1. The Augmented Dickey-Fuller stationarity test was applied and unit root was rejected at 1% significance level in the all analyzed countries. Obviously, time domain representation of the growth business cycles provides information about the aggregate economic activity movements. We can see negative significant symmetric shock caused by financial crisis in the years 2008–2010. Before these years all selected countries achieved high economic growth. The other detailed information about the specific cyclical movements is hidden. The results could be biased by country-specific shocks.

To identify possibility of spurious synchronization we apply analysis in frequency domain, especially dynamic correlation. Consequently, the identification of business cycles synchronization does not suppose any lag. However, the lagged business cycles are common problem. It is unreal that international trade or consumer sentiment channel is not lagged. Because in reactions among economies exists some lag, we will consider this fact. According to the Table I with respect to the behaving of troughs, it will be taken lag in maximum order two between selected country, Eurozone and Germany. That means calculation of dynamic correlation will be done for EA, Germany at time t, and any chosen country at time t, $t-1$, $t-2$.

From the Tab. I is visible that differences between dynamic correlation in full range and in business



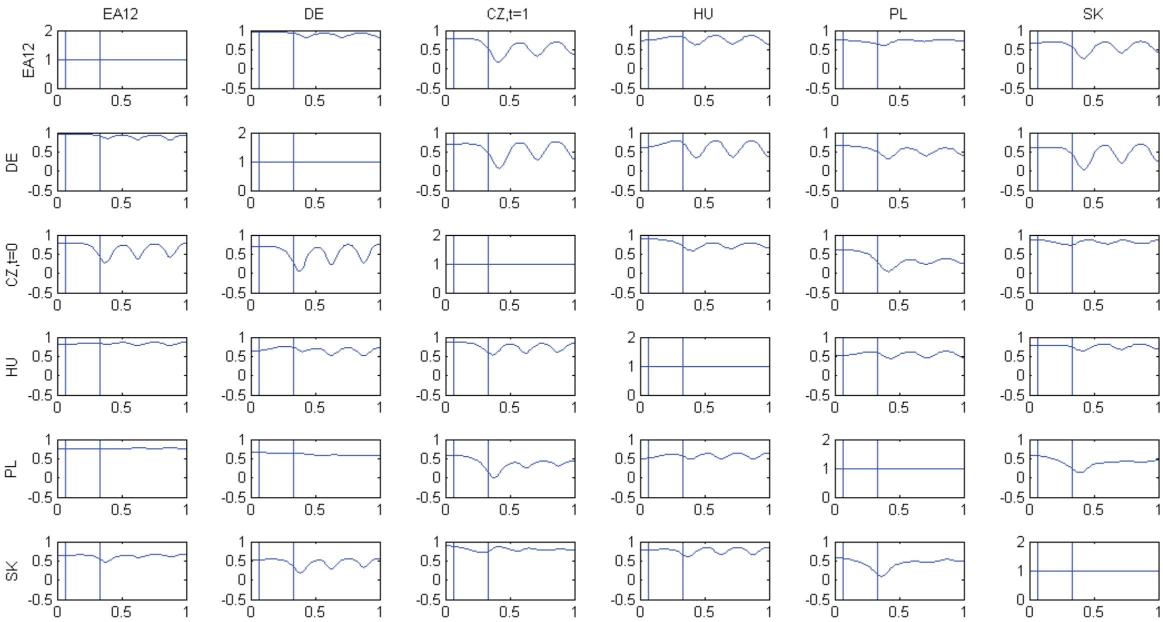
1: *Growth business cycles of V4 countries, Germany and EA12*

I: *The co-movement among countries measured by dynamic correlation*

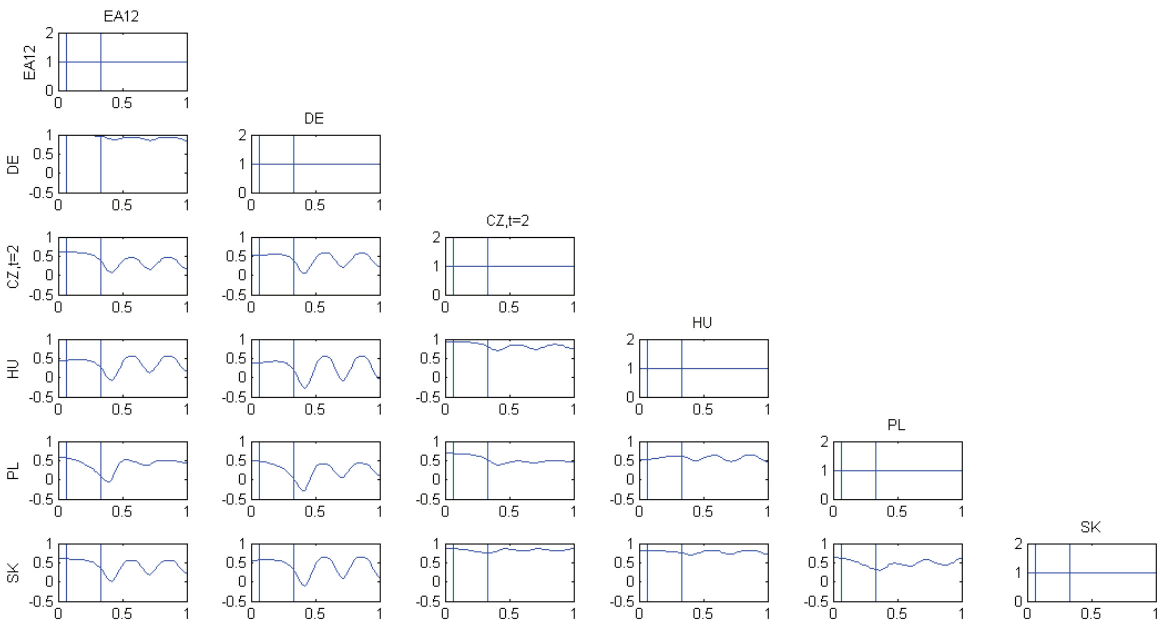
Lag = 0	EA12	DE	CZ	HU	PL	SK
EA12	1.0000	0.9447	0.7679	0.8262	0.7483	0.6464
DE	0.9420	1.0000	0.6562	0.6978	0.6442	0.5260
CZ	0.7625	0.6498	1.0000	0.8405	0.5244	0.8125
HU	0.8193	0.6761	0.8405	1.0000	0.5655	0.7878
PL	0.7500	0.6467	0.5221	0.5488	1.0000	0.4781
SK	0.6416	0.5169	0.8328	0.7813	0.4957	1.0000
Lag = 1	**EA12**	**DE**	**CZ**	**HU**	**PL**	**SK**
EA12	1.0000	0.9530	0,7666	0.7915	0.7207	0.6835
DE	0.9491	1.0000	0.0688	0.6996	0.6285	0.6019
CZ	0.7463	0.6694	1.0000	0.8623	0.5666	0.8236
HU	0.7739	0.6677	0.8564	1.0000	0.5612	0.7895
PL	0.7264	0.6243	0.5518	0.5474	1.0000	0.4943
SK	0.6677	0.5837	0.8376	0.7837	0.5032	1.0000
Lag=2	**EA12**	**DE**	**CZ**	**HU**	**PL**	**SK**
EA12	1.0000	0.9770	0.5766	0.4424	0.4430	0.5636
DE	0.9724	1.0000	0.5277	0.3946	0.3778	0.5445
CZ	0.5598	0.5106	1.0000	0.9107	0.6532	0.8265
HU	0.4308	0.3725	0.9035	1.0000	0.5687	0.7955
PL	0.4682	0.3868	0.6439	0.5561	1.0000	0.5238
SK	0.5550	0.5318	0.8368	0.7936	0.5441	1.0000

Source: own calculation
Note: Lower left triangle contains dynamic correlation in full range, upper right triangle presents dynamic correlation in business cycle frequencies. All correlation coefficients are significant at the 5% significance level.

cycle frequencies are mostly (in 95%) of the ±0.02 maximum. In percentage evaluation, 89% of changes are to 3% of the change the dynamic correlation in full range. This conclusion makes an impression there is no reason to calculate 'complicated' dynamic correlation coefficient, but classical correlation coefficient should be enough. However, there are significant differences in dynamic correlation with the time lags. The coefficient of dynamic correlation is lower with lags, especially with lag of order two. This result shows that there are no lagged cyclical co-movements between analyzed countries.



2: *Dynamic correlation between the Eurozone and selected V4 countries*
Note: Lower left triangle presents dynamic correlation without delay and upper right triangle presents dynamic correlation with lag of the order one.



3: *Dynamic correlation between the Eurozone and selected V4 countries (second order lag)*

The most important results of this empirical analysis are presented in Fig. 2 and 3. The lower left triangle presents scaling behavior of dynamic correlation in different frequencies without the lags. We can see that dynamic correlation is changing in the case of Czech Republic and Slovakia. In comparison with lagged time series (order one), the variability did not significantly change in the Czech Republic and Slovakia but increased in Hungary and Poland. The variability of dynamic correlation increased even more with second order lag.

Let us focus now on different frequencies. There is high correlation in low business cycle frequencies. When frequencies decreases to the upper bound of business cycle frequencies (6 quarters), dynamic correlation is going to decrease. This picture is visible for the lag of the order zero, one and order two as well. In frequencies higher then business cycles frequencies (closer to 1 at the x-axis; Fig. 2 and 3) the shape of the dynamic correlation curve looks similar, having slowly decreasing values. In case of Hungary is visible accretive tendency of variability in the cross of lags. Also changes in shape of

II: *The variability of the dynamic correlation*

Lag = 0	EA12	DE	CZ	HU	PL	SK
EA12	0.0000	0.0002	0.0172	0.0002	0.0000	0.0015
DE	0.0018	0.0000	0.0210	0.0014	0.0001	0.0049
CZ	0.0238	0.0371	0.0000	0.0092	0.2059	0.0024
HU	0.0006	0.0042	0.0100	0.0000	0.0010	0.0023
PL	0.0002	0.0008	0.0212	0.0028	0.0000	0.0177
SK	0.0024	0.0107	0.0018	0.0042	0.0158	0.0000
Lag = 1	**EA12**	**DE**	**CZ**	**HU**	**PL**	**SK**
EA12	0.0000	0.0001	0.0080	0.0011	0.0013	0.0020
DE	0.0022	0.0000	0.0070	0.0024	0.0029	0.0042
CZ	0.0329	0.0392	0.0000	0.0043	0.0113	0.0021
HU	0.0055	0.0207	0.0081	0.0000	0.0008	0.0005
PL	0.0017	0.0094	0.0257	0.0031	0.0000	0.0123
SK	0.0161	0.0344	0.0019	0.0028	0.0124	0.0000
Lag = 2	**EA12**	**DE**	**CZ**	**HU**	**PL**	**SK**
EA12	0.0000	0.0001	0.0058	0.0051	0.0227	0.0070
DE	0.0018	0.0000	0.0031	0.0060	0.0217	0.0082
CZ	0.0265	0.02327	0.0000	0.0017	0.0027	0.0014
HU	0.0301	0.05439	0.0047	0.0000	0.0009	0.0003
PL	0.0268	0.04244	0.0087	0.0028	0.0000	0.0096
SK	0.0279	0.04665	0.0011	0.0013	0.0078	0.0000

Source: own calculation
Note: Lower left triangle presents full range of frequencies, upper right triangle presents business cycle frequencies.

dynamic correlation in business cycle frequencies came up especially for the lag of the order two. For Poland the dynamic of dynamic correlation curve increased simultaneously with lag order. The biggest increase in variability corresponds to the lag of the order two. Slovakia has also increased variability, but opposite to Hungary and Poland the biggest growth is yet for the lag of the order one.

The variability of dynamic correlation in different frequencies is summarized in the Tab. II. According to the theoretical argumentation, there is possibility of spurious synchronization in the Czech Republic. Simultaneously, the mentioned variability decreases in business cycle frequencies. Obviously, the variability of dynamic correlation changes with time lag in all analyzed countries.

Note: Lower left triangle presents full range of frequencies, upper right triangle presents business cycle frequencies.

The Tab. III points out the possible spurious synchronization. There are results of dynamic correlation in full range and business cycles frequencies and its variability. Note that high correlation could be spurious if there is high variability in different frequencies. We can assume that all V4 countries are correlated with the Eurozone and Germany. In case of the Czech Republic the dynamic correlation (in different range of frequencies) is changing. There is possibility of biased results of correlation in time domain. On the contrary, the variability in the case of Poland is very low.

III: *Possibility of spurious synchronization in V4 countries*

Country or region	Dynamic Correlation in f.r.		Dynamic Correlation in BC		Dynamic Correlation variability (f.r., Lag=0)		Dynamic Correlation variability (BC, Lag=0)	
	EA12	DE	EA12	DE	EA12	DE	EA12	DE
EA12	1.0000	0.9447	1.0000	0.9420	0.0000	0.0002	0.0000	0.0002
DE	0.9420	1.0000	0.9447	1.0000	0.0018	0.0000	0.0002	0.0000
CZ	0.7625	0.6498	0.7679	0.6562	0.0238	0.0371	0.0172	0.0210
HU	0.8193	0.6761	0.8262	0.6978	0.0006	0.0042	0.0002	0.0014
PL	0.7500	0.6467	0.7483	0.6442	0.0002	0.0008	0.0000	0.0001
SK	0.6416	0.5169	0.6464	0.5260	0.0024	0.0107	0.0015	0.0049

Source: own calculation
Note: f.r. – full range of frequencies; BC – in business cycle frequencies (6 to 32 quarters)

DISCUSSION AND CONCLUSIONS

Actual indicators of business cycle synchronization in time domain do not provide detailed information about the co-movements at different frequencies. Concurrently, the central banks affect aggregate economic activity. Synchronization of short, medium and long-term waves is important in the context of the loss of autonomous monetary policy. Dynamic correlation changes (value, variability, variability changes with lags in time domain) provide a new instrument to identify spurious relationship between the economic indicators, especially spurious business cycle synchronization.

On the basis of preceding empirical work we define decision rules in Tab. IV. These criteria help to decide whether synchronization between the business cycles are real or spurious. Denote that dynamic correlation is correlation of two spectra in frequency domain. From this point of view we will distinguish situation, whether variability of dynamic correlation is increasing, decreasing or stable.

Assume a few cases. (1) Two time series are not synchronized, time series have different spectra thus dynamic correlation is insignificant. (2) Two time series are synchronized, they have similar shapes of spectra and corresponding dynamic correlation with small variability in different frequencies. In that case the lag between countries does not have significant impact on variability of dynamic correlation. (3) If time series are synchronized in time t (without lag), than imposing lag on country does not have significant impact on spectra shape. In this way dynamic correlation and its variation is not significantly different from the case without lag. We can allow some small changes in variability of dynamic correlation with respect to the lag. (4) When variability of dynamic correlation with respect to the first and consequently second lag caused its decrease, the synchrony arises. When its stay stable, we talk about synchronization.

On the contrary, the spurious synchronization is wrongly inferred co-movements in economic activity which limit single monetary policy efficiency in the currency area. In this paper is spurious synchronization based on the idea of significant variability of dynamic correlation in different frequencies. Tab. IV presents basic decision criteria with the monetary policy effects. The spurious synchronization is identified if correlation in time domain (full range of frequencies) is significant and positive and at the same time the dynamic correlation variability is high. In that case, exogenous shocks are country-specific shocks and common monetary policy efficiency is limited in the currency union.

The business cycle synchronization in all selected countries, excluding Slovakia, is reduced with the lags. All correlation coefficients are statistically significant and presents highly synchronized business cycles. The best synchrony shows Hungary and Poland and the lowest Slovakia. However, the following empirical analysis of dynamic correlation contests the results of time domain instruments. According to the decision criterion, it is important to decide if the variability of spurious correlation in different frequencies is low or high.

There are now exact decision limits. There is possibility to compare the results with Germany, important economy of the Eurozone where we can suppose the endogeneity of European integration process. Using decision rules defined in article we found possible spurious synchronization in case of the Czech Republic. In the case of Hungary and Poland we can identify lower dynamic correlation variability in comparison with Germany. The synchronization of Slovakia is discussable. According to the decision rules, there is possibility of spurious synchronization but variability approaches the reference value. The spurious synchronization with the Eurozone was evidently identified in the case of Czech Republic. According to the OCA theory and asymmetric shocks probability, the authors conclude that the single monetary policy is not suitable for this country regardless the correlation (in time domain – in full range of frequencies) is significant and positive.

IV: *Decision criteria for identification of spurious synchronization*

Correlation	Dynamic Correlation Variability	Result	Single Monetary Policy
not significant	low	not synchronized	not efficient
	high	not synchronized	not efficient
significant and positive	low	business cycles synchronization, symmetric shocks	efficient
	high	spurious synchronization	not efficient
significant and negative	low	asymmetric shocks	not efficient
	high	spurious synchronization	not efficient

SUMMARY

The paper starts to discuss country-specific shocks and cross-country specialization within the currency area and continues to identify possibility of spurious synchronization in the economic

activity co-movements. The empirical part of the paper is based on the dynamic correlation analysis, especially on the variability of dynamic correlation in different range of frequencies.
The authors define the spurious synchronization as wrongly inferred co-movements in economic activity which limits single monetary policy efficiency in the currency area. They suppose four situations of synchronized or asynchronized time series with similar or different shapes of spectra. The authors apply a lag in time series too. Finally, they provide decision criteria to identify spurious synchronization of business cycles. According to this criterion they found spurious synchronization in the case of the Czech Republic. The results are discussed with the OCA theory assumptions.

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