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## **Business Cycle Synchronization in European Union: Regional Perspective**

**JEL Classification:** E32; E50; F44; R10

**Keywords:** *business cycle synchronization; regional economics; optimum currency area theory; Hodrick-Prescott filter; European integration*

**Abstract:** *The recent turmoil in the euro area once more forces the EU authorities to reconsider the future of further monetary integration. One of the most commonly used criteria for successful monetary integration in contemporary research is business cycle synchronization (BCS). Though BCS has been vastly described at country level, not as much attention has been paid to the degree of BSC at regional level. The topic is important for two main reasons. Firstly, determining the degree of BCS at the regional level can help in the assessment of monetary policy effectiveness on the country level, as well as give a point of reference for evaluation of prospective costs of participation in a monetary union. Secondly, there is a theoretical dispute within the optimum currency areas literature between the ‘European Commission’ and the ‘Krugman’ view that can be resolved to a large extent through regional analysis. In order to assess BCS in the EU, Hodrick-Prescott, as well as Christiano and Fitzgerald filter to time series of real GDP for 24 countries, 82 NUTS 1, 242 NUTS 2 and 1264 NUTS 3 regions over the period between 1998 and 2010. The data was later used to create bilateral measures of BSC, which gave 276 observations on the country level, 3321 on NUTS 1, 29161 on NUTS 2 and 798216 on NUTS 3 level. The results of the analysis support the*

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*'European Commission' view and show a very high degree of BSC within EU countries. The country level analysis also reveals that within the EU there is a group of countries that could form an effectively working monetary union based on the BCS criterion.*

## **Introduction**

The turmoil in the euro area once more forces the EU authorities to reconsider the future of further monetary integration. One of the most commonly used criteria for successful monetary integration in contemporary research is business cycle synchronization (BCS). This paper attempts to assess the degree of business cycle synchronization at regional NUTS 1, 2 and 3 levels and for country pairs. This analysis allows to assess the extent to which each of the national central banks, as well as European Central Bank, can conduct monetary policy effectively. The higher the business cycle synchronization between two countries/regions, the better the ability of their central banks to conduct common monetary policy for these two countries/regions.

This article proposes the measure of business cycle synchronization based on the correlation coefficient of deviations of cyclical component of real GDP from trend. The measure is, then, used to establish which groups of countries can introduce common currency at a relatively low cost. Same measures are used to check the monetary policy effectiveness within countries.

Section 1 presents the literature review, which is mostly concentrated around the theory of optimum currency areas and business cycle synchronization at country and regional levels. Section 2 presents data sources and methodology used to construct the business cycle synchronization measure. Section 3 presents results and section 4 concludes.

## **Literature Review**

The prospect of a monetary unification in economics is usually considered in the context of the theory of optimum currency areas (OCA), based on seminal works of Mundell (1961), McKinnon (1963) and Kenen (1969). Nowadays, the 'new' theory of optimum currency areas (Tavlas, 1993) also considers a more dynamic approach closely related to the works of Krugman (1993) as well as Frankel and Rose (1998) and their 'The Endogeneity of the Optimum Currency Area Criteria' hypothesis, as well as Mundell (1973a, 1973b). Both international (Grubel, 1970; Mongelli, 2002

and 2008; Tavlas, 2008) and Polish (Nowak *et al.*, 1999; Łon, 2007; Lis, 2008; Żyżyński, 2009; 2011; Osiatyński, 2011) economists have discussed the potential benefits and costs of introducing a common currency on the theoretical level. A more complex measure of countries' readiness to form a monetary union has been proposed by Bayoumi and Eichengreen (1997), who introduced a unified index based on nominal exchange rate volatility, trade intensity, trade similarity (intra-industry trade intensity) and differences in real GDP growth rate.

Empirical research in this area is very complicated due to the difficulties inherent in the attempts to measure with the measurement of potential costs and benefits. For this reason, researchers focus their attention on testing the conclusions from the OCA theory using two main approaches. In both cases, the authors try to find similarities in either economic shocks or business cycles; if there are strong, monetary policy and externally flexible exchange rate become very effective tools of common central bank.

The first approach uses the Structural Vector Auto Regression models (Blanchard & Quah, 1989; Taylor, 2004) to identify economic shocks and was firstly utilized for OCA purposes by Bayoumi and Eichengreen (1993). They examined demand shocks among European countries and US census regions, and found out that regions in the US are characterized by a higher degree of cohesion. Using a similar approach, Dumitru and Dumitru (2011) found a significant role of idiosyncratic demand shocks among European countries, even some of its core countries. Beck and Janus, using SVAR approach, discovered low correlation of economic shocks among the Euro Area countries (2013) and a high degree of synchronization of shocks for V4 countries (2014).

The second approach is concentrated on the business cycle synchronization (BCS), and the literature on BCS has put high interest on parts of determinants. Using multi-equation approach, Imbs (2004) found evidence that trade, inter-industry trade, structural similarity and financial integration positively influence BCS, using data on Developed countries and states in the USA. He also found evidence for Endogeneity: direct and indirect of trade and financial linkages on business cycles synchronization. Results have later been reproduced on a sample of European countries by Siedschlag (2010), as well as Déés and Zorell (2011). Kalemli-Ozcan *et al.* (2009), in contrast with Imbs, found that financial integration influences business cycles synchronization negatively, using the single equation approach. They argue that cross-section analysis suggests a positive impact of financial integration on business cycles synchronization, but panel approach reveals the opposite effect. Beck (2013), using multi-equation approach reports intermediate effects of GDP per capita distance through struc-

tural similarity on business cycle synchronization and Chang *et al.* (2013) show the impact of similarities in ruling parties.

Complex analysis with sensitivity checks (Leamer & Leonard, 1981; Leamer, 1983; 1985; Levine & Renelt, 1992; Sala-I-Martin, 1997a; 1997b) has been performed for BSC by Baxter and Kouparitsas (2004). They employ extreme bounds analysis to several potential determinants of business cycles synchronization, but, besides the gravity variables, they only found trade significant. In a more recent approach, Bößer and Guillemineau (2006), using the same methodology but focusing their attention on the Euro Area, found only trade, economic specialization at industry level, fiscal deficits, price competitiveness and stock market differentials to be significant as business cycles synchronization determinants. In yet another attempt to use extreme bound analysis, Sachs and Schleer (2013) obtained significant results for institutional similarities and directions of structural reforms, but found trade, structural similarities and fiscal and monetary policy similarities insignificant in many of their specifications. Beck (2013), using Sala-I-Martin version of extreme bound analysis, discovered the robust impact of structural similarities and GDP per capita distance on BSC.

Gogas (2011), using the one equation approach, found positive effects of introducing common currency on BSC using sample of twelve European countries. On the other hand, Bordo and Helbling (2010) argued that increasing business cycles synchronization is a worldwide phenomenon. Lehwald (2012), using Bayesian dynamic factor model, argued that a great part of increased business cycles synchronization among Euro Area countries comes from worldwide tendencies, rather than the ongoing integration.

All research mentioned above was only taking into consideration countries as a unit of measurement. As noticed by Alesina and Barro (2002), the number of countries in the world is changing, but this does not necessarily mean that the number of OCAs is changing with them. As a result, the country perspective instantly eliminates the possibility of OCAs existing within countries or amongst parts of countries. In order to assess them, a lower level of aggregation is required, hence the regional perspective. For these reasons, this paper tries to concentrate on regional business cycles synchronization which did not gain as much attention in the literature.

Artis *et al.* (2009) find no evidence of convergence of regional business cycles for European regions and for the USA, and claim that BSC have been stable over 1982–2007. Correia and Gouveia (2013) examined business cycle synchronization in Portuguese regions between 1988 and 2010 and concluded that it had decreased over the period. Anagnostou, Panteladis and Tsiapa (2012), in a comprehensive research, found differences

in regional BSC for 14 European countries that could be explained by trade and differences in the level of development. Marino (2013), on the sample of 12 European countries, found that changes in regional business cycle synchronization could be explained by distance and differences in economic structure.

### **Data and Measurement**

In the investigation, only European countries with data available on regional level were taken into consideration. The list of all the countries and number of different NUTS 1,2,3 regions along with the number of possible pairs is available in Table 1.

**Table 1.** Data description

<b>Name</b>	<b>Country</b>	<b>NUTS 1</b>	<b>NUTS 2</b>	<b>NUTS 3</b>
Belgium	1	3	10	42
Bulgaria	1	2	6	28
Germany	1	16	31	427
Greece	1	4	12	50
Spain	1	7	17	51
France	1	8	20	96
Italy	1	5	21	104
Hungary	1	3	6	20
Holland	1	4	12	38
Austria	1	3	9	34
Poland	1	6	16	66
Romania	1	4	8	42
Finland	1	2	4	19
Sweden	1	3	8	20
UK	1	12	36	130
Czech	1	-	8	11
Denmark	1	-	5	10

Table 1 continued

Name	Country	NUTS 1	NUTS 2	NUTS 3
Ireland	1	-	2	8
Portugal	1	-	5	27
Slovenia	1	-	2	12
Slovakia	1	-	4	7
Estonia	1	-	-	5
Latvia	1	-	-	6
Lithuania	1	-	-	10
<b>Sum (countries/regions)</b>	<b>24</b>	<b>82</b>	<b>242</b>	<b>1263</b>
<b>Maximum number of pairs</b>	<b>276</b>	<b>3321</b>	<b>29161</b>	<b>796953</b>
<b>Data Frequency</b>	<b>quarterly</b>	<b>annual</b>	<b>annual</b>	<b>annual</b>
<b>nominal GDP/GVA Source</b>	<b>Eurostat</b>	<b>Cambridge Econometrics</b>		
<b>P (national level) source</b>	<b>Eurostat</b>	<b>Penn World Table</b>		
<b>Period for filtration</b>	<b>1998q1-2014q1</b>		<b>1991-2010</b>	
<b>Period for correlation</b>	<b>1998q1-2010q4</b>		<b>1998-2010</b>	

Source: own work.

For countries, quarterly data about nominal GDP and price level (2005=100) from the first quarter of 1998 to the first quarter of 2014 obtained from Eurostat was used. The data was seasonally adjusted with X-13 ARIMA<sup>1</sup>. For regions (NUTS 1,2,3), annual data of nominal gross value added (GVA) and the price level was collected. Due to a lack of data of the prices at regional level, the data of national price level has been used as a deflator. This is a common practice in regional research, including Sachs and Sala-I-Martin (1991). GVA data comes from Cambridge Econometrics, and the price level data from Penn World Table 8.0, both cover the 1991-2010 period. For comparisons between countries and regions, the data for 1998–2010 used. Longer periods have been used in order to get better results from the Hodrick-Prescott filter. For the same reason, quarterly data was used for GDP and prices and the national level.

<sup>1</sup> Newest method of season adjustment available to the author. For more detailed information: <https://www.census.gov/srd/www/winx13/WinX13Doc.html> (15.02.2016)

To justify the usage of detrending methods, tests for the presence of unit root have been used. Since Nelson and Plosser (1982), there has been substantial disagreement over the nature of the GDP trend (Rudebusch, 1993) – whether it is deterministic or stochastic. Due to that fact, an ADF (Said & Dickey, 1984) test was performed with two variations of the following equation<sup>2</sup>:

$$\Delta Y_t = \alpha + \beta t + \delta Y_{t-1} + \sum_{i=1}^p \gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

where  $\Delta Y_t$  denotes a change in real GDP,  $\alpha$  is a constant term (drift),  $\beta t$  is a deterministic trend,  $\delta$  is a coefficient on lagged real GDP and  $\gamma_i$  is a coefficient on  $i$ -th lag of change in real GDP and  $\varepsilon_t$  is a residual term. The number of lags has been chosen with Schwarz information criterion. In the first specification, the deterministic trend is ignored, but it is included in the second. Diebold and Senhadji (1996) showed that whether these tests detect presence of deterministic or stochastic trend depends on the analyzed time period – the longer the period the higher the chance of encountering a deterministic trend. This implies that for the periods used in this paper, the test is expected to be biased towards the stochastic trend. The presence of the trend was also confirmed with the KPSS (Kwiatkowski *et al*, 1992) test. Results for specification without deterministic trend for countries have been presented in Table 2. Results for regions at NUTS 1 level are in the appendix. Since the number of observations is very high, (242 for NUTS 2 and 1260 for NUTS 3) the results for lower levels of disaggregation are not presented, but they confirm the presence of a trend in the data.

**Table 2.** Results of unit root test: specification (1) without  $\beta t$  (ADF  $H_0$ : series has a unit root; KPSS  $H_0$ : series is stationary)

Country	ADF	t-1	d(-1)	d(-2)	d(-3)	d(-4)	d(-5)	d(-6)	d(-7)	d(-8)	C	KPSS
Austria	0.398	0.084									0.050	I(1)***
Belgium	0.451	0.104	0.00	0.84							0.075	I(1)***
Bulgaria	0.449	0.103	0.56								0.031	I(1)***
Czech	0.628	0.201	0.00								0.099	I(1)***
Denmark	0.305	0.055									0.047	I(1)**
Estonia	0.634	0.206	0.01								0.112	I(1)***

<sup>2</sup> The case with no drift is not considered due to the increasing nature of real GDP.

Table 2 continued

Country	ADF	t-1	d(-1)	d(-2)	d(-3)	d(-4)	d(-5)	d(-6)	d(-7)	d(-8)	C	KPSS
Finland	0.277	0.048	0.07								0.035	I(1)***
France	0.219	0.034	0.01								0.023	I(1)***
Germany	0.833	0.473									0.390	I(1)***
Greece	0.137	0.018	0.78	0.15	0.49	0.80	0.01	0.02			0.021	I(1)*
Holland	0.174	0.025	0.00								0.020	I(1)***
Hungary	0.362	0.072	0.00								0.052	I(1)***
Ireland	0.111	0.014									0.005	I(1)***
Italy	0.265	0.045	0.00								0.043	I(1)*
Latvia	0.365	0.073	0.05	0.00							0.053	I(1)***
Lithuania	0.781	0.369	0.02								0.203	I(1)***
Poland	0.996	0.317									0.532	I(1)***
Portugal	0.015	0.001									0.001	I(1)**
Romania	0.651	0.219	0.44								0.130	I(1)***
Slovakia	0.946	0.928									0.393	I(1)***
Slovenia	0.395	0.083	0.15	0.01							0.064	I(1)***
Spain	0.069	0.008	0.00								0.005	I(1)***
Sweden	0.769	0.354	0.29	0.00	0.18	0.00	0.22	0.42	0.02	0.00	0.197	I(1)***
UK	0.358	0.071									0.039	I(1)***

Table presents p values for ADF test as well as for all variables.

\*/\*\*/\*\*\* denotes 0.1/0.05/0.01 significance level for KPSS statistic

Source: own calculations.

ADF test detects presence of unit root in time series for all countries except Portugal and Spain, two geographically close countries that have experienced significant turmoil during the recent crisis. According to the KPSS test results, unit root is present in all countries. Results for the specification (1) are presented in Table 3.

For specification (1), the ADF test shows the presence of unit root in time series for all countries. KPSS shows presence of unit root in all cases except for Germany. This result, along with the analysis of p values in both specifications, gives strong support to the deterministic trend only in the case of Germany, though evidence for stochastic trend can be found. Table 3 shows that deterministic trend is significant also for Bulgaria, Estonia, Greece, Poland, Romania and Slovakia. In most of the cases, the results point to a stochastic trend and drift. As mentioned above, this result was expected because of a relatively short time period. This result has consequences for the measurement of business cycle component and final result.



It points out to changes in trend underlying GDP. This difficulty is addressed and overcome later in the text.

**Table 3.** Results of unit root test: specification (1) (ADF  $H_0$ : series has a unit root; KPSS  $H_0$ : series is stationary)

Country	ADF	t-1	d(-1)	d(-2)	d(-3)	d(-4)	d(-5)	d(-6)	d(-7)	d(-8)	C	t	KPSS
Austria	0.598	0.052									0.039	0.120	I(1)*
Belgium	0.378	0.020	0.00								0.015	0.053	I(1)**
Bulgaria	0.962	0.438	0.52								0.220	0.761	I(1)**
Czech	0.947	0.359	0.00								0.233	0.582	I(1)**
Denmark	0.847	0.162									0.128	0.822	I(1)**
Estonia	0.321	0.015	0.03	0.43	0.01						0.009	0.054	I(1)**
Finland	0.871	0.188	0.07								0.124	0.676	I(1)**
France	0.589	0.050	0.00								0.037	0.169	I(1)**
Germany	0.121	0.003	0.01								0.003	0.005	I(0)
Greece	0.999	0.556									0.619	0.000	I(1)***
Holland	0.938	0.325	0.00								0.250	0.957	I(1)**
Hungary	0.803	0.128	0.00								0.079	0.564	I(1)***
Ireland	0.785	0.116									0.037	0.768	I(1)***
Italy	0.855	0.170	0.00								0.134	0.277	I(1)***
Latvia	0.423	0.025	0.04	0.00							0.015	0.134	I(1)**
Lithuania	0.804	0.129	0.01								0.076	0.204	I(1)**
Poland	0.627	0.059	0.17	0.54	0.10						0.037	0.058	I(1)**
Portugal	0.750	0.098									0.060	0.105	I(1)***
Romania	0.396	0.022	0.91								0.013	0.045	I(1)**
Slovakia	0.701	0.080									0.050	0.075	I(1)*
Slovenia	0.778	0.113	0.11	0.00							0.070	0.388	I(1)**
Spain	0.983	0.651	0.01								0.310	0.177	I(1)***
Sweden	0.725	0.091	0.18	0.00	0.06	0.00	0.31	0.31	0.01	0.01	0.070	0.122	I(1)*
UK	0.800	0.126									0.078	0.416	I(1)***

Table presents p values for ADF test as well as for all variables.  
 \*/\*\*/\*\* denotes 0.1/0.05/0.01 significance level for KPSS statistic

Source: own calculations.

For regions, the KPSS test find unit root for every region at NUTS 1 level. The ADF test fails to find unit root at 5% level of confidence for 5 regions, namely: Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt (all Germany) and Alföld és Észak (Hungary). These results

point to the presence of a trend in the analyzed data set, and allows for proceeding with filtering.

In order to extract cyclical and trend components of real GDP time series, high pass Hodrick-Prescott (HP) filter has been used. HP filter assumes that the time series ( $y_t$ ) can be divided into the cycle component ( $c_t$ ) and the trend component ( $g_t$ ):

$$y_t = c_t + g_t \quad \text{for } t = 1, 2, \dots, T. \quad (2)$$

The HP filter extracts the trend component by solving the following mathematical programming problem (Hodrick & Prescott, 1997):

$$\min \left\{ \sum_{t=1}^T (y_t - g_t)^2 + \lambda \sum_{t=1}^T [(g_{t+1} - g_t) - (g_t - g_{t-1})]^2 \right\}. \quad (3)$$

$$\{g_t\}_{t=-1}^T$$

In that context, HP filter can be seen as a generalization of the exponential smoothing procedures used analyzed by Brown (1962). If  $c_t$  and the second differences of  $g_t$  are normally and independently distributed, HP filter is an optimal filter (Rawn & Uhlig, 2002).  $\lambda$  is a parameter penalizing for variability of the trend component and its value is given by:

$$\lambda = \frac{\sigma_c^2}{\sigma_{\Delta^2 g_t}^2}, \quad (4)$$

which is the ratio of variance in the cyclical component to variance of the second differences in the trend component. The higher the value of  $\lambda$ , the smoother the trend component, and it becomes an OLS estimate as  $\lambda$  approaches  $\infty$ . The value has been set to 1600 for quarterly and to 100 for annual data, which are the values recommended by authors, as well as commonly used in the most of business cycles literature (e.g. Backus & Kehoe, 1992). A great advantage of Hodrick-Prescott filter is the fact that it directly corresponds to the definition of business cycle commonly used in the economic literature as: movements about trend in gross national product (Lucas, 1977).

Finally, the cyclical component  $c_t$  is divided by the trend component  $g_t$ , to create a time series of deviations of cyclical part of real GDP from trend part, or in other words deviations of cyclical GDP from the natural level:

$$dev_t = c_t / g_t. \quad (5)$$

This transformation deals with the problem of stochastic trend, as the cyclical component is scaled by trend component.

For each pair of countries/regions  $i$  and  $j$ , for each level of aggregation separately, the value of the correlation coefficient is calculated for data obtained with HP filter:

$$hp_{ij} = cor(dev_{ti}, dev_{tj}) \quad (6)$$

This measure takes values from -1 to 1, where 1 reflects perfect business cycle synchronization. Because BCS can be analyzed using at least two countries, the unit used in this research is pairwise oriented. An advantage of this approach is that the number of observations ( $o$ ) for a given number of countries/regions ( $n$ ) is given by:

$$o = \frac{n(n-1)}{2}, \quad (7)$$

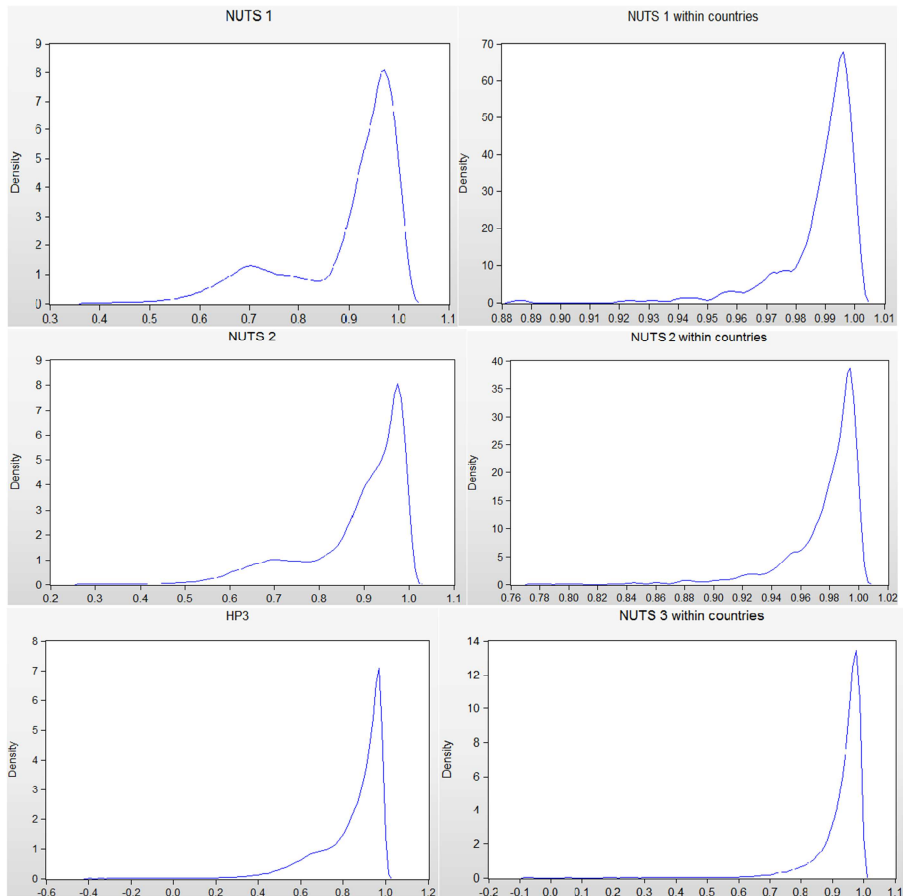
so, for 24 countries, the number of observations is 276, for 82 NUTS 1 – 3321, for 242 NUTS 2 – 29161, for 1263 NUTS 3 – 796953 observations. In the case of, NUTS 3 one can be sure that all asymptotical theorems work very well. The rest of the reasoning is based on the values of these results.

## Results

The descriptive statistics for values of  $hp$  measure for region pairs at NUTS 1, 2 and 3 are presented in Table 4. The headers of columns with „IN’ present results only for pairs of regions inside the countries (a Polish region with a Polish region, a German one with a German one, but not a Polish one with a German one). The degree of business cycle synchronization is very high at all three levels of aggregation though the highest is at NUTS 1 level (0.89). The average value of  $hp$  is decreasing with disaggregation, which is the expected result. Nevertheless, this very high value for all three levels of disaggregation indicates that the conduction of monetary policy would be on average rather effective, judging from the regional perspec-

tive. On the other hand, the distribution in all cases is far from normal, which might indicate that there is some systematic factor attributing to skewness. For this reason, statistics were calculated separately for pairs of regions within countries. Mean values within countries are significantly higher – by approximately 0,1 for NUTS 1 and NUTS 2 and 0,08 NUTS region pairs. Standard deviation for ‘inside’ pairs is on the other hand significantly lower, approximately by factor of 12, 4 and 2.1 for NUTS 1, 2 and 3 region pairs respectively.

**Figure 1.** Kernel Densities for NUTS 1, 2 and 3 region pairs: all and within countries



Source: own calculation.

Conclusions from Table 4 are supported by comparison of the distribution between all pairs of regions and pairs within countries. Kernel densities for region pairs are presented in Figure 1.

**Table 4.** Descriptive statistics of *hp* for NUTS 1, 2 and 3 region pairs: all and within countries\*

Statistic	NUTS1	NUTS1IN	NUTS2	NUTS2IN	NUTS3	NUTS3IN
Mean	0.89	0.99	0.88	0.98	0.85	0.93
Median	0.94	0.99	0.92	0.99	0.90	0.95
Maximum	1.00**	1.00	1.00	1.00	1.00	1.00
Minimum	0.40	0.89	0.29	0.78	-0.39	-0.08
Std. Dev.	0.12	0.01	0.12	0.03	0.15	0.07
Skewness	-1.38	-3.03	-1.40	-2.45	-1.60	-2.59
Kurtosis	3.96	16.86	4.40	11.17	5.80	13.76
Jarque-Bera	1178	2784	11866	7992	602586	703580
P(J-B)	0.00	0.00	0.00	0.00	0.00	0.00
Sum	2962	289	25681	2064	675351	110500
Sum Sq. Dev.	44.57	0.05	392.55	1.35	16873.30	515.73
Observations	3321	292	29161	2112	795691	118449

\*ENDFIX "IN" denotes correlations within countries

\*\*Values of correlations equal to 1 are results of rounding up

Source: own calculation.

The distributions for all and inside pairs are not normal and get more concentrated around mean with the level of aggregation, which can be attributed to the sample size changes. The distribution for 'inside' pairs is more centered and only covers very high values of correlation coefficient. These results suggest that the business cycle of regions inside countries are on average more synchronized than those of regions from different countries. This result contradicts 'Krugman's View' which states that the elimination of barriers to all economic activities (ex. Trade, mobility of labor and capital) leads to higher degree of concentration of economic activity due to internal and external economies of scale. This, in turn, leads to higher specialization, fragility of regions exports to changes in demand, and lower business cycles synchronization with other regions. The obtained result shows that regions are characterized by a very high degree of business cycle synchronization, especially within countries. This also supports the 'European Commission View'. Further economic integration by eliminating barriers to economic activity and introducing similar policies – *ergo*

making groups of countries more like one country – will lead to tighter business cycle synchronization and can make common monetary policy effective.

The results for regions are very different from pairs of countries, which are presented in Table 5.

**Table 5.** Descriptive statistics of *hp* for pairs of countries and NUTS 3 level pairs within Poland, Germany, France and UK\*

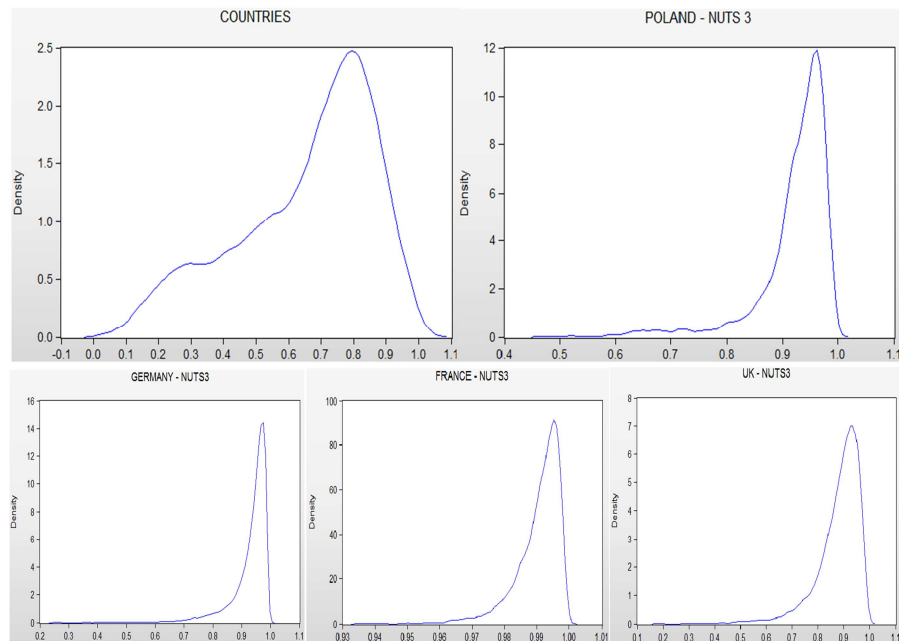
Statistic	COUNTRIES	POLAND	GERMANY	FRANCE	UK
Mean	0.65	0.92	0.93	0.99	0.88
Median	0.71	0.94	0.95	0.99	0.90
Maximum	0.95	1.00	1.00	1.00	1.00
Minimum	0.11	0.47	0.25	0.94	0.18
Std. Dev.	0.21	0.07	0.06	0.01	0.08
Skewness	-0.80	-2.58	-2.38	-2.04	-1.94
Kurtosis	2.61	11.23	10.97	9.77	8.67
Jarque-Bera	31	8424	327137	11875	16490
P(J-B)	0.00	0.00	0.00	0.00	0.00
Sum	180	1975	84843	4517	7377
Sum Sq. Dev.	11.71	10.09	332.78	0.23	60.11
Observations	276	2145	90951	4560	8385

\*For brevity data for only 5 countries is reported. All results are available upon request

Source: own calculation.

The mean value of correlation coefficient for country pairs is equal 0.65, which is lower by 0.3 from NUTS 3 region pairs. Standard deviation is equal to 0.21, which, in turn, indicates a lower concentration of the results. The distribution is not normal, which can be seen from kernel densities in Figure 2. The distribution almost exclusively covers values from 0 to 1. This suggests that, in total, business cycle synchronization among European countries is fairly strong, but the degree differs significantly between pairs. The highest density of observations is around 0.75 which strengthens the point.

**Figure 2.** Kernel Densities for country pairs and pairs of regions at NUTS 3 level inside: Poland, Germany, France and UK



Source: own calculation.

Table 5 also displays descriptive statistics for NUTS 3 region pairs inside Poland, Germany, France and UK. Results for these countries confirm that, in all cases, monetary policy can be implemented very effectively. This is especially true in the case of France, where the mean value of  $hp$  measure is equal to 0.99 with standard deviation equal to approximately 0.01. The degree of business cycle synchronization is also very high for Poland, with the mean of 0.92 and standard deviation of 0.07. The distribution in all cases is not normal, which can be seen in Figure 2. Kernel distributions for regions inside countries are very concentrated and only cover very high values of correlation.

The results of the detailed analysis are presented in Tables 6 through 9. For each country, possible partners for monetary union are arranged according to  $hp$  measure in a descending order. NUTS 1/2/3 denotes the average value for region pairs inside this country at a different 1/2/3 level of aggregation, while mean denotes the average value in all countries. If the country has higher business cycle synchronization with some other country than among regions inside it, then this country is a good partner to form

**Table 6.** Ordered values of *hp* measure with all possible partners and inside countries at NUTS 1, 2 and 3 levels for Belgium, Bulgaria, Finland, Germany and Greece

No.	Belgium		Bulgaria		Finland		Germany		Greece		Poland	
	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner
0												
1	<b>1.00</b>	<b>NUTS 1</b>	<b>0.95</b>	<b>NUTS 2</b>	<b>0.97</b>	<b>NUTS 2</b>	<b>0.99</b>	<b>NUTS 1</b>	<b>0.98</b>	<b>NUTS 1</b>	<b>0.98</b>	<b>NUTS 1</b>
2	<b>0.99</b>	<b>NUTS 2</b>	<b>0.93</b>	<b>France</b>	<b>0.92</b>	<b>NUTS 1</b>	<b>0.98</b>	<b>NUTS 2</b>	<b>0.96</b>	<b>NUTS 2</b>	<b>0.96</b>	<b>NUTS 2</b>
3	<b>0.98</b>	<b>Lithuania</b>	<b>0.80</b>	<b>NUTS 3</b>	<b>0.92</b>	<b>Italy</b>	<b>0.95</b>	<b>NUTS 3</b>	<b>0.88</b>	<b>NUTS 3</b>	<b>0.92</b>	<b>NUTS 3</b>
4	<b>0.92</b>	<b>NUTS 3</b>	0.79	<b>Germany</b>	<b>0.90</b>	<b>France</b>	<b>0.94</b>	<b>Slovakia</b>	0.56	<b>Belgium</b>	0.77	
5	<b>0.91</b>	<b>Spain</b>	0.75	<b>Italy</b>	<b>0.90</b>	<b>NUTS 3</b>	<b>0.93</b>	<b>Spain</b>	0.50	<b>Holland</b>	0.76	
6	<b>0.89</b>	<b>Romania</b>	0.74	<b>Spain</b>	<b>0.89</b>	<b>Austria</b>	<b>0.91</b>	<b>Czech</b>	0.49	<b>Austria</b>	0.71	
7	<b>0.88</b>	<b>Slovenia</b>	0.74	<b>NUTS 1</b>	<b>0.89</b>	<b>Finland</b>	<b>0.90</b>	<b>Bulgaria</b>	0.48	<b>Slovenia</b>	0.69	
8	<b>0.86</b>	<b>Finland</b>	0.70	<b>Austria</b>	<b>0.88</b>	<b>Belgium</b>	<b>0.88</b>	<b>Slovenia</b>	0.46	<b>Spain</b>	0.68	
9	<b>0.85</b>	<b>Czech</b>	0.70	<b>Slovenia</b>	<b>0.88</b>	<b>Holland</b>	<b>0.87</b>	<b>Lithuania</b>	0.44	<b>France</b>	0.64	
10	<b>0.85</b>	<b>Slovakia</b>	0.70	<b>Denmark</b>	<b>0.87</b>	<b>Denmark</b>	<b>0.87</b>	<b>Latvia</b>	0.41	<b>Czech</b>	0.64	
11	<b>0.85</b>	<b>Latvia</b>	0.66	<b>Sweden</b>	<b>0.86</b>	<b>Spain</b>	<b>0.86</b>	<b>Poland</b>	0.39	<b>Germany</b>	0.63	
12	<b>0.82</b>	<b>UK</b>	0.63	<b>Belgium</b>	<b>0.85</b>	<b>Sweden</b>	<b>0.85</b>	<b>UK</b>	0.35	<b>Finland</b>	0.61	
13	<b>0.79</b>	<b>Estonia</b>	0.61	<b>UK</b>	<b>0.84</b>	<b>Slovenia</b>	<b>0.85</b>	<b>Romania</b>	0.33	<b>Ireland</b>	0.59	
14	<b>0.79</b>	<b>Austria</b>	0.60	<b>Czech</b>	<b>0.84</b>	<b>Czech</b>	<b>0.80</b>	<b>mean</b>	0.32	<b>Denmark</b>	0.58	
15	<b>0.77</b>	<b>Hungary</b>	0.59	<b>Holland</b>	<b>0.83</b>	<b>Ireland</b>	<b>0.76</b>	<b>Holland</b>	0.31	<b>Italy</b>	0.58	
16	<b>0.77</b>	<b>Mean</b>	0.58	<b>Estonia</b>	<b>0.82</b>	<b>Estonia</b>	<b>0.74</b>	<b>Estonia</b>	0.30	<b>mean</b>	0.54	
17	<b>0.71</b>	<b>Holland</b>	0.56	<b>Latvia</b>	<b>0.80</b>	<b>mean</b>	<b>0.74</b>	<b>Austria</b>	0.30	<b>UK</b>	0.53	



Table 6 continued

No.	Belgium	Bulgaria	Finland	Germany	Greece	Poland
18	mean	Denmark	Lithuania	UK	Finland	Sweden
19	Hungary	France	Ireland	Latvia	Germany	Portugal
20	Latvia	Germany	mean	Hungary	Belgium	Latvia
21	Portugal	Italy	Hungary	Portugal	Hungary	Bulgaria
22	Estonia	Greece	Bulgaria	Poland	Ireland	Hungary
23	Lithuania	Poland	Slovakia	Lithuania	Italy	Greece
24	Slovakia	Belgium	Portugal	Slovakia	Denmark	Estonia
25	Bulgaria	Ireland	Poland	Bulgaria	France	Lithuania
26	Greece	Sweden	Romania	Romania	Portugal	Slovakia
27	Romania	Portugal	Greece	Greece	Sweden	Romania

Source: own calculation.

**Table 7.** Ordered values of  $hp$  measure with all possible partners and inside countries at NUTS1, 2 and 3 levels for Spain, Holland, Hungary, Italy, Sweden and UK

No.	Spain		Holland		Hungary		Italy		Sweden		UK	
	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner
0												
1	<b>1.00</b>	<b>NUTS 1</b>	<b>0.99</b>	<b>NUTS 1</b>	<b>0.98</b>	<b>NUTS 1</b>	<b>1.00</b>	<b>NUTS 1</b>	<b>0.98</b>	<b>NUTS 1</b>	<b>0.98</b>	<b>NUTS 1</b>
2	<b>0.99</b>	<b>NUTS 2</b>	<b>0.97</b>	<b>NUTS 2</b>	<b>0.96</b>	<b>NUTS 2</b>	<b>0.99</b>	<b>NUTS 2</b>	<b>0.97</b>	<b>NUTS 2</b>	<b>0.97</b>	<b>NUTS 2</b>
3	<b>0.97</b>	<b>NUTS 3</b>	<b>0.97</b>	<b>NUTS 3</b>	<b>0.90</b>	<b>NUTS 3</b>	<b>0.98</b>	<b>NUTS 3</b>	<b>0.95</b>	<b>NUTS 3</b>	<b>0.95</b>	<b>NUTS 3</b>
4	<b>0.92</b>	<b>Spain</b>	<b>0.88</b>	<b>Estonia</b>	<b>0.87</b>	<b>Germany</b>	<b>0.95</b>	<b>France</b>	<b>0.89</b>	<b>Finland</b>	<b>0.89</b>	<b>Finland</b>
5	<b>0.90</b>	<b>France</b>	<b>0.88</b>	<b>Latvia</b>	<b>0.86</b>	<b>France</b>	<b>0.94</b>	<b>Denmark</b>	<b>0.88</b>	<b>Estonia</b>	<b>0.88</b>	<b>Estonia</b>
6	<b>0.89</b>	<b>Germany</b>	<b>0.87</b>	<b>Lithuania</b>	<b>0.82</b>	<b>Finland</b>	<b>0.90</b>	<b>Italy</b>	<b>0.87</b>	<b>Latvia</b>	<b>0.87</b>	<b>Latvia</b>
7	<b>0.89</b>	<b>Austria</b>	<b>0.87</b>	<b>Denmark</b>	<b>0.80</b>	<b>Belgium</b>	<b>0.89</b>	<b>Finland</b>	<b>0.86</b>	<b>Lithuania</b>	<b>0.86</b>	<b>Lithuania</b>
8	<b>0.88</b>	<b>Belgium</b>	<b>0.86</b>	<b>Sweden</b>	<b>0.79</b>	<b>Austria</b>	<b>0.88</b>	<b>Belgium</b>	<b>0.85</b>	<b>Spain</b>	<b>0.85</b>	<b>Spain</b>
9	<b>0.87</b>	<b>Slovenia</b>	<b>0.84</b>	<b>Czech</b>	<b>0.79</b>	<b>Denmark</b>	<b>0.88</b>	<b>Germany</b>	<b>0.85</b>	<b>France</b>	<b>0.85</b>	<b>France</b>
10	<b>0.86</b>	<b>Finland</b>	<b>0.83</b>	<b>UK</b>	<b>0.79</b>	<b>Sweden</b>	<b>0.87</b>	<b>Austria</b>	<b>0.82</b>	<b>Sweden</b>	<b>0.82</b>	<b>Sweden</b>
11	<b>0.86</b>	<b>Denmark</b>	<b>0.82</b>	<b>Finland</b>	<b>0.77</b>	<b>Spain</b>	<b>0.84</b>	<b>Hungary</b>	<b>0.79</b>	<b>Hungary</b>	<b>0.79</b>	<b>Hungary</b>
12	<b>0.84</b>	<b>Italy</b>	<b>0.81</b>	<b>Italy</b>	<b>0.75</b>	<b>Holland</b>	<b>0.81</b>	<b>UK</b>	<b>0.79</b>	<b>Denmark</b>	<b>0.79</b>	<b>Denmark</b>
13	<b>0.82</b>	<b>Portugal</b>	<b>0.80</b>	<b>France</b>	<b>0.74</b>	<b>Czech</b>	<b>0.81</b>	<b>Estonia</b>	<b>0.78</b>	<b>Slovenia</b>	<b>0.78</b>	<b>Slovenia</b>
14	<b>0.81</b>	<b>Czech</b>	<b>0.77</b>	<b>Austria</b>	<b>0.73</b>	<b>Ireland</b>	<b>0.80</b>	<b>Ireland</b>	<b>0.75</b>	<b>Italy</b>	<b>0.75</b>	<b>Italy</b>
15	<b>0.81</b>	<b>Poland</b>	<b>0.76</b>	<b>Spain</b>	<b>0.73</b>	<b>Slovenia</b>	<b>0.78</b>	<b>Czech</b>	<b>0.74</b>	<b>Czech</b>	<b>0.74</b>	<b>Czech</b>
16	<b>0.77</b>	<b>Sweden</b>	<b>0.70</b>	<b>Germany</b>	<b>0.72</b>	<b>Estonia</b>	<b>0.78</b>	<b>Spain</b>	<b>0.74</b>	<b>Austria</b>	<b>0.74</b>	<b>Austria</b>
17	<b>0.77</b>	<b>Ireland</b>	<b>0.70</b>	<b>Slovenia</b>	<b>0.71</b>	<b>UK</b>	<b>0.76</b>	<b>Slovenia</b>	<b>0.72</b>	<b>Germany</b>	<b>0.72</b>	<b>Germany</b>

Table 7 continued

No.	Spain	Holland	Hungary	Italy	Sweden	UK
18	Estonia 0.77	mean 0.69	Belgium 0.70	Hungary 0.75	Latvia 0.71	Ireland 0.71
19	Lithuania 0.76	UK 0.63	Ireland 0.69	Latvia 0.74	Holland 0.70	Belgium 0.71
20	Bulgaria 0.75	Latvia 0.59	mean 0.66	mean 0.73	mean 0.68	mean 0.70
21	Sweden 0.74	Bulgaria 0.56	Bulgaria 0.59	Portugal 0.69	Lithuania 0.60	Slovakia 0.65
22	Hungary 0.73	Slovakia 0.53	Slovakia 0.57	Lithuania 0.63	Portugal 0.58	Holland 0.63
23	Slovakia 0.68	Estonia 0.53	Holland 0.51	Poland 0.58	Poland 0.53	Bulgaria 0.63
24	Poland 0.68	Hungary 0.51	Poland 0.40	Slovakia 0.53	Slovakia 0.47	Poland 0.53
25	Portugal 0.60	Lithuania 0.48	Romania 0.36	Bulgaria 0.49	Bulgaria 0.43	Portugal 0.40
26	Greece 0.50	Romania 0.32	Portugal 0.24	Romania 0.25	Romania 0.23	Romania 0.37
27	Romania 0.50	Greece 0.31	Greece 0.22	Greece 0.22	Greece 0.11	Greece 0.35

Source: own calculation.

**Table 8.** Ordered values of *hp* measure with all possible partners and inside countries at NUTS1, 2 and 3 levels for Romania, France, Austria, Czech Republic, Denmark and Ireland

No.	Romania		France		Austria		Czech		Denmark		Ireland	
	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner
1	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp
2	<b>NUTS 1</b>	<b>0.96</b>	<b>NUTS 1</b>	<b>1.00</b>	<b>NUTS 1</b>	<b>1.00</b>	<b>NUTS 3</b>	<b>0.97</b>	<b>NUTS 2</b>	<b>0.99</b>	<b>NUTS 2</b>	<b>0.97</b>
3	<b>NUTS 2</b>	<b>0.95</b>	<b>NUTS 2</b>	<b>1.00</b>	<b>NUTS 2</b>	<b>0.99</b>	<b>NUTS 2</b>	<b>0.96</b>	<b>NUTS 3</b>	<b>0.99</b>	<b>NUTS 3</b>	<b>0.90</b>
4	<b>NUTS 3</b>	<b>0.87</b>	<b>NUTS 3</b>	<b>0.99</b>	<b>NUTS 3</b>	<b>0.98</b>	Spain	<b>0.89</b>	France	<b>0.93</b>	Denmark	<b>0.83</b>
5	Bulgaria	0.74	Germany	<b>0.94</b>	Belgium	<b>0.91</b>	Slovenia	<b>0.87</b>	Sweden	<b>0.88</b>	France	<b>0.81</b>
6	Lithuania	0.54	Italy	<b>0.94</b>	Germany	<b>0.91</b>	Denmark	<b>0.84</b>	Italy	<b>0.88</b>	Italy	<b>0.80</b>
7	Spain	0.50	Denmark	<b>0.93</b>	France	<b>0.90</b>	Finland	<b>0.84</b>	Germany	<b>0.87</b>	Belgium	0.79
8	Slovenia	0.45	Finland	<b>0.92</b>	Spain	<b>0.90</b>	Latvia	<b>0.83</b>	Finland	<b>0.87</b>	Austria	0.79
9	Finland	0.44	Belgium	<b>0.92</b>	Finland	<b>0.88</b>	Estonia	<b>0.82</b>	Spain	<b>0.86</b>	Latvia	0.78
10	Austria	0.39	Austria	<b>0.90</b>	Italy	<b>0.88</b>	Italy	<b>0.81</b>	Austria	<b>0.85</b>	Finland	0.77
11	UK	0.37	Sweden	<b>0.89</b>	Holland	<b>0.87</b>	Germany	<b>0.80</b>	Belgium	<b>0.85</b>	Spain	0.77
12	Hungary	0.36	Holland	<b>0.88</b>	Slovenia	<b>0.86</b>	Austria	<b>0.80</b>	Czech	<b>0.84</b>	Germany	0.76
13	Czech	0.35	Spain	<b>0.87</b>	Denmark	<b>0.85</b>	France	0.79	Ireland	<b>0.83</b>	Estonia	0.75
14	mean	0.34	Ireland	<b>0.81</b>	Sweden	<b>0.82</b>	Hungary	0.79	Holland	<b>0.82</b>	Sweden	0.75
15	Greece	0.33	Slovenia	<b>0.80</b>	Czech	<b>0.80</b>	Lithuania	0.78	Estonia	<b>0.81</b>	Czech	0.73
16	Latvia	0.33	UK	0.79	Ireland	0.79	Belgium	0.77	Slovenia	<b>0.80</b>	UK	0.71
17	France	0.33	Czech	0.79	UK	0.75	Holland	0.77	Hungary	<b>0.80</b>	Holland	0.70

Table 8 continued

No.	Romania	France	Austria	Czech	Denmark	Ireland
18	Germany 0.32	Estonia 0.75	mean 0.74	Slovakia 0.75	Latvia 0.79	Slovenia 0.70
19	Holland 0.32	mean 0.74	Latvia 0.73	UK 0.75	UK 0.77	Hungary 0.69
20	Estonia 0.31	Hungary 0.74	Hungary 0.73	Sweden 0.74	mean 0.73	mean 0.65
21	Slovakia 0.28	Latvia 0.72	Poland 0.71	mean 0.74	Lithuania 0.65	Poland 0.59
22	Italy 0.25	Portugal 0.71	Estonia 0.71	Ireland 0.73	Portugal 0.59	Lithuania 0.58
23	Sweden 0.23	Poland 0.64	Portugal 0.66	Bulgaria 0.70	Poland 0.58	Slovakia 0.47
24	Poland 0.23	Lithuania 0.61	Lithuania 0.64	Poland 0.64	Slovakia 0.57	Portugal 0.46
25	Denmark 0.22	Bulgaria 0.54	Bulgaria 0.60	Portugal 0.49	Bulgaria 0.55	Bulgaria 0.44
26	Belgium 0.19	Slovakia 0.50	Slovakia 0.54	Greece 0.49	Romania 0.22	Greece 0.22
27	Portugal 0.18	Romania 0.33	Romania 0.39	Romania 0.35	Greece 0.22	Romania 0.12
28	Ireland 0.12	Greece 0.19	Greece 0.30			

Source: own calculation.

**Table 9.** Ordered values of *hp* measure with all possible partners and inside countries at NUTS1, 2 and 3 levels for Portugal, Slovakia, Slovenia, Estonia, Latvia and Lithuania

No.	Portugal		Slovakia		Slovenia		Estonia		Latvia		Lithuania	
	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp	Partner	hp
1												
2	NUTS 2	0.99	NUTS 2	0.96	NUTS 2	1.00	NUTS 3	0.96	Estonia	0.92	NUTS 3	0.90
3	NUTS 3	0.96	NUTS 3	0.93	NUTS 3	0.99	Latvia	0.92	Lithuania	0.89	Latvia	0.89
4	Holland	0.80	Lithuania	0.80	Spain	0.92	Hungary	0.87	Hungary	0.86	Estonia	0.87
5	France	0.71	Slovenia	0.77	Finland	0.88	Lithuania	0.87	Czech	0.83	Hungary	0.82
6	Germany	0.71	Czech	0.75	Czech	0.87	UK	0.83	UK	0.82	UK	0.81
7	Italy	0.69	Latvia	0.73	Austria	0.86	Czech	0.82	Spain	0.81	Bulgaria	0.80
8	Belgium	0.66	Bulgaria	0.70	Germany	0.85	Finland	0.82	Finland	0.80	Slovakia	0.80
9	Austria	0.66	Spain	0.68	Holland	0.84	Denmark	0.81	Slovenia	0.80	Finland	0.78
10	Finland	0.64	Estonia	0.67	Denmark	0.80	Italy	0.78	Denmark	0.79	Slovenia	0.78
11	Spain	0.60	Finland	0.66	France	0.80	Sweden	0.78	Ireland	0.78	Czech	0.78
12	Denmark	0.59	UK	0.65	Latvia	0.80	Spain	0.77	NUTS 3	0.75	Spain	0.76
13	Sweden	0.58	Germany	0.58	Belgium	0.79	Ireland	0.75	Italy	0.74	Denmark	0.65
14	Slovenia	0.58	mean	0.57	Italy	0.78	France	0.75	Germany	0.73	mean	0.65
15	Czech	0.49	Hungary	0.57	Lithuania	0.78	Germany	0.74	Austria	0.73	Austria	0.64
16	Poland	0.48	Denmark	0.57	Slovakia	0.77	Slovenia	0.71	Slovakia	0.73	Italy	0.63
17	mean	0.47	Greece	0.56	UK	0.77	Austria	0.71	France	0.72	Germany	0.63
18	Ireland	0.46	Austria	0.54	mean	0.75	mean	0.68	Sweden	0.71	France	0.61

Table 9 continued

No.	Portugal	Slovakia	Slovenia	Estonia	Latvia	Lithuania
19	UK	Holland	Bulgaria	Slovakia	mean	Sweden
	0.40	0.53	0.74	0.67	0.70	0.60
20	Slovakia	Italy	Sweden	Belgium	Belgium	Ireland
	0.32	0.53	0.72	0.65	0.67	0.58
21	Bulgaria	France	Estonia	Bulgaria	Bulgaria	Romania
	0.31	0.50	0.71	0.61	0.66	0.54
22	Estonia	Ireland	Hungary	Holland	Holland	Belgium
	0.25	0.47	0.71	0.53	0.59	0.51
23	Latvia	Sweden	Ireland	Poland	Poland	Holland
	0.24	0.47	0.70	0.39	0.48	0.48
24	Hungary	Belgium	Poland	Romania	Greece	Greece
	0.24	0.46	0.69	0.31	0.41	0.44
25	Romania	Poland	Portugal	Greece	Romania	Poland
	0.18	0.36	0.58	0.30	0.33	0.37
26	Lithuania	Portugal	Greece	Portugal	Portugal	Portugal
	0.18	0.32	0.46	0.25	0.24	0.18
27	Greece	Romania	Romania			
	0.15	0.28	0.45			

Source: own calculation.

a monetary union with. In other words, monetary policy could be implemented in these two countries, as effectively as for regions of one country – the costs of participation in monetary union do not apply. This criterion is extremely rigorous and has not been met in many cases.

The values of correlation coefficient for NUTS 1, 2 and 3 level region pairs is higher than with any other country in the case of Belgium, Greece, Poland, Spain, Holland, Hungary, Sweden, UK, Romania, France, Austria, the Czech Republic, Denmark, Ireland, Portugal, Slovakia, Slovenia, Estonia and Lithuania. Bulgaria has hp value for NUTS 3 ‘inside’ equal to 0.79, while with Lithuania – 0.8, so this country is a suitable candidate for monetary union with Bulgaria. Germany has higher value of hp with Italy and France than for region pairs at NUTS 3 level of aggregation (0.93). Latvia is characterized by a very low value of correlation coefficient for pairs of NUTS 3 regions within countries (0.75), in comparison with other countries. This indicates that, from a regional perspective, monetary policy cannot be implemented very effectively (especially in comparison with other countries). Values of hp for Latvia with Estonia, Lithuania, Hungary, Czech Republic, UK, Spain, Finland, Slovenia, Denmark, Ireland (in descending order) are higher than for within country NUTS 3 level region pairs. This means that the possible number of candidates for monetary union with Latvia is quite extensive. In case of Finland, hp with France is higher than for inside regions at NUTS 3 level inside countries (0.92), and with Germany, Italy and Spain is higher for than for NUTS 1 level regions. This indicates four very favorable candidates to form monetary union with Finland.

Even though there are possible partners for monetary union in case of Bulgaria, Germany, Latvia and Finland, none of them are conceding – there is not even one pair of countries that could form monetary union at virtually no loss in monetary policy effectiveness. But the criterion used here was extremely rigorous, especially if one takes a closer look at values of hp, one can see that they are very high in many cases. Values of hp measure above 0.8 were denoted in bold.

The chosen value of 0.8 is somehow arbitrary but it expresses a rather high degree of business cycle synchronization. Taking this value as a point of reference, Poland does not find any suitable partners with which to form a monetary union. The highest value of hp is observed with Belgium and its equal to 0.77. A similar situation can be seen in the instance of Greece, which has the worst results among all examined countries. In other words, the Greek business cycle is very poorly synchronized with cycles all of analyzed countries – monetary policy that is optimal for any of these countries would be inappropriate for Greece.



Using 0.8 as a reference value, some countries have considerable numbers of possible candidates for introduction of a common currency: Belgium (9 countries), Finland (14), Germany (11), Spain (12), Holland (10), Italy (11), France (12), Austria (12), Denmark (15) and Slovenia (10). Numbers for other countries are not as big, but still multiple pairs of countries with highly synchronized business cycles can be found. This also indicates that a lot of countries from the Euro Area form an organism that can be considered quite close to an optimum currency area. Germany, France, Italy, Austria, Belgium, Holland, Spain, Austria and Finland constitute such an entity – an optimal monetary policy for one of these countries is very close to optimal policies for all others. Unfortunately, the same thing cannot be said about other members of Euro Area with Greece being a leading outlier.

## **Conclusions**

The extraction of the cyclical components with Hodrick-Prescott filter from real GDP time series in order to obtain the correlation coefficient of deviations of cyclical component from trend resulted in obtaining 276 measures for country pairs, as well as 3321, 29191 and 796953 measures for NUTS 1, 2 and 3 level region pairs respectively. The analysis revealed that the average value of *hp* measure for countries and NUTS 1, 2 and 3 regions are equal to 0.65, 0.89, 0.88 and 0.85 respectively. This shows that business cycle synchronization at regional level is generally higher than at country level, but is mostly driven by high degree of business cycle synchronization among regions within countries. This result contradicts 'Krugman's View' which states that the elimination of barriers to all economic activities leads to a higher degree of concentration of economic activity due to economies of scale. These, in turn, would lead to higher specialization, fragility of regions exports to changes in demand and lower business cycles synchronization with other regions. To the contrary, it gives support to 'European Commission View'. Further economic integration by eliminating barriers to economic activity and introducing similar policies – *ergo* making groups of countries more like one country – will lead to tighter business cycle synchronization and can make common monetary policy effective.

Very restrictive criterion that used comparisons of business cycle synchronization at regional level within countries with country level correlations was used to assess whether two countries can enter a monetary union with each other with virtually no cost of monetary policy effectiveness loss. This restrictive criterion showed that four countries have candidates for

effective monetary union formation, namely: Bulgaria, Finland, Germany and Latvia. On the other hand, requirement must be fulfilled for two countries – and that criterion was not met. Using a less restrictive criterion of correlation coefficient equal to 0.8, it turned out that many countries have many good candidates with which to introduce a common currency. For example: Belgium (9 countries), Finland (14), Germany (11), Spain (12), Holland (10), Italy (11), France (12), Austria (12), Denmark (15) and Slovenia (10). Numbers for other countries are lower, but still many pairs of countries with highly synchronized business cycles can be found. This also indicates that a lot of countries from the Euro Area form an organism that can be considered quite close to optimum currency area. Germany, France, Italy, Austria, Belgium, Holland, Spain, Austria and Finland constitute such an entity – optimal monetary policy for one of these countries is very close to optimal policies for all others. Unfortunately, the same thing cannot be said about other members of Euro Area with Greece being a leading outlier.

The results also show that the Polish National Bank can use monetary policy very effectively, no matter what regional level of aggregation is used as reference point. On the other hand, the values of business cycle synchronization for Poland and other countries are very low. This indicates that there are no good candidates to form a monetary union with Poland. Poland is additionally the second outlier, after Greece, within the analyzed group. This result should not be worrying as a low degree of business cycle synchronization with other European countries can be attributed to a good economic performance of Poland during the recent crisis.

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## APPENDIX

**Table A1.** ADF and KPSS result for NUTS 1 region real GDP time series

Country	Region name	ADF	KPSS	Country	Region name	ADF	KPSS
Belgium	Région de Bruxelles-Capitale	0,939	I(1)**	Italy	Nord Est	0,332	I(1)**
Belgium	Vlaams Gewest	0,854	I(1)**	Italy	Centro (IT)	0,699	I(1)**
Belgium	Région Wallonne	0,934	I(1)**	Italy	Sud (IT)	0,598	I(1)**
Bulgaria	Severna and iztochna Bulgaria	0,953	I(1)**	Italy	Isole (IT)	0,675	I(1)**
Bulgaria	Yugozapadna and yuzhna central Bulgaria	0,996	I(1)**	Hungary	Közép-Magyarország	0,952	I(1)**
Germany	Baden-Württemberg	0,811	I(1)**	Hungary	Dunántúl	0,723	I(1)**
Germany	Bayern	0,880	I(1)**	Hungary	Alföld és Észak	0,045	I(1)**
Germany	Berlin	0,560	I(1)*	Holland	Noord-Nederland	0,908	I(1)**
Germany	Brandenburg	0,012	I(1)**	Holland	Oost-Nederland	0,890	I(1)**
Germany	Bremen	0,963	I(1)**	Holland	West-Nederland	0,825	I(1)**
Germany	Hamburg	0,906	I(1)**	Holland	Zuid-Nederland	0,790	I(1)**
Germany	Hessen	0,911	I(1)**	Austria	Ostösterreich	0,839	I(1)**
Germany	Mecklenburg-Vorpommern	0,010	I(1)**	Austria	Südösterreich	0,777	I(1)**
Germany	Niedersachsen	0,908	I(1)**	Austria	Westösterreich	0,906	I(1)**
Germany	Nordrhein-Westfalen	0,863	I(1)**	Poland	Centralny	0,940	I(1)**
Germany	Rheinland-Pfalz	0,883	I(1)**	Poland	Poludniowy	0,937	I(1)**
Germany	Saarland	0,787	I(1)**	Poland	Wschodni	0,860	I(1)**
Germany	Sachsen	0,009	I(1)**	Poland	Północno-Zachodni	0,943	I(1)**
Germany	Sachsen-Anhalt	0,007	I(1)**	Poland	Poludniowo-Zachodni	0,977	I(1)**
Germany	Schleswig-Holstein	0,952	I(1)**	Poland	Północny	0,881	I(1)**
Germany	Thüringen	0,191	I(1)**	Romania	Macroregiunea unu	0,365	I(1)**
Greece	Voreia Ellada	0,664	I(1)**	Romania	Macroregiunea doi	0,353	I(1)*
Greece	Kentriki Ellada	0,473	I(1)**	Romania	Macroregiunea trei	0,860	I(1)**
Greece	Attiki	0,671	I(1)**	Romania	Macroregiunea patru	0,705	I(1)**
Greece	Nisia Aigaïou, Kriti	0,486	I(1)**	Finland	Manner-Suomi	0,961	I(1)**
Spain	Noroeste	0,804	I(1)**	Finland	Åland	0,976	I(1)**
Spain	Noreste	0,960	I(1)**	Sweden	Östra Sverige	0,989	I(1)**

Table A1 continued

Country	Region name	ADF	KPSS	Country	Region name	ADF	KPSS
Spain	Noreste	0,960	I(1)**	Sweden	Östra Sverige	0,989	I(1)**
Spain	Comunidad de Madrid	0,708	I(1)**	Sweden	Södra Sverige	0,971	I(1)**
Spain	Centro (ES)	0,996	I(1)**	Sweden	Norra Sverige	0,427	I(1)**
Spain	Este	0,875	I(1)**	UK	North East (ENGLAND)	0,898	I(1)**
Spain	Sur	0,789	I(1)**	UK	North West (ENGLAND)	0,786	I(1)**
Spain	Canarias (ES)	0,757	I(1)**	UK	Yorkshire and The Humber	0,756	I(1)**
France	Île de France	0,872	I(1)**	UK	East Midlands (ENGLAND)	0,864	I(1)**
France	Bassin Parisien	0,581	I(1)**	UK	West Midlands (ENGLAND)	0,485	I(1)**
France	Nord - Pas-de-Calais	0,759	I(1)**	UK	Eastern	0,817	I(1)**
France	Est	0,321	I(1)**	UK	London	0,958	I(1)**
France	Ouest	0,662	I(1)**	UK	South East	0,764	I(1)**
France	Sud-Ouest	0,861	I(1)**	UK	South West (ENGLAND)	0,870	I(1)**
France	Centre-Est	0,871	I(1)**	UK	Wales	0,828	I(1)**
France	Méditerranée	0,945	I(1)**	UK	Scotland	0,982	I(1)**
Italy	Nord Ovest	0,575	I(1)**	UK	Northern Ireland	0,628	I(1)**

Source: own calculation.