Discussion Paper and Working Paper Series

Synchronization and Diversity in Business Cycles: A Network Approach Applied to the European Union

David Matesanz Gomez, Guillermo J. Ortega and Benno Torgler

Abstract:

This paper analyses synchronization in business cycles across the European Union (EU) since 1989. We include both old and new European Union members and countries which are currently negotiating accession, as well as potential European Union members. Our methodological approach is based on the correlation matrix and the networks within, which allows us to summarize the individual interaction and co-movement, while also capturing the existing heterogeneity of connectivity within the European economic system. The results indicate that the synchronization of the old EU countries remained stable until the current financial crisis. Additionally, the synchronization of the new and potential members has approached to the old EU members although we observe the existence of different synchronization levels and dynamics in output growth in single countries as well as in groups of countries. Some countries have achieved an important degree of co-movement (such as the Baltic Republics, Hungary, Slovenia and Iceland), while others have experienced reduced synchronization, or even desynchronization (such as Romania, Bulgaria and even Greece and Ireland).

SYNCHRONIZATION AND DIVERSITY IN BUSINESS CYCLES:

A NETWORK APPROACH APPLIED TO THE EUROPEAN UNION

DAVID MATESANZ GOMEZ
Applied Economics Department, University of Oviedo
Avda. Cristo s/n, 33006, Oviedo, Spain

GUILLERMO J. ORTEGA
Science and Technology Department, Universidad Nacional de Quilmes
and CONICET, Argentina

BENNO TORGLER
The School of Economics and Finance, Queensland University of Technology
GPO Box 2434, Brisbane, QLD 4001, Australia
CREMA – Center for Research in Economics, Management and the Arts, Switzerland
CESifo, Germany
National Centre for Econometric Research (NCER), Australia

(this version, 19 January, 2012)

Abstract

This paper analyses synchronization in business cycles across the European Union (EU) since 1989.

We include both old and new European Union members and countries which are currently negotiating

accession, as well as potential European Union members. Our methodological approach is based on

the correlation matrix and the networks within, which allows us to summarize the individual

interaction and co-movement, while also capturing the existing heterogeneity of connectivity within

the European economic system. The results indicate that the synchronization of the old EU countries

remained stable until the current financial crisis. Additionally, the synchronization of the new and

potential members has approached to the old EU members although we observe the existence of

different synchronization levels and dynamics in output growth in single countries as well as in

groups of countries. Some countries have achieved an important degree of co-movement (such as the

Baltic Republics, Hungary, Slovenia and Iceland), while others have experienced reduced

synchronization, or even desynchronization (such as Romania, Bulgaria and even Greece and Ireland).

Key Words: Business cycle synchronization, European Union countries, EU candidates, complex systems, network topology.

JEL codes: E320, C450, O470

1. Introduction

The regional integration process of the European Union (EU) is rapidly increasing the number of the member countries. This geographic, economic and population expansion has been especially intense with respect to the Eastern European countries, as the group has experienced the difficulty of transitioning from a planned economic structure to an open market economy and a democratic political system. Following those important transitions during the 1990s, the next challenge has been integration into a common market and, for some of them, into a monetary area with a common currency.

On the first of May 2004, ten New European Eastern countries became members of the EU (Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovenia and Slovakia). Less than three years later (January 2007), Bulgaria and Romania joined EU. Currently, Croatia, Iceland, the Former Yugoslav Republic of Macedonia (henceforth referred to as Macedonia) and Turkey are current candidates for membership. Lastly, another five countries are identified as potential candidates to join the EU (Albania, Bosnia and Herzegovina, Kosovo, Montenegro and Serbia)[1]. Additionally, five of the Eastern European countries have given up their own currencies and joined the euro area during the last four years (Cyprus, Estonia, Malta, Slovenia and Slovakia[2]). In the coming years, it is possible that other countries will move further in the European integration process by joining the monetary union of the euro area.

Giving up their own currencies and joining the euro area implies that these[3] countries have voluntarily relinquished control over their monetary and exchange rate policies. Thus, the effectiveness of monetary policy and the benefits of the currency union depend on the

---

[1] We call the group of new, currently negotiating and potential members as NCP. For the classification of countries see the Appendix.

[2] Each of the five countries joined individually and at different times. Slovenia joined the Euro on the first of January 2007, Cyprus and Malta one year later. Slovakia joined on the first of January 2009 and, finally, Estonia joined two years later, the first of January 2011.

[3] The European Monetary Union (EMU) is currently formed by 17 countries including Austria, Belgium, France, Finland, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain, apart from the five previously mentioned.

extent to which member countries share certain common characteristics[4]. The political climate of the EU does not support several of these important characteristics, which suggests that the synchronization of business cycles among member countries is a key concern[5]. The lower the business cycle integration among countries in the euro area, the larger the possibility of asymmetric shocks. In the presence of these kinds of shocks, the cost of the loss of countries' exchange and monetary policies could be severe for various member country economies. Additionally, asymmetric shocks may spread to the rest of the euro countries through spillover effects as evidenced by the contagion of the Greek crisis.

The aim of this study is to analyze the network topology, hierarchy and evolution of business cycle synchronization across Europe. Specifically, we investigate the GDP co-movements within a group of "old" European countries (OEU) and the synchronization of the NCP countries with these OEU members. To characterize synchronization of the business cycle we employ an approach different from that of previous studies. We base our work on the organization of the correlation matrix according to the closeness of the relation among its elements (due to countries´ output growth) and the construction of a network inside it. This methodology was first employed to analyze topology and hierarchy in financial markets (Mantegna, 1999; Ortega and Matesanz, 2006) but was extended to the analysis of business cycle synchronization (Miskiewicz and Ausloos, 2010; Matesanz, Ortega and Torgler, 2011). As we will explain in the next section, this methodology captures the presence of heterogeneity and diversity of co-movements between all countries due to taking into account all existing country output correlations. We obtain several main results from the analysis presented in this paper: (1) The synchronization of the OEU countries has remained stable over the last 20 years but has sharply increased during the current financial crises; (2) Synchronization of the NCP countries has increased due to the euro area in the last few years although we observe different synchronization and diversification dynamics in single countries and in groups of countries. Some countries have achieved an important degree of co-movement (such as the Baltic Republics, Hungary, Slovenia and Iceland) and some countries have shown less coordination; while others may have commenced desynchronization processes (such as

---

[4] The theoretical foundations of currency unions have been developed in the optimum currency areas (OCA) literature pioneered by Mundell (1961).

[5] The OCA literature has also emphasized the role of the common budget and fiscal policy and the integration of the job markets as important characteristics to reduce the effects of asymmetric shocks in the currency areas. These two features seem to be politically difficult to achieve for the EU even in the European current fiscal and debt crisis situation.

Romania, Bulgaria and even Greece in the OEU countries). In general, our methodological approach suggests an interesting route for the study of global interdependence and diversification in the business cycle.

The rest of the paper is organized as follows. The next section introduces some of the most interesting literature relevant to the purposes of this study and outlines our main contribution to the existing literature. Section three describes the dataset and the numerical methods we have employed. The fourth section presents and discusses the main findings of the study stressing the differences with previous and methodologically different works. Finally, the paper offers a brief summary and some concluding remarks.

2. Related literature and contribution of our study

The potential costs of a currency union change as the monetary integration process evolves over time. The literature highlights two key controversial features regarding the influence of the monetary integration process on business cycle synchronization. On the one hand, the increasing economic liaisons (especially trade) that should arise from membership to the currency union may result in tighter synchronization in the business cycle (Artis and Okubo, 2011; Baxter and Kouparistsas, 2005; Frankel and Rose, 1998). On the other hand, as countries become more economically integrated, each country can achieve a higher level of specialization, resulting in de-synchronized transmission of shocks as countries are now affected by sector-specific shocks (Imbs, 2004). Finally, several studies have emphasized the role of other key factors affecting the evolution of synchronization among currency union members, such as fiscal policies, institutional settings or market regulations (De Grauwe, 2006).

Theoretical controversies have encouraged the recent development of a vast empirical literature specifically dealing with the issue of synchronization (Adalet and Öz, 2010; Savva, Neanidis and Osborn, 2010; Aslanidis, 2010; Darvas and Szapáry, 2008; Buissière, Fidmurc and Schnatz, 2008; Fidmurc and Korhonen, 2006; Camacho, Perez-Quiros and Saiz, 2008,

2006; Eickmeier and Breitung, 2005; Fidmurc and Korhonen, 2004)[6]. Both the methodologies implemented and the findings of this literature are mixed.

For instance, Savva et al. (2010) modeled a bivariate VAR-GARCH specification with a smoothly time-varying correlation which allowed for structural change in the monthly industrial production index of new and negotiating European countries. The analysis covered 1980 to 2006 and discovered that most of the countries experienced an abrupt transition to a new regime around 2002. They report that at the end of 2006, most of the countries have at least doubled the extent of their business cycle synchronization with the euro area compared with the synchronization in the early 1990s (some have changed from negative to positive correlations). Meanwhile, only Slovenia and Hungary show an intense co-movement with euro countries since the end of the 90s.

Aslanidis (2010) uses a new technique based on threshold seemingly unrelated regressions. In Aslanidis study, monthly seasonally-adjusted values of the logarithmic indices of industrial production are employed for the period 1993:2 to 2006:4. The results indicate that Hungary demonstrates strong business cycle synchronization with the euro area while the Czech Republic and particularly Poland are less synchronized.

A study by Adalet and Öz (2010) applies simple VAR modelling to the quarterly rate of growth of per capita GDP from 1994 to 2009, and includes the Czech Republic, Hungary, Poland, Romania and Slovakia in the analysis. We highlight three key findings among their results: (1) There is no common business cycle among the selected Eastern countries; (2) Hungary and Poland are related to the US business cycle, while Slovakia is closer to the Russian cycle; (3) The influence of Russia on these economies has declined over the last decade, and Slovakia is synchronized with Germany.

Ferreira, Dionisio and Pires (2010) apply General Maximum Entropy to evaluate the degree of financial integration based on covered interest parity in the European Union. The study analyses the degree of financial integration of five non-euro countries: Denmark, Sweden, United Kingdom, the Czech Republic and Hungary. Their results suggest that the degree of financial integration of non-euro countries is lower than that previously achieved

---

[6] This empirical literature can be included in the group of synchronization of world business cycles studies (Matesanz, Ortega and Torgler, 2011; Aruoba, et al. 2011; Artis, Chouliarakis and Harischandra, 2011; Miskiewicz and Ausloos, 2010; Anatonakakis   Scharler, 2010; Crucini, Kose and Otrok, 2008; Kose, Otrok, and Whiteman, 2008; Helbling and Bayoumi, 2003; Kose, Otrok and Whiteman, 2003).

among euro-countries. Additionally, the Czech Republic, Hungary and the UK are found to violate the covered interest parity, suggesting no financial integration.

The work by Artis, Fidrmuc and Scharler (2008) uses quarterly real GDP data from 1990 to 2004 and reports that Estonia, Hungary, Poland and Slovenia are substantially correlated with the euro area. The Czech Republic and Slovakia appear as potential exceptions in the degree of synchronization.

In an extensive study on the issue, Darvas and Szapáry (2008) include seasonally-adjusted quarterly output, industrial production, exports, services, and consumption data from 1983 to 2002. By comparing different detrending methods, they apply several measures of synchronization to a wide group of NCP, euro and other non-European countries as a control group). The authors find that Hungary, Poland and Slovenia have achieved a high degree of synchronization in their GDP, industry and exports, whereas the Czech Republic and Slovakia are less synchronized, and the Baltic States do not appear to be synchronized at all. Additionally, they report higher synchronization in the core countries belonging to the EMU (Germany, Austria, Belgium, France, Italy and the Netherlands) and a second group of less synchronized countries; the "periphery" (Finland, Ireland, Portugal and Spain). Finally, they document the emergence of a business cycle at the global level when other control countries are included in the analysis.

Buissière, Fidmurc and Schnatz (2008) estimate a trade gravity model augmented with other relevant variables. Their results show that most of the NCP countries have reoriented their trade with the European Union between 1993 and 2003. Trade integration between most new EU members and the euro area is close to the estimated gravity model trade levels while there is still room for Central and Eastern European countries to strengthen trade links with the euro area. Only smaller South Eastern countries such as Albania, Bosnia-Herzegovina and Macedonia demonstrate a small degree of trade integration with both the euro area and the world economy, reflecting the overall closeness of their economies. Finally, they document a significant heterogeneity in trade intensity across countries.

The co-movement of the industrial sector cycle across European countries is characterized by Camacho, Perez-Quiros and Saiz (2006), without imposing any given model. Their results conclude that there is no evidence of a "European business cycle" that acts as an attractor to other economies. Moreover, there has been no appreciable increase in business cycle synchronization since 1990, and the business cycle of euro economies is more

synchronized than the business cycle of the new members. Finally, linkages among new members are closer than their synchronization with euro countries. Furthermore, Camacho, Perez-Quiros and Saiz (2008) find evidence refuting the existence of a single European cycle by applying model-based clustering methods to several features of the business cycle.

Fidrmuc and Korhonen (2006) present a survey summarizing 35 previous studies of this issue. Their meta-analysis confirms that the economic cycle in several New and Negotiating countries is highly correlated with the euro area. In particular, Hungary, Poland and Slovenia have achieved a higher degree of cycle integration than the rest of the countries. Similarly, Estonia displays a certain degree of convergence with the euro area. Some of these countries have demonstrated an even higher correlation with the euro area than some of the other peripheral countries that already belong to the euro area. Finally, the authors illustrate how empirical studies that only include rates of growth present higher correlations than models which include economic structure. They also demonstrate that studies using monthly data report stronger correlations than others using higher frequency data.

Regardless of methodology, most of the previous works have used some variant of a country size weighted average measure of world or regional real output to quantify synchronization; and have analyzed how (over time) each country has become more or less synchronized to that measure (Aruoba, et al. 2011; Adalet and Öz, 2010; Savva, et al., 2010; Aslanidis, 2010; Darvas and Szapáry, 2008). Other studies have included additional variables such as consumption, investment or industrial production (Aruoba, et al. 2011; Aslanidis, 2010; Darvas and Szapáry, 2008; Kose, Otrok and Whiteman, 2008; Kose, Prasad and Terrones, 2003). Taken on its own, this research approach deals with the existence of a world or at least regional business cycle path. From this point of view, the analysis considers the synchronization between two agents (economies); that is, every single country and the regional or global aggregate world trend. However, there are controversies regarding the synchronization results of several single countries. In particular, Poland seems to be a contentious case, as some studies report a high degree of synchronization (Fidrmuc and Korhonen, 2006; Darvas and Szapáry, 2008; Artis, Fidrmuc and Scharler, 2008) while others show less or no synchronization (Adalet and Öz, 2010; Aslanidis, 2010). On the other hand, most of the studies have shown that Hungary and Slovenia have achieved a high degree of co-movement with the OEU countries while the Czech Republic and Slovakia appear to be less synchronized (Savva, et al., 2010; Artis, Fidrmuc and Scharler, 2008; Darvas and Szapáry, 2008; Fidrmuc and Korhonen, 2006).

As previously mentioned, the principal aim of this study is to better describe business cycle synchronization across Europe. The proposed methodology (explained in the next section) permits the construction of integration measures which include not only quantifying synchronization of the business cycle but also a diversification measure of co-movement interdependence for any single country and for different groups of countries represented as a whole. This framework takes into account the deep complexity and heterogeneity of the evolving economic system rather than summarizing it into an aggregate weighted measure.

As some economic and non-economic literature has emphasized, diversification is a key factor for potential survival, higher stability and potential positive performance in the medium and long run of the related systems. In the economic field, for instance, Hidalgo et al. (2007) and Hidalgo and Haussman (2009) suggest that development is associated with an increase in the number of individual activities and with the complexity and diversity that emerge from the interactions between them. Similarly, Saviotti and Frenken (2008) show that greater export variety is consistent with the long run development in OECD countries between 1964 and 2003. These facts appear to be in line with general principles governing dynamics in complex networks. Synchronizability in certain kinds of networks is facilitated as the underlying network becomes more heterogeneous, at least in the number of links that each node has (Gómez-Gardeñes, Moreno and Arenas, 2007).

We apply this methodology to a group of OEU and NCP countries. In so doing, we first construct correlation and distance matrices for GDP and GDP per capita over the 1989–2010 period. Based on these matrices, we build nested hierarchical structures of interactions that enable an analysis of the network topology and hierarchy that affect the overall dynamics. We then calculate different synchronization indices to analyze the evolution of business synchronization.

Our approximation contributes to the existing literature in several ways. Firstly, we are able to simply describe the dynamics of synchronization in real output in European countries; not only from the viewpoint of the integration to a common output trend (as achieved by previous papers), but also by including the diversity and complexity of output connections for each country. Therefore, the paper takes into account a wider and probably more relevant measure of synchronization for the potential monetary implications of asymmetric shocks within the euro area. Secondly, by exploiting the information in the correlation matrix as well as the networks within, we can clearly observe the evolution of the

topological configuration of countries' co-movement over their business cycle. This topological analysis clarifies the regionalization of European correlations in output growth and is useful to better explain macroeconomic dynamics.

3. Data and methodology

3.1 Data

The dataset consists of annual gross domestic product (GDP) and per capita gross domestic product (GDPpc)[7] as reported by the Groningen Growth and Development Centre at the University of Groningen (data are available online at: http://www.ggdc.net/databases/ted.htm). GDP per capita is presented in 1990 U.S. dollars converted into Geary Khamis PPPs to permit international and intertemporal comparisons across the entire database. The data covers the period1989 to 2010. We have included a group of new European countries, all current and potential countries, and ten old European Union countries[8]. We include Canada, China, Russia, United States and United Kingdom to control for the possibility of different business cycle co-movements[9] (a complete list of countries can be found in the appendix).

We have calculated the annual rate of growth, *rGDP,* in the usual way; therefore our complete dataset conforms to a matrix of 21 rows (yearly rates of growth) and 31 columns (countries). As this work addresses the structure and evolution of the topology and hierarchy, constructed upon the synchronization degree between countries economies, we have only implemented data on global output as a measure of the business cycle. Other variables such as industrial production and exports are tradable and do not fully capture general economic performance. Conversely, more specifically domestic variables such as consumption or services do not respond to some international synchronization linkages.

---

[7] Results arising from the GDP per capita are similar than those obtained with the GDP; consequently, they are not reported in this work. They can be directly obtained from the authors.

[8] We will also refer OEU countries as euro area countries, since all of them gave up their currencies and joined the Euro.

[9] A complete list of countries can be found in the Appendix.

3.2 Numerical methods

3.2.1 Hierarchical analysis

To quantify the interaction or synchronization between two or more time series, we use the Kendall rank correlation, τ.

Given two time series $\bar{x}_i = x_i(k), k = 1, N_{dat}$ and $\bar{x}_j = x_j(k), k = 1, N_{dat}$, the Kendall τ rank correlation between country i and country j, τ_{ij} in a time window of N_{dat} is defined as

$$\tau_{i,j} = \frac{C - D}{N} \tag{1}$$

Where C is the number of *concordant* pairs of GDP returns, that is, if both $x_i > x_j$ and $y_i > y_j$ or if both $x_i < x_j$ and $y_i < y_j$. D is the number of *discordant* pairs; that is, if both $x_i > x_j$ and $y_i < y_j$ or if both $x_i < x_j$ and $y_i > y_j$. T is the number of *tied* pairs of data points that occur when one or both variables remain constant. Finally, $N = C + D + T$ represents the total number of data points in the time series. Broadly speaking, the Kendall correlation measures the proportion of concordant pairs minus the proportion of discordant pairs over the total number of pairs. Therefore, the Kendall correlation summarizes the number of times each pair of data points move in the same direction. This measure is especially useful in quantifying associations between co-movements regardless of linearity. Thus, Kendall´s τ better describes the association between two variables than do traditional linear correlation coefficients. This is particularly true in the presence of the curvature observed in NCPs' GDP data for the period. In line with the Pearson correlation, Kendall's τ is, $-1 < \tau < 1$.

In our particular case, $\bar{x}_i = x_i(k), k = 1, N_{dat}$ corresponds to each of the *rGDP_i(k)* time series so that $1 \le i \le 31$ (number of countries) and $1 \le k \le N_{dat}$ (number of years analyzed). To transform correlations, $\tau_{i,j}$, into distances, we follow Gower (1966) and define the distance *d(i,j)* between the evolution of two time series x_i and x_j as

$$d(i, j) = \sqrt{\tau_{i,i} + \tau_{j,j} - 2\tau_{i,j}} = \sqrt{2(1 - \tau_{i,j})} \tag{2}$$

where $\tau_{i,j}$ is the absolute value of the rank correlation and $d(i, j)$ fulfills the three axioms of a distance:

- $d(i, j) = 0$ if and only if $i = j$

- $d(i, j) = d(j,i)$

- $d(i, j) \leq d(i,l) + d(l, j)$ (3)

Using the nodes (countries) and the corresponding links (distances) among them, a hierarchical tree and interactions network can be obtained. By using the Kruskal algorithm (Kruskal, 1956), construction of the so-called minimum spanning tree (MST) is straightforward. The interaction network in the MST is a simple loop-free network that can comprehensively display the most important links and communities in a complex network. We can then calculate the "cost" of the MST by summing all the links among all the MST nodes. MST cost sheds light on the degree of correlation (or synchronization) among the whole set of elements in the network: the lower the cost, the less the distance between the MST members and thus the tighter the links among them.

It is also possible to construct a hierarchical organization (hierarchical tree (HT)) of the data by using the single-linkage clustering algorithm (Johnson, 1967) in which "similar" objects (i.e., single countries or groups of countries) are clustered in each step according to their characteristics. This classical agglomerative single-linkage algorithm enables the construction of a hierarchical dendogram to illustrate the clustering characteristics of data organization. In fact, clustering data into groups of members that demonstrate tight connections is a usual way to define *communities* (Wasserman and Faust, 1994) in a complex network of interactions, where each member of a particular community shares some characteristics with the other members of the same community. There are several algorithms aimed at detecting communities in a network (Boccaletti, et al., 2006). The simplest is based on the analysis of the dendogram, because a simple horizontal cut of a hierarchical tree at a particular distance automatically yields clusters/communities of tightly connected members. In the rest of the paper, we use a more refined method (Langfelder, Zhang and Horvath, 2008) to extract communities from a hierarchical tree. This method dynamically analyzes the structure of the hierarchical tree and extracts the relevant clusters/communities.

3.2.2. Time windows analysis

To examine the temporal behavior of interdependence relations among elements of the business cycle, we also calculate distance correlation matrices for overlapping windows of 5, 10, and 15 years forward in time. Beginning with 1989, we move each temporal window over the entire sample period in one-year increments. Usually, short temporal windows are strongly affected by temporal circumstances and they could potentially yield misleading results. On the other hand, longer period windows show a long term view reflecting more permanent structural changes. As the time sample we use in this paper only covers 22 years, the 10 years temporal window has been selected as the most appropriate temporal length to show the synchronization business cycle evolution with sufficient data points (12 data points for the whole period)[10]. To enable comparisons among different clusters containing unequal number of countries, we sum matrix coefficients for each window and normalize them to the number of countries. Each dataset thus represents the sum of metric distances among all countries in the past time window. We also calculate the corresponding MSTs in each time window and we build another synchronization measure by summing all the metric distances represented in each tree branch. In line with our previous methodology, we normalize the sum of branch distances to the number of countries, thereby allowing comparison between different groups of countries.

The sum of matrix coefficients represents the lev7 el of interdependence among all countries. We call this synchronization measure *global correlation*. The *MST cost* represents the interdependence of the closest connections in the business cycle for each country. In the case of *global correlation*, the higher the value of the normalized correlation coefficients, the tighter the coupling inferred among all countries. Conversely, the lower the value of the sum of distances represented in the *MST cost*, the tighter the co-movement of the first distances among countries.

4. Empirical results

4.1. Cross-country hierarchical structure

Figure 1(a) and 1(b) shows the MST and HT, respectively, for GDP in our group of countries across the entire sample. The structure of the Figure 1(a) is based on the distance matrix

---

[10] We have also calculated 5 and 15 year windows obtaining similar results. These figures are directly available from the authors.

among all countries, providing a rough idea of the topological organization accordingly with its business cycle synchronization. Hence, we are only able to observe which countries are more connected with others and which ones seem to have a specific output cycle. However, Figure 1(b) permits analysis of the hierarchy in that structure according to the proximity in the GDP dynamics. The HT shows groups of countries with similar business cycle dynamics and countries with more isolated economic growth paths.

[figure 1 around here]

In Figure 1 we observe four groups of countries, clustered by their similar economic growth dynamics over the sample period. Firstly, there is a large group of European countries including Austria, Belgium, France, the Netherlands, Spain, Portugal, Italy and Ireland. There is a separate group of primarily Anglo-Saxon countries (United Kingdom, United States, Canada and, interestingly, Hungary). Interestingly, the United Kingdom is more closely connected to the United States than to European Union countries, confirming the commonly known fact about this "duality" in UK relationships and interests. In a previous study, we have found similar groups of synchronized countries when including more than 100 countries in the sample covering a long period (from 1950 to 2009). We observe a long term structural arrangement of output growth correlations that seems to be fairly stable over time (Matesanz, Ortega and Torgler, 2011).

A third group of Eastern European countries is observed: Romania, the Czech Republic, Bulgaria, Slovakia, Croatia and Russia. The Slavic republics of Estonia, Lithuania and Latvia form the fourth group to which Iceland and Greece are linked. Meanwhile, other countries have shown more isolated country-specific economic growth dynamics. This is the case for Turkey, China and Albania. In a similar situation, Greece appears located far from the OEU countries growth dynamics, even from those of the South of Europe such as Spain, Portugal or Italy. We can observe that even Germany has shown less connectivity and larger distance than those achieved by OEU countries despite of, or perhaps due to, its central role in the euro area monetary policy.

Additionally, clusters in Figure 1 confirm the idea of business cycle synchronization heterogeneity among the OEU and NCP countries pointed out by Buissière, Fidmurc and Schnatz (2008). However, the MST and HT in Figure 1 show a structural approach to business cycle synchronization that provides an idea of long-term output growth connections in our set of countries. As business cycle synchronization evolves while economic,

institutional and policy liaisons change through time, we further investigate the evolution of the co-movements for both individual countries and NCP countries.

4.2. Time windows analysis

In this section we introduce some dynamic analysis into the previous structural analysis. The aim (as previously explained) is to describe the evolution of business cycle synchronization. Figures 2(a) and 2(b) plot the *global correlation* coefficients and the *MST Cost*, respectively, for OEU and NCP countries and North America in 10-year overlapping windows. Each data point represents the normalized sum of the metric distance among all the countries (Figure 2(a)) and the sum of the branches in the MST (Figure 2(b)) over the past 10 years. Thus, we describe co-movements inside each group.

Within these groups, North America and the OEU countries are more tightly linked in terms of output dynamics while NCP countries have less synchronized co-movement. Furthermore, we observe that synchronization increases for most of the groups after 2002-2003. The change particularly affects NCP nations, suggesting that incorporation into the European Union in 2004 increased the degree of interdependence in the economic cycle for these countries. An increase of synchronization is observed for "Potential Countries", but this occurs later and may be related to the recent global financial crises. Finally, as previously mentioned, the financial crisis triggered an intense increase in economic cycle synchronization across the world, especially in developed countries. Of particular interest is the degree to which co-movement of the OEU members reached its maximum in 2008. After this time, synchronization decreased, which indicates that the European Union is experiencing heterogeneity in countries' economic paths of recovery[11]. We can infer therefore that the dynamics of these subsystems are becoming on the one hand side more synchronized but on the other hand interdependent in business cycle.

[figure 2 around here]

Changes in the common business cycle due to incorporation of new members is relevant to the efficiency of the Common Monetary Policy; that is, it is interesting to question

---

[11] As we know, some southern European countries (Greece, Ireland, Portugal and Spain) are suffering longer stagnation in their economic performance over the last two years. Meanwhile, Germany, France and Netherlands, among others, are performing much better in aggregate terms.

how co-movements have evolved as the number of members has altered over time. Contrary to most of the previous papers which deal with the idea of single countries' synchronization with some weighted measure of European output, we measure single country synchronization as the evolution of co-movements for each country with the business cycle of all other countries. In this sense, we take into account the dynamics between all countries involved in the economic system and therefore test not only the degree of synchronicity but also the degree of diversification of co-movements and resilience. We then analyze the effects of adding new members to the existing group rather than solely focus on how every single country becomes (or does not become) synchronized with some trend measure.

Firstly, we estimate the Integration Coefficients of each country. These coefficients are calculated as the normalized sum of the correlation coefficients between a single country and every member belonging to the group of the OEU countries. For instance, the Integration Coefficient for Poland is the sum of the bivariate correlation coefficients between Poland and OEU countries divided by the number of countries in this group. In this manner, our Integration Coefficients summarize the way in which every single country is connected with every other member through time. We call these coefficients System Integration Coefficients (SIC). Additionally, trend correlation coefficients (Trend Integration Coefficients, (TIC)) are calculated to represent the co-movement of every country with the overall output of OEU countries that comprise the European output trend. Furthermore, we have done calculations using the Pearson correlation coefficient to allow for comparisons between both association measures.

[Insert table 1 around here]

Table 1 shows both Trend (TIC) and System (SIC) coefficients. First, we note that TIC coefficients are higher than SICs suggesting that the country diversification of the output co-movement is lower than co-movements around the trend. As the output trend is basically created by large countries, this demonstrates the relatively greater importance of these countries. Secondly, we observe that some countries are more synchronized, and some are less synchronized. Inside the European Union, Greece is significantly less connected than the rest of the OEU members suggesting that is the weakest OEU member in terms of the efficiency of the common monetary policy because of its country-specific business cycle. Judging by the SICs, Germany, Ireland and the United Kingdom appear to be less synchronized than France, the Netherlands or Spain. Regarding NCP countries, the Baltic

republics, Slovenia, Bosnia and Herzegovina, Hungary, Poland and Iceland have shown more synchronization in the whole period than other countries. On the other hand, Romania, Macedonia, the Czech Republic, Slovakia and Bulgaria show little evidence of synchronization in the whole time sample. Finally, it is clear that Kendall coefficients are lower than Pearson's. Taking into account that Trend coefficients are higher than System coefficients and Pearson's are higher than Kendall's, the traditional linear-trend approach to business cycle synchronization that is extensively used in the empirical literature appears to be overestimating co-movements. Poland is the only country which presents higher coupling with the OEU countries when using System Kendall correlation. Notably, Poland is probably the country that generates more controversy in the empirical literature; some studies report a high level of synchronization (Fidrmuc and Korhonen, 2006; Darvas and Szapáry, 2008; Artis, Fidrmuc and Scharler, 2008) while others show less or no synchronization at all (Adalet and Öz, 2010; Aslanidis, 2010).

 [Figure 3 around here]

The coefficients in table 1 provide a rough idea of the role each country plays in the synchronization of the OEU members. To explore the dynamics of the SIC and TIC correlation coefficients in more detail, we have calculated these coefficients in overlapping ten-year windows. Figure 3 displays these calculations as follows; for every country the difference between the OEU global synchronization and synchronization when enlarging OEU members with the inclusion of each single NCP is plotted. This difference shows the impact of each country's inclusion on the synchronization and resilience of the system. The information presented in the figure implies that the higher the results for each country, the less synchronization is observed in the whole system on inclusion of that country. Similarly, figure 4 represents this difference for the OEU countries. In this case, the difference is calculated as the synchronization in the OEU (9) minus synchronization of the OEU (10)[12]. Positive results for one single country imply higher synchronization when that country is excluded from the system.

[Figure 4 around here]

---

[12] OEU (9) is calculated excluding each Old European Union country at a time, as if it had given up the currency area.

Therefore, both figures present the impact of every single country in the resilience and synchronization in the euro area. We can observe that the inclusion of all NCP countries significantly reduces the synchronization of the system as long as positive results are achieved. However, most of the countries have shown an increase in the degree of co-movement through time, especially after 2004. Only Macedonia, Serbia and Montenegro and Hungary seem to move away from the EU connections[13]. Additionally, we can infer that several countries have managed a quick "transition" since 1989, and have become more integrated with the European business cycle. The Baltic Republics, the Czech Republic and Slovakia clearly fall into this category. Meanwhile, Poland, Slovenia and even Turkey seem to have had a more parsimonious synchronization trend towards the OEU output system. Finally, by looking at the vertical axis we are able to ascertain any loss in degree of synchronization. Hungary, Bosnia and Herzegovina, Poland, Macedonia, Iceland and Slovenia are closer to the euro area independently of their own evolution through time.

As clearly demonstrated in figure 4, all OEU countries are more synchronized than NCP countries. Moreover, some of the OEU countries return negative results, signaling that their absence would produce less synchronization in the co-movement of European output. France, Belgium and Netherlands are the most synchronized while Greece, Ireland and to some extent Germany appear to be the least connected in the European system. Clearly, Greece appears to weaken the business synchronization of the euro area and, therefore, the resilience of the whole system.

4.3. Country dynamic importance in the network

Finally, we have analyzed the importance of our set of countries in the network. In line with the previous methodology, we calculate the evolution of the importance through time by means of the overlapping windows analysis. In this manner, we are able to calculate two different measures. Firstly, we present the evolution of the number of connections (NC) of each country across the MST network. This simple measure indicates how every country is more or less connected with other countries, but says nothing about the intensity of these

---

[13] We must bear in mind that window correlations including 2008-2010 are affected by the current economic crises and co-movement increases at this period quite independently from previous synchronization. Therefore, we need to carefully look at this part of the results, and maintain some distance from permanent improvements in the synchronization process across European economies.

connections. Secondly, to investigate the intensity of the connections (IC), we build an intensity measure based on the number of connections for each country inside the MST corrected by the metric distance of these connections (intensity of the synchronization). Therefore, we compute the number of connections divided by their metric distances, which reveals not only how every country moves over the network through time but also shows if this movement is becoming more or less synchronized.

Figure 5 shows the number of connections. Every colored square represents the previous ten years' NC and IC inside the MST for every country. Pinker colors indicate little NC or IC, while bluer colors indicate high NC or IC. We observe a group of more highly connected countries in both OEU and NCP countries, comprising of France, Spain, the Netherlands, Austria and Belgium. A separate group of countries with a small number of connections consists of both European countries (Greece, Portugal, Ireland, and Italy) and NCP countries (Serbia and Montenegro, Bosnia and Herzegovina, Albania, Turkey, and Iceland). However, connections vary significantly over time. Some countries report the tendency of higher NC values over time such as Bulgaria or Lithuania. In others such as Hungary, Croatia or Macedonia we observe lower values over time although the values for Croatia and Macedonia seemed to improve in the last period. Moreover, in some countries we observe irregular changes over time (for example, Spain, Ireland, or Poland).

[Figure 5 around here]

Figure 6 shows the colorful matrix for the intensity of connections (IC). The results show some similarities when looking at countries with high intensity connections such as France, Latvia, the Netherlands, Spain or Belgium. Countries such as Bulgaria and Lithuania also report an increase in intensity over time while for Hungary the intensity has decreased. When looking at IC instead of NC we observe that the difference between Western and Eastern Europe is less striking.

[Figure 6 around here]

5. Concluding remarks

This paper evaluates the network topology, and its own evolution, constructed upon co-movements in business cycles in order to assess the diversification and synchronization in economic connectivity that arises from interdependence between European countries. Our methodological approach is based on the analysis of the Kendall non-linear correlation matrix

and the networks it contains (Mantegna, 1999; Miskiewicz and Ausloos, 2010; Ortega and Matesanz, 2006). Several results are extracted from the analysis.

First of all, this methodology is useful for analysis of global co-movements as it provides a framework for summarizing synchronization in a group of countries. Moreover, it sheds light on the resilience and diversity in connectivity across such a system, and therefore it describes countries' interaction. This methodology can be relevant for analyzing spillover effects of asymmetric shocks, and can usefully inform monetary policy regarding the connections and resilience of all the elements involved in an economic system. For example, through the clustering analysis we find evidence of different European business cycle synchronization paths. Given the actual differences in output dynamics (Camacho, Perez-Quiros and Saiz, 2008, 2006), this finding emphasizes the high potential costs of the common monetary policy facing non-synchronized countries.

We also analyze the evolution of synchronization in the European business cycle over time by means of overlapping windows. We apply these methods to single countries and to different groups of countries.

Within OEU members, synchronization and diversification have remained stable until the current financial crises. However, several countries have displayed a lower degree of synchronization than others. In particular, Greece and Ireland have shown the lowest degree of co-movement, and have decreased Europe synchronization overall. To a lesser extent, the United Kingdom and Germany have demonstrated less synchronization than most connected countries in Europe such as France, the Netherlands and Belgium. These results suggest that the common euro area monetary policy appears to be less effective for countries less aligned with the "core" euro area economic cycle. In fact, the common monetary policy should have been more in line with synchronized countries such as France, Belgium and the Netherlands.

Co-movements show less correlation when NCP countries are added to OEU members. However it seems that the path is becoming more synchronized, especially after 2006. In this sense, the creation of a more synchronized and economically integrated currency area is an ongoing process that is advancing faster for a group of NCP countries. Among this last group, Iceland, the Baltic Republics, Poland, Slovenia and even Turkey are achieving a rate of growth in output that is more synchronized with OEU members (in line with the results of Ferreira, Dionisio and Pires, 2010, Savva et al. 2010). Conversely, Romania, Macedonia, Bulgaria and Serbia and Montenegro have presented less co-movement

with OEU members. Poland remains the most controversial country. In our study, Poland appears to be one of the most synchronized countries through time, in line with the results of Fidrmuc and Korhonen (2006), Darvas and Szapáry (2008) and Artis, Fidrmuc and Scharler (2008). Another interesting case is Hungary, which has not reported a high degree of synchronization with OEU members, but has shown a permanent and parsimonious desynchronization path in the period analyzed, and consistently appears jointly linked to the Anglo-Saxon group in Figure 1.

Overall, our results demonstrate the existence of different synchronization and diversification dynamics in output growth in both single countries and groups of countries. This finding highlights the difficulty of choosing an appropriate common monetary policy for current and future member countries. Furthermore, our results may suggest that it is necessary to deepen in other structural characteristics of individual countries to reinforce the stability of the common currency area. The contagion of the Greek debt crisis to other South European countries, such as Portugal, Italy, Spain and even France, supports this idea.

References

Adalet, M., Öz, S. (2010). 'Business cycle dynamics in the CEE countries: A political economy approach', Tüsiad-Koç University Economic Research Forum Working Paper No. 1014, Istanbul, Turkey.

Antonakakis, N. and Scharler, J. (2010). 'The synchronization of GDP growth in the G7 during U.S. recessions: Is this time different? ', Johannes Kepler University of Linz Working Paper No. 1005, Germany.

Artis, M., Chouliarakis, G. and Harischandra, P. K. G. (2011). 'Business Cycle Synchronization Since 1880', The Manchester School, 79, pp. 173–207.

Artis, M. and Okubo, T. (2011). 'Does international trade really lead to business cycle synchronization? A panel data approach', The Manchester School, 79(2), pp. 318-332.

Artis, M. J., Fidrmuc, J. and Scharler, J. (2008). 'The transmission of business cycles', The Economics of Transition, 16(3), pp. 559-582.

Aruoba, S. B., Diebold, F. X., Kose, M. A. and Terrones, M. E. (2011). 'Globalization, the business cycle, and macroeconomic monitoring', IMF Working Paper No. 11/25, Washington, DC.

Aslanidis, N. (2010). 'Business cycle synchronization between the CEEC and the Euro-Area: Evidence from threshold seemingly unrelated regressions', The Manchester School, 78(6), pp. 538-555.

Baxter, M. and Kouparitsas, M. A. (2005). 'Determinants of business cycle comovement: a robust analysis', Journal of Monetary Economics, 52(1), pp. 113-157.

Boccaletti, S., Latora, V., Moreno, Y., Chavez, M. and Hwang, D. U. (2006). 'Complex Networks: Structure and Dynamics', Physical Reports, 424, pp. 175-308.

Bussière, M., Fidrmuc, J. and Schnatz, B. (2008). 'EU Enlargement and Trade Integration: Lessons from a Gravity Model', Review of Development Economics, 12(3), pp. 562-576.

Camacho, M., Perez-Quiros, G. and Saiz, L. (2008). 'Do European business cycles look like one? ', Journal of Economic Dynamics and Control, 32(7), pp. 2165-2190.

Camacho, M., Perez-Quiros, G. and Saiz, L. (2006). 'Are European business cycles close enough to be just one? ', Journal of Economic Dynamics and Control, 30(9-10), pp. 1687-1706.

Crucini, M. J., Kose, M. A. and Otrok, C. (2008). 'What are the driving forces of international business cycles?', NBER Working Paper No. 14380, Cambridge, MA.

Darvas, Z. and Szapáry G. (2008). 'Business cycle synchronization in the enlarged EU', Open Economies Review, 19(1), pp. 1–19.

De Grauwe, P. (2006). 'Economics of Monetary Union', Oxford: Oxford University Press.

Eickmeier, S. and Breitung J. (2005). 'How synchronized are Central and East European economies with the euro are? Evidence from a structural factor model', Journal of Comparative Economics, 34(3), pp. 538–563.

Ferreira, P., Dionisio, A. and Pires, C. (2010). 'Adopt the Euro? The GME approach', Journal of Economic Interaction and Coordination, 5, pp. 231-247.

Fidrmuc, J., and Korhonen, I. (2006). 'Meta-analysis of the business cycle correlation between the euro area and the CEECs', Journal of Comparative Economics, 34(3), pp. 518-537.

Firdmuc, J. and Korhonen, I. (2004). 'The euro goes East: Implications of the 2002 economic slowdown for synchronization of business cycles between the euro area and CEECs', Comparative Economic Studies, 46, pp. 45–62.

Frankel, J.A. and Rose, A. K. (1998). 'The Endogeneity of the Optimum Currency Area Criteria', Economic Journal, 108(449), pp. 1009-1025.

Gómez-Gardeñes, J., Moreno, Y. and Arenas, A. (2007). 'Synchronizability determined by coupling strengths and topology on complex networks', Physical Review E, 75, 066106.

Gower, J. C. (1966). 'Some distance properties of latent root and vector methods used in multivariate analysis', Biometrika, 53, pp. 325−338.

Helbling, T. and Bayoumi, T. (2003). 'Are they all in the same boat? The 2000−2001 growth slowdown and the G−7 business cycle linkages', IMF Working Paper No. 46, Washington, DC.

Hidalgo, C. A. and Haussman, R. (2009). 'The building blocks of economic complexity', PNAS, 106 (26), pp. 10570-10575.

Hidalgo, C. A., Klinger, B., Barabási, A. L. and Hausmann, R. (2007). 'The product space conditions and the development of nations', Science, 317(5837), pp. 482–487.

Imbs, J. (2004). 'Trade, finance, specialization, and synchronization', Review of Economics and Statistics, 86, pp. 723–734.

Johnson, S. C. (1967). 'Hierarchical Clustering Schemes', Psychometrika, 2, pp. 241-254.

Kose, M. A., Otrok, C. and Whiteman, C. H. (2008). 'Understanding the evolution of world business cycles', Journal of International Economics, 75, pp. 110−130.

Kose, M. A., Otrok, C., and Whiteman, C. H. (2003). 'International busi0ness cycles: World, region, and country-specific factors', American Economic Review, 93, pp. 1216-1239.

Kruskal, J. B. (1956). 'On the Shortest Spanning Subtree of a Graph and the Traveling Salesman Problem', Proceedings of the American Mathematical Society, 7, pp. 48–50.

Langfelder, P., Bin Zhang, B. and Horvath, S. (2008). 'Defining clusters from a hierarchical cluster tree: the dynamic tree cut package for R', Bioinformatics, 24, pp. 719–720.

Mantegna, R. N. (1999). 'Hierarchical structure in financial markets',European Physical Journal B, 11, pp. 193−197.

Matesanz, D., Ortega, G. J. and Torgler, B. (2011). 'Measuring globalization: A hierarchical network approach', CREMA Working Paper Series 2011-11, Center for Research in Economics, Management and the Arts (CREMA).

Miskiewicz, J. and Ausloos, M. (2010). 'Has the world economy reached its globalization limit? ', Physica A, 389, pp. 797−806.

Mundell, R. (1961). 'A theory of optimum currency areas', American Economic Review, 51, pp. 657–665.

Ortega, G. J. and Matesanz, D. (2006). 'Cross-country hierarchical structure and currency crises', International Journal of Modern Physics C, 17(3), pp. 333–341.

Savva C., S., Neanidis, K. C. and Osborn, D. R. (2010). 'Business cycle synchronization of the euro area with the new and negotiating member countries', International Journal of Finance and Economics, 15(3), pp. 288-306.

Saviotti, P.P. and Frenken, K. (2008). 'Export variety and the economic performance of countries', Journal of Evolutionary Economics, 18, pp. 201–218.

Wasserman, S. and Faust, K. (1994). 'Social Networks Analysis', Cambridge, Cambridge University Press.

APPENDIX

List of countries.

Austria *AUS*, Belgium *BEL*, France *FRA,* Germany *GER,* Greece *GRE,* Iceland *ICE,* Ireland *IRE,* Italy *ITA,* Netherlands *HOL,* Portugal *POR,* Spain *SPA,* Turkey *TUR,* Czech Republic *CZR*, Estonia *EST*,

Hungary *HUN*, Latvia *LTV*, Lithuania *LTH*, Poland *POL*, Romania *ROM*, Slovak Republic *SRE*, Slovenia *SLO*, Croatia *CRO*, Macedonia *MCD,* Albania *ALB*, Bosnia and Herzegovina *BYH*, Serbia and Montenegro *SYM,* USSR *USSR,* China *CHI,* United Kingdom *UK,* Canada *CAN,* United States *US,*

Countries by region

Old European members (OEU, European Union)
Austria, Belgium, France, Germany, Netherlands, Italy, Greece, Ireland, Portugal, Spain

New Members. East European Union Countries (10 countries)
Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, Slovenia.

Current Candidates (4 countries)
Croatia, Macedonia, Turkey, Iceland

Potential Candidates (3 countries)
Albania, Bosnia and Herzegovina, Serbia and Montenegro (due to data restrictions Serbia and Montenegro are taken as a unique country)

Control countries (5 countries)
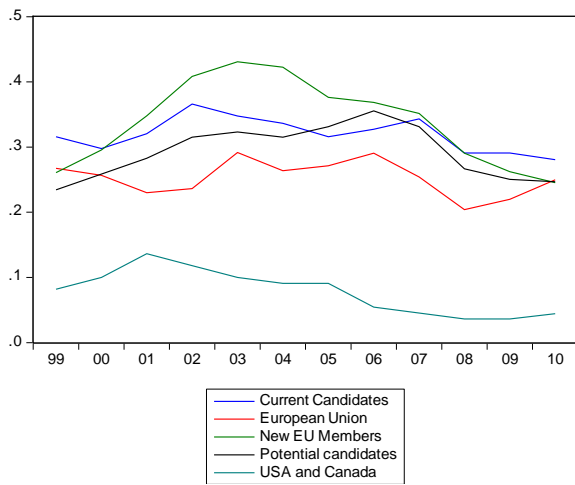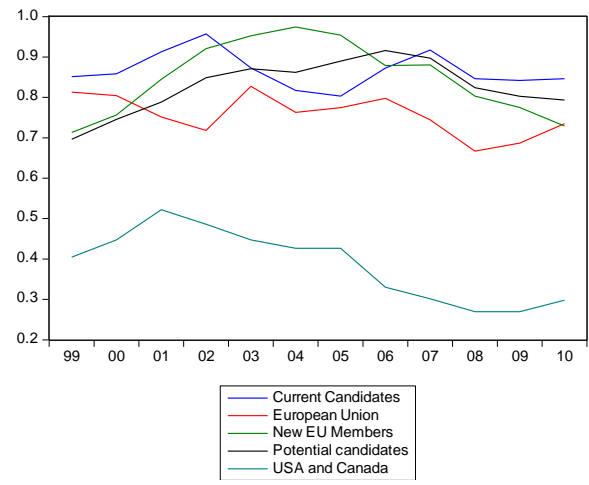*Canada, China, Russia, United Kingdom and United States*
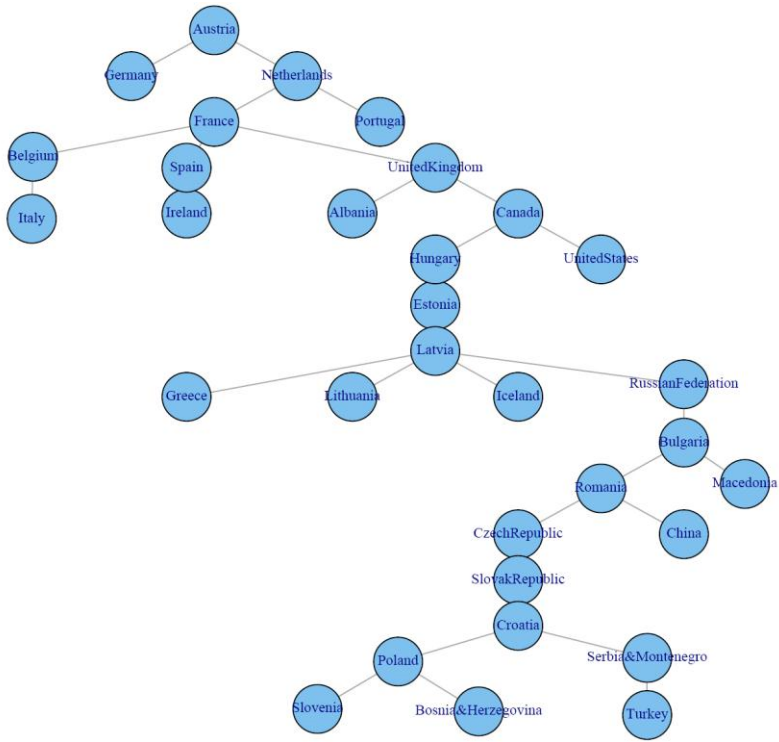
(a)
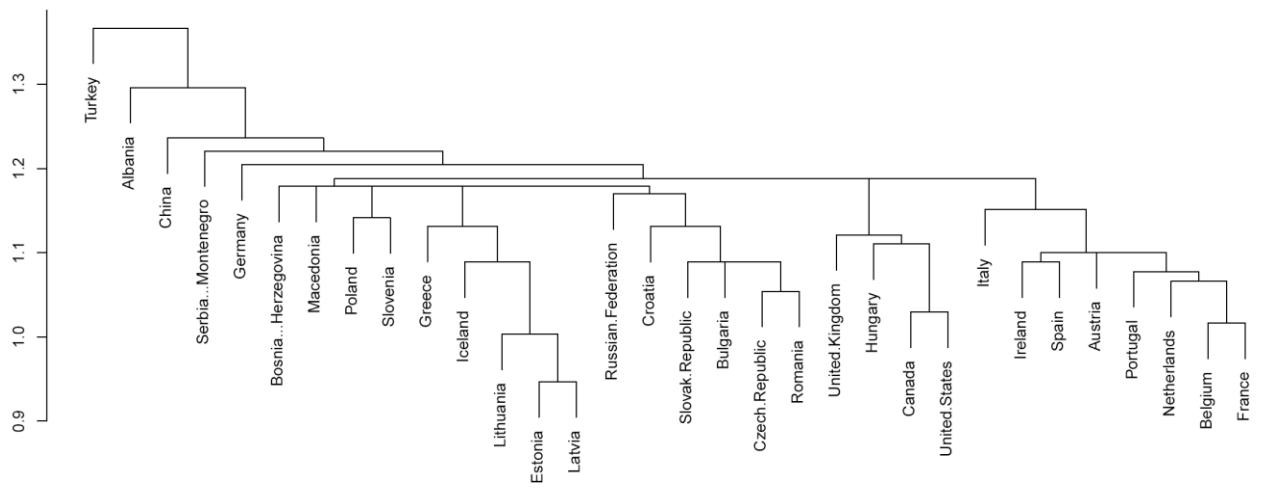
(b)

Figure 1. MST (a) y HT (b): 1989-2010, 31 countries.
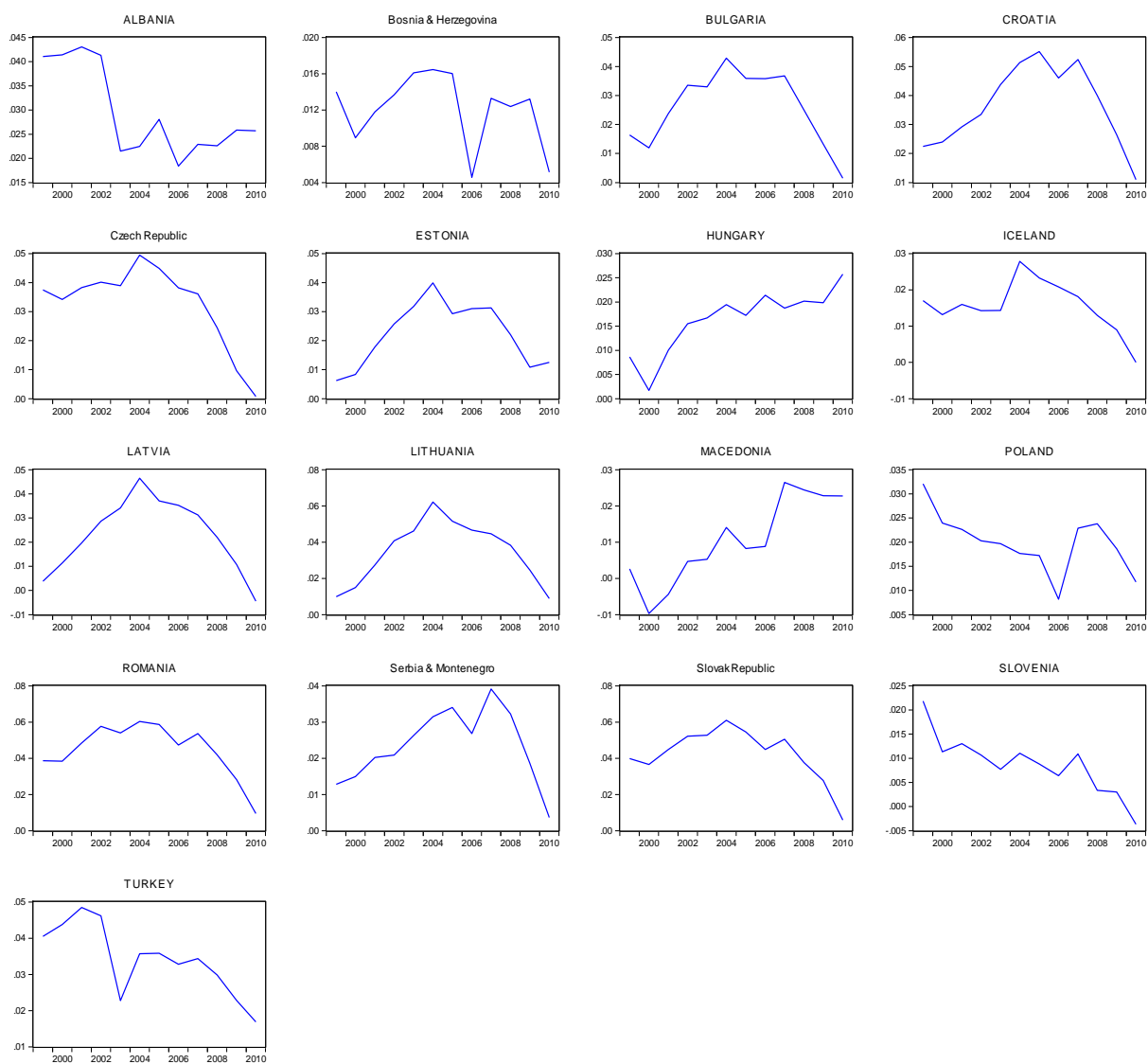
(a)

(b) (b)

Figure 2. (a) Normalized correlation coefficients: ten-year overlapping windows, selected regions. (b) Normalized MST cost: ten-year overlapping windows, selected regions.

Table 1. Normalized integration coefficients, 1989-2010.

	Integration Coefficients (system)		Integration Coefficients (trend)	
	1989-2010 (Pearson)	1989-2010 (Kendal)	1989-2010 (Pearson)	1989-2010 (Kendal)
Bulgaria	0.14	0,08	0.25	0,06
Czech Republic	0.22	0,1	0.34	0,05
Estonia	0.46	0,25	0.58	0,16
Hungary	0.31	0,246	0.44	0,23
Latvia	0.48	0,27	0.57	0,25
Lithuania	0.43	0,16	0.50	0,12
Poland	0.04	0,21	0.13	0,08
Romania	0.07	0,00	0.18	-0,06
Slovak Republic	0.18	0,07	0.29	-0,02
Slovenia	0.34	0,3	0.48	0,3
Croatia	0.23	0,14	0.32	0,06
Macedonia	0.12	0,17	0.16	0,15
Turkey	0.23	0,09	0.27	0,06
Iceland	0.57	0,29	0.66	0,23
Albania	-0.02	0,06	0.05	0,03
Bosnia & Herzegovina	0.31	0,31	0.31	0,22
Serbia & Montenegro	0.21	0,16	0.26	0,07
Austria	0.76	0,49	0.89	0,71
Belgium	0.78	0,51	0.92	0,65
France	0.80	0,53	0.95	0,72
Germany	0.67	0,35	0.82	0,62
Netherlands	0.78	0,54	0.91	0,68
Italy	0.80	0,49	0.97	0,68
Greece	0.47	0,23	0.57	0,28
Ireland	0.71	0,42	0.83	0,44
Portugal	0.71	0,48	0.77	0,64
Spain	0.79	0,50	0.90	0,64
UK	0.64	0,37	0.81	0,38

*Integration Coefficients for EU10 countries represent the connections of every country with EU10 excluding itself

Source: Own calculations based on Maddison Total Economy Database (http://www.ggdc.net/)

Figure 3. Normalized correlation coefficients: 10-year overlapping windows. New, Currently negotiating and Potential candidates. Each graph represents the difference between the normalized global correlation of the "Old" UE members (10 member countries) and the normalized global correlation of EU(11). That is, EU(11) = "Old" EU(10)+country$_i$.
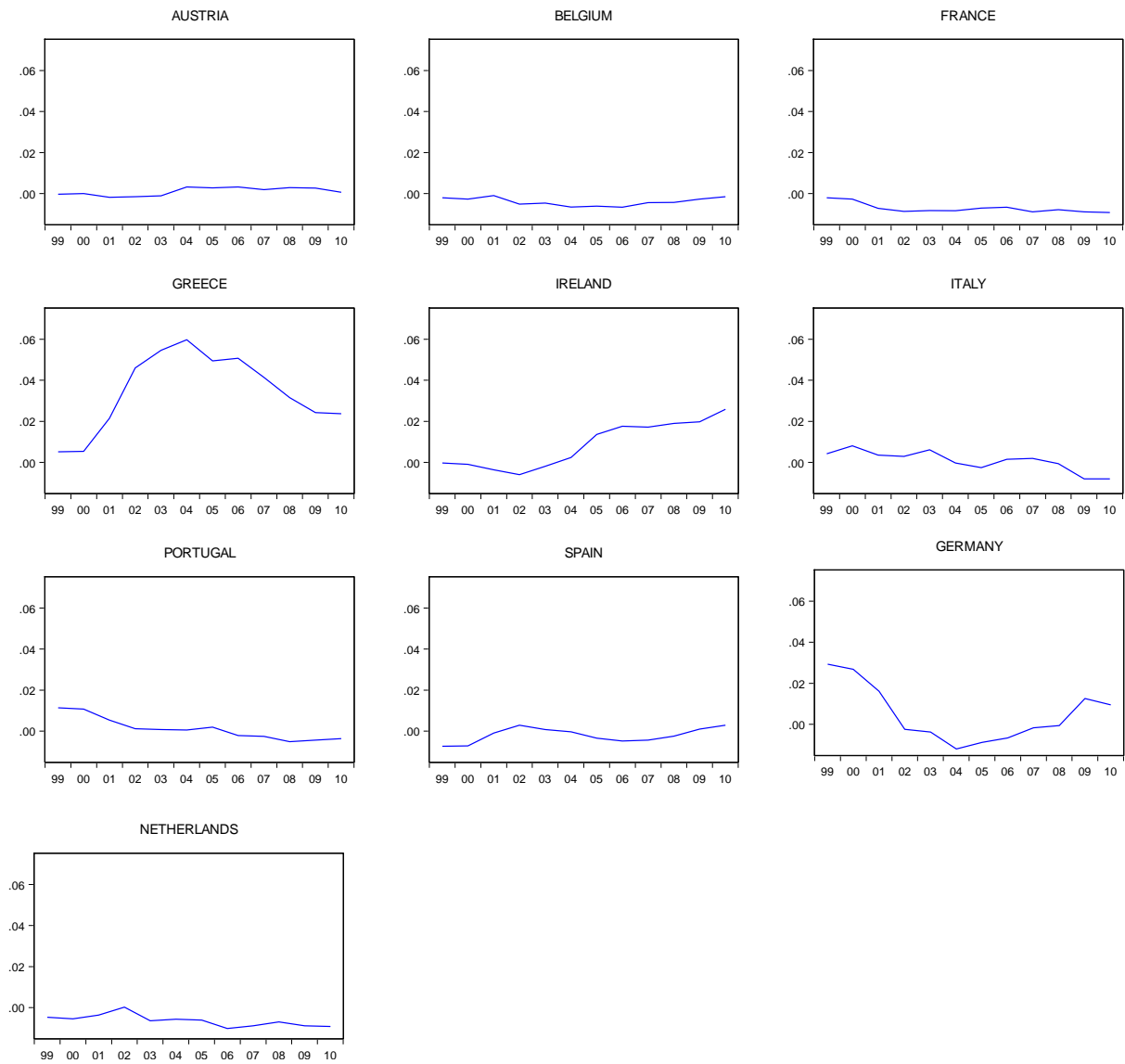
Figure 4. Normalized correlation coefficients: ten-year overlapping windows. "Old" European Union member countries (10 countries). Each graph represents the difference between the normalized global correlation of UE(9) and the normalized global correlation of "Old" EU. Therefore, EU(9) = "Old" EU(10)-country$_i$.
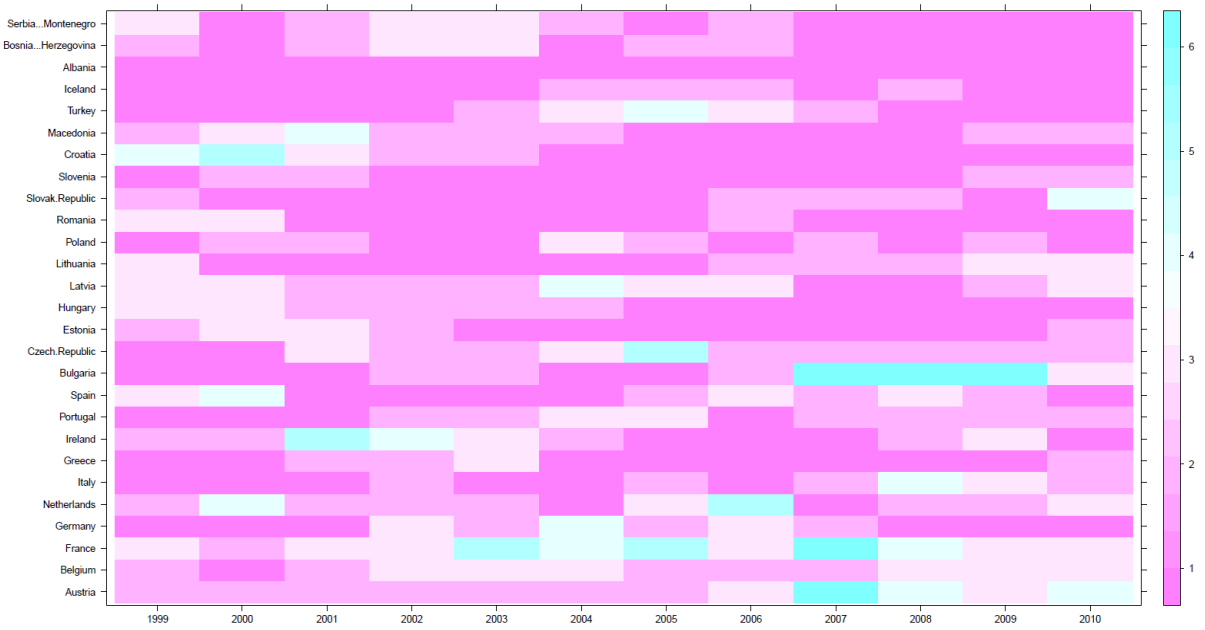
Figure 5. Number of connections inside the MST. Single countries. MST is built over ten-year overlapping windows
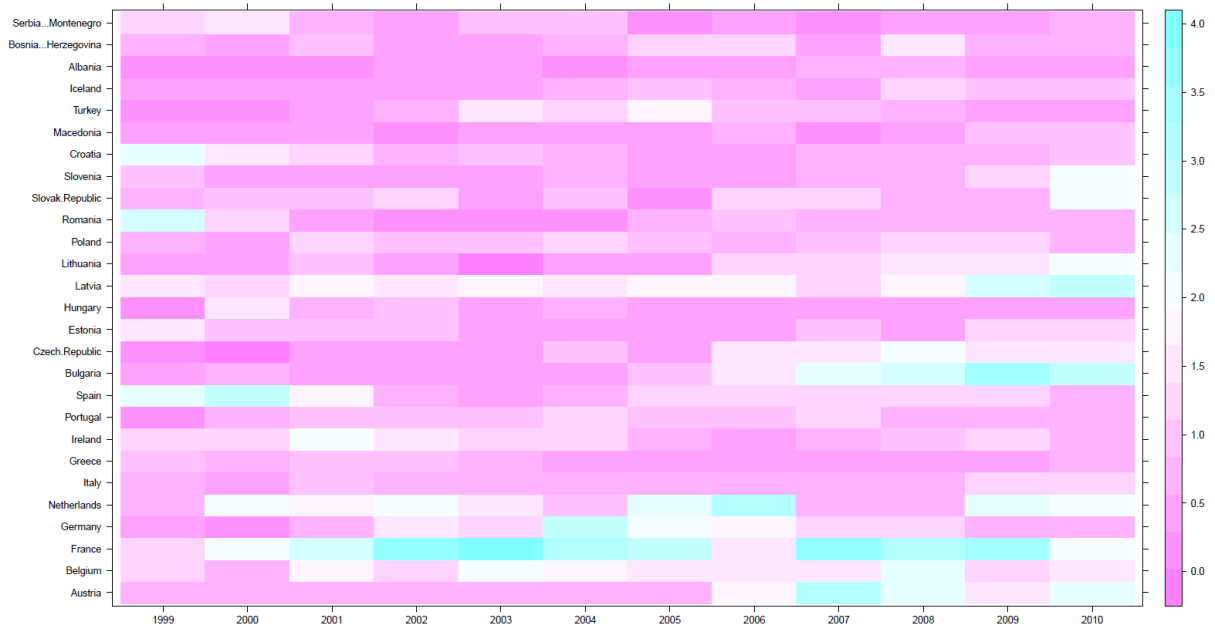
Figure 6. Intensity of connections inside the MST. Single countries. MST is built over ten-year overlapping windows