ISCTE Business School
Instituto Universitário de Lisboa

BUSINESS CYCLE DYNAMICS ACROSS EUROPE: A CLUSTER ANALYSIS

Daniel Fernandes Gonçalves

Dissertation submitted as partial requirement for the conferral of

Master in Economics

Supervisor:
Prof. Doutor Luís Filipe Martins, Assistant Professor, ISCTE-IUL
Department of Quantitative Methods for Management and Economics

Co-supervisor:
PhD Candidate Rui Silva, University of Milan, Department of Economics, Management and Quantitative Methods

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Abstract

This dissertation aims to analyze the dynamics of business cycles across European countries between 1960Q1 and 2016Q1. For such purpose we identify country-groups of national *deviation* cycles through Hierarchical Agglomerative Clustering with the Ward's method. The clustering technique suggests the existence of three country-groups, which include, aside from other countries, France and Spain in Cluster 1, United Kingdom and Denmark in Cluster 2 and Germany and Italy in Cluster 3. We execute an extensive analysis on business cycle stylized facts, synchronization and turning points detection over the clusters' *deviation* cycles. Further on, we analyze the propagation of economic shocks through a VAR model, over which we study Granger-causalities, Impulse Response Functions and Forecast Error Variance Decomposition.

Our results show that both Cluster 1 and Cluster 2 share similar cyclical characteristics when compared to Cluster 3. Nevertheless, Cluster 1 and Cluster 3 appear to be the most synchronous pair, and simultaneously verify the largest proportion of time spent in the same cyclical phase. We show that there has been an increasing business cycle synchronization in Europe since the beginning of the 90's. The structural analysis shows that Cluster 1 and Cluster 2 have the strongest permanent cumulative shocks, whereas Cluster 3 induces not only the weakest impulses but also explains the smallest fraction of the counterparts' forecast error variance decomposition. These conclusions question the "German Dominance" hypothesis and allow the identification of alternative major economic propellers in Europe.

JEL Classification: E32, E37

Key words: Business Cycle stylized facts and synchronization; Hierarchical Agglomerative Clustering; Impulse-Response Functions; Forecast Error Variance Decomposition

Sumário

A presente tese pretende analisar as dinâmicas dos ciclos económicos na Europa no período compreendido entre 1960Q1 e 2016Q1. Como tal, procedemos à identificação de grupos de ciclos económicos nacionais através de Clusterização Hierárquica Aglomerativa com o método de Ward. A Clusterização sugere a existência de três grupos que incluem, além de outros países, França e Espanha no Cluster 1, Reino Unido e Dinamarca no Cluster 2, e Alemanha e Itália no Cluster 3. Analisamos as principais características, sincronização e cronologia de pontos de inflexão dos ciclos económicos dos clusters. Estudamos ainda a propagação de choques económicos com um modelo VAR, sobre o qual concluímos sobre causalidade à Granger, funções de impulso-resposta e decomposição de variância.

Os resultados mostram que o Cluster 1 e Cluster 2 apresentam maiores semelhanças nas características dos seus ciclos quando comparados ao Cluster 3. Simultaneamente, o Cluster 1 e Cluster 3 apresentam quer o maior nível de sincronização quer a maior fração de tempo partilhada na mesma fase cíclica. Concluímos também que o nível de sincronização dos ciclos económicos na Europa apresenta uma tendência crescente, especialmente após os anos 90. A análise estrutural conclui que o Cluster 1 e Cluster 2 produzem os choques permanentes mais fortes, enquanto que o Cluster 3 induz os impulsos mais fracos, além de explicar a menor parte da decomposição de variância do erro de previsão dos restantes. As presentes conclusões questionam a hipótese de "Domínio Alemão" e permitem a identificação de outros propulsores económicos na Europa.

Classificação JEL: E32, E37

Palavras-Chave: Sincronização de Ciclos Económicos; Técnicas de Clusterização Hierárquica Aglomerativa; Funções Impulso-Resposta; Erros de Previsão e Decomposição de Variância

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List of Abbreviations

ADF: Augmented Dickey-Fuller

AIC: Akaike Information Criterion

AT: Austria

BB: Bry-Boschan

BBQ: Bry-Boschan Quarterly

BC: Business Cycle

BEL: Belgium

BK: Baxter-King

COIRF: Cumulative Orthogonal Impulse Response Function

DEN: Denmark

ECB: European Central Bank

EMU: European Monetary Union

ERM: Exchange-Rate Mechanism

ESS: Error Sum of Squares

FEVD: Forecast Error Variance Decomposition

FIN: Finland

FRA: France

GDP: Gross Domestic Product

GER: Germany

GRE: Greece

HAC: Hierarchical Agglomerative Clustering

HP: Hodrick-Prescott

IRF: Impulse Response Function

IRL: Ireland

ITA: Italy

MA: Moving Average

NBER: National Bureau of Economic Research

NTH: Netherlands

OCA: Optimum Currency Area

OECD: Organization for Economic Co-operation and Development

OLS: Ordinary Least Squares

POR: Portugal

PPP: Purchasing Power Parity

RBC: Real Business Cycle

SPA: Spain

SSR: Sum of Squared Residuals

SWE: Sweden

UK: United Kingdom

VAR: Vector Autoregression

VARMA: Vector Autoregression Moving Average

1 Introduction

The creation of the European Monetary Union (EMU) considering Optimum Currency Area (OCA) theories (introduced by Mundell (1961), McKinnon (1963) and Kenen, 1969), seek for an higher level of economic integration. As a consequence, the interdependence between domestic rose due to an increase in trade relations, labor market mobility and financial activities.

The analysis of business cycle synchronization helps understanding if European economies minimize the costs of belonging to an OCA area (namely the loss of monetary policy) and helps to understand in this specific case, the success of the EMU as an OCA. There are some constraints in this process, such as the loss of monetary policy, as European economies are dependent on central guidance that may not suit their own growth perspectives. The literature is not consensual on whether the membership on the EMU leads to a higher degree of economic association between European cycles. While Afonso and Furceri (2007) consider that the EMU creation increased the degree of synchronization in Europe, Mink *et al.* (2007) show that there is no upward behavior in domestic cycles co-movement.

We consider that our research contributes to the literature in several aspects, namely:

i We identify country-clusters with through a Hierarchical Agglomerative Clustering technique with the Ward's algorithm, and further on estimate the *deviation* cycle for each identified country-group;

ii We assess the behavior of business cycles throughout time, its main stylized facts and co-movement. We provide a turning point schedule, which is compared with some real economic events occurrences;

iii Lastly, we present a novel to previous works by analyzing the economic shock propagation within the country-clusters through a VAR model that includes as variables the *deviation* cycles of each cluster, with the objective of observing which are the main propellers of economic growth in Europe.

This research is organized as follow. Section 2 includes a broad literature review on business cycles, namely several theoretical approaches and empirical works concerning business cycle synchronization in industrial countries, institutional events, shocks, propagation mechanisms and core-periphery analysis. Section 3 presents an econometric framework and statistical metrics applied in the analysis and identification of business cycle stylized facts, synchronization and turning points detection. Section 4 describes the dataset and provides the estimation of the business cycle. Section 5 exposes the main results on the analysis of the business cycle, its stylized facts and synchronization, and structural relations through Granger-causality, IRF and FEVD. The work is concluded with Section 6, on which we resume the main findings and suggest clues for future research.

2 Literature Review

2.1 Business Cycle Theories

Amid different conceptualizations and empirical characterizations of the concept of business cycle, the one proposed by Burns and Mitchell (1946) is set as the most prominent, as it is broadly considered a benchmark definition in the literature. In this definition, the business cycle is defined as a "*type of fluctuation found in the aggregate activity of nations*" which implies co-movement among some macroeconomic variables and allows its division into distinct phases such as expansions, recessions, contractions and revivals, that would merge into the expansion phase of the next cycle (Burns and Mitchell, 1946).

2.1.1 From the Classicals to the Austrian School of Thought

The concept of Business Cycle has been approached by each of the Economic Schools of Thought.

Classical economists did not explored on their works the issue regarding the existence of "*economic fluctuations*", as they would disappear on the long-term equilibrium. Jean-Baptiste Say (1803) and David Ricardo (1817) introduced on their works the concept of "*economic fluctuations*", although only considering it in the absence of external shocks (*e.g.* wars). Contemporaneous of these former authors, Sismond di Sismondi (1819) on his work "*Nouveaux Principes d'economie politique*" refutes the dominant paradigm of that period, as a situation of non equilibrium could be driven by either external shocks (*e.g.* war) and overproduction or underconsumption. This contradicts Say (1803) since it allows to the possibility of a mismatch between aggregate supply and demand. Ricardo (1817) recognized that the Law of the Market [1] may be distorted by crisis and overproduction, and managed to explain it through the existence of exogenous events. These events would deviate the natural state of an economy from the equilibrium, forcing it to enter in a period of re-adjustment. Juglar (1862) extends the debate on the importance of endogenous events

[1] Say's Law of the Market states that aggregate demand is sourced by aggregate production.

deviating the economic activity from the normal pace, as he linked different crisis' events and identified the existence of a cyclical component. For Juglar (1862), crisis were the result of turning points of prosperity [2] into depression, for which the periodicity of fluctuations he managed to approximately calculate. He then relates crisis' events as a result of a expansion in credit cycles, as an increase in credit lending volumes would alter the agent speculative behavior causing over-investment tendencies, even though such situation would be "*beneficial from an evolutionary perspective of capitalist development*" (Legrand and Hagemann, 2005). Juglar (1863) stated that the agent speculative behavior would alter the price levels, having shown in a later work (Juglar, 1896) that price levels are exposed to endogenous dynamics . Juglar (1862) identified a business cycle composed by 3 phases (prosperity, crisis and liquidation) with a length of approximately seven to eleven years.

Economic recessions are also considered by the Austrian School, although under a different perspective. The works of Mises (1912) and Hayek (1931) consider over-investment [3] as the major determinant of business cycles dynamics, on which central banks play a major role. When the monetary base increases, low interest rates stimulate private investment leading to a "*mismatch between the economy's productive capacity and consumers intertemporal spending plans*" (Oppers, 2002). The agent intertemporal decisions influence equilibrium interest rate levels, a potential intervention from monetary policy makers may create a disruption between present investments and future expected gains, violating the law of the market and prompting an economic crisis. For the English economist Pigou (1927), too optimistic expectations (enlarged by consumption/investment impulses due to new information, in order to build capital in expectation of future demand) will enhance an economic boom. As economic agents may not find similarities between expectations and results, an economic crisis takes place, affecting "systematically" all the economy, as

[2] The concept of "*prosperity*" was later introduced by Schumpeter (1954) while emphasizing the work of Clement Juglar.

[3] Austrian scholars also name over-investment as "*mal-investment*". As monetary policy makers' policies stimulate a liquidity injection in the economy not considering economic agent's preferences, wrong interest-rate signals would be set. In this way, demand for goods materializes even before goods are available to be consumed (Oppers,2002).

firms are intrinsically related [4].

2.1.2 Schumpeter's Revolutionary Business Cycle Scheme

Schumpeter (1912, 1939) contradicts the Austrians on what concerns the role of "*mal-investment*" on the explanation of economic recessions, as he considered that economic fluctuations are intrinsically related with economic growth and "*the phenomenon becomes understandable only if we start with the neighborhood of equilibrium preceding prosperity and end up with the neighborhood of equilibrium following revival*". Schumpeter (1939) also believed that the cause of economic recessions was the increase of the price level of investment goods during an economic boom - as the demand for new innovative products decreases, its price level consequently increases forcing entrepreneurs to pay back their credit loans and leading to a credit deflation. In order to reestablish equilibrium, Schumpeter (1939) contrary to Keynes (1936) considered that no exogenous interventions should be taken (*e.g.* monetary or fiscal policies). From all of his theoretical contributions, Schumpeter (1954) was mainly responsible for the introduction of a revolutionary business cycle scheme, distinguishing four different economic cycles as he stated: "*it is possible to count off, historically as well as statistically, six Juglars to a Kondratieff and three Kitchins to a Juglar – not as an average but in every individual case*".

Kuznets contributed to this topic due to the use of mathematical functions to forecast business cycles, having analyzed intensively different types of time-series (as in Kuznets 1934, 1937, 1949). Through the study of such linkage, Kuznets (1930) was able to prove the existence of economic fluctuations with a length varying between 15 and 25 years, enhanced by the birth of an innovative good. As its demand increases, the mismatch between supply and demand drives the economy to a peak of production, imposing to firms the necessity of innovating in order to continue in the market. As consequence firms lower its prices and an economic recession takes place. Innovation and technological changes were also approached by Kondratieff as determinants of economic booms, although

[4] Bikhchandani *et al.* (1992), Chamley and Gale (1994) or Zeira (1994) also focus on the role of available information on forecasting future gains from present investments.

paired with monetary reserves and countries economic strength. According to Rostow (1975), Kondratieff is "*regarded as the father of the notion that capitalist economies are subject to cycles of fifty years in length*", as he dated three long cycles between 1790 and 1920 (see Kondratieff, 1935)[5]. In addiction, Kondratieff (1925) defended that the major economic cycles were not completely tied with economic processes (such as innovation and technological progress) but also dependent of other endogenous phenomena related with social and historic events. Schumpeter (1954) also identified the short-term inventory cycles introduced by Kitchin (1923), provided his conclusions on market asymmetries resulting from information time lags. On a scenario of overproduction, Kitchin (1923) considered that a readjustment in price levels would be effective in order to normalize production and to put her back in an equilibrium level. The "*economic fluctuations*" during the equilibrium process were distinguished between minor cycles (with an average length of forty months) and major cycles or trade cycles (which may include several minor cycles and with a length of eight years, dependent on the money supply in the economy).

2.1.3 The behavior of economic agents and its implications on Business Cycles

The Keynesian Revolution had set up an effort to explain business cycles, as it was "directed at identifying institutional sources of instability" that would be corrected by immediate policy decision-making, leading the economic activity from an undesirable state to a better one (Lucas, 1977). Indeed, Keynes (1936) stated that an equilibrium theory could not be attained as he was not neither able to link unemployment as a consequence of economic agents' choices nor agreed in fluctuations in wages (as pointed by the classical economists). The role of rational expectations is further approached in Muth (1961), as agents would react to cyclical movements as an increase in the risk, and would use simultaneously the available information in order to forecast the future "*free of systematic and easily correctable*

[5]Kondratieff (1935) also presented one of the first econometric research works, having collected data on which he smoothed its deviations from the trend with a 9-year moving average in order to keep only long cycles in the series, although "*turning points of the long cycles were dated not from the smoothed, but from the unsmoothed data*" (Garvy, 1943).

biases" (Lucas, 1977). For Lucas (1977), as there are different information sets possessed by firms and workers, the explanation of business cycles supported on systematic real wage movements may may not be possible to be done.

The combination of Schumpeter (1939) and Kondratieff's (1925,1935) long cycle consideration with "*medium term Keynesian dynamic embodied in the Samuelson (1939)-Hicks (1950) approach to the business cycle*" motivated Minsky's Financial instability hypothesis (Minsky, 1993). As it relates the medium-term business cycles with long-term swings, Minsky's hypothesis was highly considered by Post-Keynesians, especially through his three stages of financing: hedge, speculative and Ponzi schema. The economic process, which evolves in stages, registers instability as it fails and collapses with a repetitive dynamic. The emergence of financial fragility at the firm level characterizes the Basic Minsky Cycle, on which companies strangle its economic activity due to reduced liquidity and low solvency, triggering a downturn in economic activity. As a process of de-leveraging takes place another upswing is initiated, and a progressive optimistic behavior from economic agents lead to higher asset valuations resulting in the elimination of the "*Market Discipline*"[6] (Palley, 2009). The consecutive recurrence of the Basic Minsky Cycles is called Super Minsky Cycle on which a process of transformation of business institutions and structures governing the market takes place (named as "*thwarting institutions*" as in Ferri and Minsky, 1993). In this process of transformation, that has the purpose of "*ensuring stability of capitalist economies*", the long-cycle begins with a "*regulatory relaxation" and increased risk taking*" on which financial institutions see their activities restricted facing a profit reduction (Palley, 2009). During a period of deep financial activity, the thwarting institutions become eroded and an uncontained cyclical bust takes place (Palley, 2009). Under a new phase of renewed regulation, the economic activity is triggered.

[6] Market Discipline consists on the existence of transparency over the risks associated with entrepreneurship, businesses or other economic activities. This happens with regulatory policies and institutions that seek market safety and risk avoidance.

2.1.4 The Real Business Cycle

The equilibrium analysis is further explored by Lucas(1973, 1975) and Barro (1980) who have studied the impact of exogenous shocks in aggregate demand, related to unpredictable changes in monetary and fiscal policy. The Real Business Cycle Theory (RBC) introduces real shocks in productivity as being mainly technological shocks that improve the marginal productivity of labor and capital, increasing wages *ceteris paribus.* As introduced by Kydland and Prescott (1982), whose theory was based on Lucas and Prescott (1971), the authors considered that"*business cycle models must be consistent with the empirical regularities of long-run growth*" (Rebelo, 2005). Kydland and Prescott (1982) studied the volatility of macroeconomic variables, finding substantial persistence and pro-cyclical and co-movement behavior, although they have not considered the role of monetary policy (contrary to Friedman, 1968). Several authors studied more profoundly the importance of technology shocks as a business cycle impulse such as King *et al.*(1998) and Gali (1999), although they obtained different results on the role of technological shocks as an economic enhancer. Either way, King and Rebelo (1999) show that a reduction in Total Factor Productivity plays a minor role on recessions, broadening the debate to other determinants such as Finn (2000) on oil shocks, Baxter and King (1993) on fiscal shocks and Fisher (2003) on investment-specific technological changes (among others). Lucas (1977) considered that"*business cycles are driven by aggregate shocks*" and not by singular sectoral shocks (Rebelo, 2005). Rebelo (2005) stresses that the RBC Theory also considers monetary shocks, provided the "*role of credit in influencing the response of the economy to both technology and monetary shocks*", as the expansionary role of technology to enhance economic production requires an adequate monetary policy (also studied by Altig *et al.*, 2004). Economic agents' expectations are also approached in Reichlin (1997), that stresses the importance of future beliefs' shocks on determining economic cycles.

2.2 Business Cycle Dynamics in Europe

2.2.1 Business Cycle Synchronization in Industrialized Countries

Nowadays, advanced economies experience an increasing interdependence and integration, stimulated through economic and financial linkages. The analysis of how business cycles in the main industrial countries co-move provides a deeper knowledge of how, consequently, European domestic cycles behave. Several authors have approached this issue, considering different geographical aggregations. Gerlach (1988), through the use of spectral methods, has found evidence of a high level of cross-correlation in industrial production between OECD countries, whether Backus *et al.* (1995) also proved the existence of a high level of synchronization between the US cycle and the European aggregate cycle. For what concerns the G7, it was proven that major industrialized countries have similar cycles (Baxter, 1995). In a later work, Kose *et al.* (2008) verified an increase on industrial countries' cycles correlation, mainly due to a common endogenous factor (decomposed after key macroeconomic aggregates such as output, consumption and investment) which explained a greater part of output volatility. On the contrary, Doyle and Faust (2002) suggest little tendency on an increase in cross-correlation in growth rates of output, consumption and investment within the G7-group for the period comprised between 1960 and 2002, while Stock and Watson (2005) discovered through a structural VAR model that an increase in trade and economic openness did not generate a higher level of synchronization for those countries.

Despite the lack of agreement in the literature concerning the existence of a unique business cycle among industrial countries, other authors have found several cyclical aggregations within OECD and G7-group members. Artis *et al.* (1997) considering industrial production classical cycles, found the existence of two main coherent groups, one comprising Euro-zone countries and the other English-speaking countries. Helbling and Bayoumi (2003) analyzed G7 economies and found an English-speaking group (composed by US, Canada and UK - and Germany to a lesser extent) business cycle and stressed that "the strength of business cycle linkages is far from being uniform and varies noticeably" on the major industrialized countries (other works on the subject include Artis and Zhang, 1997 and Del Negro and Otrok, 2003). Considering a wider sample, Kose *et al.* (2003b) applied a Bayesian dynamic latent factor model to a 60-country sample covering seven regions "*providing evidence of a world business cycle*", confirming the results of Lumsdaine and Prasad (2003), whom instead relied on a weighted aggregation procedure to determine an increase of cross-correlation in 17 OECD countries. Considering the same sample size, Otto *et al.* (2001) pointed to an increase in cross-country economic integration, which resulted on similar responses to common shocks (other authors approached this issue recurring to different econometric methods, also finding similarities in cycles across developed countries such as Blackburn and Ravn (1992), Backus and Kehoe (1992) and Gregory *et. al*, 1997).

2.2.2 Major Institutional Events in Europe and Business Cycle Synchronization

The approach to business cycle dynamics in Europe implies taking into consideration some institutional events, which led to the economic and financial integration between European countries. Among others, the establishment of the Exchange Rate Mechanism in 1979 (henceforth ERM), the Maastricht Treaty (1992) and the creation of the European Monetary Union that began in 1990 (henceforth EMU) have been highly regarded in the literature due to their economic and financial relevance on business cycle synchronization. As this paper considers countries which belong to the EMU, one may have a closer look into the theories on Optimum Currency Areas (OCA), which provides a pertinent introduction to cross-correlation study within European countries.

As stressed by Mundell (1961), McKinnon (1963) and Kenen (1969) [7], a high level of

[7] Relevant studies on Optimum Currency Areas can be found in Tavlas (1993), Bayoumi and Eichengreen (1996) or Dellas and Tavlas (2009). Other branch of the literature devoted interest on the criteria that should be fulfilled in order to support the creation of an OCA, such as Friedman (1953) on price and wages flexibility; Mundell (1961, 1973) on labor mobility and financial integration respectively; Fleming (1971) on inflation rates and terms of trade; and political integration on Mintz (1970) and Haberler (1970). For another important review on OCA theories, see Mongelli (2002).

economic inter-dependency between countries would suit the implementation of a common monetary policy, which in the case of the Euro Area is regulated by the European Central Bank (ECB). Concerning the creation of the EMU system, Christodoulakis *et al.* (1995) stated that its establishment was a success as it generated a higher degree of business cycle synchronization among European economies. Frankel and Rose (1998) consider that even though the adherence to a monetary union implied the loss of a macroeconomic "*potentially stabilizing too*l" it enhanced economic integration within its member states (Rose and Engel, 2002). Camacho *et. al* (2006) also refer that external countries showing strong economic and financial linkages to members of the Euro Zone will also see themselves "restricted to the achievement of close-to-balance budget constraints" has they are quite influenced by the ECB's policies.

The literature does not share a total agreement on whether business cycles in Europe had become more synchronized with the establishment of the European Monetary System (EMS) and its ERM. Nevertheless, the authors agree on the timing of classical recessions across euro area countries, as it can be seen in Artis *et al.* (2004b) and Harding and Pagan (2006). The satisfaction of the Maastricht criteria justified the application of an homogeneous fiscal and monetary framework, even though this is not sufficient to justify the emergence of the European business cycle if we take into consideration the importance of supra-national relations in trade and finance (Artis, 2003). The works of Artis and Zhang (1997,1999) introduce the debate, showing that the membership in the EMU system promoted the synchronization of domestic business cycles, which led to the emergence of an European Business Cycle, which had decoupled from the US cycle and converged to the German one after early 80's. Lumsdaine and Prasad (2003) stated that the emergence of the European business cycle occurs in 1973, whether Canova *et al.* (2007) and Massman and Mitchell (2004) conclude that this synchronization only takes place in the 90's after the German reunification. Even though the creation of the ERM implied an exchange-rate stability system, Inklaar and de Haan (2001) do not link it with the increase of the synchronization within the business cycles. This topic is also approached by Wynne and Koo (2000), that related exchange rate disciplines to increasing business cycle synchronization, finding a more accurate relation in the US census regions than inside the European countries. In the same line, Bergman (2006) shows that European Business cycles are more synchronized during periods of more flexible exchange rates (having changed considerably since the early 1960s), although other authors do not find any relationship between exchange rate regimes and business cycle synchronization [8].

Other authors show that one cannot state the existence of an European Business Cycle since national business cycles do not exhibit an upward tendency (Mink *et al.* ,2007), nor move in the same direction (Artis, 2003)[9]. Although a great branch of the literature focuses on the effects of ERM and the early stages of EMU on European Business cycles, a far more contemporaneous list of economists approached the effects that resulted from the creation of the Euro currency. Considering the effects of the Euro changeover (2002), Lehwald (2012) found out that the Euro increased disparities between the core and peripheral business cycles within the Euro Area, contrasting with the endogeneity argument of the OCA from Frankel and Rose (1998). For instance, Canova *et al.* (2012), which considered a VAR model with quarterly data in six variables for ten European countries, found out that the establishment of the ECB and the Euro changeover did not have deep consequences on national real business cycles, as the present level of synchronization was the result of a "general process of convergence" that started in the 80-90's. These authors also underline the ambiguity on the effects from the Maastricht Treaty as its effects were in some sort predictable by economic agents. Furthermore, Gayer (2007) finds the existence of an euro-area distinct business cycle but pointing that the Euro changeover explains little of the recent increase in the synchronization level, contrasting with Furceri and Karras (2008) whose results show that Euro Area countries register a higher level of synchronicity with the EMU-wider area after joining the Euro. Altavilla (2004) reaches the same results, proving that adhering to the common currency leads to stronger synchronization of business cycles of countries belonging to the EMU-wide area. Nevertheless, Afonso and Sequeira

[8]For instance Baxter and Stockman (1989), Sopraseuth (2003), Baxter and Kouparitsas (2005).

[9]Baxter and Kouparitsas (2005) and Camacho *et al.* (2006) also highlight the fact that European business cycles are registering a decrease on its cross-correlation degree.

(2010) show an increase in the synchronization of business cycles for 27 EU countries during the period 1970-2009, as Koopman and Valle e Azevedo (2003) find an increasing resemblance between national business cycles in Europe. In another perspective, Clark and Wincoop (2001) analyzed US census regions and European countries and came to the conclusion that there is more synchronization in the United States than across European countries. They have also confirmed the existence of a "border effect" in Europe, as "*within-country correlations are substantially larger than cross-country correlations*". Contrary to these results, Fatás (1997) considered that national borders have lost importance with the creation of the EMS, as cross-border relations have increased and within-border co-movements have decreased.

2.3 Shocks and propagation mechanisms

The literature presents different driving forces that explain business cycle synchronization. Artis (2008) enhances the fact that regional business cycle affiliations across Europe are superseded by wider business cycles, provided the increase in international trade and economic and financial integration. The importance of the world factor in the European business cycles has been approached by Kose *et al.* (2003a), that have shown that regional-specific factors play a minor role in explaining economic fluctuations [10]. In another perspective, the works of Forni and Reichlin (2001) and Croux *et al.* (2001) came to the conclusion that regional-specific components explains largely national business cycles in Europe. Another branch of the literature focuses on the importance of Euro Area specific driving forces, which largely explain business cycle synchronization, for instance Giannone and Reichlin (2006) conclude that a large part of the members' business cycle can be explained by common European-specific shocks (other references include Mansour (2003), Del Negro and Ottrok (2003), Artis *et al.* 2004a). Contrasting with all of these results, Camacho *et al.* (2006) conclude that there is no evidence that the European business cycles are driven by a common force.

[10]Other works on the subject include Canova *et. al* (2007) and Monfort *et al.* (2004).

In what concerns the main determinants for business cycle synchronization, trade appears to be on the top of the list. As countries are more connected via intra-industry trade, their business cycles will achieve a higher level of synchronization (as referred by Frankel and Rose (1998), Canova and Dellas (1993) and Imbs, 2004). These results are shared by Bower and Guillemineau (2006), although these authors claim that trade as lost importance on explaining synchronization upon the Euro changeover, noticing that the determinants of business cycle synchronization vary depending on the different phases of the European Union construction. Furthermore, Krugman (1993) relates the inter-industry trade between countries and increasing specialization, which allied to industry specific shocks can lead to business cycles divergence.

Although Baxter and Kouparitsas (2005) considered that bilateral trade is more important to the explanation of synchronization when compared with industrial specialization, some authors enhance the importance of the latter. For instance, Otto *et al.* (2001), Kalemli-Ozcan *et al.*(2001) and Imbs (2001) present positive relation between sectoral specialization and business cycle synchronization, whether Calderón *et al.* (2002) assures that asymmetric production structure lowers co-movements between business cycles. Imbs (2001) stresses that a common structure in employment and manufacturing will justify co-movements between business cycles. On a later study, Kalemli-Ozcan *et al.* (2003) found that idiosyncratic shocks smoothed by the financial system throughout risk-sharing in the euro area were limited even though there is a high level of financial integration [11].

Fiscal policy effects are also approached in the literature. Mongelli (2002) distinguishes the different roles of fiscal policy as a driver of the business cycle. Among others, fiscal policy ensures a smooth cycle inside the framework of the Stability and Growth Pact. Bower and Guillemineau (2006) stated that fiscal policy harmonization has played a major role on the business cycle synchronization in the EMU countries. De Grauwe (2007) highlights the importance of spillovers from indebted countries, as interest rates might increase inside the

[11] Kose *et al.* (2003b) and Imbs (2004, 2006) also have also studied the positive link between financial integration and co-movement of business cycles. Imbs (2006) further explains that the effects of financial integration on sectoral specialization remains ambiguous.

monetary union. Afonso and Furceri (2007) found evidence of a "shock-smoothing role" of fiscal policy enhanced inside the enlarged EMU. Crespo-Cuaresma *et al.* (2011) found that fiscal policy coordination and trade integration are both great determinants of business cycle synchronization, suggesting that there should be a greater concern on fiscal policy inside the European Union.

2.4 Core-Periphery aggregations and country-clusters analysis

The literature appears to be divergent on the determination of the major economic trigger at the European economy. The importance of the US cycle has been approached by many [12], but the seminal work of Artis and Zhang (1997) resembles a changeover from the US cycle to the German one, under the creation of the EMU, as the major leading cycle to the rest of domestic European cycles, results shared by Inklaar and de Haan (2001). In a later study, Sopraseuth (2003) considers that the establishment of the EMS forged a higher degree of synchronization between the member states with the German cycle, decoupling from the US cycle. Perez *et al.* (2007) examined lead and lag relationships and found an increasing level of synchronization with the German cycle, although reporting the role of the US cycle especially since 1993 (after a decrease in importance due to the German reunification). Nevertheless, other studies highlight the fact that the importance of German shocks in other European countries is decreasing since the EMU regime, in some cases even considered insignificant (Canova *et al.* (2012) and Fichtner, 2003) as country specific shocks are more effective than other common shocks (Karras, 1996) [13].

Provided these diverging results on the importance of the German cycle in its homologous in the European context, a branch of the literature focuses instead on the existence of core and periphery groups within the continent, amid the consideration of more than one cycle of major importance. Camacho *et al.* (2006) do not expand the debate as they do not

[12] Agresti and Mojon (2001), Canova *et al.* (2006), Del Negro and Otrok (2008) and Giannone and Reichlin (2006, 2010)

[13] Karras (1996) also states that a common currency in Europe will not have a stabilization effect on business cycles in the EMU-wide area.

find strong evidence that could support the existence of a core group and a periphery group in Europe, as there is no concrete economic attractor. Bayoumi and Eichengreen (1996) considering 12 European countries discovered a core group composed by Germany, France, Benelux and Denmark. This result is replied extensively across the literature as normally economists find a core group always with Germany as the attractor economy [14]. Darvas and Szapary (2005) have explored intensively the core-periphery groups, considering that the position of a country relative to the central core is relevant to determine the potential gains and losses of supranational policies or interventions. These results highlight the fact that those decisions should be optimal due the subset of countries related to the core, a subject that can be pertinently raised upon supranational policies implemented by European institutions and the European Central Bank. For instance, Camacho *et al.* (2008) reject the existence of an "European business cycle" reinforcing the results of de Haan *et al.* (2008), proving that there is a "difficulty of choosing an appropriate monetary policy stance given the actual differences in business cycle features".

Other branch of the literature focus on determining country clusters, applying a wide variety of methods and econometric methodologies in order to identify core and periphery regions. Artis and Zhang (2001) determined the existence of a core group within Europe, driven by Germany, and a northern and southern periphery groups. These authors considered a cyclical component of the German series, showing that this country was actually the largest and the most influential among all countries analyzed, suggesting that the monetary policy of the "Bundesbank" is a leader for the ERM and EMS wide area. In a following work, Artis and Zhang (2002) used fuzzy clustering techniques replicating the same previous results. Crowley (2008) using model-based cluster analysis to a sample of European members and other countries according with their correlations to the German cycle, concluded that macroeconomic variables are diverging inside the Euro Area, although he had registered an increase in convergence for the Central and Eastern Europe countries. Ap-

[14] Examples of works considering core-periphery analysis finding a core group leaded by Germany include Artis and Zhang (1997,1999), Artis *et al.* (1997), Christodoulakis, *et al.* (1995), and Dickerson *et al.* (1998)

plying a different method, Lopes and Pina (2008) use fuzzy clustering and rolling window techniques, comparing the evolution of synchronization and core-periphery distinctions in Europe with two other monetary unions - Canada and the United States of America. They have found that the common currency in the Euro Area enhanced synchronization among its members and that the EMU is economically viable as cyclical correlations have developed positively. Papageorgiou *et al.* (2010) provides more recent results on clustering analysis in Europe, on which he has considered business cycles in the 1960-2009 time span and four data breaks according to institutional events. They have found the existence of a core and periphery groups in Europe but concluded that the degree of synchronization is decreasing and the number of clusters increases throughout the considered period. More recently, Aguiar and Soares (2011) examined synchronization across the EU-15 and the Euro Zone countries through spectral approaches and found a core in the Euro area, composed by France and Germany.

Table 1 includes some references on the application of clustering techniques in business cycle analysis.

Table 1: Some Literature Review on Business Cycle Cluster Analysis

Author(s)	**Data and Cluster Method**	**Main Findings**
Artis and Zhang (2001)	Several data used: GDP de-trended with HP filter. Application of HAC with the centroid and average-linkage methods.	Core Group: France, Netherlands, Belgium, Austria; Northern Periphery: Denmark, Ireland, UK, Switzerland, Sweden, Norway and Finland; Southern Periphery: Italy, Spain, Portugal, Greece and 2 other non-European groups.
Artis and Zhang (2002)	Set of variables inspired on the OCA Criteria. Fuzzy clustering techniques are applied (with Germany as the center country.	Core group: France, Netherlands, Belgium and Austria. Northern Group: UK, Denmark, Ireland, Sweden and Finland. Southern Group: Italy, Spain, Greece and Portugal.
Artis and Claeys (2007)	Quarterly GDP de-trended with a band-pass filter based on HP filter. Cross-correlations are used with HAC with average-linkage and Euclidean Distance.	EU-group set apart of a Canada-U.S. group. Scandinavian Group also identified.
Artis and Okubo (2009)	Hierarchical average linkage with Euclidean distance (over HP-filtered GDP cross-correlations between countries)	Clusters identified: U.S., UK and Canada; France, Germany and other European continental countries; Nordic countries group.
Crowley (2008)	Estimation of cyclical component of Business Cycle Indicators. Cross-Correlations with Germany and Euro Area are used on a model-based clustering framework.	Divergence of macroeconomic variables' development in Euro Area; a core-periphery division cannot be fully defined.
Graff (2006)	Capital utilization indicator composed, furtherly de-trended with HP filter.	Clusters identified: France, Switzerland, Italy and Japan; Australia, the Netherlands and USA and Canada, UK and Sweden.
Van Aarle *et al.* (2008)	GDP de-trended with CF band-pass filter. Hierarchical Agglomerative Clustering with Ward's algorithm and Euclidean Distance.	Three Clusters identified: Austria, Netherlands and Germany; Belgium, France, Italy and Spain; Greece and Portugal plus three isolated countries (Ireland, Finland, Luxembourg).

3 Methodology

This thesis investigates how European Business Cycles can be grouped into country-aggregate clusters, assessing its level of synchronicity, interdependence and response to economic permanent shocks. Through the emprical analysis made in the present work, we have chosen a specific econometric and statistical framework, which is based in the following features: Hierarchical Agglomerative Clustering (HAC), detection of Turning Points, metrics for Business Cycle Synchronicity, stationarity analysis, Vector Autoregressive Model (VAR), Granger-causality, Impulse Response Functions (IRF) and Forecast Error Variance Decomposition (FEVD).

3.1 Hierarchical Agglomerative Clustering

Having as a goal the identification of synchronous and identical groups of countries we have pursuit a cluster analysis based on the Hierarchical Agglomerative Clustering (HAC) approach. The approach can be briefly described as follows: at first, each individual country belongs to its own cluster; then, the algorithm groups the different countries in pairs that are the "most similar" (*i.e.* that have the smallest dissimilarity level); the process is repeated iteratively until all countries in the sample belong to a unique cluster. Given our aims, we can say that the algorithm combines pairs of "most-synchronous" countries.

Albeit the variety of algorithms applied and explored in the literature, we chose to use the Ward's algorithm introduced by Ward (1963) and the Euclidean distance as the metric distance (dissimilarity measure). As it maximizes the homogeneity within the clusters, the Ward's algorithm is considered a suitable tool for BC synchronization research (Van Aarle *et al.*, 2008).[15].

The Ward's algorithm calculates the distance for each pair of countries' cyclical com-

[15]Other approaches to the Ward's algorithm in Business Cycle research include Graff (2006), Van Aarle *et al.* (2008) and Ductor and Leiva-Leon (2015). For robustness check, we have also tested the group-average and centroid algorithms following Artis and Zhang (2001). These methods were unable of grouping all countries into distinct clusters at some stage, and therefore were discarded due to the purpose of the present research.

ponents y_i and y_j based on the root of the quadratic linear Euclidean distance:

$$d(y_i, y_j) = \sqrt{\sum_i (y_i - y_j)^2} \qquad , y_i \neq y_j \tag{1}$$

then the Ward's algorithm proceeds to calculate the clusters on the basis of the minimum increase in $d(y_i, y_j)$. After merging two clusters into another, the algorithm then calculates the distance between two other clusters as the increase in the error sum of the squares (ESS), *i.e.*, the sum of squares of the deviations from the mean value, expressed as

$$ESS(X) = \sum_{i=1}^{N_x} |x_i - \frac{1}{N_x} \sum_{j=1}^{N_x} x_j|^2 \tag{2}$$

where X is a set of N_x values, x_i represents the observation i from the set X, and x_j represents all the observations included in X used for the calculation of the mean value. The linkage function that expresses the distance between two clusters X and Y is

$$d(X, Y) = ESS(XY) - [ESS(X) + ESS(Y)] \tag{3}$$

where XY stands for the new cluster formed by the merge of the cluster X and the cluster Y [16].

A variable (or in our case, a country *deviation* cycle) belongs to its own initial cluster at the last stage whenever it displays such a high level of dissimilarity to is counterparts that the algorithm could not assign it to a specific group.

3.2 Turning Points Dating and Business Cycle metrics

The choice for the application of a filtering methodology (as described in section 4) to estimate a *deviation* cycle has further implications on the dating of turning points in the series (Artis *et al.*, 2004a). For dating the turning points we consider the Bry-Boschan Quarterly (BBQ) algorithm developed by Harding and Pagan (2002), a modified version of the Bry-Boschan (BB) algorithm from Bry and Boschan (1971). Although initially designed to be applied on classical business cycles (on series in levels or in growth rates),

[16] The Ward's algorithm is applied with a MATLAB routine. The codes and execution steps are shown in Annex A.5.

there is no impediment on its extension to de-trended series [17].

The BBQ algorithm defines peaks and troughs in the data as the local *minima* and *maxima*. Considering z_t as the cyclical component at time t a peak is defined as:

$$z_{t-2} - z_t < 0, z_{t-1} - z_t < 0; z_{t+1} - z_t < 0, z_{t+2} - z_t < 0 \tag{4}$$

and a trough is defined as:

$$z_{t-2} - z_t > 0, z_{t-1} - z_t > 0; z_{t+1} - z_t > 0, z_{t+2} - z_t > 0 \tag{5}$$

The BBQ considers a window over which local *minima* (trough) and *maxima* (peak) are calculated as being two quarters. The minimum phase length is set on two quarters and the minimum full cycle length on five quarters in order to avoid spurious turning points. The BBQ algorithms also requires that phases alternate (a peak is always followed by a trough and *vice-versa*) [18]. The STATA outcome from the BBQ algorithm is *-1* for a trough, *1* for a peak and *0* otherwise.

After the turning point dating, we pursuit stylized measures to assess dis(similarities) between the clusters business cycles on frequency, duration, amplitude and slope. The outcome of the STATA BBQ algorithm is substituted manually into a binary variable S_t that assumes the value 1 whenever there is an expansion (*i.e.* between a *-1* and a *1*) and 0 whenever there is a contraction (*i.e.* between a *1* and a *-1*). We measure the average duration of a contraction between a peak and a trough as

$$D_{PT} = \frac{\sum_{t=1}^{T} S_t}{\sum_{t=1}^{T-1} (1 - S_{t+1}) S_t} \tag{6}$$

and the average duration of an expansion between a trough and a peak as

$$D_{TP} = \frac{\sum_{t=1}^{T-1} (1 - S_t)}{\sum_{t=1}^{T-1} (1 - S_t) S_{t+1}} \tag{7}$$

The numerators in (16) and (17) measure respectively the time spent in contractions and expansions, and the denominators measure respectively the number of peaks and

[17]Examples of the BBQ application for growth cycles can be seen in Altissimo *et al.* (2001), Zarnowitz and Ozyildirim (2006), Massman and Mitchel (2004) and an adaption in Artis *et. al* (2004b), among others

[18]We apply the BBQ algorithm on STATA with the code *sbbq* developed by Philipe Bracke from the London School of Economics.

troughs. The amplitude of a phase A_i is the total growth between a peak (trough) and a trough(peak), expressed as

$$A_i = z_{i(t+d)} - z_{it} \tag{8}$$

where d is the total duration of a phase, z_t the value for the growth cycle at a peak(trough) and z_{t+d} the value for the growth cycle on the succeeding trough(peak). The average amplitude of an expansion phase is given by

$$A_{TP} = \frac{\sum_{t=1}^{T} A_i(1 - S_t)}{\sum_{t=1}^{T-1}(1 - S_t)S_{t+1}} \tag{9}$$

and the average amplitude of a contraction phase by

$$A_{PT} = \frac{\sum_{t=1}^{T} A_i S_t}{\sum_{t=1}^{T-1}(1 - S_{t+1})S_t} \tag{10}$$

Following Harding and Pagan (2002), we may consider A_i and $D_i = d$ as being the height and base of a triangle, respectively. The area of such triangle provides the welfare (or cumulative) loss(gain) of output in a recession(expansion), expressed as

$$C_{Ti} = \frac{A_i D_i}{2} \tag{11}$$

Further we can consider an index of excess cumulated movements measure E_i given by

$$E_i = \frac{(C_{Ti} - C_i)}{C_i} \tag{12}$$

with

$$C_i = \frac{A_i}{2} + \sum_{s=1}^{d-1}(y_{t+s} - y_t), s = 1, ..., d \tag{13}$$

C_i represents the actual output cumulative movements, as C_{Ti} is the triangular approximation for such. The excess cumulated movements E_i are calculated as the phase does not evolve linearly between two extreme points.

We also consider a measure for the *deviation* cycle steepness for both expansionary and contraction phases which represents the slope of the triangle. The steepness of phase i is given by:

$$Steepness_i = \frac{A_i}{D_i} \tag{14}$$

In order to measure synchronicity between the estimated *deviation* cycles, we calculate the Index of Concordance, the Pearson correlations and the Spearman's rank correlations.

The Index of Concordance, introduced by Harding and Pagan (2002a), calculates the percentage of phases on which two series are synchronized, express as [19]:

$$c_{xy} = T^{-1}\sum_{t=1}^{T}[S_{x,t}S_{y,t} + (1 - S_{x,t})(1 - S_{y,t})] \tag{15}$$

where $S_{i,t}$ is the business cycle phase of the country i at time t (the same applies for $S_{j,t}$) and T is the number of quarters considered in the sample. $S_{i,t}$ and $S_{j,t}$ assume the value of 1 whenever there is an expansion (growth is above trend) and 0 whenever there is a contraction (growth is bellow trend). As censoring rules were applied for the detection of turning points, the distributional properties of c_{ij} are unknown. Therefore, the Index of Concordance may be transformed into an empirical correlation between $S_{i,t}$ and $S_{j,t}$ as follows:

$$c_{xy} = 1 + 2\rho_s\sigma_{Sx}\sigma_{Sy} + 2\mu_{Sx}\mu_{Sy} - \mu_{Sx} - \mu_{Sy} \tag{16}$$

where μ_{si} and σ_{si}, with $i = x, y$, represent respectively the mean and standard deviation of $S_{i,t}$. Further on, there is a linear relationship between c_{xy} and ρ_S expressed as:

$$\frac{S_{y,t}}{\sigma_{Sy}} = \eta + \rho_S\frac{S_{x,t}}{\sigma_{Sx}} + u_t \tag{17}$$

where η is a constant and u_t the error term. Equation (17) is estimated through OLS with robust-standard errors to ensure that the estimator is consistent, since u_t includes serial correlation from S_{yt} under the null hypothesis $\rho_s = 0$. This metric may be used whenever pair is considered.

The Spearman's rank correlation (1904) measures the strength and direction of the monotonic relationship between two variables. It is calculated as the same as Pearson's correlation but on the ranks and average ranks as follows:

$$r = 1 - \frac{6\sum{d_i}^2}{T^3 - T} \tag{18}$$

on which d_i is the difference of ranks from the two variables for each observation, and T the total number of observations.

[19]The Index of Concordance is also used in several works, for instance McDermott and Scott (2000), Harding and Pagan (2002), Krolzig and Toro (2005) and Harding and Pagan (2006), among others.

3.3 Econometric Framework

The existence of stationarity on a time-series ensures the robustness of the statistical inference, avoiding spurious regressions. In fact, the to-be-executed econometric framework based on the VAR model requires that all variables are stationary. The unit root test indicates if the time-series verify a time-invariant mean, variance and autocovariance, *i.e.* if they are a stationary process.

The Augmented Dickey-Fuller (ADF) test is an extension of the Dickey-Fuller tests and assume that residuals are serially correlated (Dickey and Fuller, 1979). The ADF test has the null hypothesis of the presence of a unit root, against the alternative of a stationary process. Assuming D_t as a vector of deterministic terms, $\mathbf{p}$ the lagged difference terms and Δy_{t-j} an approach to an ARMA structure, the ADF test can be formulated as follows:

$$y_t = \beta_0 D_t + \varphi y_{t-1} + \sum_{j=1}^{p} \psi \Delta y_{t-j} + \varepsilon_t \tag{19}$$

where the coefficient φ is the parameter of interest and included in a test statistic $DF = \hat{\varphi}/SE(\hat{\varphi})$, analyzed after the critical values of the DF t-distribution.

Amid the identification of the country-clusters on the first-stage, the VAR methodology is applied to both validate the component countries within and Cluster, and to assess further on the economic impacts from the structural analysis. The VAR methodology, introduced by Sims (1980), consists on a n-equation, n-variable linear model in which each variable is explained by its own lagged values and the past values of the remaining n-1 variables. Considering its reduced form, each variable is assigned with a linear function estimated by OLS (Ordinary Least Squares) or Maximum Likelihood, on a dynamic simultaneous-equation economic model. A VAR of lag length equal to p - a VAR(p) - is a process that evolves according to:

$$\mathbf{y}_t = \Phi_0 + \Phi_1 \mathbf{y}_{t-1} + \Phi_2 \mathbf{y}_{t-2} + ... + \Phi_p \mathbf{y}_{t-P} + \varepsilon_t, \quad t = 1, ..., T \tag{20}$$

where $\mathbf{y}_t$ is a n by 1 vector stochastic process, Φ_0 is a k by 1 vector of intercept parameters and Φ_j, $j = 1$, ..., p is a k by k parameter matrix. The white noise process is denoted by ε_t. Moreover $E[\varepsilon_t] = 0$ and $E[\varepsilon_t \varepsilon'_{t-s}] = \sum = 0$, where $\sum$ is a positive definite time-invariant covariance matrix [20].

To determine the optimum lag length of each country-cluster VAR we proceed to use the Akaike Information Criterion (AIC) through the minimization of the estimated number of lags j on the following equation:

$$\min log(SSR_j/T) + (j+1)C(T)/T \tag{21}$$

Where SSR_j is the Sum of Squared Residuals for the autoregression of j lags and $j+1$ denotes the inclusion of the intercept term.

We also test the presence of autocorrelation of disturbances after computing the VARs with a Lagrange Multiplier test (LM Test). The LM test statistic is defined as:

$$LM_s = (T - d - 0.5) ln \frac{|\widehat{\sum}|}{|\widetilde{\sum_s}|} \tag{22}$$

where T is the total number of observations, d is the number of coefficients estimated, $\widehat{\sum}$ is the maximum likelihood estimate of $\sum$ and $\widetilde{\sum_s}$ the maximum likelihood estimate for the variance-covariance matrix $\sum$ in the augmented VAR. The null hypothesis of the LM test is the non-existence of autocorrelation at an *ex-ante* defined lag order, and its asymptotic distribution is a $\chi^2_{K^2}$.

Amid the VAR specification, we initially verify its stability in order to proceed to structural inference analysis, as covariance stationarity is not a sufficient condition to do so. A VAR is said to be stable if it can be re-written as a vector moving average (VMA), which means that its respective polynomials are invertible. As such, IRF and FEVD results are keen to be interpreted. In this process, a matrix of eigenvalues **A** is computed, on which the stability is confirmed whenever the modulus of each eigenvalue in **A** is strictly less than 1 (Lutkepohl, 2005 and Hamilton, 1994).

On the next step we pursuit a Granger-causality analysis, introduced by Granger (1969). Assuming a VAR(p) as in (20) it is said that $y_{j,t}$ does not Granger cause $y_{i,t}$ if all the

[20]More detailed information on VAR theory can be read in Hamilton, J. D. (1994) chapter 11 or at chapter 5 of Sheppard, available at https://www.kevinsheppard.com/images/5/56/Chapter5.pdf.. Further equations and methodologies were retrieved from the latter source.

coefficients of coefficient values of the latter on the first's equation are zero. The Likelihood Ratio Test for Granger-causality is

$$(T-(pk^2)).(ln|\widehat{\sum_r}|-ln|\widehat{\sum}|) \sim^A \chi^2_P \tag{23}$$

where $\sum_r$ represents the estimated residual covariance matrix for the null hypothesis of no Granger-causality and $\sum_u$ is the estimated covariance of VAR(p).

Next we compute the IRF as the second approach of analysis. An IRF is a function of derivative/change of y_i (an element of $\mathbf{y}$) with respect to a shock in ε_j (an element of $\mathbf{e}$) for any j and i. Given that y_t is covariance-stationary, the stable VAR(p) can be re-written as a VMA process such

$$\mathbf{y}_t = \mu + \varepsilon_t + \Xi\varepsilon_{t-1} + \Xi\varepsilon_{t-2}... = \mu + \sum_{i=0}^{\infty}\Xi_i\varepsilon_{t-i} \tag{24}$$

where μ is a k x 1 time-invariant mean of y_t and Ξ_i represent the IRFs. *Ceteris paribus*, a one-unit standard-deviation increase in the kth element of ε_{t-i} on the jth element of y_t after i periods is given by the j,k element of Ξ_i. Given the contemporaneous correlation between the terms ε, a matrix $\mathbf{P}$ is calculated to orthogonalize ε_t where $\mathbf{P}$ is the Cholesky decomposition of $\sum$ for the Orthogonal IRFs (such that $\sum = PP^T$), which is dependent on the variables' order in the VAR.

The third instrument we rely on for the structural analysis is the FEVD. It measures the part of the error of the variable's j forecast variance after h periods that is due to the orthogonalized innovations in the kth variable. The FEVD depends on the choice of the matrix $\mathbf{P}$. Re-writing the forecast errors as orthogonalized, the FEVD will measure the part of total forecast-error variance that is due to each orthogonalized shock.

4 Data and Business Cycle Estimation

In order to estimate the national business cycles we consider quarterly GDP retrieved from the OECD Quarterly National Accounts. The series are volume estimates in chain, measured in US Dollars and constant prices with fixed PPPs (with OECD reference year equal to 2010). The data is already seasonally adjusted and expressed at annual levels [21]. The choice of the VPVOBARSA database was mainly due to the harmonization of each national series in the same currency (US Dollar), which allows the estimation of further country-cluster aggregates without the need of using exchange-rates for such a long period.

As the data is presented in volumes, we transform it into logarithms and proceed to calculate the growth rates of each quarter compared to the same quarter of the previous year. The dataset comprehends a time span between the first quarter of 1960 (1960Q1) and the first quarter of 2016 (2016Q1). Given our research purpose, we only consider European countries that were part of the European Exchange Rate Mechanism (ERM) at some point of time, which accounts for the majority of Western, Northern and Southern European countries. Norway is not considered as it was never part of the ERM system nor belongs to the Euro Area and European Union. The countries included are:

- Austria (AT)
- Belgium (BEL)
- Denmark (DEN)
- Finland (FIN)
- France (FRA)
- Germany (GER)
- Greece (GRE)
- Ireland (IRL)
- Italy (ITA)
- the Netherlands (NTH)
- Portugal (POR)
- Spain (SPA)
- Sweden (SWE)
- United Kingdom (UK)

In the words of Harding and Pagan (2002), *to depict a cycle one first needs to define it.* Here we deal with the *deviation* (or growth) business cycle in the light of the work of Lucas

[21] The database measure code is VPVOBARSA, available at the OECD Quarterly National Accounts website

(1977), also considered in Sargent (1987), Blanchard and Fisher (1989) and Zarnowitz (1992). Contrary to *classical* business cycles, introduced by Burns and Mitchell (1946), the *deviation* cycles contemplate cyclical fluctuations in GDP as being deviations from its long-run trend, or in other words, the output gap. As such, we estimate the cyclical component of real GDP, which can be considered a *real proxy for the business cycle* (Stock and Watson, 1999).

The growth rate series are de-trended with the Christiano Fitzgerald (CF) band-pass filter introduced by Christiano and Fitzgerald (2003)[22].

Amid other alternatives, we used the CF band-pass filter as it presents a solution to endpoints problem. The endpoints problem is a disadvantage not surpassed by the HP filter (introduced by Hodrick and Prescott, 1980) as it becomes asymmetrical at the beginning and end of the sample which may distort the estimation of the cyclical component (recall Canova (2007) for a survey). The CF filter uses an asymmetrical weighting scheme, which contrary to the BK filter (from Baxter and King, 1995) does not lead to a loss of information at the beginning and end of samples.

The CF band-pass filter considers the following stylized decomposition, on which it separates the time-series y_t into the trend component τ_t and cyclical component c_t as follows:

$$y_t = \tau_t + c_t \tag{25}$$

The STATA routine for the CF band-pass filter has the advantage of calculating the cyclical component in the presence of a unit root in the series. Further on, the CF band-pass filter follows Burns and Mitchell (1946) and considers business cycles' periods ranging between 1.5 and 8 years (6 and 32 quarters respectively).

On the next section we will consider aggregate cluster business cycles, which are built with a weighted diffusion index:

$$Y_{jt} = \sum_{i=1}^{N} w_{i,t} y_{i,t} \tag{26}$$

[22]We have applied the CF Filter routine in STATA (command *tsfilter cf*)

where Y_{jt} is the value for the cyclical component of cluster j at time t, w_{it} is the value for country i weight (or ratio) of its Quarterly GDP (in levels) on overall cluster members total Quarterly GDP(in levels) at time t (with $\sum_i w_{i,t} = 1$), $y_{i,t}$ is the value for country i Quarterly GDP (in levels) at time t, and N is the total number of countries in cluster j.

5 Empirical Findings

In this section we identify the country-clusters with the Ward's method. In order to compute the aggregate *deviation* cycle for each cluster, we evaluate if the countries inside of each cluster have importance in the explanation of each other by computing the Granger Causality. This is made after the estimation of a stable VAR. Then, we aggregate the series through a generic summation of the terms of the series of each of the countries composing the cluster *deviation* cycles. From here we do an empirical analysis in two steps. Firstly, we analyze stylized facts between the clusters deviation cycles, its turning point dating and synchronicity. Secondly, we create a robust and stable VAR model with the three deviation cycles, and do a structural analysis with Granger-causality, IRFs and FEVD.

5.1 Cluster Analysis

Amid the application of the HAC through the Ward's method we assigned each domestic *deviation* cycle to a country-cluster. The results from the Ward's method are expressed in a dendrogram, a linkage tree composed by leaf nodes and connection leafs.

The leaf nodes represent a singleton that contains a single data point. Its height, measured in the vertical axis, gives the dissimilarity level attained at that point (higher leaf nodes indicates higher dissimilarity levels). The connection leafs link each country or group to its closest pair(s), under a hierarchical sequence. This sequence ends at the last node (or root node) that includes all observations and agglomerates all countries in a single cluster.

Figure 1: Dendrogram for Hierarchical Agglomerative Clustering with Ward's method

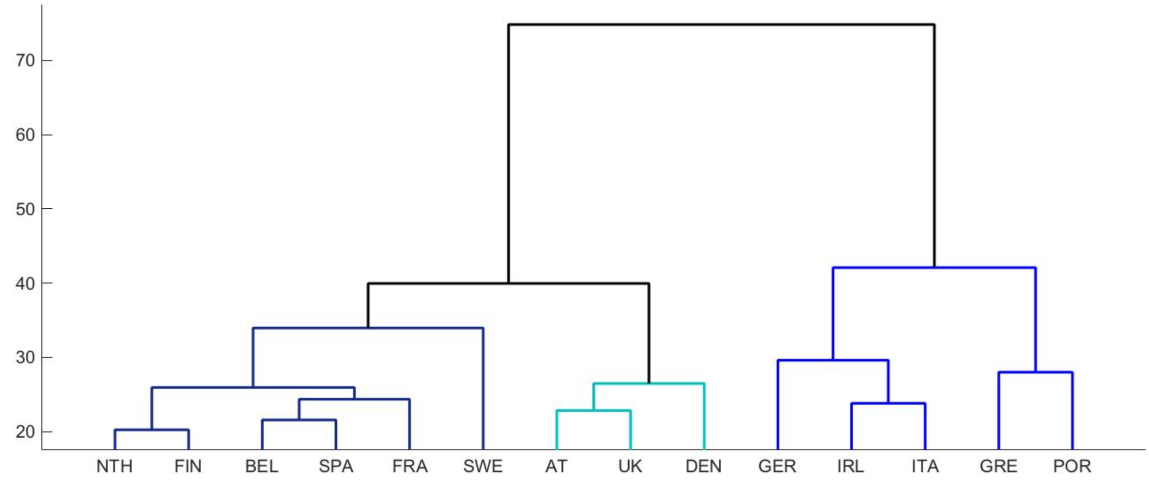


Figure 1 plots the dendrogram of the HAC with the Ward's method. It is possible to immediately distinguish between three main groups of countries, revealed by different shades. The determination of the clusters occurs iteratively after four stages, and the final node is reached on the sixth stage. The sequence of stages is the following:

- **Stage 1:** Six pairs of countries are identified (the Netherlands-Finland, Belgium-Spain, Austria-United Kingdom, Ireland-Italy and Greece-Portugal) plus four isolated countries (France, Sweden, Denmark and Germany).
- **Stage 2:** France joins the pair Belgium-Spain and Germany joins Ireland and Italy. Cluster 2 is formed as Denmark joins the United Kingdom and Austria.
- **Stage 3:** The Netherlands and Finland join France, Spain and Belgium. Greece and Portugal join Germany, Ireland and Italy forming Cluster 3.
- **Stage 4:** Sweden joins the remaining countries not assigned to any cluster, forming Cluster 1.
- **Stage 5:** Cluster 1 and Cluster 2 merge into a single cluster.
- **Stage 6:** Cluster 3 joins its counterparts at the final node, on which all countries in the sample belong to the same group.

The clusters that we will consider for the empirical analysis are the ones identified at stage 4, the first moment on which all countries are assigned some group. Cluster 1 and Cluster 2 have the most similar pair of clusters, as its merge is concluded at the dissimilarity level of 40. Cluster 3 is less similar as its counterparts are grouped two stages after at a dissimilarity level higher than 70. In *summa*, the identified clusters are:

- **Cluster 1** : France, Belgium, the Netherlands, Spain, Sweden and Finland.
- **Cluster 2:** United Kingdom, Denmark and Austria.
- **Cluster 3:** Germany, Italy, Ireland, Portugal and Greece.

Results from HAC analysis, even under the consideration of the same panel of countries, may be divergent, and as such one must be cautious while making comparisons. Nevertheless, there must be an economic, geographical and institutional sense supporting the country-groups obtained. Some caveats from the literature are enumerated to aware the reader of the influence of economic and econometric frameworks on the identification of country-clusters:

i We do not set nor calculate an optimum number of clusters, which were assumed by default. Nevertheless, the MATLAB routine allows for the selection of a predefined number of clusters;

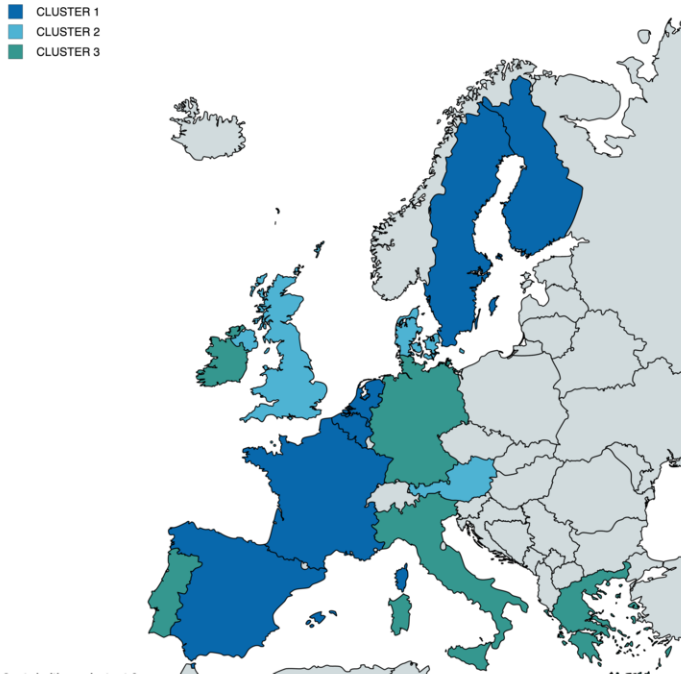
ii The clusters are not identified *ad hoc* nor built in reference to a specific business cycle, *e.g.* Artis *et al.* (2003) considers the Euro Area whereas Van Aarle *et al.* (2008) uses Germany as the reference cycle.

iii The choice of a panel of countries also influences the results. In this work, Luxembourg and Norway are the only Western European countries which are not included. If they were included, possibly the clusters would have been set differently.

iv The time span of the series also affects the results, and especially when data breaks related to institutional, economic or financial events are considered. In our case we consider the entire time span without breaks in order to have accurate results over the structural analysis.

v Lastly, the business cycle concept used, whether a *classical* or a *deviation* one, also affects results as the series will have a different statistical distribution. The treatment of the raw series also have implications on the turning point detection, and on the stylized and synchronization analysis.

Figure 2: Geographical location of the identified Clusters



Cluster 1 is composed by continental countries, including France plus two countries that border it namely Spain and Belgium (see Figure 2). Netherlands is geographically close to France as well. The group also includes two Nordic countries, the pair Finland-Sweden albeit its geographical location.

Denmark and the United Kingdom appear together in Cluster 2, sharing common characteristics as the non-membership of the Euro Area and its geographical proximity. Surprisingly Austria is included in Cluster 2, contrary to what would be expected due to a closer geographical location with Germany or other European continental countries (*via* stronger trade relations and financial linkages).

Finally, Cluster 3 includes Germany, the most peripheral economies in Europe (Portugal, Greece and Ireland) and Italy (with whom it shares not only a border but also strong industrial and financial linkages). Germany has been broadly used in the literature as a reference cycle, on which synchronicity is measured on its basis. Artis and Zhang (1997) consider that Germany has the most influential economy in the EU and in parallel that the *Bundesbank* is the leader of the monetary policy of both ERM and EMS. On a following work, Artis and Zhang (2001) found a synchronous Southern periphery group that included Portugal, Italy and Greece, with reference to the German cycle. In a more recent work Poirson and Weber (2011) found a high level of synchronization between Germany and the peripheral economies (Portugal, Ireland and Greece), which have increased since the 80's.

After the identification of the clusters we confirmed that all national series were stationary in order to compute the individual clusters' VAR models (*vide* Annex A.3 for the ADF test results).

Each cluster's model includes as variables the *deviation* cycles of its component countries. We determined the optimum lag length for the VAR models with the AIC, which indicated a lag length of 10 periods for Cluster 1, 9 periods for Cluster 2 and finally 10 periods for Cluster 3 (*vide* Annex A.7, A.8 and A.9 for Cluster 1 VAR, Cluster 2 VAR and Cluster 3 VAR respectively).

The stability tests after each VAR with those lag-lengths did not yield that all roots of the companion matrix lied inside the unit circle. The VAR stability was then obtained with 6 lags in Cluster 1, 8 lags in Cluster 2 and 4 lags in Cluster 3 (*vide* Annex A.7, A.8 and A.9 for Cluster 1 VAR, Cluster 2 VAR and Cluster 3 VAR respectively). This process simply intended to obtain the optimal fit between the lag order and the stability of the model (essential for the computation of the IRFs and FEVDs).

As we confirm that all VARs are stable, we tested for autocorrelation. The results from the LM test statistic failed to reject the null hypothesis of no autocorrelation at the lag order for all the VARs (*vide* Annex A.7, A.8 and A.9 for Cluster 1 VAR, Cluster 2 VAR and Cluster 3 VAR respectively). Although the presence of autocorrelation in the residuals biases the estimated coefficients, it does not compromise the stability of a VAR. As a forecast analysis based on the coefficients is not part of the objectives of this work, the presence of autocorrelation does not avoid a structural analysis. Nevertheless, the existence of autocorrelation is a structural characteristic of GDP growth series, and it is broadly referred in the literature, for instance Nelson and Plosser (1982), Watson (1986) and Campbell and Mankiw (1987)[23].

With the necessary conditions reunited in order to perform a structural analysis at the VAR of each of the individual clusters, we tested for Granger-causality. We have found that all national deviation cycles are Granger-caused by all the other component countries within their respective cluster. If all countries within a cluster *linearly predict* each one of the members, then there is a sense of economic feedback between the countries, which increases the accuracy on the forecast (*vide* Annex A.7, A.8 and A.9 for Cluster 1 VAR, Cluster 2 VAR and Cluster 3 VAR respectively).

For the estimation of a cluster *deviation* cycle we applied the diffusion index from equation (30) to aggregate the quarterly GDP series in levels of the members; next, we applied the logarithms and computed the series' homologous growth rates and then, we used the CF band-pass filter to estimate the cyclical component and trend component of the series.

5.2 Stylized facts of the *Deviation* Cycles

5.2.1 Descriptive Statistics

In this part we analyze the main stylized facts for each cluster *deviation* on what concerns business cycle dynamics and behavior for the period 1961Q1-2016Q1, as depicted in Table 2.

[23]This issue will be again approached in Section 5.3.1.

Table 2: Deviation Cycle Characteristics per Cluster

	Cluster 1	**Cluster 2**	**Cluster 3**
Mean	0.0529495	0.0217311	0.0536171
Standard Deviation	1.182837	1.616867	1.660082
Min.	-4.476114	-5.235421	-6.286825
Max.	3.080753	4.456617	4.094049
Skewness	-0.3366574	-0.4481096	-0.5519538
Kurtosis	4.485278	4.022959	4.283371

Source: Author's own calculations. The value for skewness is given by $\mu_3/(\mu_2)^{1.5}$ and the kurtosis by $\mu_4/(\mu_2)^2$.

On what concerns the average growth rate above the trend, Cluster 1 and Cluster 3 registered practically the same value (0.0529% and 0.0536% respectively). Cluster 2 grew less on average compared to its counterparts, as it registered only 0.021%. Nevertheless, Cluster 2 achieved the highest growth rate above trend with 4.45%, whereas Cluster 1 and Cluster 3 reached the highest local *maxima* at 3.08% and 4.09% respectively. Cluster 3 has the highest growth rate bellow trend (-6.29%), followed by Cluster 2 (-5.34%) and Cluster 1 (-4.47%).

We consider the standard deviation as a proxy for business cycle volatility, which is more accurate when applied to de-trended series (Mills, 2000). The volatility measurement captures the dispersion of GDP growth deviations from the trend. Cluster 3 has the most volatile *deviation* cycle as it presents the highest standard deviation (1.66). Cluster 2 shows a slightly lower standard deviation when compared to Cluster 3, but Cluster 1 is in fact the less volatile of all, with a value of 1.182.

We use the values for the skewness as a proxy measure of the severity of recessions, as done by Cashin and Ouliaris (2001). All clusters show negative skewness, which indicates that downward spikes in real GDP are slightly higher than upward spikes. Cluster 1 has milder recessions when compared to its counterparts as it presents the highest skewness, followed by Cluster 2 and Cluster 3, which verify respectively the strongest recessions.

On what concerns the kurtosis, all deviation cycles have values higher than 3, which is the benchmark value for a normal distribution. As all the *deviation* cycles have heptokurtic distributions since their tails are fatter compared to the normal distribution, which indicates that large GDP movements are not that common compared to a normal distribution (and are more present in Cluster 2, followed by Cluster 3 and Cluster 1).

5.2.2 Dissecting the ***Deviation*** Cycles

In order to evaluate at which extent the deviation cycles have the same pattern several metrics, broadly used in the literature, are applied. Although the assessment of synchronicity after turning points detection is relevant for the comparison of the business cycles, its as(symmetries) should also take into consideration the characteristics of cycles and phases, such as length, amplitude, slope and cumulative movements (Krolzig and Toro, 2005).

The turning points of each *deviation* cycle were detected through the BBQ algorithm introduced by Harding and Pagan (2002) . As we deal with *deviation* cycles and not with *classical* cycles, the interpretation of phases and local *maxima* and *minima* is not the same. Following Cotis and Coppel (2005), a different taxonomy is considered for *deviation* cycles terminologies. A peak (*i.e.*, a local *maxima*) in the *deviation* cycle consists on an economic upturn, whereas a trough (*i.e.*, a local *minima*) represents a downturn in GDP growth on reference to the trend. A low-rate phase takes place between a upturn and a downturn - similar to a contraction in a *classical* cycle - on which GDP grows bellow the trend, and a high-rate phase occurs between a downturn and a upturn (in line with the expansion phase of a *classical* cycle) on which GDP grows above trend. The complete dating of upturns (peaks) and downturns (troughs) for the *deviation* cycles is depicted in Annex A.10.

Amid the identification of turning points and the subsequently scheduling of complete phases and cycles, we follow Burns and Mitchell (1946) and Harding and Pagan (2002) suggestions and make a deeper analysis on the main components of the business cycle: frequency and amplitude of phases and cycles, asymmetric behavior of phases and cumulative movements within phases. The business cycle characteristics per phase and cycle for all Clusters is depicted in Table 3.

Table 3: Business Cycle Characteristics in cycles and phases per Cluster *deviation* cycle

	Cluster 1	**Cluster 2**	**Cluster 3**
High-rate Phases (Expansions)			
Frequency (quarters)	21	20	18
Average Duration (quarters)	5.04	5.9	5.72
Amplitude (%)	2.17	2.93	3.35
Steepness (%)	0.41	0.5	0.58
Cumulation (Triangle Approximation) (%)	6.62	9.84	10.53
Excess Cumulation	0.086	0.089	-0.06
Low-rate Phases (Contractions)			
Frequency (quarters)	21	19	18
Average Duration (quarters)	4.9	4.9	6.2
Amplitude (%)	-2.25	-2.83	-3.62
Steepness (%)	-0.43	-0.58	-0.61
Cumulation (Triangle Approximation) (%)	-6.5	-7.87	-12.77
Excess Cumulation	0.029	-0.05	0.13
Complete Cycles: Peak-to-Peak			
Frequency (quarters)	21	19	18
Average Duration (quarters)	10.4	10.8	11.5
Complete Cycles: Trough-to-Trough			
Frequency (quarters)	20	19	17
Average Duration (quarters)	10	10.6	11.8

Source: Author's own calculations. For calculation purposes, we only consider complete cycles, as the series do not begin nor end specifically at one peak or trough.

For high-rate phases, Cluster 1 registers the highest frequency (21 phases) but simultaneously presents the lowest length of all, with an average of 5.04 quarters. Cluster 2 registers 20 phases which have the highest average length (5.9 quarters), but not so apart from Cluster 3, on which its 18 high-rate phases last on average 5.72 quarters. The output gains, measured by the amplitude of the cycle over a high-rate phase, are more significant on Cluster 3 (3.5%), followed by Cluster 2 and Cluster 1 with 2.93% and 2.17% respectively.

In concordance with the results of the high-rate phases, Cluster 3 verified a frequency of 18 phases between a peak and a trough, with the highest average length of all with 6.2 quarters. An interesting result is the same average length of low-rate phases for Cluster 1 and Cluster 2, both with 4.9 quarters. Nevertheless, Cluster 1 has 2 more phases (21 total) than Cluster 2 (19 total). Longer phases for Cluster 3 also mean higher output losses, as output growth decreases on average 3.62% on low-rate phases. Cluster 1 registered output losses of 2.25% relative to its trend, whereas Cluster 2 presents a value of 2.83%.

In what concerns the excess cumulation of output measurement for high-rate phases, a positive value indicates that actual cumulative movements is exceeded by triangular representation of output gains, whereas a negative value has the inverse meaning (Krolzig and Toro, 2001). Cluster 1 and Cluster 2 show positive and close values (0.086 and 0.89) which means that on average there is a fast economic growth after a trough that levels off on the reach of the succeeding peak (which is stronger in Cluster 2). On the contrary, Cluster 3 reveals an excess cumulation of -0.06, which indicates a larger gain of output during a high-rate phase compared to the triangular approximation and thus it presents a gradual growth path that is stronger near the peak. On low-rate phases, Cluster 1 and Cluster 3 have an excess cumulation of 0.029 and 0.13, which represents a smooth decline in output growth after the beginning of the phase. Differently, Cluster 2 has a negative excess cumulation measure (-0.05) which indicates that there is a rapid subsequent decline in growth after a peak, since the actual cumulative movements are larger than the triangular approximation.

The steepness for both low-rate and high-rate phases are similar in all Clusters. Cluster 3 has steeper phases, followed by Cluster 2 and Cluster 1.

Both Cluster 1 and Cluster 2 *deviation* cycles yield, on average, longer complete cycles from peak-to-peak compared to complete cycles from trough-to-trough (10.4 quarters to 10 quarters in Cluster 1 and 10.8 quarters to 10.6 quarters for Cluster 2). Cluster 3 has the lowest number of complete cycles (18 from peak-to-peak and 17 from trough-to-trough), but the first with an average length of 11.5 quarters and the latter with 11.8 quarters. A perfect symmetry for the number of complete cycles is verified in Cluster 2, as it has a frequency of 19 cycles for both peak-to-peak cycles and trough-to-trough cycles.

To assess if there is a significant relationship between a phase's amplitude and its duration we computed the Spearman's-rank correlations as in Cashin and Ouliaris (2001), which results are depicted in Table 4. The null hypothesis stands for the non-existence of rank correlation between the severity of phases and its duration.

Table 4: Relationship Amplitude-Duration per phase

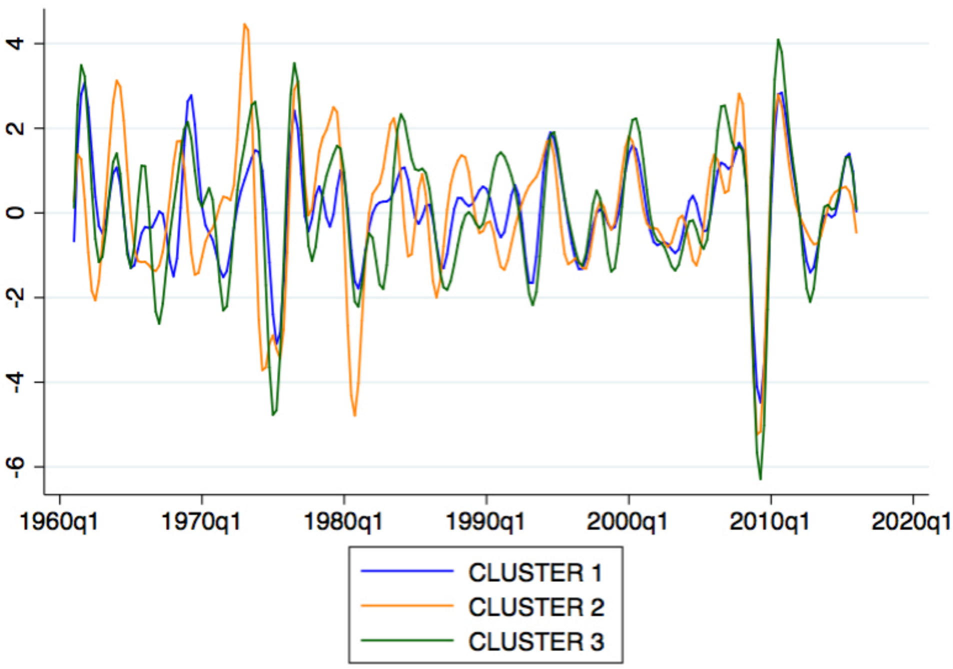
	Cluster 1	**Cluster 2**	**Cluster 3**
Spearman-rank Correlation			
High-rate Phases	0.6641*	0.5501*	0.5380*
Low-rate Phases	-0.8660*	-0.6364*	-0.7108*

Source: Author's calculations with STATA routine "*spearman*". *5% significance level.

The concept of severity is considered as being the absolute amplitude from the triangular approximation (Harding and Pagan, 2002). In none of the cases there is an acceptance of the null hypothesis of no rank correlation between a phases' amplitude and duration. The strongest significant relationship between amplitude and duration is observed in the high-rate phases from Cluster 1, followed by Cluster 2 and Cluster 3. In low-rate phases the statistic yields negative rank correlations for all Clusters. The strongest rank correlation is again observed in Cluster 1, followed by Cluster 3 and Cluster 2.

Figure 3 shows the graphical representation of the Clusters *deviation* cycles. A comparison between the most steep phases and recurrent events in global economy is made, which serves the purpose of crossing our schedule of turning points the the official events' timing.

Figure 3: *Deviation* Cycle for each Cluster



The phases which capture the most interest are the steepest ones, usually coincident with important economic or political events. In the analysis we neglect high-rate phases as low-rate phases are more studied, well documented, and have higher absolute values. On low-rate phases is possible to distinguish three events:

i Oil Crisis (1973);

ii Early 1980's Crisis;

iii Subprime crisis and European Sovereign Debt Crisis (2007-2009).

Other important economic events took place in the data span that we consider in this work, although its influence on the Clusters' *deviation* cycles is not so remarkable, namely the Early 1990's Crisis, the Asian Financial Crisis (1997) and the Dot-Com Bubble (1997-2000). The complete list of phases and cycles can be seen in Annex A.10.

The first major event in our dataset is the first oil crisis that began on October 1973 (1973Q4), prompt by the embargo from the Organization of Arab Petroleum Exporting

Countries over which the oil barrel price quadrupled. This event can be clearly detected on Figure 3, on which the three clusters register a strong low-rate phase over more than 3% fall bellow trend. Cluster 1 initiated a low-rate phase on that quarter, which lasted seven periods up to 1975Q2. Cluster 2 initiated a low-rate phase three quarters before the beginning of the embargo, which lasted four quarters up to 1974Q2. The United Kingdom was in fact one of the most affect countries by 1973-1974 bear market, as its real GDP decreased fell 1.1%. Aside from its counterparts, Cluster 3 registered a phase of GDP growth bellow the trend later in 1975Q2 (Cluster 2 began the second low-rate phase after the embargo on this same quarter), which lasted six quarters.

In this sequence, one may observe that Cluster 2 has a strong low-rate phase in the beginning of the 1980's whether its counterparts registered a smoother one. This event, known as the Early 1980's Crisis, was prompt by the deep recession in the U.S. as the Federal Reserve adopted a contractionary monetary policy to reduce high inflation rates, still under the effect of the 70's oil crisis. The steep downward path of Cluster 2 *deviation* cycle is mainly due to the strong effects from the crisis in the United Kingdom, which registered a *manufacturing meltdown*: its industrial production decreased sharply in line with privatizations from the Tatcher's Administration, both in the presence of an inflation rate higher than 10% and an historical unemployment rate (The Guardian, 2012). The crisis lasted around five quarters in the UK, between 1980Q1 and 1981Q1. In Cluster 2, the low-rate phase began in 1979Q2 and lasted up to 1980Q4, with six quarters of length.

Two contemporaneous events, still under focus, affected, almost, simultaneously the economic growth of European countries. In the first hand, the Great Recession, prompt by the 2007-2008 financial crisis and the U.S. subprime mortgage crisis of 2007-2009; right after, the European sovereign debt crisis that began in 2009 in the aftermath of the collapse of the Icelandic banking system in the late 2008. Cluster 1 initiated a low-rate phase on the last quarter of 2007 after a rapid recovery phase on the three preceding quarters. This low-rate phase lasted up to 2009Q2, almost coinciding perfectly with the low-rate phase of Cluster 2 (that began on 2007Q4 and ended in 2009Q1). Differently synchronized, Cluster 3 registered a low-rate phase only in 2009Q2, when its counterparts began to grow above trend. The interest of this result is driven by the members that compose the cluster, which have the highest levels of sovereign debt, such as Greece, Portugal, Ireland and Italy. In another perspective, the strength of the German economy may have sustained such delay on economic decline. Germany, that has been entitled by the Economist (2004) as being "*the sick man of Europe*" in the aftermath of the Early 1990's crisis, saw its economy getting more consolidated due not only to the Hartz reforms in mid-2000's (legislative labor maket reforms) but also due to the high competitiveness of the German export sector (Dustmann *et al.*, 2014).

5.2.3 Synchronization Assessment

The analysis of synchronicity enables to see at which extent the considered *deviation* cycles share a degree of association. The co-movement of business cycles is of major importance for policy makers, especially under an optimum currency area (Cotis and Coppel, 2005). We consider several metrics to assess the existence and the strength of the co-movement between *deviation* cycles, namely cross-correlations, Index of Concordance and rolling window cross-correlations.

Table 5 includes the results of the Pearson's cross-correlations and the Index of Concordance, all statistically significant.

Table 5: Synchronization Metrics: Cross-Correlations and Index of Concordance

	Cluster 1	**Cluster 2**	**Cluster 3**
Cluster 1	-	0.5807*	0.8700*
Cluster 2	*0.6063***	-	0.6168*
Cluster 3	*0.7511***	*0.6380***	-

Source: Author's calculations. The contemporaneous cross-correlations are presented in the upper right corner of the table. The Index of Concordance results are presented on the lower left corner of the table, in *italic*, and were calculated using equation (15).
*5% significance level. **Index of Concordance statistically significant at 5% significance level (*vide* Annex A.11 for OLS estimation results).

The Pearson's cross-correlations measure the linear (or contemporaneous) relationship between the *deviation* cycles, as a proxy for co-movement. It is a simple metric to compute, but not absent of criticism as its values are sensible to the de-trending method used (Canova, 1998). Its results show that there is a positive and firm bilateral co-movement between all Clusters. The two strongest linear relationships include Cluster 3; the highest co-movement is observed between Cluster 3 and Cluster 1 (0.87) followed by the bilateral correlation between Cluster 3 and Cluster 2 (0.61). The weakest co-movement is verified between Cluster 1 and Cluster 2 with a cross-correlation of 0.58, albeit the similarities within its *deviation* cycles.

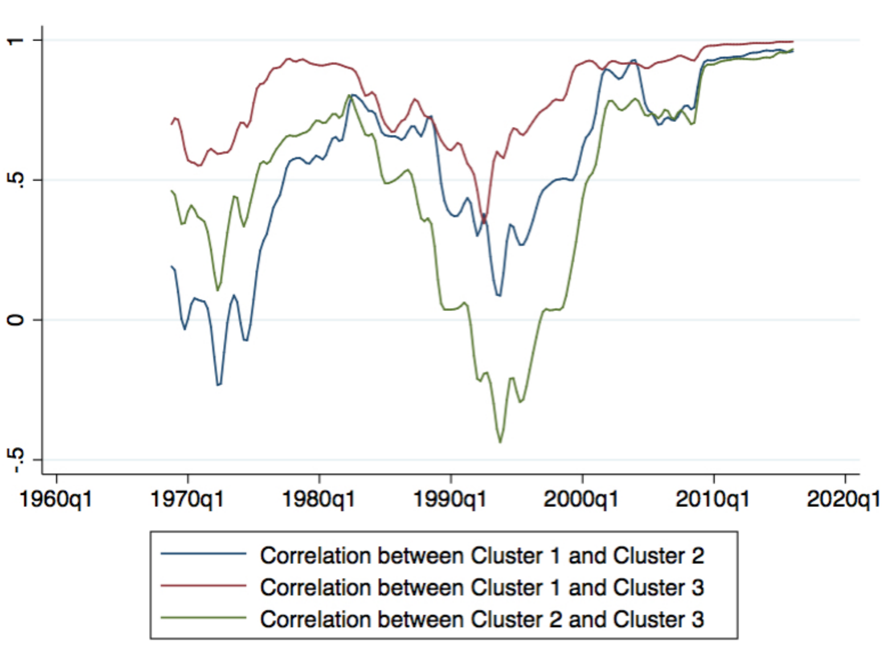
The following measure of conformity considered is the Index of Concordance. This measurement is scaled between 0 and 1 and indicates the proportion of time that each pair of clusters have shared on the same phase. A value of 0 indicates that the *deviation* cycles are countercyclical whereas a value of 1 indicates a procyclical relationship. As the Index of Concordance has an expected value of 0.5 in the presence of two independent and identically distributed series, it is expected that a positive relationship between the *deviation* cycles yield results higher than 0.5 (McDermot and Scott, 2000). When compared with the contemporaneous correlations, the Index of Concordance detects both linear and non-linear association between two series (Belo,2001). Cluster 1 and Cluster 3 share the same phase in 75% of the time, whereas Cluster 1 only shares 60% of the time with Cluster 2. Cluster 2 and Cluster 3 yield a close result, on which they share the same phase more than 63% of the time. This results strengthen the conclusions from the cross-correlations: although Cluster 1 and Cluster 2 have similar *deviation* cycles on what concerns its stylized facts and characteristics, Cluster 1 and Cluster 3 are the most synchronous pair of Clusters. Cluster 1 and Cluster 2 do not share such a strong co-movement during the entire period.

We calculate rolling window cross-correlations to assess how cross-correlations between the Clusters' *deviation* cycles have evolved on the considered time span, since simple contemporaneous correlations are less sensitive to time effects [24]. We consider rolling windows of length equal to 8 years (32 quarters), as it is the maximum length allowed by the CF

[24] The rolling-window correlations were computed with STATA routine *mvcorr*.

band-pass filter for a complete business cycle (and also considered in Montoya and de Haan (2007). The advantages of using rolling-window cross-correlations are the consideration of less arbitrary data breaks in order to compare the evolution of co-movements (Massman and Mitchel,2004). The results are depicted in Figure 4.

Figure 4: Correlations between the Clusters (8-year rolling windows)



The previous results from Table 5 can again be confirmed, this time visually. Cluster 1 and Cluster 3 register almost all the time the highest values for cross-correlations, whereas the cross-correlations Cluster1-Cluster2 and Cluster2-Cluster3 alternate. The cross-correlations are positive in the majority of time, except in early 1970's and during the decade of 1990. We compare the behavior of cross-correlations across time with institutional and economic events although "*we seek to establish the facts rather than explain them*"(Massmann and Mitchel, 2004).

The wave path of cross-correlations begins with a downward movement in early 1970's, which coincides with the Oil Crisis but also with the collapse of the Bretton Woods system. The first abrupt growth in cross-correlations occurs between mid 1970's and mid 1980's, a period that includes the establishment of the European Monetary System (1979). A strong decrease on cross-correlations is observed from mid 1980's to 1990's ,although more persistent in the pair Cluster 2 - Cluster 3 than in the other cases. This period includes the unification of Germany (1989) and the Early 1990's Crisis. Synchronization between the Clusters *deviation* cycles increase sharply after the mid 1990's. At the time of the Euro-changeover, all cross-correlations were higher than 0.5. Our results are similar to the ones from Gayer (2007), that has proved that business cycle synchronization in Europe is increasing since the Euro introduction. From the beginning of the 2000 decade afterwards, the Clusters synchronization began a more stable period, with values higher than 0.7, on average. Since 2010 all cross-correlations are converging to the unity, which may indicate a full business cycle convergence (Massman and Mitchel, 2004).

5.3 Structural Analysis

5.3.1 Insights on the Structural Analysis

The utilization of a stable VAR ensures that it is possible to perform a structural analysis upon its estimation. Gourieroux and Monfort (2014) highlight the existence of contemporaneous correlation between white noise components in a VARMA process. In order to turn the residuals of a stable VARMA contemporaneously uncorrelated one may use a Cholesky decomposition as in Sims (1980) on which the residuals are orthogonalized. The transformation of the VAR(p) into a VMA(q) form is absent of economic content and only aims to ensure that a particular shock can be traced out singularly (see Chapter 4 in Canova, 2007).

The main issue in this work regards the existence of serial autocorrelation of the residuals, that has been seen as one of the main issues in the literature related with the time-series analysis, and especially on the literature focused on the study of the GDP. Estimating each equation in a VARMA(p, q) dynamic system through OLS in the presence of serial correlation provides an unbiased estimator, but simultaneously its OLS statistics are invalid for inference purposes (Wooldridge, 2002). According to the Gauss-Markov Theorem, the OLS is no longer BLUE (best linear unbiased estimator), since errors are spherical and the $Cov(e_t, e_s) \neq 0$, where the residuals can be written as an AR(p) process, such that $e_t = \rho e_{t-1} + \zeta_t$, with $\rho \neq 0$. That is, the coefficients are reliable, however, the standard errors are not correct, and generally, overevaluated. This situation implies that also the t-tests and the respective p-values are not trustworthy. The presence of autocorrelation may be surpassed with the inclusion of the optimum lag length. For our VAR model the optimum lag length was set at 13 lags under a maximum length of 15 with both LR test statistic and AIC (*vide* Annex 12). There is some evidence in the literature that this issue may be "overpassed": in Blanchard and Watson (1996) the authors do not corroborate that the disturbances of their model's equations are uncorrelated, and Bernanke (1986) and Bayoumi and Eichengreen (1996) do not present proper well specified VAR models (*i.e.* the existence of serial correlation, heteroskedasticity and normality).

Ivanov and Kilian (2001) aware about the importance of the lag lenght choice plays a major role on the permanent shocks in IRFs. Therefore it is necessary to obtain an intermediate point between the maximum lag length (according to the results of the respective criteria) and the maintenance of stability in the structure of the VAR. Nonetheless, a VAR with 13 lags could not verify the stability condition and thus we reduced the lag length in order for all roots of the companion matrix to lie inside of the unit circle (*vide* Annex 12).

Here we followed Enders (2003) on what concerns the dilemma on the choice of the lag length: a small lag length may lead do a misspecification of the model, whereas a model with too many lags would be overparameterized.

The confidence bands for the estimated IRF after a VAR process are also sensible to the presence of serial correlation. The majority of the literature follows the asymptotic normal approximations from Lūtkepohl (1990), among other alternatives like the nonparametric bootstrap method from Runkle (1987) or the parametric Monte Carlo integration procedure of Doan (1990). The estimated VAR model will further impact the IRF built upon it. In the presence of serial correlation the increased estimated standard deviation will cause wider confidence bands, although not affecting the coefficients of the cumulative orthogonal IRF (Jordá (2009) approaches this subject and suggests conditional error bands to remove the excess in the normal confidence bands due to serial correlation). Simultaneously a high number of VAR coefficients may induce wrong estimated values and higher standard deviations, which increases the confidence band of the estimated IRF (Lūtkepohl, 1990).

5.3.2 Granger-causality

First we see if a Cluster *deviation* cycle linearly predicts its counterparts cycles through a Granger-causality analysis (*vide* Annex A12). One must be aware that in fact Granger-causality does not represent a relation of causality *per si* but rather the capacity of one variable of linearly predict another.

The results show that there is a bidirectional Granger-causality among all possible pairs of Clusters. The less significant results concern the Granger-causality of Cluster 3 on Cluster 2, followed by the Granger-causality of Cluster 1 on Cluster 2. The highest value for the Wald test chi-squared statistic is observed on the Granger-causality of Cluster 2 on Cluster 3. If we consider the overall joint Granger-causality of two clusters on the remain, the highest chi-squared statistic value belongs to the Granger-causality of Cluster 1 and Cluster 3 on Cluster 2, whereas the lowest value is obtained on the Granger-causality from Cluster 2 and Cluster 3 on Cluster 1.

We verify that all *deviation* cycles are not strictly exogenous among itself, which ensures that there will be a response from innovation shocks from each Cluster on the remain.

5.3.3 IRF and FEVD analysis

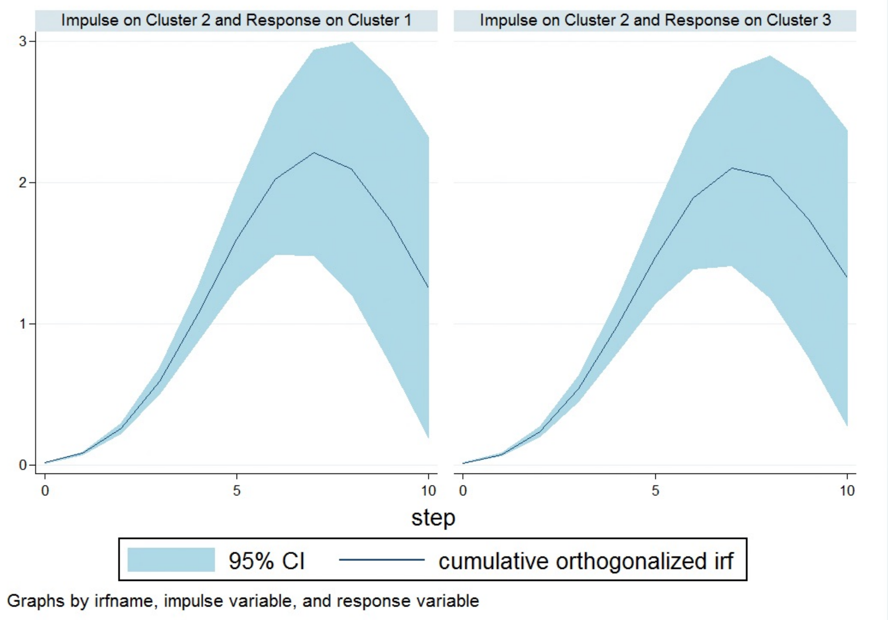
To analyze the responses of one Cluster *deviation* cycle to innovation shocks from its counterparts we consider cumulative orthogonal impulse response functions. The orthogonalization of residuals ensures that they are contemporaneous uncorrelated and thus the innovation shocks are uncorrelated as well (since ε_t are orthogonal). The cumulative part of the IRF stands from the fact that new shocks in a variable are linear combinations of the past shocks.

The matrix $\mathbf{P}$ used in the Cholesky decomposition takes into consideration the order of the variables of the VAR model, and as such that the instantaneous causal ordering should be specified (designated as Wold-causality). Nevertheless, the causal ordering cannot be established with a proper statistical method and relies solely on both economic theory and common-sense. The choice of a clear ordering for the Cholesky decomposition "*is much less clear that such a stark assumption about causation is appropriate in a VAR containing growth across countries*" (Bayoumi and Swiston, 2007).

We look for an evidence of Wold-causality by establishing a transitivity relationship between the Clusters' *deviation* cycles using for such purpose the Granger-causality results. In fact, there cannot be an exclusively ordering of Clusters supported on the literature nor in common sense, as economies in Europe share a strong degree of integration *via* trade, financial linkages and institutional policies (both from EU and ECB). Recall that there is bi-directional Granger-causality for all possible pairs, and thus this new ordering would have several possibilities. We use the value of the chi-squared statistic to achieve such ordering, on which a higher chi-squared statistic value means a higher Granger-causality in order to provide a Wold-causality relationship based on our results. Nevertheless we present the three different scenarios on which each Cluster has the first impulse.

In the first scenario, based on the values of the chi-squared statistic, the Granger-causality from Cluster 2 on Cluster 3 has the highest value (63.513). Following, Cluster 1 may impulse Cluster 2 or be impulsed firstly by Cluster 3: comparing both cases, the highest value belongs to the case of Cluster 3 Granger-causing Cluster 1 (28.301 against 21.328). The first causal relationship is then set: impulse in Cluster 2, then the following responses on Cluster 3 and Cluster 1 (the order of the second and third clusters does not matter since we are not constructing nor interested in a chain shock linkage). The graphical results are depicted on Figure 5.

Figure 5: Impulse on Cluster 2 and responses on Cluster 1 and Cluster 3

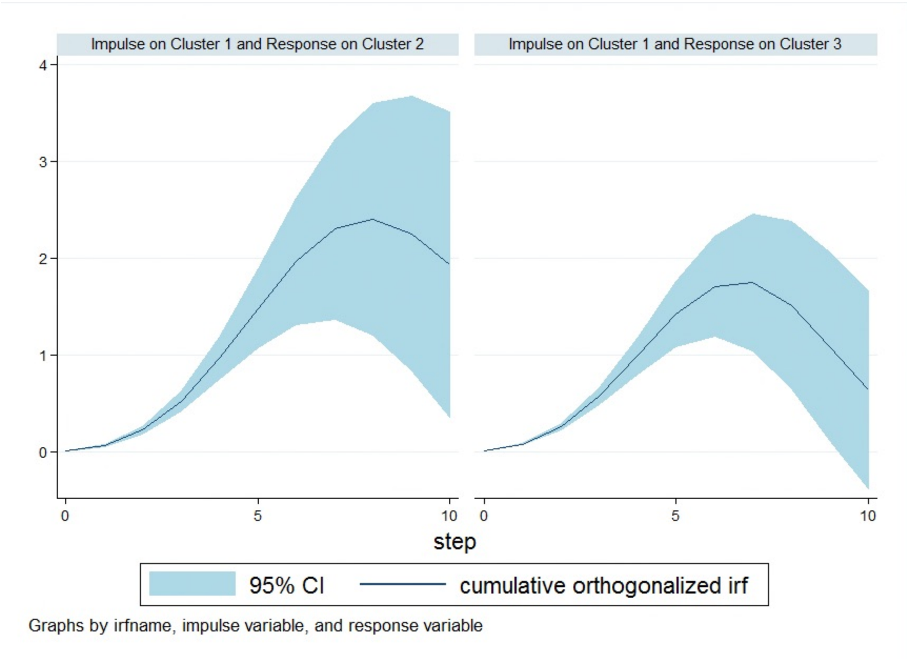


The behavior of both Cluster 1 and Cluster 3 responses to a one-unit standard-deviation shock in the *deviation* cycle from Cluster 2 is similar in amplitude and in the inverted "U" shape. The responses in both cases die out seven quarters after the shock (Cluster 1 reaches the maximum of 2.2% whilst Cluster 3 reaches 2.1%) although in none of the cases its dissipation occurs before two and a half years in the future. This behavior is congruent with what would be expected in stationary series.

As Cluster 2 does include the UK, it would be interesting to understand these results having in mind the BREXIT scenario. OECD (2016) analyzed the impact of UK financial shocks in several European and non-European economies in the context of the BREXIT (even though they only consider negative shocks). Nevertheless, it is possible to compare their findings with our results in order to assess which countries will verify the strongest responses to such impulses. Their results show that the majority of Western European countries are impacted severely and moderately but the behavior of both groups is not so dissimilar: the severely affected group (that includes Ireland and the Netherlands) would see its real GDP decrease 0.6%, whilst the moderate group (which includes all countries that we consider in our dataset except Portugal and Italy) 0.4% up to 2018 (although this analysis is not cumulative).

In the second scenario we consider the case of an impulse in Cluster 1 *deviation* cycle and the correspondent responses on Cluster 2 and Cluster 3 (see Figure 6).

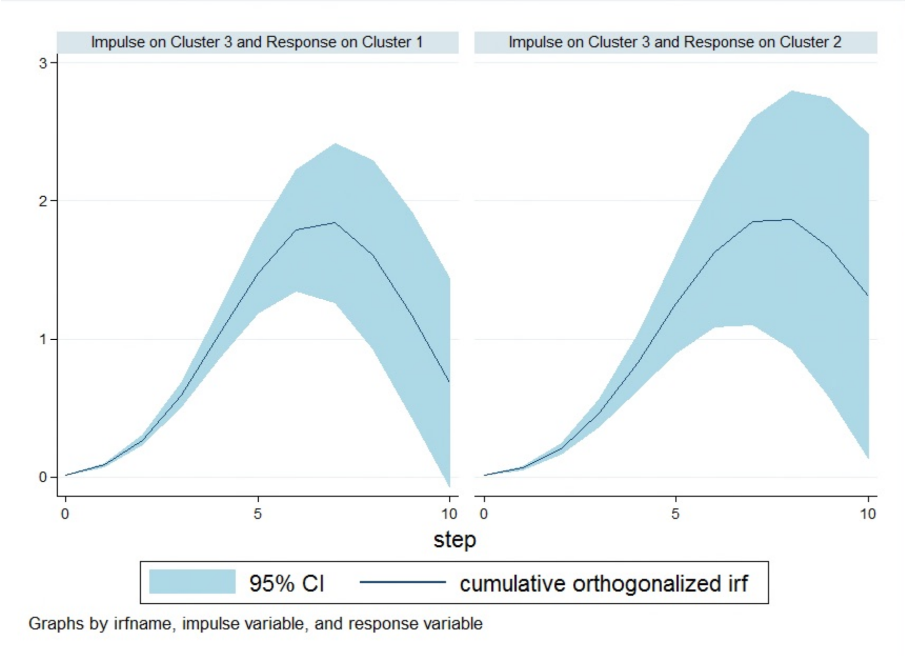
Figure 6: Impulse on Cluster 1 IRF and responses on Cluster 2 and Cluster 3



In this particular scenario Cluster 2 and Cluster 3 do not behave similarly to a one-unit standard-deviation permanent shock in the *deviation* cycle from Cluster 1. Again, both responses also have an inverted "U" shape, but in the case of Cluster 2 the permanent responses are steeper. The maximum response is reached after eight quarters (verifying an extra growth above trend of 2.4%), whereas in Cluster 3 the maximum response occurs at the seventh quarter after the shock, with a lesser value of 1.75%. As it was verified in the previous scenario, the shocks do not dissipate to zero two and a half years after the impulse, and this is especially persistent Cluster 2.

The third and last scenario considers Cluster 3 as the first to register a permanent shock on its *deviation* cycle (see Figure 7 for the graphical representation).

Figure 7: Impulse on Cluster 3 IRF and responses on Cluster 1 and Cluster 2



The permanent shocks in the Cluster 3 *deviation* cycle have the less persistent responses on its counterparts when compared to the previous scenarios. The response from Cluster 1 to a permanent shock from Cluster 3 is the less persistent of all since it registers the lower level two and a half years after the permanent shock (0.681%). Cluster 1 reaches the maximum response after seven quarters at 1.84% growth above the trend, whereas a less persistent response from Cluster 2 reaches the maximum after eight quarters at 1.86%. Nevertheless, the same inverted "U" shape is present, which indicates that the shocks will end up dissipating towards zero.

One may ask why a Cluster that includes the economy with the highest real GDP in Europe (Germany) and the most volatile economies (Greece, Ireland and Portugal) would not verify the strongest impulses on its counterparts. A plausible answer for such question would lie on the behavior of the German economy, which in this case accounts for the majority of the Cluster 3 real GDP.

Danninger (2008), through a VAR framework, considered a country ordering on which Germany appears ahead of other industrial countries (namely the U.S., Japan and the Euro

Area country-aggregate) and found small but positive spillovers from German permanent shocks in those economies. In another perspective Poison and Weber (2011) also consider a VAR framework and found that the spillovers from Germany to other European countries are relatively low (inferior to the ones from U.S. and, surprisingly, UK) and consider it as a novel given its enormous economic weight. The authors also claim that in fact Germany's economic growth is highly prompt by global growth due to a high dependence on worldwide trade, and thus its outward spillovers are less expressive. Moreover, they recognize the important role of France growth shocks in Europe after the Great Recession, and that Spain and France are less sensitive to growth shocks from both Italy and Germany - which is in line with our results, as there is a stronger dynamic shock from an impulse from Cluster 1 and response on Cluster 3 compared to the opposite case.

The results from the three IRFs present a similar dynamics, on which the economic shocks have an inverted "U" shape. The path of the permanent responses to the shocks follow the properties of the business cycle and tend to reach the peak around seven periods after the impulses (which may represent an expansion phase). In sequence, and as it is expected to occur in stationary series, the responses decay to zero on what can be associated to a contraction phase. The responses to permanent shocks will eventually dissipate towards zero, at the end of a complete cycle.

Lastly, we analyze the FEVDs. A FEVD is defined as a fraction of the total variance decomposition which can be attributed to a permanent shock. The graphical representations for each IRF correspondent FEVDs are depicted in Annex A.13.

The first major conclusion is that the similar behavior verified in the IRFs cannot be confirmed on the FEVDs. On what concerns the impulse on Cluster 1, the fraction of total variance due to its permanent shock for Cluster 2 has a steep increase in the first two quarters (on which it reaches more than 60%), followed by a smooth decrease path that closely converges to 50% after two and a half years. For Cluster 3, the total variance due to a permanent shock in the Cluster 1 *deviation* cycle as an even steeper behavior reaching more than 80% in the following two quarters; then it begins a decreasing path on the following quarters but always with values higher than 50%.

For the FEVD in the case of a one-unit standard-deviation shock in Cluster 2 *deviation* cycle, the fraction of total variance attributed to that shock is relatively low, reaching slightly more than 15% after eight quarters. In Cluster 3, the fraction increases to more than 25% after eight quarters as well.

The path of the variance decomposition in Cluster 1 and Cluster 2 due to a permanent shock in Cluster 3 is relatively stable. For Cluster 1, the fraction of total variance due to a shock in Cluster 3 is never higher than 4%, whereas in Cluster 2 shows a slightly higher value of 8% after ten quarters.

The results from the FEVD analysis show that taking into consideration each Cluster as the primordial provider of economic shocks in its counterparts, Cluster 3 verifies the weakest impulses and accounts for the small fractions of total variance decomposition in both Cluster 1 and Cluster 2 responses. Cluster 1 registers the highest proportions of total variance decomposition on its counterparts although Cluster 2 verifies in fact the strongest impulses on other Clusters.

6 Concluding Remarks

This work had two main objectives: firstly, the identification of country-clusters through Hierarchical Agglomerative Clustering with the Ward's method; and secondly the application of a statistical and econometric framework in order to evaluate business cycle stylized facts, synchronization and the variance and magnitude of relations between the Clusters (with Granger-causality, IRFs and FEVDs).

We intended to compare our results with the ones reported by the existent literature, mainly on issues related with the cyclical behavior of the European Economies (at least the ones that we have chosen to include in our sample) and conceptual topics regarding the existence of country clubs in the European continent.

As a consequence of the results obtained, we found the necessity and the justification to discuss German Economic Dominance within the European continent, stated by Artis and Zhang (1997). In this sequence, our results and the clusters obtained are discussed having in mind the magnitude of the permanent shocks and their relation with the notion of economic spillovers.

These questions were discussed with the support of an estimation of the *deviation* cycles for fourteen European countries between 1960Q1 and 2016Q1 and the application of Hierarchical Agglomerative Clustering (HAC) technique based on the Ward's method and the Euclidean distance as the dissimilarity measure applied to form country-clusters by the absolute distance between observations and, consequently, the similarity of their characteristics. The HAC results suggest that there are three main groups of countries: Cluster 1 (France, Belgium, the Netherlands, Spain, Sweden and Finland), Cluster 2 (United Kingdom, Denmark and Austria) and finally Cluster 3 (Germany, Greece, Ireland, Italy and Portugal).

Identified the country-clusters, we analyzed some stylized facts associated with the *deviation* cycles. To achieve that, we employed an analysis based on the evaluation and comparison of the statistical properties of each cluster (which resulted from the aggregation made by the HAC). This process allowed the analysis of the characteristics of each aggregated business cycle (on what mainly concerns phases and cycles, achievable through the identification of turning points), and their respective synchronization. We highlight that the results are sensitive to the countries chosen, the time considered and breaks, de-trending method and clustering framework. We use GDP series in volume chain in US Dollars, and thus converting original series from domestic currencies to a reference currency would also distort results.

We have found that although Cluster 1 and Cluster 2 have more similar *deviation* cycles (which can be seen in the HAC dendrogram) compared to Cluster 3, Cluster 1 and Cluster 3 share a higher level of synchronization, both contemporaneously and historically. Both Clusters also share the higher proportion of time spent on the same cyclical phase. Overall, we confirm that synchronicity in European economies is increasing, which became more pronounced after the early 1990's - coinciding with the Maastricht Treaty and the creation of the EMU.

These results are in concordance with the main findings of, *inter alia*, Gayer (2007), Darvas and Szapry (2005) and Michaelides *et al.* (2013). Our results show also that the turning point detection method performed quite well on identifying outlier cyclical phases associated to specific economic events. This process generally considered the main economy inside of the cluster, and that has hold on the cases of the United Kingdom (Cluster 2) for the Early 1980's crisis and for Germany (Cluster 3) on what concerns the Great Recession.

By the structural analysis, we confirm that the similarities of the *deviation* cycles from Cluster 1 and Cluster 2 reveal a stronger Granger-causality when compared to Cluster 3. The IRF analysis shows that Cluster 1 and Cluster 2 induce the strongest permanent shocks, either on each other and on Cluster 3, giving the edge, in this category, to the economies of France and Spain (Cluster 1) and United Kingdom (Cluster 2). This less persistent behavior from Cluster 3 is also verified on the FEVD analysis, as it accounts for the lowest proportions of variance decomposition due to its permanent shocks on the others.

Our final results do not corroborate the theory related with the "German Dominance", but indeed confirm that major economic propellers may be identified in the European continent. We failed to identify the existence of a core and periphery in European *deviation* cycles, as none of the Clusters are keen to own such designations. And this result can be seen as concordant with the efforts of the EU in promoting an increased integration between the European economies. Simply the continuation of a core and periphery in Europe, as stated in old works, would prove the failure of the European project.

Moreover, it is interesting to notice that the lower magnitude of the shocks from the Cluster 3 (and the respective lower FEVD) may correspond as well to the idea that Germany and Italy (the main economies inside of this cluster) do not create as much economic spillovers as other groups. This result, however, may be due to a balance between the greater volatility of weaker economies (as Greece, Ireland and Portugal) and the stable path of Germany. Or can be the corroboration of some results in the literature (*e.g.* Poison and Weber, 2011) that Germany presents a resilient mechanism in absorbing shocks, but has a trade organization spread all over the globe, and an industrial sector that does not depend massively from other European economies (existence of primary goods and energetic sources). The Italian case is also highlighted as having a similar behavior as Germany.

Further research clues include the importance of analyzing the existence of economic country-clusters using different time spans and countries, in order to analyze changes in affiliations as in Artis (2003). For instance, it would be relevant to replicate the previous analysis taking into consideration the time span before and after the creation of the EMU to observe if in fact there were significant developments on the European business cycles. Simultaneously, new techniques to assess business cycle synchronization can be applied, namely HAC with the centroid method and the average link method explored by Artis and Zhang (2001) or with Classical Multidimensional Scaling techniques (as in Artis, 2003). Other relevant approaches may pass by the identification of the clusters through the application of different methods, and to confirm if there are patterns concerning trade, financial linkages, unemployment and geography proximity, which follows the work of Van Aarle *et al.* (2008).

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A Appendices

A.1 Descriptive Statistics

Table 6: Descriptive Statistics for Domestic *deviation* cycles

Country	Obs.	Mean	Std. Deviation	Min.	Max
Austria	221	0.0285988	1.492856	- 5.166464	3.387644
Belgium	221	0.0355828	1.492716	- 4.934762	4.814393
Denmark	221	0.0475981	2.024559	- 5.922454	5.358594
Finland	221	0.023562	2.249331	- 9.479554	5.890062
France	221	0 .0398462	1.223559	- 4.013381	3.247477
Germany	221	0.0337838	1.903543	- 7.739065	4.509193
Greece	221	0.0767807	2.923136	- 14.47487	8.098357
Ireland	221	0.1907098	2.875272	- 6.091899	16.06784
Italy	221	0.068573	2.07038	- 6.317465	6.672428
Netherlands	221	0.018053	1.587407	- 4.976922	4.048311
Portugal	221	0.0435208	2.170715	- 9.267553	6.317918
Spain	221	0.1124212	1.633197	- 3.57567	7.416827
Sweden	221	0.052317	1.927453	- 7.368414	6.614815
United Kingdom	221	0.0182353	1.79089	- 5.355452	5.246177

Source: Author's calculations.

A.2 Cross-Correlations between National *Deviation* Cycles

Table 7: Cross-Correlations between National Business Cycles

	AT	BEL	DEN	FIN	FRA	GER	GRE	IRL	ITA	NTH	POR	SPA	SWE	UK
AT	1													
BEL	0.6424	1												
DEN	0.6354	0.6356	1											
FIN	0.5914	0.5428	0.4270	1										
FRA	0.6953	0.7203	0.6554	0.6257	1									
GER	0.7795	0.6479	0.7346	0.5077	0.6656	1								
GRE	0.1925	0.1956	0.3338	0.0858	0.2097	0.3135	1							
IRL	0.1194	0.2365	0.2034	0.2472	0.2610	0.2881	0.0606*	1						
ITA	0.6229	0.7155	0.4191	0.5213	0.7586	0.5494	0.1260	0.2200	1					
NTH	0.5943	0.6861	0.5561	0.3404	0.5919	0.7084	0.0327*	0.2038	0.5251	1				
POR	0.4760	0.4902	0.4293	0.1972	0.3847	0.4014	0.1950	0.1287	0.5075	0.3101	1			
SPA	0.4661	0.5142	0.4471	0.4603	0.6081	0.4694	0.1561	0.4149	0.6335	0.2334	0.3312	1		
SWE	0.5475	0.6006	0.4396	0.7238	0.5346	0.6145	0.0610	0.4296	0.5062	0.5383	0.1779	0.3886	1	
UK	0.4942	0.3741	0.4865	0.4025	0.4801	0.5038	0.3649	0.2336	0.3155	0.3727	0.4780	0.2525	0.4065	1

Source: Author's calculations. *Not significant at 5%.

A.3 Stationarity Tests

Table 8: ADF Test Results for Domestic Quarterly GDP Growth series

Country	Test Statistic	Critical Value 5%	McKinnon p-value for $z(t)$
Austria	-5.291	-2.882	0.0000*
Belgium	-3.839	-2.882	0.0025*
Denmark	-4.456	-2.882	0.0002*
Finland	-4.771	-2.882	0.0001*
France	-5.712	-2.882	0.0000*
Germany	-4.666	-2.882	0.0001*
Greece	-4.557	-2.882	0.0002*
Ireland	-4.674	-2.882	0.0001*
Italy	-3.731	-2.882	0.0037*
Netherlands	-6.407	-2.882	0.0000*
Portugal	-3.267	-2.882	0.0164*
Spain	-3.438	-2.882	0.0097*
Sweden	-5.309	-2.882	0.0000*
United Kingdom	-4.611	-2.882	0.0001*

Source: Author's calculations with STATA routine "*dfuller*". *5% significance level.

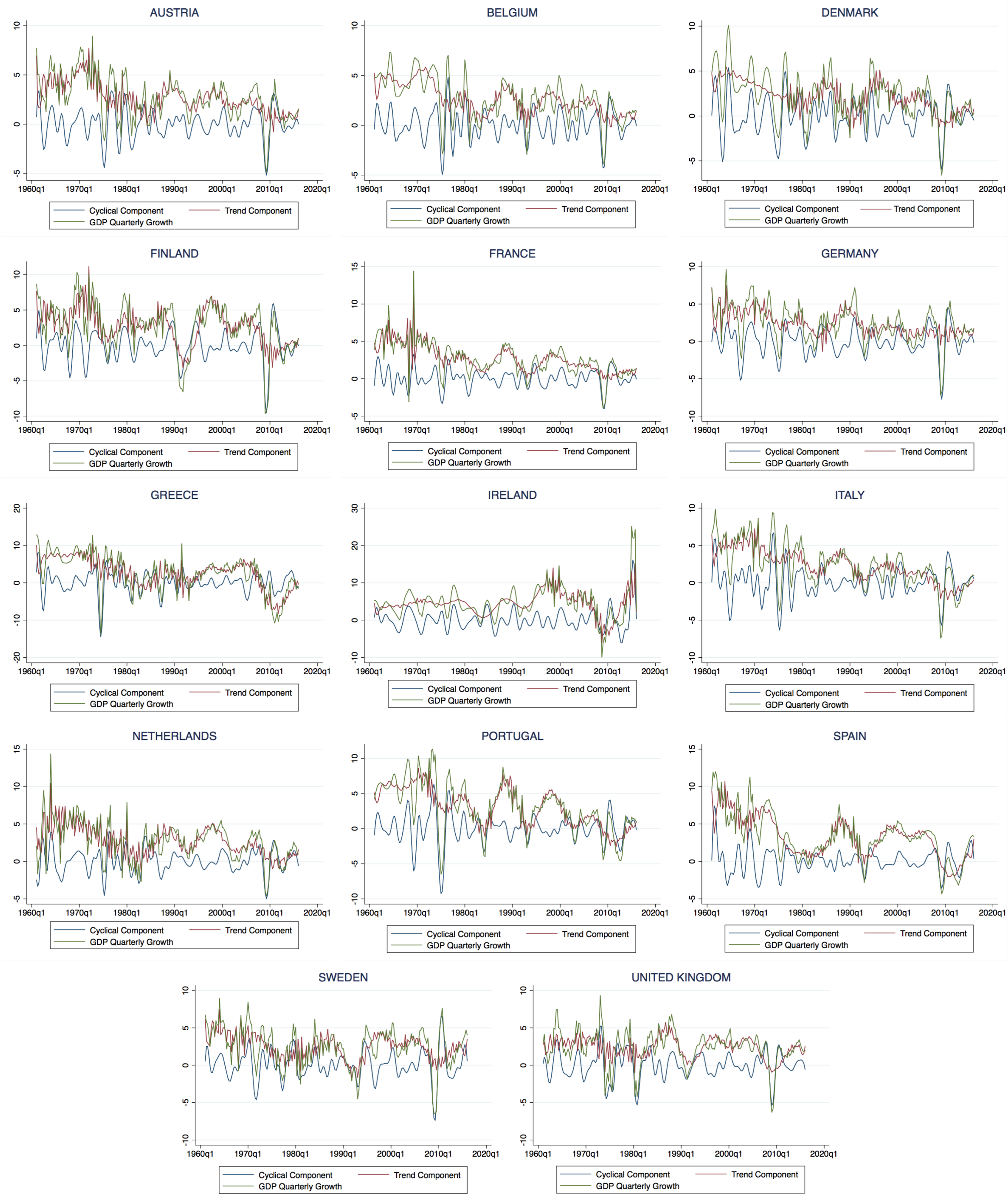
Table 9: ADF Test Results for Domestic *Deviation* Cycle Series

Country	**Test Statistic**	**Critical Value 5%**	**McKinnon p-value for** $z(t)$
Austria	-3.897	-2.882	0.0021*
Belgium	-4.531	-2.882	0.0002*
Denmark	-3.923	-2.882	0.0019*
Finland	-3.633	-2.882	0.0052*
France	-4.226	-2.882	0.0006*
Germany	-3.470	-2.882	0.0088*
Greece	-4.536	-2.882	0.0002*
Ireland	-3.693	-2.882	0.0042*
Italy	-4.136	-2.882	0.0008*
Netherlands	-4.288	-2.882	0.0005*
Portugal	-3.843	-2.882	0.0025*
Spain	-3.883	-2.882	0.0022*
Sweden	-3.730	-2.882	0.0037*
United Kingdom	-3.691	-2.882	0.0042*

Source: Author's calculations with STATA routine "*dfuller*". *5% significance level.

A.4 Graphical representation of Domestic time-series

Figure 8: Graphical representation of the National Business Cycles (GDP Quarterly Growth, Cyclical Component and Trend Component)



A.5 MATLAB routine for HAC analysis

Steps for the MATLAB rountine:

Step 1: Generate Matrix X, where each country is a vector.

X = [CFAT, CFBEL, CFDEN, CFFIN, CFFRA, CFGER, CFGRE, CFIRL, CFITA, CFNTH, CFPOR, CFSPA, CFSWE, CFUK]

Step 2: Generate the linkage function *Z*, and specify the Ward's method and Euclidean Distance as dissimilarity measure.

Z = linkage(X, 'ward', 'euclidean')

Step 3: Plot the dendrogram, specifying that it must only include the 14 vectors of each country to avoid the inclusion of cross-country additional vectors.

[H,T,outperm] = dendrogram(Z, 14);

Step 4: For analysis purposes, label each vector in the dendrogram *H*.

set(H,'LineWidth',2)

L = 'AT', 'BEL', 'DEN', 'FIN', 'FRA','GER', 'GRE', 'IRL', 'ITA', 'NTH', 'POR', 'SPA', 'SWE', 'UK'

ind = str2num(get(gca,'XTickLabel'));

set(gca, 'XTickLabel',L(ind))

Note: The prefix "CF" on the matrix X stands for Christiano-Fitzgerald filtered series.

A.6 Stationarity Tests for the identified Clusters

Table 10: ADF Test Results for the Clusters' *deviation* cycles

Cluster	Test Statistic	Critical Value 5%	McKinnon p-value for $z(t)$
Cluster 1	-3.901	-2.882	0.0020*
Cluster 2	-3.627	-2.882	0.0053*
Cluster 3	-3.700	-2.882	0.0041*

Source: Author's Calculations with STATA routine "*dfuller*". *5% significance level.

A.7 Econometric Framework for Cluster 1 VAR Model

Figure 9: National Business Cycles in Cluster 1

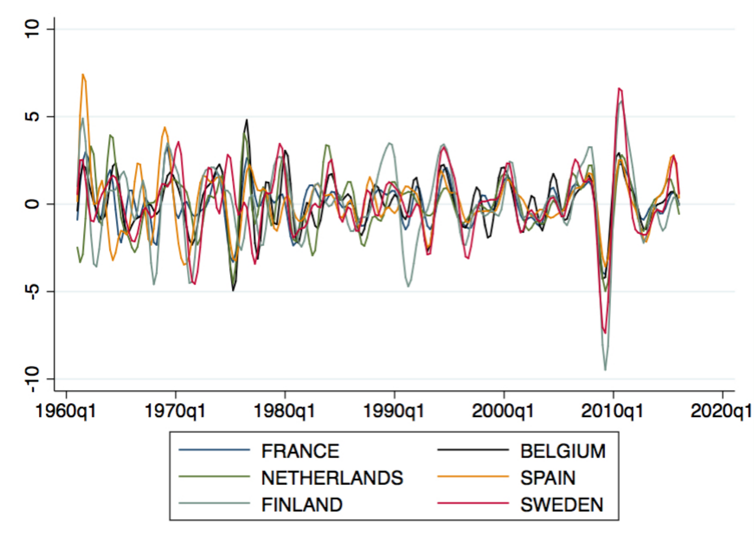


Table 11: Optimum Lag Criteria for Cluster 1 National Business Cycles VAR (lag 1-10)

Lag	LL	LR	df	p	AIC
0	-2012.54				19.1331
1	-1126.37	1772.3	36	0.000	11.0746
2	47.6056	2348	36	0.000	0.288098
3	810.117	1525	36	0.000	-6.59827
4	2053.41	2486.6	36	0.000	-18.0418
5	2926.51	1746.2	36	0.000	-25.9764
6	4159.94	2466.9	36	0.000	-37.3265
7	4939.22	1558.6	36	0.000	-44.3718
8	6451.65	3024.9	36	0.000	-58.3663
9	5778.09	-1347.1	36	0.000	-51.9819
10	8 6738.96	**1921.7***	36	0.000	**- 60.7485**

Source: Author's calculations with STATA routine "*varsoc*".

Figure 10: Roots of the Companion Matrix for Cluster 1 VAR Model (6 lags)

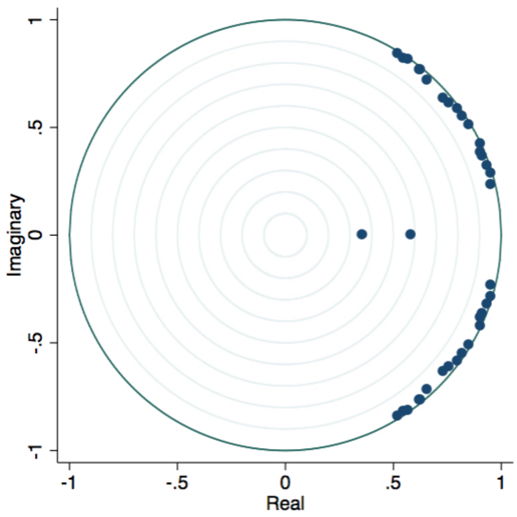


Table 12: Granger Causality for Cluster 1 VAR Model (6 lags)

Country	Excluded	chi2	df	Prob>chi2	Country	Excluded	chi2	df	P. >chi2
FRA	BEL	55.804	6	**0.000**	NTH	FRA	80.798	6	**0.000**
FRA	NTH	54.265	6	**0.000**	NTH	BEL	97.591	6	**0.000**
FRA	FIN	24.557	6	**0.000**	NTH	FIN	30.463	6	**0.000**
FRA	SPA	299.71	6	**0.000**	NTH	SPA	40.026	6	**0.000**
FRA	SWE	160.21	6	**0.000**	NTH	SWE	21.993	6	**0.001**
FRA	ALL	809.47	30	**0.000**	NTH	ALL	556.23	30	**0.000**
BEL	FRA	63.695	6	**0.000**	FIN	FRA	73.325	6	**0.000**
BEL	NTH	22.887	6	**0.001**	FIN	BEL	101.91	6	**0.000**
BEL	FIN	15.148	6	**0.019**	FIN	NTH	122.65	6	**0.000**
BEL	SPA	205.72	6	**0.000**	FIN	SPA	209.17	6	**0.000**
BEL	SWE	109.77	6	**0.000**	FIN	SWE	125.31	6	**0.000**
BEL	ALL	679.48	30	**0.000**	FIN	ALL	640.98	30	**0.000**
SPA	FRA	31.963	6	**0.000**	SWE	FRA	20.809	6	**0.002**
SPA	BEL	30.911	6	**0.000**	SWE	BEL	28.687	6	**0.003**
SPA	NTH	36.842	6	**0.000**	SWE	NTH	49.247	6	**0.000**
SPA	FIN	25.213	6	**0.000**	SWE	FIN	7.9803	6	**0.240**
SPA	SWE	47.932	6	**0.000**	SWE	SPA	74.17	6	**0.042**
SPA	ALL	184.46	30	**0.000**	SWE	ALL	350.07	30	**0.000**

Source: Author's calculations with STATA routine "*vargranger*".

Table 13: Lagrange-Multiplier test for Autocorrelation in Cluster 1 (lag 1 to 6)

Lag	**chi2**	**df**	**Prob>chi2**
1	1.1e+03	36	0.00000
2	279.9102	36	0.00000
3	381.0852	36	0.00000
4	703.2150	36	0.00000
5	585.7313	36	0.00000
6	354.9056	36	0.00152

Source: Author's calculations with STATA routine "*varlmar, mlag(6)*". Null Hypothesis stands for "No Autocorrelation at Lag Order".

A.8 Econometric Framework for Cluster 2 VAR Model

Figure 11: National Business Cycles in Cluster 2

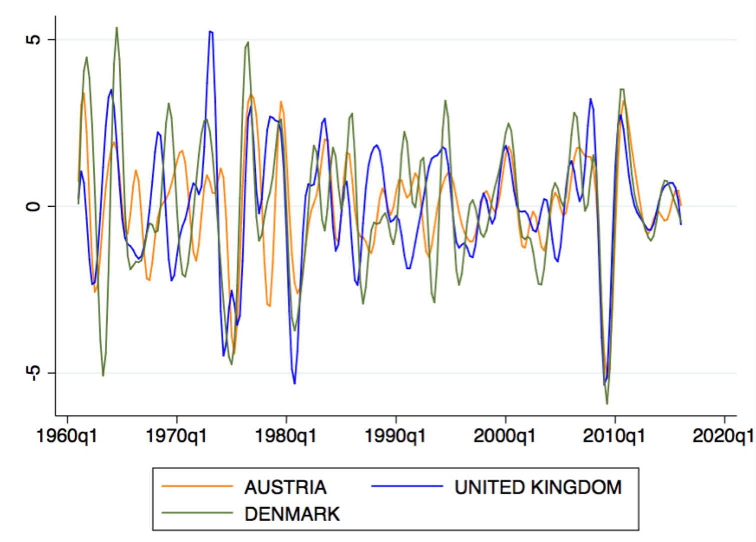


Table 14: Optimum Lag Criteria - VAR for Cluster 2 National Business Cycles

Lag	LL	LR	df	p	AIC
0	-1142.97				10.8622
1	-688.128	909.67	9	0.000	6.63628
2	-105.231	1165.8	9	0.000	1.19651
3	239.943	690.35	9	0.000	-1.98998
4	817.221	1154.6	9	0.000	-7.3765
5	1151.12	667.8	9	0.000	-10.4561
6	1723.47	1144.7	9	0.000	-15.7959
7	2001.7	556.46	9	0.000	-18.3479
8	2440.49	877.58	9	0.000	-22.4217
9	2727.31	**573.64***	9	0.000	**-25.0551***
10	2470.33	-513.97	.	0.000	–22.5908

Source: Author's calculations with STATA routine "*varsoc*".

Figure 12: Roots of the Companion Matrix for Cluster 2 VAR Model (8 lags)

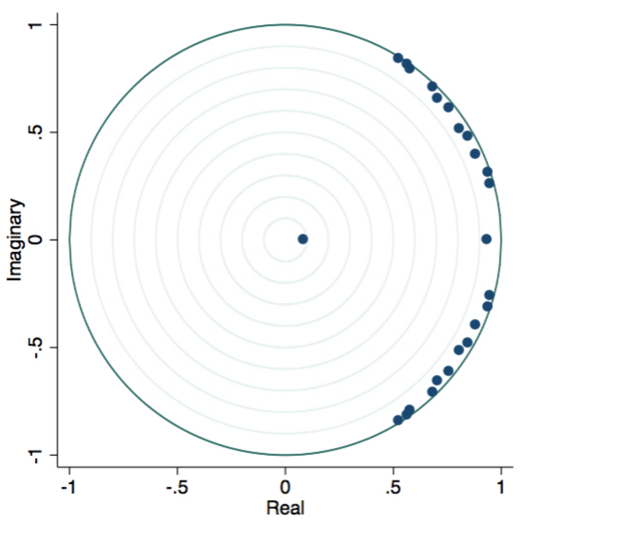


Table 15: Granger Causality after Cluster 2 VAR Model (8 lags)

Country	Excluded	chi2	df	Prob > Chi2
UK	DEN	17.931	8	**0.000**
UK	AT	34.573	8	**0.000**
UK	ALL	123.75	16	**0.000**
DEN	UK	56.958	8	**0.000**
DEN	AT	317.96	8	**0.000**
DEN	ALL	413.46	16	**0.000**
AT	UK	9.943	8	**0.269**
AT	DEN	27.565	8	**0.001**
AT	ALL	38.633	16	**0.000**

Source: Author's calculations with STATA routine "*vargranger*".

Table 16: Lagrange-Multiplier test for Autocorrelation for Cluster 2 VAR Model (8 lags)

Lag	chi2	df	Prob>chi2
1	485.0728	9	0.00000
2	64.6632	9	0.00000
3	164.0349	9	0.00000
4	168.4070	9	0.00000
5	82.8545	9	0.00000
6	26.7869	9	0.00152
7	45.5216	9	0.00000
8	41.7070	9	0.00000

Source: Author's calculations with STATA routine "*varlmar, mlag(8)*". Null Hypothesis stands for "No Autocorrelation at Lag Order".

A.9 Econometric Framework for Cluster 3 VAR Model

Figure 13: National Business Cycles in Cluster 3

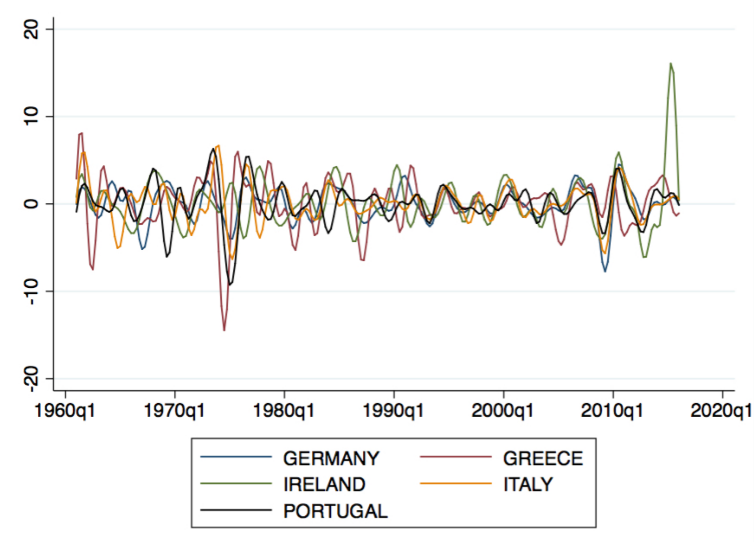


Table 17: Optimum Lag Criteria - VAR for Cluster 3 National Business Cycles

Lag	**LL**	**LR**	**df**	**p**	**AIC**
0	-2289.86				21.7522
1	-1426.63	1726.5	25	0.000	13.8069
2	-460.323	1932.6	25	0.000	4.88458
3	217.049	1354.7	25	0.000	-1.29904
4	1130.95	1827.8	25	0.000	-9.72469
5	1803.24	1344.6	25	0.000	-15.8601
6	2890.17	2173.9	25	0.000	-25.92589
7	3491.14	1201.9	25	0.000	-31.3852
8	4415.42	1848.6	25	0.000	-39.9092
9	4314.37	-202.09	25	.	-38.8566
10	4485.3	**341.86***	25	0.000	**-40.3346***

Source: Author's calculations with STATA routine "*varsoc*".

Table 18: Granger Causality for Cluster 3 National Business Cycles VAR

Country	Excluded	chi2	df	Prob>chi2	Country	Excluded	chi2	df	Prob>chi2
GER	GRE	11.145	4	**0.025**	GRE	GER	38.759	4	**0.000**
GER	IRL	7.4901	4	**0.112**	GRE	IRL	19.063	4	**0.001**
GER	ITA	22.296	4	**0.000**	GRE	ITA	68.929	4	**0.000**
GER	POR	5.4435	4	**0.245**	GRE	POR	23.191	4	**0.000**
GER	ALL	131.18	16	**0.000**	GRE	ALL	169.78	16	**0.000**
IRL	GER	19.414	4	**0.001**	ITA	GER	37.874	4	**0.000**
IRL	GRE	19.836	4	**0.001**	ITA	GRE	23.721	4	**0.000**
IRL	ITA	25.452	4	**0.000**	Italy	IRL	24.131	4	**0.000**
IRL	POR	19.292	4	**0.001**	IITA	POR	41.758	4	**0.000**
IRL	ALL	55.877	16	**0.000**	ITA	ALL	162.15	16	**0.000**
POR	GER	8.1135	4	**0.088**					
POR	GRE	27.754	4	**0.000**					
PORl	IRL	18.28	4	**0.001**					
POR	ITA	29.16	4	**0.000**					
POR	ALL	108.75	16	**0.000**					

Source: Author's calculations with STATA routine "*vargranger*".

Table 19: Lagrange-Multiplier test for Autocorrelation in Cluster 3 National Business Cycles VAR

Lag	**chi2**	**df**	**Prob>chi2**
1	1.9e+03	25	0.00000
2	158.2640	25	0.00000
3	411.0301	25	0.00000
4	673.6949	25	0.00000

Source: Author's calculations with STATA routine "*varlmar, mlag(4)*". Null Hypothesis stands for "No Autocorrelation at Lag Order".

A.10 Turning Points, Phases and Cycles per Cluster *Deviation* Cycle

Table 20: List of Turning Points

P	**Cluster 1**	**Cluster 2**	**Cluster 3**	**T**	**Cluster 1**	**Cluster 2**	**Cluster 3**
1	1961Q4	1964Q1	1961Q3	1	1963Q1	1962Q2	1962Q4
2	1964Q1	1968Q3	1964Q1	2	1965Q1	1966Q4	1965Q1
3	1967Q1	1971Q3	1965Q4	3	1968Q1	1969Q3	1967Q1
4	1969Q2	1973Q1	1969Q1	4	1971Q3	1972Q1	1970Q1
5	1973Q4	1975Q1	1970Q3	5	1975Q2	1974Q2	1971Q3
6	1976Q3	1976Q4	1973Q4	6	1977Q3	1975Q3	1975Q1
7	1978Q2	1979Q2	1976Q3	7	1979Q1	1977Q3	1977Q4
8	1979Q4	1983Q3	1979Q3	8	1981Q1	1980Q4	1981Q1
9	1984Q2	1985Q3	1981Q4	9	1985Q2	1984Q3	1982Q4
10	1986Q1	1988Q2	1984Q1	10	1987Q1	1986Q3	1987Q2
11	1988Q1	1990Q2	1988Q4	11	1988Q4	1989Q3	1989Q3
12	1989Q4	1994Q3	1991Q1	12	1991Q1	1991Q2	1993Q2
13	1992Q1	1996Q2	1994Q4	13	1993Q2	1995Q4	1996Q4
14	1994Q3	1998Q1	1997Q4	14	1996Q3	1997Q1	1998Q4
15	1998Q1	2000Q1	2000Q3	15	1998Q4	1998Q4	2003Q2
16	2000Q2	2003Q4	2004Q3	16	2002Q1	2002Q4	2005Q2
17	2002Q3	2006Q1	2006Q4	17	2003Q2	2004Q4	2009Q2
18	2004Q3	2007Q4	2010Q3	18	2005Q2	2006Q4	2012Q4
19	2006Q3	2010Q3	2015Q3	19	2007Q1	2009Q1	-
20	2007Q4	2015Q2	-	20	2009Q2	2013Q1	-
21	2010Q4	-	-	21	2012Q4	-	-
22	2015Q3	-	-	22	-	-	-

Source: Author's calculations with STATA routine "*sbbq*". **P:** Peak ; **T:** Trough

Table 21: List of Phases and Cycles for Cluster 1 *Deviation* Cycle

	Low-Rate Phase	**High-Rate Phase**	**Cycle (P-P)**	**Cycle (T-T)**
1	1961Q4 - 1963Q1	1963Q1 - 1964Q1	1961Q4-1964Q1	1963Q1-1965Q1
2	1964Q1 - 1965Q1	1965Q1- 1967Q1	1964Q1-1967Q1	1965Q1-1968Q1
3	1967Q1 - 1968Q1	1968Q1 - 1969Q2	1967Q1-1969Q2	1968Q1-1971Q3
4	1969Q2 - 1971Q3	1971Q3 - 1973Q4	1969Q2 -1973Q4	1971Q3-1975Q2
5	1973Q4 - 1975Q2	1975Q2 - 1976Q3	1973Q4-1976Q3	1975Q2-1977Q3
6	1976Q3 - 1977Q3	1977Q3 - 1978Q2	1976Q3-1978Q2	1977Q3-1979Q1
7	1978Q2 - 1979Q1	1979Q1 - 1979Q4	1978Q2-1979Q4	1979Q1-1981Q1
8	1979Q4 - 1981Q1	1981Q1 - 1984Q2	1979Q4-1984Q2	1981Q1-1985Q2
9	1984Q2 - 1985Q2	1985Q2 - 1986Q1	1984Q2-1986Q1	1985Q2-1987Q1
10	1986Q1 - 1987Q1	1987Q1 - 1988Q1	1986Q1-1988Q1	1987Q1-1988Q4
11	1988Q1 - 1988Q4	1988Q4 - 1989Q4	1988Q1-1989Q4	1988Q4-1991Q1
12	1989Q4 - 1991Q1	1991Q1 - 1992Q1	1989Q4-1992Q1	1991Q1 - 1993Q2
13	1992Q1 - 1993Q2	1993Q2 - 1994Q3	1992Q1-1994Q3	1993Q2 - 1996Q3
14	1994Q3 - 1996Q3	1996Q3 - 1998Q1	1994Q3-1998Q1	1996Q3 - 1998Q4
15	1998Q1 - 1998Q4	1998Q4 - 2000Q2	1998Q1-2000Q2	1998Q4 - 2002Q1
16	2000Q2 - 2002Q1	2002Q1 - 2002Q3	2000Q2-2002Q3	2002Q1 - 2003Q2
17	2002Q3 - 2003Q2	2003Q2 - 2004Q3	2002Q3-2004Q3	2003Q2 - 2005Q2
18	2004Q3 - 2005Q2	2005Q2 - 2006Q3	2004Q3-2006Q3	2005Q2 - 2007Q1
19	2006Q3 - 2007Q1	2007Q1 - 2007Q4	2006Q3-2007Q4	2007Q1 - 2009Q2
20	2007Q4 - 2009Q2	2009Q2 - 2010Q4	2007Q4-2010Q4	2009Q2 - 2012Q4
21	2010Q4 - 2012Q4	2012Q4 - 2015Q3	2010Q4 - 2015Q3	.

Source: Author's calculations with STATA routine "*sbbq*". **P:** Peak ; **T:** Trough

Table 22: List of Phases and Cycles for Cluster 2 *Deviation* Cycle

	Low-Rate Phase	**High-Rate Phase**	**Cycle (P-P)**	**Cycle (T-T)**
1	1964Q1 - 1966Q4	1962Q2 - 1964Q1	1964Q1-1968Q3	1962Q2 - 1966Q4
2	1968Q3 - 1969Q3	1966Q4 - 1968Q3	1968Q3 - 1971Q3	1966Q4 - 1969Q3
3	1971Q3 - 1972Q1	1969Q3 - 1971Q3	1971Q3 - 1973Q1	1969Q3 - 1972Q1
4	1973Q1 - 1974Q2	1972Q1 - 1973Q1	1973Q1 - 1975Q1	1972Q1 - 1974Q2
5	1975Q1 - 1975Q3	1974Q2 - 1975Q1	1975Q1 - 1976Q4	1974Q2 - 1975Q3
6	1976Q4 - 1977Q3	1975Q3 - 1976Q4	1976Q4 - 1979Q2	1975Q3 - 1977Q3
7	1979Q2 - 1980Q4	1977Q3 - 1979Q2	1979Q2 - 1983Q3	1977Q3 - 1980Q4
8	1983Q3 - 1984Q3	1980Q4 - 1983Q3	1983Q3 - 1985Q3	1980Q4 - 1984Q3
9	1985Q3 - 1986Q3	1984Q3 - 1985Q3	1985Q3 - 1988Q2	1984Q3 - 1986Q3
10	1988Q2 - 1989Q3	1986Q3 - 1988Q2	1988Q2 - 1990Q2	1986Q3 - 1989Q3
11	1990Q2 - 1991Q2	1989Q3 - 1990Q2	1990Q2-1994Q3	1989Q3 - 1991Q2
12	1994Q3 - 1995Q4	1991Q2 - 1994Q3	1994Q3 - 1996Q2	1991Q2 - 1995Q4
13	1996Q2 - 1997Q1	1995Q4 - 1996Q2	1996Q2 - 1998Q1	1995Q4 - 1997Q1
14	1998Q1 - 1998Q4	1997Q1 - 1998Q1	1998Q1 - 2000Q1	1997Q1 - 1998Q4
15	2000Q1 - 2002Q4	1998Q4 - 2000Q1	2000Q1 - 2003Q4	1998Q4 - 2002Q4
16	2003Q4 - 2004Q4	2002Q4 - 2003Q4	2003Q4 - 2006Q1	2002Q4 - 2004Q4
17	2006Q1 - 2006Q4	2004Q4 - 2006Q1	2006Q1 - 2007Q4	2004Q4 - 2006Q4
18	2007Q4 - 2009Q1	2006Q4 - 2007Q4	2007Q4 - 2010Q3	2006Q4 - 2009Q1
19	2010Q3 - 2013Q1	2009Q1 - 2010Q3	2010Q3 - 2015Q2	2009Q1 - 2013Q1
20	.	2013Q1 - 2015Q2	.	.

Source: Author's calculations with STATA routine "*sbbq*". **P:** Peak ; **T:** Trough

Table 23: List of Phases and Cycles for Cluster 3 *Deviation* Cycle

	Low-Rate Phase	**High-Rate Phase**	**Cycle (P-P)**	**Cycle (T-T)**
1	1962Q4 - 1964Q1	1961Q3 - 1962Q3	1961Q3 - 1964Q1	1962Q4 - 1965Q1
2	1965Q1 - 1965Q4	1964Q1 - 1965Q1	1964Q1 - 1965Q4	1965Q1 - 1967Q1
3	1967Q1 - 1969Q1	1965Q4 - 1967Q1	1965Q4 - 1969Q1	1967Q1 - 1970Q1
4	1970Q1 - 1970Q3	1969Q1 - 1970Q1	1969Q1 - 1970Q3	1970Q1 - 1971Q3
5	1971Q3 - 1973Q4	1970Q3 - 1971Q3	1970Q3 - 1973Q4	1971Q3 - 1975Q1
6	1975Q1 - 1976Q3	1973Q4 - 1975Q1	1973Q4 - 1976Q3	1975Q1 - 1977Q4
7	1977Q4 - 1979Q3	1976Q3-1977Q4	1976Q3 - 1979Q3	1977Q4 - 1981Q1
8	1981Q1 - 1981Q4	1979Q3 - 1981Q1	1979Q3 - 1981Q4	1981Q1 - 1982Q4
9	1982Q4 - 1984Q1	1981Q4 - 1982Q4	1981Q4 - 1984Q1	1982Q4 - 1987Q2
10	1987Q2 - 1988Q4	1984Q1 - 1987Q2	1984Q1 - 1988Q4	1987Q2 - 1989Q3
11	1989Q3 - 1991Q1	1988Q4 - 1989Q3	1988Q4 - 1991Q1	1989Q3 - 1993Q2
12	1993Q2 - 1994Q4	1991Q1 - 1993Q2	1991Q1 - 1994Q4	1993Q2 - 1996Q4
13	1996Q4 - 1997Q4	1994Q4 - 1996Q4	1994Q4 - 1997Q4	1996Q4 - 1998Q4
14	1998Q4 - 2000Q3	1997Q4 - 1998Q4	1997Q4 - 2000Q3	1998Q4 - 2003Q2
15	2003Q2 - 2004Q3	2000Q3 - 2003Q2	2000Q3 - 2004Q3	2003Q2 - 2005Q2
16	2005Q2 - 2006Q4	2004Q3 - 2005Q2	2004Q3 - 2006Q4	2005Q2 - 2009Q2
17	2009Q2 - 2010Q3	2006Q4 - 2009Q2	2006Q4 - 2010Q3	2009Q2 - 2012Q4
18	2012Q4 - 2015Q3	2010Q3 - 2012Q4	2010Q3 - 2015Q3	.

Source: Author's Calculations with STATA routine "*sbbq*". **P:** Peak ; **T:** Trough

A.11 Statistical Significance for the Index of Concordance

Table 24: OLS Regression for each pair of Clusters' Index of Concordance

Regression	**Coefficient**	**t-statistic**	**p-value**
Cluster 1 and Cluster 2	0.2095223	3.17	0.02*
Cluster 1 and Cluster 3	0.505832	8.71	0.000*
Cluster 2 and Cluster 3	.278503	4.30	0.000*

Source: Author's calculations with STATA routine "*reg <varlist>, vce(robust)*".
* Null hypothesis of $\rho_s = 0$ is rejected. Significant values for the three Index of Concordance values.

A.12 Econometric Framework for all Clusters VAR Model

Table 25: Optimum Lag Criteria for the 3 Clusters Var (15 lags maximum)

Lag	LL	LR	df	p	AIC
0	-909.807				8.86221
1	-451.713	916.19	9	0.000	4.50207
2	90.2441	1083.9	9	0.000	-0.672272
3	458.294	736.1	9	0.000	-4.15819
4	1006.53	1096.5	9	0.000	-9.39353
5	1347.73	682.39	9	0.000	-12.6187
6	1855.73	1016	9	0.000	-17.4634
7	2139.43	567.39	9	0.000	-20.1304
8	2523.3	767.75	9	0.000	-23.7699
9	2771.48	496.36	9	0.000	-26.0921
10	2598.1	-346.77	9	.	-24.4087
11	2764.09	331.98	9	0.000	-25.962
12	2795.92	63.678	9	0.000	-26.242
13	2857.33	**122.81***	9	0.000	**-26.7799***
14	2638.78	-437.1	9	.	-24.6289
15	2555.16	-167.23	9	.	-23.788

Source: Author's calculations with STATA routine "*varsoc*".

Figure 14: Roots of the companion matrix for the 3 Clusters' VAR model (13 lags)

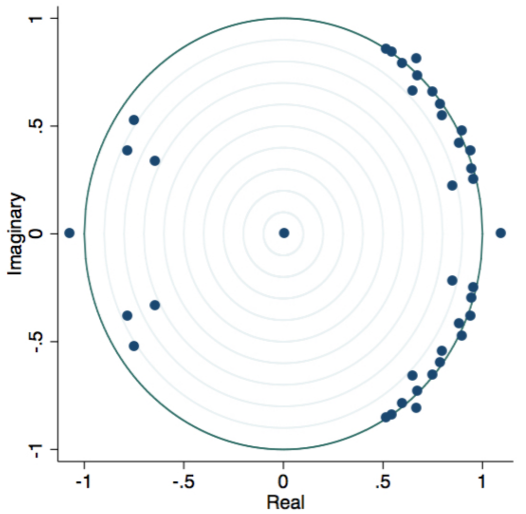


Table 26: Eigenvalue Stability Condition for all Clusters' VAR model (7 lags)

Eigenvalues		**Modulus**
0.5453535 +	$0.8299004i$	0.993048
0.5453535 -	$0.8299004i$	0.993048
0.5751977 +	$0.8032989i$	0.987999
0.5751977 -	$0.8032989i$	0.987999
0.6171559 +	$0.768597i$	0.985709
0.6171559 -	$0.768597i$	0.985709
0.7608114 +	$0.6224964i$	0.983024
0.7608114 -	$0.6224964i$	0.983024
0.9361722 +	$0.2990767i$	0.982784
0.9361722 -	$0.2990767i$	0.982784
0.9214584 +	$0.3376625i$	0.981377
0.9214584 -	$0.3376625i$	0.981377
0.803068 +	$0.5588756i$	0.978397
0.803068 -	$0.5588756i$	0.978397
0.7299085 +	$0.6502864i$	0.977568
0.7299085 -	$0.6502864i$	0.977568
0.8883578 +	$0.3977068i$	0.973319
0.8883578 -	$0.3977068i$	0.973319
0.877651 +	$06732659i$	0.88023
0.877651 -	$06732659i$	0.88023
0.03218054		0.032181

Source: Author's calculations with STATA routine "*varstable*". All eigenvalues lie inside the unit circle. The VAR satisfies the stability condition.

Figure 15: Roots of the companion matrix for all Clusters VAR (7 lags)

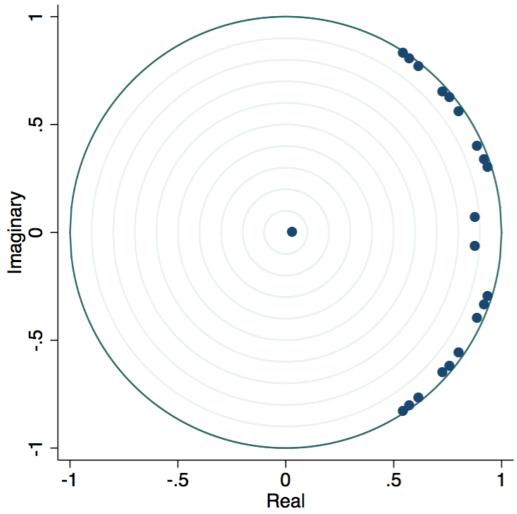


Table 27: Lagrange-Multiplier test for Autocorrelation in all Clusters' VAR model (7 lags)

Lag	chi2	df	Prob>chi2
1	621.3801	9	0.00000
2	59.6980	9	0.00000
3	203.0671	9	0.00000
4	234.2713	9	0.00000
5	84.8030	9	0.00000
6	25.1163	9	0.00000
7	40.9907	9	0.00000

Source: Author's calculations with STATA routine "*varlmar, mlag(7)*". Null Hypothesis stands for "No Autocorrelation at Lag Order".

Table 28: Granger Causality for the all Clusters' VAR Model (7 lags)

Cluster	**Excluded**	**chi2**	**df**	**P >chi2**
CLUSTER1	CLUSTER2	31.155	7	**0.000**
CLUSTER1	CLUSTER3	28.301	7	**0.000**
CLUSTER1	ALL	62.998	14	**0.000**
CLUSTER2	CLUSTER1	21.328	7	**0.003**
CLUSTER2	CLUSTER3	17.642	7	**0.014**
CLUSTER2	ALL	195.71	14	**0.000**
CLUSTER3	CLUSTER1	40.798	7	**0.000**
CLUSTER3	CLUSTER2	63.513	7	**0.000**
CLUSTER3	ALL	92.557	14	**0.000**

Source: Author's calculations with STATA routine "*vargranger*".

A.13 FEVD for all Clusters VAR Model

Figure 16: Impulse on Cluster 1: FEVD for Cluster 2 and Cluster 3

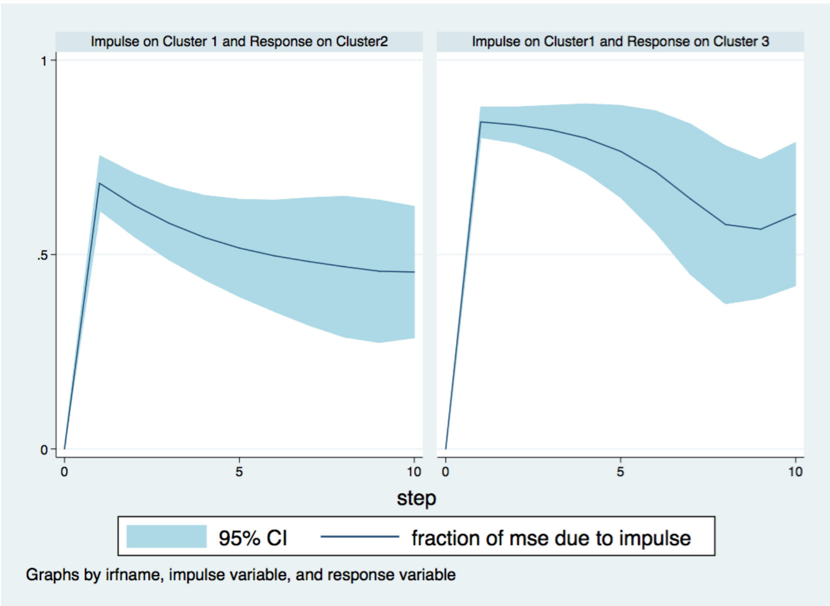


Figure 17: Impulse on Cluster 2: FEVD for Cluster 1 and Cluster 3

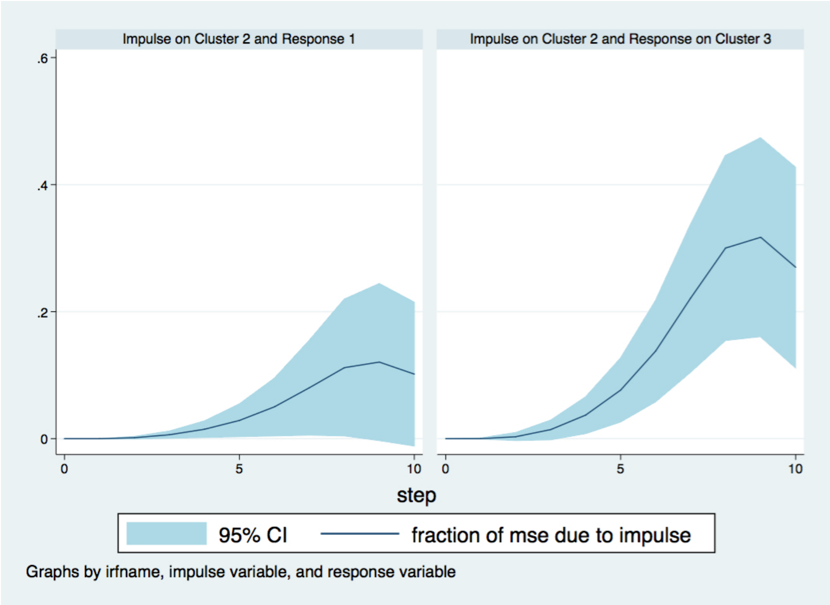


Figure 18: Impulse on Cluster 3: FEVD for Cluster 1 and Cluster 2