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Business Cycle Synchronisation in the European Monetary Union

A core-periphery analysis

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Abstract

The creation of the Euro common currency implied substantial consequences for the member states, such as the renouncement of national currencies and their related policy instruments. In the pursuit of an optimal currency area, concerns regarding the business cycle synchronisation of the euro member countries arose, especially related to the disparities between the core and periphery economies. The current work focuses on analyzing the business cycle synchronisation within the euro area, comparing the 20 year period before and after the introduction of the Euro, contrasting the core and periphery country groups. Based on Markov-switching Autoregressive models, the synchronisation of the phases of slow and high growth of the business cycles are estimated, through measures such as concordance, expected duration, amplitude and steepness. The main results indicate that the period following the introduction of the Euro is associated with decreased business cycle synchronisation between the core and periphery countries of the euro area, especially during the time frame following the financial crisis, a pattern that applies to all periphery countries except for Italy. Additionally, higher intra-group business cycle synchronisation is estimated for the core countries, while for the periphery group, increased volatility is revealed after the introduction of the Euro as compared to before. In addition to the estimated de-synchronisation present between the core and periphery countries, differences also exist between the amplitude of their business cycle phases. These findings suggest possible complications for the feasibility of the common monetary policies, and potentially higher costs of renouncing monetary sovereignty, in the absence of alternative adjustment mechanisms.

Keywords: Business Cycle Synchronisation, Euro Area, Core-periphery, MS-AR modelling

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1 | Introduction

The decision to pursue the creation of a currency area in 1999 by the European economies implied substantial consequences for the member states, such as the renouncement of the national currency and the related policy instruments (Altavilla, 2004; De Grauwe, 2020). Prior to the institution of the Euro, the discussion surrounding the feasibility and prosperity of this arrangement was concerned about the ability of a single currency to adequately serve such a diverse group of nations. Mainly, of paramount relevance is the question of the existence of a unique business cycle among the member countries of the euro area (Artis et al., 2004).

The business cycle synchronisation (BCS) of the members of a currency union is established as a crucial criteria for a successful constitution and operation of an optimal currency area (Gächter et al., 2012; Mundell, 1961). In the setup of the euro area, weak synchronisation would imply divergences between the preferred monetary policy approach, while depending on the business cycle phase of each economy, expansionary or restrictive actions would be optimal (De Grauwe, 2020). Regarding the member countries of the euro area, the main concerns surround the heterogeneity between the core and periphery countries, which have seen diverging patterns already before the introduction of the Euro (Bayoumi and Eichengreen, 1993). Whether strengthened business cycle synchronisation between these groups of countries was in place after the introduction of the Euro is the discussion topic of a considerable body of academic work (Grigoraş and Stanciu, 2016).

The existing findings related to the business cycle synchronisation within the euro area differ widely, an occurrence partly linked to the employment of diverse data and methodology (De Haan et al., 2008). While analysis of the period immediately after the introduction of the Euro finds support for higher synchronisation between the member countries (Altavilla, 2004), expanding the examined time frame leads to contradicting conclusions. Even when the core countries of the euro area exhibit a stronger business cycle synchronisation during the period following the introduction of the Euro (Lehwald, 2013), this pattern is not retrieved when contrasting the core and periphery countries between themselves, giving rise to the core-periphery paradigm (Blanchard et al., 2017; Wortmann and Stahl, 2016).

The goal of the current work is to analyse the business cycle synchronisation within the euro area, comparing the 20 year period before and after the introduction of the Euro, and focusing on contrasting the core and periphery country groups. The business cycles considered in this work correspond to the growth cycles of an economy, with the recession phase being defined as a period of decelerated growth, and the expansion phase indicating acceleration of the growth rates. The recessionary or expansionary phases of the business cycles are simulated based on Markov-switching Autoregressive (MS-AR) models, a methodology that is most appropriate when modeling business cycles by accounting for the possible endogeneity and non-linearity at hand (Hamilton and Raj, 2013). Across-time differences in the dynamics surrounding the business cycles of the countries analysed are accounted for by estimating Markov-switching models with time-dependent transition probabilities. The business cycle synchronisation between the core and periphery countries is evaluated using both concordance measures based on the probability of recession and expansion, and using average characteristics of the business cycles, such as expected duration, amplitude and steepens.

The contribution of the current work concerns the application of the Markov-switching methodology to the analysis of business cycle synchronisation in the euro area, extending the analysed time frame, and examining the impact of the financial crisis. Additionally, an extension to the traditional analysis of business cycle synchronisation is presented, by estimating supplementary aspects of the business cycle phases, such as expected duration and amplitude, differences in which can serve as further indications towards diverging or converging cyclical conditions (Belke et al., 2017). This work builds on other research in this area by further extending the methodology applied with the usage of the Markov-switching (MS) models, aiming for increased robustness of the inferences drawn. While some prior work exists focusing on applying this methodology to the analysis of business cycle synchronisation in the euro area, it seldom involves analysis of data past the first few years after the introduction of the Euro. Within the estimation of the MS models, both time-constant and time-dependent transition probabilities between the business cycle phases are considered, thus allowing for separating across-time differences in the switching pattern.

The results of the current analysis indicate that the period following the introduction of the Euro is associated with decreased business cycle synchronisation between the core and periphery countries of the euro area as compared to the period before, a pattern that applies to all the periphery countries considered, except for Italy. Considering the impact of the financial crisis on the business cycle synchronisation following the introduction of the Euro, higher synchronisation is present before the crisis for countries such as Italy and Portugal, with this relationship no longer being observed after the crisis. For the core group of countries, higher business cycle synchronisation is estimated between themselves, with longer periods of expansion and shorter periods of recession after the introduction of the Euro. For the periphery group of countries, higher volatility is estimated for the period following the introduction of the Euro, as given by increased probabilities of switching between the two phases of the business cycle. In addition to an apparent de-synchronisation present between the core and periphery country, differences also exist between the amplitudes of their business cycle phases, with the periphery countries being characterized by lower levels of expansions and recession phases as compared to the core countries. These findings suggest possible complications for the feasibility of the "one-size-fits-all" monetary policies, and potentially higher costs of renouncing monetary sovereignty.

The remainder of this work is structured in several chapters, as described in this paragraph. Chapter 2 introduces the existing literature framework around currency unions and its implications for business cycle synchronisation, and expands on the research contribution of the current work. Chapter 3 discusses the data employed and outlines the methodology behind the analysis of this work. The main findings resulting from the analysis are presented in Chapter 4 while Chapter 5 links these findings to the economic framework, comparing them to existing results from the literature around the topic discussed, while also presenting a summary of the main elements of this work, discussed in the Conclusion section. Additional figures and tables, with further information and alternative specification for the analysis of this paper are presented in Appendix A. The last chapter of this work, Appendix B, contains the statistical script employed for obtaining the results of the analysis presented in this work.

2 Literature review

"*Uniform monetary policy and inflexible exchange rates will create conflicts whenever cyclical conditions differ among the member countries*" (Feldstein, 1997, p.41).

2.1 Monetary unions

2.1.1 Background information

Historically, a common trait observed among countries was the possession of a unique currency, different from that of other countries. Given the scarcity of monetary unions in earlier days, concomitant with the increasing numbers of countries in the world, growing from 76 countries in 1947 to 193 nowadays, a significant increase in the number of currencies circulated in the world is observed (Alesina and Barro, 2002). However, linked to the increasing integration of international markets, the logical expectation would be that the optimal number of currencies in the world would diminish, instead of the almost triple increase observed.

The history of monetary unions distinguishes between two types of such structures: national monetary unions and multinational ones (Bordo and Jonung, 2003). A national monetary union is ruled by a single monetary authority, usually a central bank, having a synchronized political and monetary sovereignty. A multinational monetary union is a cooperation between independent states, based on connecting currencies together through a fixed exchange rate, with the extreme case when members adopt the same currency. In the setup of a multinational monetary union, the participating members operate with one currency without a common monetary authority, historical such unions being the Latin Monetary Union and the Scandinavian Currency Union (Ögren, 2020).

The core reasoning behind the creation of a monetary union is highly linked to diminishing the costs of trade: while national currencies can be seen as barriers to international trade, entering a monetary union can boost trade by removing these restrictions (Rose and Van Wincoop, 2001). Countries with strong trade ties between each other were the ones historically more likely to adopt a unified currency, that being a practical and risk-decreasing approach (Flandreau, 1996). After the creation of the monetary unions, trade intensity increases. It is estimated that countries sharing the same currency have three times higher trade than those which do not (Rose, 2000), estimates which are however criticized for being too high (Nitsch, 2002), and re-estimated to much lower levels (Glick and Rose, 2016).

Next to the increasing trade goal for the creation of currency unions, several other reasons are present. Elements such as the facilitation of the financial markets and borrower-lender relationships also play a role in pursuing currency unification (Gale and Vives, 2002). Additionally, the political component is another reason that can not be underestimated (Feldstein, 1997), which has proven crucial in the successful creation of the US monetary union (Rockoff, 2000). The decision to join a monetary union is ultimately highly dependent on the officials governing a country, who are motivated by political considerations that go beyond the performance of the unified bank or the fulfillment of the criteria for an optimal monetary union (Feldstein, 1997).

The process of monetary union creation can follow two paths: according to the first path, the client country adopts the currency of the larger anchor country; according to the second path, a group of countries create a new currency and a joint central bank (Alesina and Barro, 2002). The second path of monetary union creation is the one that gave rise to the euro area.

Immediately after World War II, there was a dream of preventing other European wars and forming a United States of Europe (Feldstein, 1997). Therefore, in 1970, following decades of political and social unrest and in the pursuit of a unified and straightened Europe, the heads of state and governments in the European Community prepared the Werner plan for economic and monetary unification (Werner, 1970). The creation of the European Monetary Union (EMU) was guided according to the Euro-monetarists' theories on the creation of an optimal currency area recommended by the Delors Commission (Delors, 1989; Jespersen, 2016). The long process of preparing for the monetary unification of Europe culminated with the introduction of the common currency the Euro, on January 1st 1999, in eleven member states of the European Union: the moment when the euro area started its existence.

2.1.2 Theory of monetary unions

According to the conventional theory of the optimal currency area (OCA), discussed in Mundell (1961), the creation of monetary unions implies a fundamental trade-off. On one side, there is monetary efficiency, such as the reduced costs of transactions, while on another side, there are the adverse macroeconomic effects of abandoning an independent monetary policy, through the weakening of mechanisms of interest rate and exchange rate variations used to pursue full employment. From this perspective, the reduced costs of transactions are predominantly the result of eradicating exchange rate uncertainties and diminishing information costs (De Grauwe and Mongelli, 2005).

However, in the established framework, factor (labour) mobility is paramount to be accounted for: "*If the world can be divided into regions within each of which there is factor mobility and between which there is factor immobility, then each of these regions should have a separate currency which fluctuates relative to all other currencies*" (Mundell, 1961, p.663). Thus, the absence of factor (labour) mobility provides a rationale in favor of national currencies: currency depreciation rather than wage deflation against high unemployment is the more feasible mechanism for inducing changes in the relative prices and wages (Krugman, 2013). This line of thought constitutes the backbone of the theory of optimal currencies, originating from the discussion surrounding the topic of fixed and flexible exchange rates regimes, set in motion by Friedman (1953) and Yeager (1958) (Rockoff, 2000). However, while discussing successful currency unions, Mundell was not advocating for them, but instead concluded that a floating exchange rate would be a logical choice (Ögren, 2020): "*This carries the argument for flexible exchange rates to its logical conclusion*" (Mundell, 1961, p.663).

Following the framework of optimal currency areas, substantial early elaborations were discussed by McKinnon (1963) and Kenen (1969), highlighting two components that are highly relevant to account for: openness of the economy and fiscal integration (Krugman, 2013). Economic openness can be best described by high levels of trade and labour mobility, which together increase the potential benefits of sharing one common currency, while fiscal integration is a paramount tool for dealing with the consequences of asymmetric shocks.

The framework of Mundell (1961) constitutes the base for a fair consensus in the academic literature regarding the four criteria that are crucial for the successful constitution of an optimal currency area (Kouparitsas, 2001):

1. Common shocks: regions should be exposed to similar sources of economic disturbance
2. Symmetric shocks: across regions, the importance of the shocks should be similar
3. Common responses: regions should have similar responses to common shocks
4. Idiosyncratic shocks: dealing with region specific shocks, quick adjustment should be possible

In the case when the above mentioned criteria are fulfilled, business cycles will be highly correlated and the common monetary policy will be optimal.

2.2 Business Cycle Synchronisation

2.2.1 Monetary union perspective

The classical definition of business cycles refers to the absolute expansions and contractions of economic activity (Burns and Mitchell, 1947), with more recent definitions focusing on deviation, or growth cycles, reflecting variations of the economic activity from a trend (De Haan et al., 2008). The degree to which the business cycles of different countries align with each other is described by business cycle synchronisation (BCS). Numerous factors have been estimated to impact business cycle synchronisation, such as monetary integration (Fatás, 1997), trade relations (Frankel and Rose, 1998), fiscal policy (Clark and Van Wincoop, 2001), specialization (Imbs, 2004), and financial relations (Imbs, 2006). Despite the theoretical and empirical research to date, there is still no consensus regarding the main determinants of business cycle synchronisation (Baxter and Kouparitsas, 2005).

Business cycles of the member countries, and more exactly the synchronisation thereof, plays a crucial role for the performance of a monetary union, being considered as the most important optimal currency area criterion (Gächter et al., 2012). With highly correlated business cycles of the member countries, the central bank of a monetary union can easier conduct stabilization policies (Clarida et al., 1999; Rogoff, 1985). However, in the absence of labour mobility, and weak correlation of business cycles among the members of a union, the costs of giving up monetary sovereignty are remarkably high, since then alternative adjustment mechanisms might be limited in availability (Eichengreen, 1990, 1992). In that situation, having a common currency is sub-optimal, since the countries in the downward phase of the cycle would benefit more from an expansionary monetary policy, while the reverse would hold for the countries in the upward phase of the cycle, preferring a more restrictive policy (Clarida et al., 1999; Rogoff, 1985).

2.2.2 Business cycle convergence within euro area

In the context of the euro area, similar concerns were considered related to the possible divergence of the business cycles of the member countries and its implications (De Haan et al., 2008). However, it was expected that once the monetary union is in effect, the member countries would see an increased synchronisation of their business cycles, independent of their situation ex ante (Alesina et al., 2002; Rose, 2000). Driven by the argument of endogeneity of business cycles, increased trade patterns following the unified currency were expected to lead to increased synchronisation among the member economies (Frankel and Rose, 1998).

The ex-post synchronisation of the business cycles of the member countries following the establishment of the euro zone has not reached a unanimity within the academic community. Papageorgiou et al. (2010) finds that the business cycles of the member countries were converging in the decade preceding the introduction of the Euro, but diverging starting from 2000. Examining the degree of business cycle synchronisation for European economies inside and outside the euro area, Willett et al. (2010) finds that the correlation of output was greater for those countries that were not inside the euro area. The work of De Haan et al. (2008) offers a comprehensive synthesis of the existing research around business cycle synchronisation, concluding that the business cycles of the European countries have seen periods of both convergence and divergence.

A possible reasoning to the divergent business cycles of the member countries of a monetary union is related to increased specialization of production, linked to the higher openness to trade occurring (according to the theory of comparative advantage and the Heckscher-Ohlin model). In line with this theory, it could be the case that with a higher integrated Europe, an increased concentration of industries occurs, leading to sector-specific shocks becoming region-specific shocks, exacerbating further the business cycle divergence (Krugman, 1991). Linked to the business cycle divergences estimated, the differences between the core and periphery members of the euro area are discussed, referred to as the core-periphery paradigm (Blanchard et al., 2017; De Santis and Cesaroni, 2016; Wortmann and Stahl, 2016).

Even before the introduction of the Euro and the establishment of the EMU, significant dissimilarities existed between the core and the peripheral member countries (Bayoumi and Eichengreen, 1993). These differences can be problematic given the theory of optimal currency areas, where the European Central Bank can react to shocks only with "one-size-fits-all" policies. It is possible that the introduction of the Euro common currency is linked to increases in the synchronisation of the business cycles among the core countries, but decreases for the countries of the periphery (Lehwald, 2013). This observation would go against the hypothesized endogeneity of synchronisation mentioned by Frankel and Rose (1998), indicating that it is not a certainty that operating under a common currency increases business cycle synchronisation.

2.3 Research contribution

Business cycle synchronisation is established to be a pivotal criterion for the successful constitution of an optimal currency area (Gächter et al., 2012; Mundell, 1961). While some view it as implicit, expecting that the adoption of a single currency would increase the business cycle synchronisation independent of its original levels (Frankel and Rose, 1998), empirical research ex-post supports a different view, finding variation between the core and periphery countries (Lehwald, 2013), and diverging business cycles across time (Papageorgiou et al., 2010).

The findings regarding the synchronisation of the business cycles in the context of the euro area differ widely, an occurrence that can be partly explained by the use of different data and methodology (De Haan et al., 2008). The conclusions related to the degree of synchronisation depend highly on the indices used to describe the business cycles: for example, while the introduction of the euro area is estimated to increase the correlation of price movements, it decreases the synchronisation of real GDP shocks (Barro and Tenreyro, 2007).

The aim of the current work is to further the analysis of business cycle synchronisation within the euro area, by comparing the core and periphery countries. There are several contributions that this works aims at fulfilling with regard to the research area considered.

Firstly, the methodology applied in this work to disentangle the dynamics of business cycle characteristics is a preferred modelling approach for simulating the fluctuations of business cycles (Hamilton, 1989), being less explored for the domain of business cycle synchronisation among the euro area members. The modelling framework considered in this work consist of Markov-switching Autoregressive models, with the further extension of allowing for both time-constant and time-dependent transition probabilities. Especially examining Markov-switching models with time-dependent transition probabilities allows for disentangling the volatility of the business cycle phases across time, given by the likelihood of switching between the periods of slow and fast growth.

Secondly, a further contribution of the current analysis is expanding the analysed time frame. Among the existing applications of the Markov-switching methodology to the examination of business cycle synchronisation among the euro area countries, the research existing to date has a restrictive time span, covering at most the first few years after the introduction of the Euro. This work analyses the period of 20 years before and 20 years after the introduction of the Euro, with the further addition of accounting for the impact of the financial crisis on the estimated dynamics surrounding BCS among the euro area countries. Accounting for the impact of the financial crisis is a paramount consideration, since this period is likely to have a significant impact on the pattern of business cycle synchronisation observed (Gächter et al., 2012), existing research for the after-crisis period being limited so far (Grigoraş and Stanciu, 2016).

Lastly, this works expands on the analysis of business cycle synchronisation by evaluating additional characteristics of the business cycles estimated. Namely, measures such as expected duration, average amplitude and steepness are computed, which broaden the scope of the BCS analysis. Accounting for additional business cycle characteristics is important since in addition to the synchronisation of the business cycles, similarities in their amplitude and steepness are equally important for establishing converging cyclical conditions (Belke et al., 2017).

The goal of this work is summarised by the research question presented below. The path towards answering this research questions starts at estimating Markov-switching Autoregressive models for the group of periphery and core countries, based on which the probability of being in one of the two business cycle phases can be deduced, the two phases considered being recession, defined as a period of slow growth, and expansion, defined as a period of high growth. Examining the synchronisation between the two phases across time allows for approximating the degree of business cycle synchronisation between countries, while analysing additional characteristics of the estimated phases leads to auxiliary insights into the cyclical convergence of the core and periphery country groups of the euro area.

> ***Research question***: *Examining whether the adoption of the common currency in the euro area was followed by an increased business cycle synchronisation among the member economies, distinguishing between the core and periphery country groups.*

3 | Data and methodology

3.1 Data

The data employed for the analysis of this work contains quarterly observations between 1980Q1 and 2019Q4, applied to examine if, and to what extent did the introduction of the Euro increase or decrease business cycle synchronisation (BCS) between the core and the periphery economies of the euro area. The data is obtained from the OECD (2020), using the quarterly GDP indicator.

The measure employed for reflecting business cycle synchronisation in this work is GDP growth. For studying BCS, it is recommended that the broadest possible output variable, such as GDP, is employed (Kalemli-Ozcan et al., 2004). While some studies also use such measures as unemployment or industrial production, these measures are less robust, being more volatile than aggregate output and thus reflecting BCS to a lesser extent (De Haan et al., 2008).

The analysis of this work focuses on comparing the core and periphery euro area countries between themselves. The core countries are considered to be Germany, Netherlands, Finland and Austria, while the periphery countries are the group consisting of Portugal, Italy, Greece and Spain. The literature generally agrees on the euro area countries considered as periphery, out of which Ireland is excluded due to unreliable values of the GDP growth variable starting in 2015Q1[1]. For the core group, variations in the selected countries exist across the academic literature, with no uniform definition. According to Schäfer (2016), clustering along country-specific economic policies is a methodology often employed for selecting the core euro area countries, leading to the Germanic coalition being considered as the core group.

In line with the Germanic coalition cluster, the core group of countries mainly considered in this work is composed by Germany, Netherlands, Finland and Austria. However, in order to ensure that the observed dynamics are not biased by the inclusion of specifically these countries in the core group, the analysis is re-estimated with the addition of France to the group of core countries, with the aim of increasing the robustness and generalizability of the estimated results. France is considered as a possible extension to the core group due to its potential high synchronisation with the other core countries (Ferroni and Klaus, 2015; Konstantakopoulou and Tsionas, 2011).

Comparing the GDP growth patterns between the core and periphery economies in the euro area reveals the patterns presented in Figure 7.1 in Appendix A. An inspection of the depicted dynamics suggests that, after the introduction of the Euro, there is an initial increase in the synchronisation of the GDP growth measure between the core and periphery countries, however significant differences start emerging following the financial crisis of 2008. Zooming into the group dynamics, bigger differences are observed between the periphery countries than between the core countries of the euro area.

[1] In recent years, Ireland has seen high increases in the GDP growth rates, largely due to multinational corporations relocating their headquarters and intellectual property to Ireland linked to low corporate tax.

3.2 Methodology

3.2.1 Preliminary analysis

The classical definition of business cycles refers to the absolute expansions and contractions of economic activity (Burns and Mitchell, 1947), with more recent definitions focusing on deviation, or growth cycles, reflecting variations of the economic activity from a trend (De Haan et al., 2008). The definition of business cycle employed for the analysis in this work focuses on the concept of the classical business cycle, during which a recession is defined as a time period of low growth, while expansion is defined as a period of high growth (Altavilla, 2004). According to this definition, it can also be the case that an economy residing in the expansion phase exhibits declining GDP, given that GDP growth is increasing.

The literature looking at business cycle synchronisation in the set-up of currency unions employs various methods and data, which often drives the differences in the conclusions drawn (De Haan et al., 2008). Correlation coefficients are often applied to measure synchronisation between output gaps. However, even when the output gaps between countries correlate highly with each other, the business cycles could still be differing, because of the variation in the magnitude of the output gaps (Mink et al., 2012). This is especially a problem when comparing the effects for large, core economies, and smaller, periphery ones (Miles and Vijverberg, 2018).

Another technique employed for identifying the pattern of shocks in the economy is filtering, such as Kalman filtering. However, the identifying assumptions underlying these methodologies are seldom fulfilled, leading to wrongful identification of the shock patterns (Von Hagen and Neumann, 1994). The issue surrounding macroeconomic policies studied in a cross-country context is endogeneity: according to Eichengreen (2001), also in the context of analysing the impact of a currency union on business cycle synchronisation, biased estimation is often a threat, due to such unobserved factors as political orientation, trade patterns, institutions, or other factors dictating the likelihood of a country joining a currency union. Such endogeneity problems make the analysis employing Markov-switching models a preferred approach (Miles and Vijverberg, 2018).

The application of Markov-switching models to the analysis of the impact of euro area on business cycle synchronisation is a less exploited method. The few studies that do apply this technique and their main findings are summarized in Table 7.1 in Appendix A. As can be seen, these studies mostly employ data before, or during the first years after the introduction of the Euro. It is therefore of interest to extend the time frame studied with the last two decades of the euro area existence, applying Markov-switching models to investigate the potential impact of the currency union creation on the degree of business cycle synchronisation between the member countries.

Increased business cycle synchronisation between the core and the periphery euro area countries should be observed in the situation when the claim that business cycle synchronisation increases after the formation of a single currency union is true. When such a pattern is not observed, this appears as an opposition to the endogeneity claim around currency unions, which states that the act of joining the euro area increases the business cycles synchronisation of the member economies.

In order to investigate this, a first step is estimating the linear regression described below, where the dependent variable y_t^{periph} is the aggregate output growth of the peripheral euro area countries, given by the percentage change in the GDP measure of these countries.

$$y_t^{periph} = \beta_0 + \beta_1 T_{99} + \beta_2 y_t^{core} + \beta_3 T_{99} y_t^{core} + \epsilon \tag{3.1}$$

Here, T_{99} is a dummy with the value of 1 starting from the first quarter of 1999, reflecting the introduction of the Euro, while y_t^{core} is the average percentage growth in the GDP measures of the core euro area countries. A support to the claim that the introduction of the Euro was linked to higher synchronisation between periphery and core would be reflected by a positive and statistically significant β_3 parameter estimate.

An important note here is that the estimates drawing for this model are to be regarded with caution, and employed solely as descriptive. This is because a linear structure applied to business cycles is not the most accurate one, given that business cycles are most likely non-linear, with recessions showing higher variation than expansions (Mitchell, 1927). Hence, in order to formulate a more robust estimation around the research question of this work, a Markov-switching model is employed, which has been shown to reflect business cycle fluctuations more accurately than other methods (Hamilton, 1989).

3.2.2 Markov-switching Autoregressive model

The specific type of the Markov-switching model applied to the analysis of business cycles is a Markov-switching Autoregressive time series model, which models the contractions and expansions of a business cycle using switching states of the stochastic process generating the growth of GDP.

As a starting point, a basic model with no dynamics for the GDP growth is presented as:

$$\Delta y_t = \mu_{s_t} + \epsilon_t, \tag{3.2}$$

with $\epsilon_t \sim N(0, \sigma^2)$ and s_t defining the state at time t (s_t being 1 or 2).

The intuition behind this type of models is that the parameter of interest, μ_{s_t}, reflecting the growth rate of GDP, depends on a random and unobservable state variable s_t. The two different states correspond to two different distributions of the growth rate of GDP, with μ being the mean value depending on the state s_t. For example, in one of the states, μ_1 could be smaller, simulating a period of slow growth, while in the second, μ_2 could be bigger, corresponding to a period of higher growth. Drawing the parallel to the business cycles movements, this type of model captures the idea of a growth cycle going through periods of deceleration and acceleration of the growth rates, with the economy moving between the two states of low and high growth, or recession and expansion.

The Markov-switching model considered in this work is based on an auto-regressive (AR(p)) model with p number of lags, defined as:

$$y_t = \alpha_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + ... + \beta_p y_{t-p} + u_t, \tag{3.3}$$

with y_{t-i} being the GDP growth at time $t - i$ for $i = 1, 2, ...p$. Reflecting the state of the economy at time t is achieved by adding the mean GDP growth depending on the state variable s_t, according to the definition of an MS-AR(p) model presented in the seminal work of Hamilton (1989):

$$y_t = \mu_{s_t} + \phi_1(y_{t-1} - \mu_{s_{t-1}}) + \phi_2(y_{t-2} - \mu_{t-2}) + ... + \phi_4(y_{t-p} - \mu_{s_{t-p}}) + \varepsilon_t. \quad (3.4)$$

The Markov-switching model based on this specification can account for both the mean and variance of the GDP growth measure, the later reflecting the volatility of growth, allowing for differing volatilities between the expansion and recession states.

When assuming constant transition probabilities between the two states, probabilities of the economy of being in state $s_t = 1$ at each time period can be computed. In this work, smoothed probabilities drawing from the estimated Markov-Switching models are employed, which represent an ex-post measure of the model state at time t (Guidolin and Pedio, 2018). Comparing the average GDP growth between the two states reveals which state exhibits lower growth, being considered as the recession state. For each of the countries analysed, the smoothed probability of being in the recession state at all time points are further contained in the vector p_{rec}.

Estimating the relationship between the GDP growth in the core countries and the probability of a recession in the periphery countries is achieved using the following model:

$$p_{rec}^{periph} = \tau_0 + \tau_1 T_{99} + \tau_2 y_t^{core} + \tau_3 T_{99} y_t^{core} + \epsilon. \quad (3.5)$$

Similarly to the interpretation of the parameters of equation (3.1), for the situation when it holds that the creation of the euro area is followed by increased synchronisation of the business cycles between the member economies, the τ_3 estimate from (3.5) should be negative and statistically significant. This would imply that, since the adoption of the currency union, an increase in the core countries' GDP growth is linked to a lower probability of recession for the periphery countries of the euro area than before the introduction of the Euro.

For the estimation of the Markov-switching models, the probability of switching between the two states considered is given by

$$p_{ij} = Pr\{s_t = j | s_{t-1} = i\}, \quad (3.6)$$

where p_{ij} $(i, j = 1, 2)$ is the transition probability from state i to state j. For a time-constant set-up of the Markov model, the following transition matrix combines all the transition probabilities between the two states:

$$P = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix}, \quad (3.7)$$

with the probabilities in this matrix satisfying the condition that $p_{i1} + p_{i2} = 1$.

In addition to estimating the Markov-switching models with constant transition probabilities, this restriction is relaxed in this work by allowing the transition matrix to depend on time. Specifically, a time variable with four periods of around 10 years each is considered. These four periods are the '80s, the '90s, the years following the introduction of the Euro, and the period following the financial crisis of 2008. The inclusion of a time variable with more periods would imply the estimation of a Markov model with increasingly more number of parameters, which is sub-optimal given the amount of observations that the data analyzed contains. Estimating the Markov models with time-dependent transition probabilities allows for examining the dynamics of state-switching across time. In the set-up of a Markov model with time-dependent transition probabilities, the transition matrix has the following form:

$$P(t) = \begin{pmatrix} p_{11}(t) & p_{12}(t) \\ p_{21}(t) & p_{22}(t) \end{pmatrix}, \tag{3.8}$$

where t here denotes one of the four time periods considered.

3.2.3 Business cycle synchronisation analysis

In order to examine in more detail the characteristics of the business cycles of the periphery and core euro area countries, as well as their synchronisation, an analysis approach is employed drawing from the methodology proposed by Hamilton and Raj (2013) in *"Advances in Markov-switching models: Applications in business cycle research and finance"*.

Initially, three measures pertaining to the business cycle characteristics are computed: expected duration, amplitude and steepness. The measure of expected duration of the expansion (D_{exp}) or recession (D_{rec}) phase of the business cycle of a country reflects the average amount of time spent in each state, and can be computed using the following:

$$D_{exp} = \frac{\sum_{t=1}^{T} P_t}{\sum_{t=1}^{T-1}(1-P_{t+1}) \cdot P_t} \quad \text{and} \quad D_{rec} = \frac{\sum_{t=1}^{T}(1-P_t)}{\sum_{t=1}^{T-1}(1-P_t) \cdot P_{t+1}}, \tag{3.9}$$

with P_t being the probability of the country investigated being in the expansion phase at time t.

Analysing the amplitude of the expansion (A_{exp}) or recession (A_{rec}) phase of the business cycle creates a measure of the deepness of the two phases, and relies on the following formulation:

$$A_{exp} = \frac{\sum_{t=1}^{T} y_t}{\sum_{t=1}^{T-1}(1-P_{t+1}) \cdot P_t} \quad \text{and} \quad A_{rec} = \frac{\sum_{t=1}^{T}(1-P_t) \cdot y_t}{\sum_{t=1}^{T-1}(1-P_t) \cdot P_{t+1}}, \tag{3.10}$$

where y_t, similarly to before, reflects the GDP growth rate at time t.

Computing the steepness measure of the expansion (S_{exp}) or recession (S_{rec}) phase of the business cycle is achieved using the definition below, creating a measure of slope of the phases:

$$S_{exp} = \frac{A_{exp}}{D_{exp}} \quad \text{and} \quad S_{rec} = \frac{A_{rec}}{D_{rec}}. \tag{3.11}$$

Estimating the above mentioned characteristics of expected duration, amplitude and steepness for the two phases of the business cycle allows for contrasting the business cycle of the periphery euro area countries with that of the core countries, based on the estimated probabilities of being in an expansion or a recession phase at time t. These measures are computed for the period preceding the Euro introduction, and for the period following the creation of the Euro currency union, in order to examine whether differences in the business cycle characteristics exist between the two time frames.

The estimated cycle duration and amplitude can be further applied to simulate the shape of the business cycles. A classical business cycle consists of two phases: the high-growth period, and the low-growth period. Assuming a quadratic form for each of the phases (Cooley, 1995), their shape can be described using the function of the form $ax^2 + bx + c = 0$.

Estimating the a, b, and c constants in the function equation is achieved by assuming that each phase of the cycle spans from time zero to time equals expected duration, and that the maximum of the quadratic function on the determined time interval is reached for a value equal to the estimated phase amplitude.
Using the starting moment of each phase as time equals zero, the following holds:

$$f(0) = 0 \Rightarrow a \cdot 0 + b \cdot 0 + c = 0 \Rightarrow c = 0.$$

Using the expected duration of each phase (denoted by D) as the end time implies the following:

$$f(D) = 0 \Rightarrow a \cdot D^2 + b \cdot D = 0.$$

Using the estimated amplitude (denoted by A) of each phase as the maximum value of the quadratic function, reached for the middle value ($\frac{D}{2}$) of the examined interval, implies the following:

$$f\Big(\frac{D}{2}\Big) = A \Rightarrow a \cdot \Big(\frac{D}{2}\Big)^2 + b \cdot \Big(\frac{D}{2}\Big) = A.$$

Combining the conditions above leads to the following:

$$\begin{cases} a \cdot D^2 + b \cdot D = 0 \\ a \cdot \Big(\frac{D}{2}\Big)^2 + b \cdot \Big(\frac{D}{2}\Big) = A \end{cases} \Rightarrow \begin{cases} b = -a \cdot D \\ a \cdot \frac{D^2}{4} + b \cdot \frac{D}{2} = A \end{cases} \Rightarrow \begin{cases} b = \frac{4A}{D} \\ a = -\frac{4A}{D^2}. \end{cases}$$

Using this estimation, the simulated phases of the business cycles based on the expected duration and amplitude measures can be plotted, with the general form as below:

$$f(x) = \Big(-\frac{4A}{D^2}\Big) \cdot x^2 + \Big(\frac{4A}{D}\Big) \cdot x = 0, \quad \text{for } x \in (0, D). \tag{3.12}$$

Finally, it is of interest to analyse the business cycle synchronisation between the core and periphery countries in the euro area, which is achieved by employing a measure of concordance, reflecting the degree of conformity between two business cycles (Harding and Pagan, 2002). The goal of analysing the degree of concordance, or synchronisation, between business cycles is to examine whether the core and periphery countries evolve following a similar GDP growth path or a diverging one. The following definition is employed for estimating the level of concordance between the business cycles of countries i and j:

$$Concordance_{ij} = \frac{1}{T}\Big\{S_{it}S_{jt} + \big(1 - S_{it}\big)(1 - S_{jt})\Big\}, \tag{3.13}$$

where S_{it} and S_{jt} are the estimated phase that country i and j are in at time t, with a value of 1 corresponding to the expansion phase, and a value of 2 corresponding to the recession phase. The estimated phase at time t is based on the smoothed probabilities drawing from the estimated Markov-switching Autoregressive models with constant transition probabilities.

4 | Results and findings

This section discusses the estimation results pertaining to the topic of business cycle synchronisation between the core and periphery countries of the euro area following the introduction of the common currency. For the statistical analysis and graphics of this work, the R programming language is employed through the R-studio software (RStudio Team, 2015), with the extensive usage of the MSwM package for the estimation of the Markov-switching models (Sanchez-Espigares and Lopez-Moreno, 2018). In addition, the Latent-Gold software (Vermunt and Magidson, 2016) is employed for the estimation of the Markov models with time-dependent transition probabilities.

4.1 Initial insights

The first step of the analysis in this paper is based on the estimation of equation (3.1), which serves as an initial insight into the relationship between GDP growth of the core euro area countries and that of the periphery ones. The parameter estimates for this model are presented in Table 4.1.

Based on the parameter estimates shown in column (1), it can be seen that, on average, the GDP growth of the periphery euro area countries was statistically significantly linked to that of the core countries before the introduction of the Euro, with this significance disappearing after the introduction of the Euro in 1999. On an individual country level, the same observation holds for Portugal (shown in column (2)) and Spain (shown in column (5)). For Greece, the same observation is valid when analysing the time period starting in 1990 rather than 1980[1] (shown in column (4) of Table 7.3 in Appendix A). Among the periphery countries of the euro area, it appears that only the GDP growth rate of Italy presents a statistically significant association with the GDP growth rate of the core countries after the introduction of the Euro.

The initial estimates of the association between the core and periphery euro area countries discussed above are solely descriptive, since they assume a linearity that is not likely present for the set-up of business cycles. To increase the robustness of the results and further the analysis of the impact of the Euro introduction on business cycle synchronisation, Markov-switching Autoregressive models are employed to disentangle the business cycle dynamics of the core and periphery euro area countries.

[1]This is likely due to the differing dynamics of the GDP growth variable that are present for Greece before the year of 1990 as compared to after. During that period, Greece has exhibited comparatively higher volatility of its GDP growth measure than in any of the following periods.

Table 4.1: Descriptive estimation results

	Dependent variable: GDP growth				
	Periph	PRT	ITA	GRC	ESP
	(1)	(2)	(3)	(4)	(5)
T99	−0.362**	−0.542***	−0.501***	−0.197	−0.206
	(0.154)	(0.183)	(0.105)	(0.440)	(0.134)
CORE	0.438***	0.376**	0.287***	0.659	0.432***
	(0.144)	(0.170)	(0.098)	(0.410)	(0.125)
T99:CORE	0.286	0.274	0.488***	0.129	0.252
	(0.186)	(0.220)	(0.126)	(0.530)	(0.162)
Constant	0.306**	0.525***	0.302***	−0.009	0.406***
	(0.121)	(0.143)	(0.082)	(0.345)	(0.105)
Observations	160	160	160	160	160
R^2	0.258	0.199	0.438	0.053	0.275
Adjusted R^2	0.243	0.183	0.427	0.034	0.261
F Statistic (df = 3; 156)	18.037***	12.901***	40.462***	2.882**	19.733***

Note: *p<0.1; **p<0.05; ***p<0.01

4.2 Markov-switching Autoregressive model results

Estimating the business cycles of the European currency union entails applying a Markov-switching Autoregressive (MS-AR) model to the GDP growth pattern of the euro area countries.

4.2.1 MS-AR model estimation

The first step towards the estimation of the MS-AR model is selecting the optimal number of lags to be included in the autoregressive structure. This is achieved by analyzing the Bayesian information criterion (BIC) (Schwarz et al., 1978), which attains lower values for a better fitting model specification. Allowing the maximum number of lags to cover the period of two years, the optimal number of lags for the MS-AR model for each country is identified by estimating the MS-AR models for all the differing lag-lengths and selecting the one that corresponds to the lowest BIC value for the model fit. The optimal number of lags for the MS-AR model for each country and the corresponding BIC values are presented in Table 7.2 in Appendix A.

Using the optimal number of lags identified, a Markov-switching Autoregressive model is estimated for all the countries in the core and periphery groups. The MS-AR models identify two underlying states that dictate the dynamics of the GDP growth rates, with the characteristics presented in Table 4.2. Here, the first state is selected to be the expansion phase of the business cycle, which, as defined above, corresponds to the period of higher growth of the economy.

Table 4.2: Model estimates based on the Markov-switching Autoregressive models

	DEU		NLD		FIN		AUT	
	Coef.	Std. er.	Coef.	Std. er.	Coef.	Std. er.	Coef.	Std. er.
μ_1	0.3964***	[0.763]	0.3071***	[0.072]	0.6416***	[0.118]	0.3060***	[0.063]
μ_2	0.3399	[0.449]	0.2671	[0.195]	- 0.3828	[0.660]	0.2783**	[0.132]
p_{11}	0.9493		0.9667		0.9521		0.9791	
p_{12}	0.2933		0.0597		0.2161		0.0214	
p_{21}	0.0507		0.0334		0.0479		0.0209	
p_{22}	0.7067		0.9403		0.7839		0.9786	
	PRT		ITA		GRC		ESP	
	Coef.	Std. er.	Coef.	Std. er.	Coef.	Std. er.	Coef.	Std. er.
μ_1	1.2824***	[0.214]	0.4156***	[0.088]	0.2099	[0.331]	0.3119***	[0.078]
μ_2	0.1150	[0.086]	- 0.0699	[0.062]	0.1522	[0.094]	0.0524	[0.037]
p_{11}	0.9476		0.8177		0.9825		0.9552	
p_{12}	0.0385		0.2911		0.0233		0.0304	
p_{21}	0.0524		0.1823		0.0175		0.0448	
p_{22}	0.9615		0.7089		0.9767		0.9696	

Note: *p<0.1; **p<0.05; ***p<0.01

The average GDP growth rates for the two states are given by the μ values presented in Table 4.2, with μ_1 corresponding to the average GDP growth for the expansion phase and μ_2 for the recession phase. Additionally, the constant transition probabilities between the two states are presented, with p_{ij} symbolizing the average probability of transitioning from state i to state j between two consecutive time points[2].

Based on the mean GDP growth estimates for the expansion (μ_1) and recession (μ_2) states presented in Table 4.2, it can be seen that significant differences exist between the countries analyzed. Countries such as Finland, Portugal, Italy and Spain are estimated to have relatively bigger differences between the two states, with the μ estimated values for each state covering a wider range than for the other countries. Contrary to this observation, countries such as Germany, Netherlands, Austria and Greece present with relatively similar states, where the average GDP growth between the two states differs by less than 0.06. While only two of the analysed countries, Finland and Italy, are estimated to have a negative average GDP growth in the recession phase, the estimated lower growth for all the other countries during this phase is in line with the definition of recession considered in this work, pertaining to a period of slower growth of the economy.

The transition probabilities described by the p_{ij} parameter estimates in Table 4.2 reflect the probability of switching between the two estimated states, or remaining in the same state between two consecutive points. Analyzing the estimated values of the p_{22} parameter reveals that some countries are more likely to remain in the recession state once there. It appears that Germany, Finland and Italy are the countries that have a lower likelihood of remaining in the slow-growth state between consecutive time points compared to the other countries analysed.

Allowing for the transition probabilities to vary across time reveals differences existing between the probabilities of switching between states across the time-periods considered. The estimated transition probabilities depending on the time-periods considered are shown in Table 7.6 in Appendix A accounting for two periods, and in Table 7.7 accounting for four periods. In these tables, state 1 corresponds to the period of high growth, and state 2 corresponds to the period of low growth, such that p_{12} is the probability of moving towards the state of slow growth and p_{22} is the probability of remaining in the state of slow growth between two consecutive time-points.

Comparing the transition probabilities for the core countries before and after the introduction of the Euro reveals that following the introduction of the Euro, the countries of the core group are estimated to have a higher probability of moving towards, and remaining in the state of low growth as compared to before the introduction of the Euro, a pattern that is not found for the case of the group of periphery countries. For that group, following the introduction of the Euro, a lower degree of stationarity is observed, with higher probabilities of switching between states across time. Examining the transition probabilities depending on four periods reveals that the higher likelihood of slow growth in the core countries following the introduction of the Euro occurs mostly during the period preceding the crisis as compared to the period after the crisis.

[2] In order to ensure the robustness of the estimation results obtained in this work based on the MS-AR models, the same analysis routine is applied to the data used in Altavilla (2004), resulting in the successful replication of the MS-AR parameter estimates discussed there, indicating towards a correct application of the MS-AR models.

4.2.2 MS-AR state probabilities

The smoothed probabilities of the economy being in the slow-growth state, referred to as the recession state, are presented in Figure 7.2 in Appendix A for the core countries and in Figure 7.4 for the periphery countries. Here, the shadow areas on the plots correspond to the slow periods of growth as identified by the Markov-switching autorgressive models. The model-fit accuracy is depicted in Figure 7.3 and Figure 7.5 in Appendix A. In these graphs, the residuals of the fitted models are shown, with a good model fit being represented by the residuals concentrated around the mean of zero, with no clear trend or patterns.

Drawing from the estimated MS-AR models for the euro area countries, the smoothed probabilities of being in the recession state at every time-point are extracted. Using these probabilities as the depended variable, the equation described in (3.5) is estimated, with the obtained parameter estimates shown in Table 4.3. Based on the parameter estimates shown, it appears that on average, following the introduction of the Euro, a higher growth rate in the core countries group has no statistically significant influence on the probability of a recession for the countries in the periphery group. This is in line with the initial descriptive results discussed previously, where the GDP growth rate of the two groups also appeared unrelated to each other after the introduction of the Euro.

Analyzing individual countries' probabilities of being in a recession as the dependent variable, reveals that while for Portugal, Greece and Spain there is no significant connection established with the core countries' GDP growth, this is not the case for Italy. Namely, Italy is estimated to be the only country among the periphery group which shows a statistically significant connection to the core countries' GDP growth. Based on these observations, it can be concluded that after the introduction of the Euro, higher growth in the core countries is significantly associated to a lower probability of recession for Italy, while for the remaining periphery countries, the introduction of the Euro has not strengthened the relationship between the probability of recession in these countries and the GDP growth rate of the core countries.

In order to ensure that the estimated results are not biased by the definition of the group of the core countries, the analysis is repeated including France into the core countries group, with the estimation results as shown in Table 7.4 in Appendix A. No differences in the estimated relationships occur after the inclusion of France as a core country, implying that the observed dynamics hold for both specification of the core countries group.

The years following the introduction of the Euro were marked by a disruptive event, the financial crisis of 2008, which affected the GDP growth pattern of all the countries analysed (as can be seen in the descriptive plots shown in Figure 7.1 in Appendix A). It is of interest to account for this event in the analysis of the relationship between the core and periphery countries following the introduction of the Euro. Using the probability of being in the recession state estimated based on the MS-AR models, the relationship between this variable and the GDP growth rate in the core countries is estimated for the period following the introduction of the Euro, with a dummy variable marking the years after the financial crisis (starting in 2009). The estimation results from this regression are shown in Table 7.5 in Appendix A.

Separating the period following the Euro introduction into before and after crisis reveals that differences exist in the relationship between probability of recession in the periphery countries and the GDP growth rate in the core countries between the two periods. For the period after the introduction of the Euro and before the crisis, for both Italy and Portugal it holds that higher growth in the core countries is statistically significantly linked with a lower probability of recession in these two countries, a relationship that appears to vanish in the years following the financial crisis. Overall, a significant connection between higher growth in the core countries and lower probability of recession in the periphery countries is not supported for Greece and Spain both before and after the financial crisis, an observation in line with the findings discussed above.

Table 4.3: Estimation results for probability of recession based on the MS-AR models

	Dependent variable: Probability of recession				
	Periph	PRT	ITA	GRC	ESP
	(1)	(2)	(3)	(4)	(5)
T99	0.500^{***}	0.549^{***}	0.278^{***}	0.685^{***}	0.537^{***}
	(0.046)	(0.066)	(0.050)	(0.069)	(0.070)
CORE	0.035	−0.006	−0.044	0.114^{*}	0.126^{*}
	(0.044)	(0.061)	(0.047)	(0.066)	(0.065)
T99:CORE	−0.023	−0.076	-0.130^{**}	0.010	0.054
	(0.055)	(0.079)	(0.061)	(0.084)	(0.084)
Constant	0.297^{***}	0.368^{***}	0.295^{***}	0.155^{***}	0.318^{***}
	(0.037)	(0.052)	(0.039)	(0.055)	(0.055)
Observations	157	159	159	157	158
R^2	0.552	0.401	0.267	0.519	0.417
Adjusted R^2	0.543	0.389	0.253	0.509	0.406
F Statistic	63.255^{***}	34.811^{***}	18.903^{***}	55.318^{***}	36.929^{***}

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

4.3 Business cycle results

Estimating the Markov-switching Autoregressive models allows for obtaining the probability of being in the slow or fast growth phases of the business cycles. Based on the predicted phases, additional business cycle characteristics can be computed.

4.3.1 Business cycle characteristics

Having estimated the two states of the business cycles of the euro area countries, it is of interest to compare them along more dimensions than solely the estimated average GDP growth. For this purpose, several business cycle characteristics are computed as shown in Table 4.4. Here, the business cycle characteristics of expected duration, amplitude and steepness are presented for the core and periphery countries, for the two periods before and after the introduction of the Euro.

Table 4.4: Estimated Business Cycle Characteristics

	Before Euro introduction		After Euro introduction	
	Core	Periphery	Core	Periphery
Expected duration				
Expansion	4.03	4.55	12.53	1.44
Recession	2.09	2.30	1.76	5.95
Amplitude				
Expansion	3.69	3.93	5.71	1.69
Recession	0.96	1.24	-0.53	1.31
Steepness				
Expansion	0.91	0.86	0.46	1.18
Recession	0.46	0.54	-0.30	0.22

Comparing the expected duration of a recession for the core countries between the two periods reveals that the introduction of the Euro is linked to a decrease in the recession duration for the core countries of the euro area. However, it appears that the opposite holds for the periphery group: for those countries, an increased duration of recession is estimated for the period after the introduction of the Euro. Linked to the amplitude of the estimated states, the core countries present with higher margins for the amplitude characteristic, having a higher expansion phase and a deeper recession phase as compared to the periphery countries. Moreover, the range of the amplitude characteristics for the core countries appears to have increased after the introduction of the Euro. Related to the steepness of the two cycles, the introduction of the Euro appears to have slightly decreased the slopes corresponding to the expansion or recession phases of both country groups. Solely the steepness of a recession in the Euro countries has seen an opposite change after the introduction of the Euro, attaining a negative value and thus describing that on average, the recession states in the core countries after the introduction of the Euro occur at a faster pace than before.

The estimated average characteristics of the business cycles of the core and periphery euro area countries are applied to simulating the visual appearance of the business cycles, depicted in Figure 7.6 for the period before the introduction of the Euro, and in Figure 7.7 for the period following the introduction of the Euro. Similarly to the observation discussed based on the business cycle characteristics, these graphs suggest that differences between the business cycles of the two groups increased after the introduction of the Euro, with higher dissimilarities in amplitude and duration being established after the introduction of the Euro.

4.3.2 Business cycle synchronisation

In order to measure the synchronisation of the business cycles of the core and periphery countries of the euro area, the index of concordance is computed, with the results as shown in Table 4.5 for the period preceding the introduction of the Euro, and in Table 4.6 for the period following the introduction of the Euro.

Table 4.5: Estimated Business Cycle Synchronisation before Euro

	Concordance before Euro introduction									
	DEU	NLD	FIN	AUT	PRT	ITA	GRC	ESP	Core	Periph
DEU	1.00	0.43	0.74	0.61	0.42	0.57	0.58	0.39	0.59	0.50
NLD		1.00	0.55	0.77	0.36	0.54	0.23	0.34	0.84	0.23
FIN			1.00	0.49	0.41	0.61	0.59	0.41	0.61	0.51
AUT				1.00	0.30	0.53	0.35	0.41	0.88	0.32
PRT					1.00	0.58	0.78	0.84	0.28	0.84
ITA						1.00	0.55	0.55	0.51	0.61
GRC							1.00	0.81	0.34	0.92
ESP								1.00	0.39	0.89
Core									1.00	0.31
Periph										1.00

Table 4.6: Estimated Business Cycle Synchronisation after Euro

	Concordance after Euro introduction									
	DEU	NLD	FIN	AUT	PRT	ITA	GRC	ESP	Core	Periph
DEU	1.00	0.99	0.99	0.77	0.15	0.51	0.08	0.02	0.99	0.05
NLD		1.00	0.98	0.79	0.17	0.50	0.07	0.01	1.00	0.04
FIN			1.00	0.76	0.14	0.50	0.07	0.04	0.98	0.04
AUT				1.00	0.38	0.55	0.17	0.20	0.79	0.23
PRT					1.00	0.62	0.79	0.82	0.17	0.85
ITA						1.00	0.55	0.51	0.50	0.54
GRC							1.00	0.94	0.07	0.94
ESP								1.00	0.01	0.98
Core									1.00	0.04
Periph										1.00

Comparing the concordance between the core and periphery countries on average, it appears that this measure sees a decrease from 0.31 to 0.04, suggesting that a higher business cycle synchronisation between the core and periphery countries was in place before the Euro introduction as compared to after. Comparing the inter-group concordance values, it appears that the synchronisation of the business cycles of the core countries between themselves has increased after the introduction of the Euro. At the same time, the synchronisation between the individual core and periphery countries has seen a decrease.

Investigating the individual-level synchronisation between the periphery countries and the core group, especially for Greece and Spain, the synchronisation with the core business cycle has decreased from values of 0.34 and 0.39 to values of 0.07 and 0.01 respectively, following the introduction of the Euro. A similar decrease is estimated for Portugal, however to a slightly lower degree, changing from a concordance value of 0.28 before the introduction of the Euro to a value of 0.17 afterwards. It appears that only for Italy there is no decrease in the synchronisation of its business cycle with that of the core group, however the measured synchronisation does not seem to increase either.

Further, it is of interest to examine the business cycle synchronisation between the core and periphery group during the period following the introduction of the Euro separated in two time frames: one before the crisis (with the estimates shown in Table 7.8 in Appendix A) and one after the crisis (with the estimates shown in Table 7.9). Separating the synchronisation measure for each of the two periods reveals that higher synchronisation was common before the crisis as compared to after. However, when comparing the measures of business cycle synchronisation to those before the introduction of the Euro, the same observation holds: it is estimated that the business cycles of the core and periphery countries have seen a lower synchronisation during the periods after the introduction of the Euro. Italy is the periphery country that is an exception to this pattern: its business cycle shows an increased synchronisation with the core group business cycle during the period after the introduction of the Euro but before the crisis, with the concordance measure increasing from 0.55 before the Euro introduction to 0.88 after the Euro introduction and before the crisis. However, after the crisis, the synchronisation measure decreases to a value lower than before the introduction of the Euro, reaching the level of 0.16. A similar pattern holds for Portugal, however to a lesser extent: its synchronisation with the core group changes from 0.28 before the Euro introduction to 0.30 for the period before the crisis, followed by a decrease to 0.05 after the crisis.

Examining how the definition of the group of core countries influences the estimated measures of concordance implies the re-estimation of the results adding France to the group of core euro area countries. Using the core group of countries containing France does not change any of the observations mentioned. Additionally, it appears that France fulfills the pattern observed specific to the other core countries: the business cycle synchronisation between France and the other core countries increases for the period following the introduction of the Euro, while the business cycle synchronisation between France and the periphery countries decreases.

5 | Discussion and limitations

The present work is directed at analyzing the process of business cycle synchronisation between the group of core and periphery countries in the common currency union of Europe. Examining the business cycles of the countries of interest is achieved through the application of Markov-switching Autoregressive models, which is the preferred approach in dealing with the endogeneity and non-linearity aspects of business cycles. Analyzing two possible states for the Markov-switching models allows for simulating two phases of the business cycle: the recession phase, defined as a time period of low growth, and an expansion phase, defined as a period of high growth. Based on the probabilities of being in the recession of expansion phases, the business cycle characteristics and synchronisation between the core and periphery countries of the euro area are assessed.

5.1 Discussion of analysis results

Initial descriptive results based on estimating a linear relationship between the GDP growth rates of the periphery and core euro area countries reveal that while a statistically significant association between the growth pattern of the periphery and core existed before the introduction of the Euro, such a connection seems to have vanished afterwards. The exception to this observed pattern is Italy, whose GDP growth rate maintains the statistical significance of its connection to the growth rate of the core countries even after the introduction of the Euro.

Analyzing the relationship between the probability of a recession in the periphery euro area countries and the GDP growth rate in the core countries entails employing the smoothed probability estimates drawing from the analysed Markov-switching Autoregressive models. In contrast to the initial descriptive results, there is no longer a statistically significant relationship estimated between the growth rate of the core countries and the average probability of a recession in the periphery countries before the introduction of the Euro. Additionally, for the combined impact of the periphery countries, also after the introduction of the Euro, no significant relationship emerges. Solely for Italy, similarly to the preliminary descriptive results, it appears that following the introduction of the Euro, a higher growth rate in the core euro area countries induces a statistically significant decrease in the probability of recession (defined as the phase of slow growth) in Italy. The economical significance of these estimates implies that for a 1% increase in the GDP growth rate per yearly quarter of the core countries, there is an estimated 13% decrease in the probability of the slow-growth state being in place for Italy, ceteris paribus[1].

Focusing on the period following the introduction of the Euro allows for examining the time before and after the financial crisis of 2008. The estimation results surrounding this analysis imply that, before the financial crisis, both Italy and Portugal presented with a statistically significant synchronisation with the business cycle of the core countries, signified

[1]The observed dynamics maintain their pattern when analyzing an alternative specification for the group of core countries, including also France as a core country.

by a negative relationship being estimated between the growth in the core countries group and the probability of recession in these periphery countries. However, after the financial crisis, this relationship is no longer present.

The findings drawing from the analysis of the relationship between the probability of a recession in the periphery countries and the GDP growth rate in the core countries suggest that, on average for the periphery countries group, there is no significant synchronisation present between the measures analysed. While on an individual country level this observation holds for most of the analysed periphery countries, the opposite holds for Italy: it appears that for this periphery country, the introduction of the Euro is associated with an increased synchronisation between the measures analysed, with higher growth in the core countries being linked to lower probabilities of recession when analyzing the whole period following the introduction of the Euro. Distinguishing between time before and after the crisis during this period, reveals that it is the period before the crisis that drives the strength of the relationship between higher growth in the core countries and lower probability of recession in the periphery countries, a relationship that holds for both Italy and Portugal for the period following the introduction of the Euro and preceding the financial crisis.

Allowing for time-dependent transition probabilities in the Markov-switching Autoregressive models reveals that differences exist in the pattern of shifting between the two phases of the business cycles across time. The estimated transition matrices imply that for the period following the introduction of the Euro, the core countries have seen higher probabilities of moving towards and remaining in the slow-growth phase of the business cycle. For the periphery country group, the introduction of the Euro is followed by a period of higher volatility as compared to before.

Focusing on more specific business cycle characteristics, the analysis of this work estimates measures such as expected duration, amplitude and steepness for the expansion and recession phases during the time periods before and after the introduction of the Euro. Based on these characteristics, it can be concluded that following the introduction of the Euro, the business cycles of the core countries have seen a shift towards shorter periods of recession and longer periods of expansion, with higher amplitudes for both states. However, the opposite is observed for the periphery countries, who present with longer recession periods and shorter expansion periods with lower amplitudes for the period following the introduction of the Euro as compared to before.

Finally, investigating the degree of business cycle synchronisation is achieved through estimating the measure of concordance between the countries studied, for the period of before and after the introduction of the Euro. Comparing the average level of concordance between the business cycles of the core and periphery groups reveals a lower level of synchronisation for the period after the introduction of the Euro than before. This decrease is mostly driven by lower business cycle synchronisation of Greece and Spain. For Italy, no decrease or increase in the business cycle synchronisation with the core group is recorded over the whole period following the introduction of the Euro. Solely when examining the period before and after the financial crisis a higher synchronisation of Italy with the core countries is estimated for the period following the introduction of the Euro and before the crisis, with a similar pattern in place for Portugal, however to a lesser extend. This finding is in line with the estimated connection between the growth in the core group and the probability of a recession in the periphery countries, where it is also Italy and Portugal that show a significant synchronisation with the core for the period following the introduction of the Euro and before the crisis. Regarding the group of core countries, it appears that these countries have experienced a stronger business cycle synchronisation among themselves over the period following the creation of the European currency union, during both time frames before and after the crisis[2].

5.2 Conclusion and implications

To sum up, following the analysis of this work focusing on the business cycle synchronisation of the core and periphery countries of the euro area, several findings have emerged, summarized in this section.

Firstly, it appears that on average, the group composed by the periphery countries are estimated to have developed a decreased business cycle synchronisation with the core countries following the introduction of the Euro. Concomitantly, it is estimated that the core countries have seen an increased business cycle synchronisation among themselves following the introduction of the Euro. These observations resonate with several of the findings of other academic work, with statistical support being presented for the decreased synchronisation of the periphery group with the core group after the introduction of the Euro (Belke et al., 2017; Camacho et al., 2006; Lehwald, 2013; Papageorgiou et al., 2010), and increased synchronisation between the core countries in the aftermath of the European currency union creation (Belke et al., 2017; Soares et al., 2011).

Secondly, there are heterogeneous dynamics present when investigating the degree of business cycle synchronisation after the introduction the Euro. For the individual periphery countries of the euro area, it is Greece and Spain that show a weak business cycle synchronisation with the core based on the probability of recession and estimated concordance measures. Solely Italy, and to a very limited degree Portugal, have seen an increased synchronisation with the core group for the period after the introduction of the Euro and before the financial crisis of 2008. These findings are in line with the conclusions drawn by Gayer et al. (2007) and Belke et al. (2017), who also identify Greece and Spain as being the periphery countries exhibiting low business cycle synchronisation with the core group. Especially following the crisis period, the synchronisation between the periphery countries and the core countries group is further decreased, an observation in line with the findings of Gächter et al. (2012). Simultaneously, Italy exhibiting an opposing pattern, with a stable degree of business cycle synchronisation across time, and an increased dependence on the growth of the core countries following the introduction of the Euro, especially for the period preceding the crisis, is a finding supported by more studies around this topic (Belke et al., 2017; Campos and Macchiarelli, 2016; Ferroni and Klaus, 2015).

Thirdly, the analysis in this paper identifies differences in the characteristics of the business cycles pertaining to the core versus periphery countries in the European currency union. It is established that following the introduction of the Euro, the core countries have seen longer periods of expansion and shorter periods of recession as compared to before. However,

[2]When re-estimating the synchronisation measures with the inclusion of France in the group of core countries, the same dynamics persist, with France exhibiting the pattern applicable to other core countries, displaying a higher business cycle synchronisation with the other core countries after the introduction of the Euro.

the opposite holds for the periphery countries: for those countries, the period after the introduction of the Euro is characterised by longer periods of slow growth and shorter periods of high growth. The increased duration of the slow growth phase for the periphery countries is possibly linked to the no-longer available mechanism of exchange rate changes for overcoming economic slow-downs, following after the adoption of a single currency (Eichengreen, 1990, 1992).

Lastly, the analysis of this work highlights another important finding, regarding the amplitude of the business cycles: comparing the amplitude of the expansion and recession phases between the core and periphery countries, significant differences emerge, with the core countries exhibiting higher amplitudes of the business cycle phases. This observation is another indication towards a problematic business cycle synchronisation between the core and periphery countries of the European currency union, where even with synchronised business cycles, differing amplitudes can imply diverging cyclical conditions (Belke et al., 2017).

According to the theory of optimal currency areas, business cycle synchronisation of the member countries is considered to be the most important criterion for a successful performance of a monetary union (Gächter et al., 2012). It is estimated that low business cycle synchronisation is a potential a threat for the optimality of a currency union, increasing the costs of relinquishing the national currencies and the adjustment mechanisms attached to them (Eichengreen, 1990, 1992). In the situation of low business cycle synchronisation among the members of a currency union, the countries in the downward phase of the cycle would benefit more from an expansionary monetary policy, while the reverse would hold for the countries in the upward phase of the cycle, preferring a more restrictive policy (Clarida et al., 1999; Rogoff, 1985).

In light of the discussion and analysis in this work, the estimated weak business cycle synchronisation between the core and periphery countries of the European common currency area following the introduction of the Euro is a challenging and potentially problematic occurrence. While weak business cycle synchronisation is an undesirable outcome, efforts need to be directed at ameliorating this situation and its consequences for the optimality of the euro area. Hypothetically, it is tools such as labour mobility and fiscal integration that are paramount in dealing with consequences of weak business cycle synchronisation (Krugman, 2013). However, labour mobility between the core and periphery countries is currently of limited scope and at lower levels than those present in other common currency areas (Arpaia et al., 2014; Barslund et al., 2014; Hancké, 2013), rendering this absolution mechanism troublesome. Therefore, in dealing with these challenging times, the one mechanism still available for solving the existing issues is the adoption of an overarching fiscal union for the countries of the euro area, an idea that continues to gain momentum among recent academic discussion (Allard et al., 2013; Berger et al., 2019).

5.3 Limitations and future research

The analysis of this work concerns the business cycle synchronisation between the core and periphery countries in the euro area, covering the time span between 1980 and 2020, which could pose several restrictions on the estimated relationships.

While the time frame between 1990 and 2000 is agreed upon as a period of higher synchronisation between the euro area countries (Papageorgiou et al., 2010), including also the 10 years preceding this period increases the volatility of the considered measures. Additionally, extending the examined time frame to include the 20 years after the introduction of the Euro leads to further expansion of the variability in the growth index analysed. This is reflected by the recession and expansion phases estimated by the Markov-switching models: when considering the shorter time frame before and immediately after the introduction of the Euro, the recession and expansion phases estimated have a higher contrast between themselves, with the recession phase having a negative estimated average growth, and the expansion having a positive estimated average growth. However, when considering a larger time frame, the recession and expansion phases estimated become more similar to each other, becoming a reflection of periods of slow versus high growth, rather than contractions versus expansions.

Analysing business cycle synchronisation, this work relies solely on the measure of GDP growth. This implies high dependency of the estimated results on the reliability and accuracy of the reported data, which can become problematic (for example when analyzing the business cycle of Ireland, the GDP growth data of which is influences by additional external factors after 2015, making an accurate analysis difficult). While the exact determinants of business cycles are still factors under investigation (Baxter and Kouparitsas, 2005), a further extension to the current work could be based on employing a different measure pertaining to the economic synchronisation between countries. A combined index based on such measures as GDP growth rates, industrial production, employment rates, financial indicators and others could be constructed in order to increase the coverage of the examined determinants of business cycle synchronisation.

Regarding the core and periphery countries considered in the current analysis, it is of interest to examine how would changes in the definition of the two core and periphery country groups impact the observed patterns, for example by creating the two clusters based on supplementary economic and political indicators. Additionally, a further extension to this research could examine also the countries that joined the euro area at a later stage: Slovenia, Cyprus, Malta, Slovakia, Estonia, Latvia and Lithuania. Examining their business cycle synchronisation with the core countries could expand on the generalizability of the findings presented in this work, while focusing especially on Estonia, Latvia and Lithuania (who joined the euro area after 2011) could allow for circumventing the potential confounds induced by the financial crisis.

6 | References

Alesina, A. and R. Barro (2002). Currency unions. *The Quarterly Journal of Economics 117*(2), 409–436.

Alesina, A., R. Barro, and S. Tenreyro (2002). Optimal currency areas. *NBER macroeconomics annual 17*, 301–345.

Allard, C., P. Brooks, J. Bluedorn, F. Bornhorst, F. Ohnsorge, and K. Puh (2013). *Toward a fiscal union for the euro area.* Number 13-19. International Monetary Fund.

Altavilla, C. (2004). Do EMU members share the same business cycle? *JCMS: Journal of Common Market Studies 42*(5), 869–896.

Arpaia, A., A. Kiss, B. Palvolgyi, A. Turrini, et al. (2014). Labour mobility and labour market adjustment in the EU. Technical report, Directorate General Economic and Financial Affairs (DG ECFIN).

Artis, M., H. Krolzig, and J. Toro (2004). The European business cycle. *Oxford Economic Papers 56*(1), 1–44.

Barro, R. and S. Tenreyro (2007). Economic effects of currency unions. *Economic Inquiry 45*(1), 1–23.

Barslund, M., M. Busse, C. Vargas-Silva, P. Kaczmarczyk, T. Baas, M. Peinado, J. Jimeno, A. Lacuesta, B. Galgóczi, and J. Leschke (2014). Labour mobility in the EU: Dynamics, patterns and policies. *Intereconomics 49*(3), 116–158.

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

Bayoumi, T. and B. Eichengreen (1993). *Shocking Aspects of European Monetary Integration.* Oxford: Cambridge University Press.

Beine, M., B. Candelon, and K. Sekkat (2003). EMU membership and business cycle phases in Europe: Markov-switching VAR analysis. *Journal of Economic Integration*, 214–242.

Belke, A., C. Domnick, and D. Gros (2017). Business cycle synchronization in the EMU: Core vs. periphery. *Open Economies Review 28*(5), 863–892.

Berger, H., G. Dell'Ariccia, and M. Obstfeld (2019). Revisiting the economic case for fiscal union in the Euro area. *IMF Economic Review 67*(3), 657–683.

Blanchard, O., C. Erceg, and J. Lindé (2017). Jump-starting the euro-area recovery: would a rise in core fiscal spending help the periphery? *NBER Macroeconomics Annual 31*(1), 103–182.

Bordo, M. and L. Jonung (2003). The future of EMU: what does the history of monetary unions tell us? In *Monetary Unions*, pp. 52–79. Routledge.

Burns, A. and W. Mitchell (1947). Measuring business cycles.

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

Campos, N. and C. Macchiarelli (2016). Core and periphery in the European Monetary Union: Bayoumi and Eichengreen 25 years later. *Economics Letters 147*, 127–130.

Clarida, R., J. Gali, and M. Gertler (1999). The science of monetary policy: a new Keynesian perspective. *Journal of economic literature 37*(4), 1661–1707.

Clark, T. and E. Van Wincoop (2001). Borders and business cycles. *Journal of international Economics 55*(1), 59–85.

Cooley, T. (1995). *Frontiers of business cycle research.* Princeton University Press.

De Grauwe, P. (2020). *Economics of the monetary union.* Oxford University Press, USA.

De Grauwe, P. and F. Mongelli (2005). Endogeneities of optimum currency areas: What brings countries sharing a single currency closer together?

De Haan, J., R. Inklaar, and R. Jong-A-Pin (2008). Will business cycles in the euro area converge? A critical survey of empirical research. *Journal of economic surveys 22*(2), 234–273.

De Santis, R. and T. Cesaroni (2016). Current account 'core–periphery dualism' in the EMU. *The World Economy 39*(10), 1514–1538.

Delors, J. (1989). *Report on economic and monetary union in the European Community. Collection of papers submitted to the Committee for the Study of Economic and Monetary Union (1989) (preparatory paper for Delors Report). By Committee for the Study of Economic and Monetary Union.*

Eichengreen, B. (1990). One money for Europe? Lessons from the US currency union. *Economic policy 5*(10), 117–187.

Eichengreen, B. (1992). Is Europe an optimum currency area? In *The European Community after 1992*, pp. 138–161. Springer.

Eichengreen, B. (2001). Capital account liberalization: What do cross-country studies tell us? *The world bank economic review 15*(3), 341–365.

Fatás, A. (1997). EMU: Countries or regions? Lessons from the EMS experience. *European Economic Review 41*(3-5), 743–751.

Feldstein, M. (1997). The political economy of the European Economic and Monetary Union: Political sources of an economic liability. *Journal of Economic Perspectives 11*(4), 23–42.

Ferroni, F. and B. Klaus (2015). Euro Area business cycles in turbulent times: convergence or decoupling? *Applied Economics 47*(34-35), 3791–3815.

Flandreau, M. (1996). The French crime of 1873: An essay on the emergence of the international gold standard, 1870–1880. *The Journal of Economic History 56*(4), 862–897.

Frankel, J. and A. Rose (1998). The endogenity of the optimum currency area criteria. *The Economic Journal 108*(449), 1009–1025.

Friedman, M. (1953). The case for flexible exchange rates. *Essays in positive economics 157*, 203.

Gächter, M., A. Riedl, D. Ritzberger-Grünwald, et al. (2012). Business cycle synchronization in the euro area and the impact of the financial crisis. *Monetary Policy & the Economy 2*(12), 33–60.

Gale, D. and X. Vives (2002). Dollarization, bailouts, and the stability of the banking system. *The Quarterly Journal of Economics 117*(2), 467–502.

Gayer, C. et al. (2007). A fresh look at business cycle synchronisation in the euro area. Technical report, Directorate General Economic and Financial Affairs (DG ECFIN).

Glick, R. and A. Rose (2016). Currency unions and trade: A post-EMU reassessment. *European Economic Review 87*, 78–91.

Grigoraş, V. and I. Stanciu (2016). New evidence on the (de) synchronisation of business cycles: Reshaping the European business cycle. *International Economics 147*, 27–52.

Guidolin, M. and M. Pedio (2018). *Essentials of time series for financial applications*. Academic Press.

Hamilton, J. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica: Journal of the Econometric Society*, 357–384.

Hamilton, J. and B. Raj (2013). *Advances in Markov-switching models: Applications in business cycle research and finance*. Springer Science & Business Media.

Hancké, B. (2013). *Unions, central banks, and EMU: Labour market institutions and monetary integration in Europe*. OUP Oxford.

Harding, D. and A. Pagan (2002). Dissecting the cycle: a methodological investigation. *Journal of monetary economics 49*(2), 365–381.

Imbs, J. (2004). Trade, finance, specialization, and synchronization. *Review of economics and statistics 86*(3), 723–734.

Imbs, J. (2006). The real effects of financial integration. *Journal of International Economics 68*(2), 296–324.

Jespersen, J. (2016). Why Was the EMU Established? Different Perspectives. In *The Euro*, pp. 23–37. Springer.

Kalemli-Ozcan, S., B. Sorensen, and O. Yosha (2004). *Asymmetric shocks and risk sharing in a monetary union: Updated evidence and policy implications for Europe.*

Kaufmann, S. et al. (2003). The business cycle of European countries Bayesian clustering of country-individual Ip growth series. Technical report.

Kenen, P. (1969). The theory of optimum currency areas: an eclectic view. *Monetary problems of the international economy 45*(3), 41–60.

Konstantakopoulou, I. and E. Tsionas (2011). The business cycle in Eurozone economies (1960 to 2009). *Applied Financial Economics 21*(20), 1495–1513.

Kouparitsas, M. (2001). Is the United States an optimum currency area? An empirical analysis of regional business cycles.

Krolzig, H. (2001). Markov-switching procedures for dating the Euro-zone business cycle. *Vierteljahrshefte zur Wirtschaftsforschung 70*(3), 339–351.

Krugman, P. (1991). *Geography and trade.* MIT press.

Krugman, P. (2013). Revenge of the optimum currency area. *NBER Macroeconomics Annual 27*(1), 439–448.

Lehwald, S. (2013). Has the Euro changed business cycle synchronization? Evidence from the core and the periphery. *Empirica 40*(4), 655–684.

McKinnon, R. (1963). Optimum currency areas. *The American economic review 53*(4), 717–725.

Miles, W. and C. Vijverberg (2018). Did the euro common currency increase or decrease business cycle synchronization for its member countries? *Economica 85*(339), 558–580.

Mink, M., J. Jacobs, and J. de Haan (2012). Measuring coherence of output gaps with an application to the euro area. *Oxford Economic Papers 64*(2), 217–236.

Mitchell, W. (1927). Introductory pages to"Business Cycles: The Problem and Its Setting". In *Business Cycles: The Problem and Its Setting*, pp. 23–0. NBER.

Mundell, R. (1961). A theory of optimum currency areas. *The American economic review 51*(4), 657–665.

Nitsch, V. (2002). Honey, I shrunk the currency union effect on trade. *The World Economy 25*(4), 457–457.

OECD (2020). Organisation for economic co-operation and development, quarterly GDP (indicator). *Accessed: 2020-05-01*.

Ögren, A. (2020). Currency Unions. *Handbook of the History of Money and Currency*, 747–770.

Papageorgiou, T., P. Michaelides, and J. Milios (2010). Business cycles synchronization and clustering in Europe (1960–2009). *Journal of Economics and Business 62*(5), 419–470.

Rockoff, H. (2000). How long did it take the United States to become an optimal currency area? Technical report, National Bureau of Economic Research.

Rogoff, K. (1985). The optimal degree of commitment to an intermediate monetary target. *The quarterly journal of economics 100*(4), 1169–1189.

Rose, A. (2000). One money, one market: the effect of common currencies on trade. *Economic policy 15*(30), 08–45.

Rose, A. and E. Van Wincoop (2001). National money as a barrier to international trade: The real case for currency union. *American Economic Review 91*(2), 386–390.

RStudio Team (2015). *RStudio: Integrated Development Environment for R.* Boston, MA: RStudio, Inc.

Sanchez-Espigares, J. and A. Lopez-Moreno (2018). *MSwM: Fitting Markov Switching Models.* R package version 1.4.

Schäfer, D. (2016). A banking union of ideas? The impact of ordoliberalism and the vicious circle on the EU banking union. *JCMS: Journal of Common Market Studies 54*(4), 961–980.

Schwarz, G. et al. (1978). Estimating the dimension of a model. *The annals of statistics 6*(2), 461–464.

Soares, Maria Joana et al. (2011). Business cycle synchronization and the Euro: A wavelet analysis. *Journal of Macroeconomics 33*(3), 477–489.

Vermunt, J. and J. Magidson (2016). Latent GOLD 5.1: innovative applications of statistical modeling. *Belmont, Massachusetts: Statistical Innovations Inc*.

Von Hagen, J. and M. Neumann (1994). Real exchange rates within and between currency areas: How far away is EMU? *The Review of Economics and Statistics*, 236–244.

Werner, P. (1970). *Report to the Council and the Commission on the Realization by Stages of Economic and Monetary Union in the Community.*

Willett, T., O. Permpoon, and C. Wihlborg (2010). Endogenous OCA analysis and the early euro experience. *The World Economy 33*(7), 851–872.

Wortmann, M. and M. Stahl (2016). One Size Fits Some: A Reassessment of EMU's Core-periphery Framework. *Journal of Economic Integration*, 377–413.

Yeager, L. (1958). Exchange Rates Within a Common Market. *Social Research*, 415–438.

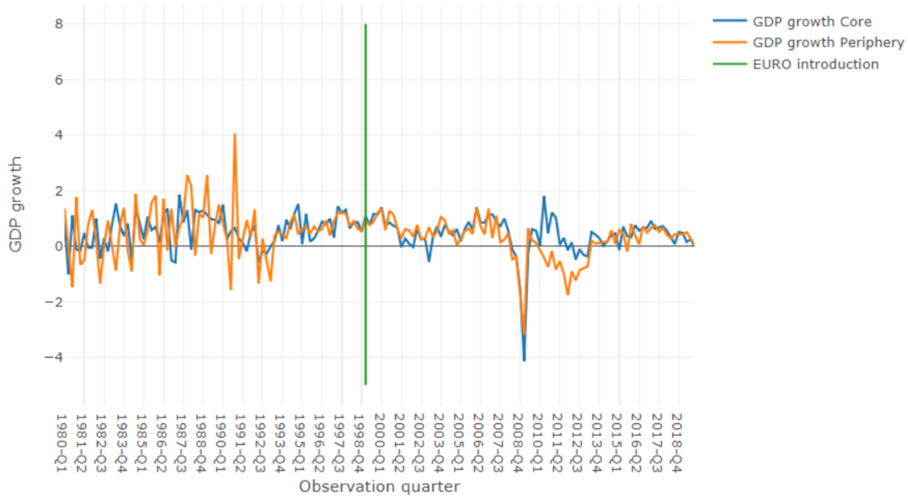
7 | Appendix A: Figures and tables

Table 7.1: Existing studies employing Markov-switching models for EMU BCS analysis

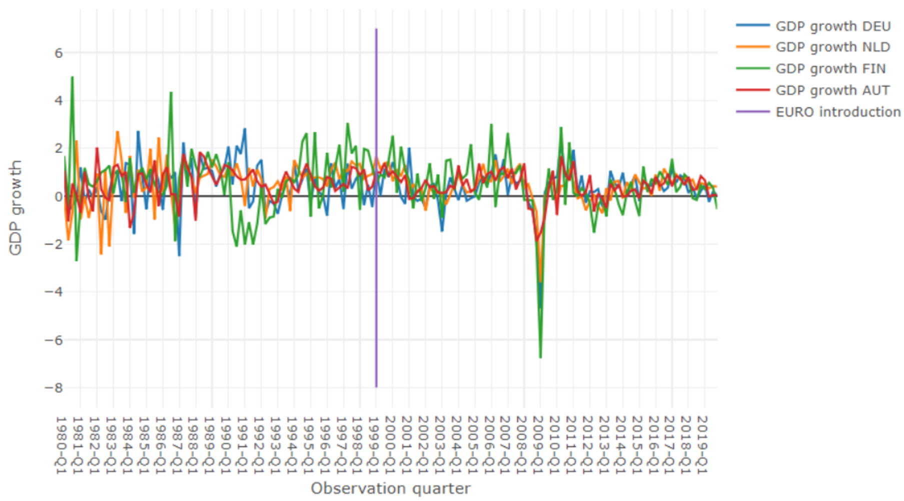
Study	Data used	Conclusions
Beine et al. (2003)	Unemployment (1975 - 1996) quarterly	Higher synchronisation among EMU members compared to periphery
Artis et al. (2004)	Industrial Prod. (1970 - 1996) monthly	Considerable commonalities in business cycles
Altavilla (2004)	GDP (1980 - 2002) quarterly	Classical business cycles became more synchronized after 1991
Kaufmann et al. (2003)	Industrial Prod. (1978 - 2001) quarterly	European countries are a cyclically coherent group
Krolzig (2001)	GDP (1979 - 1998) quarterly	Presence of Euro-zone cycle although not perfectly synchronized

Table 7.2: Lag length selection for the MS-AR models

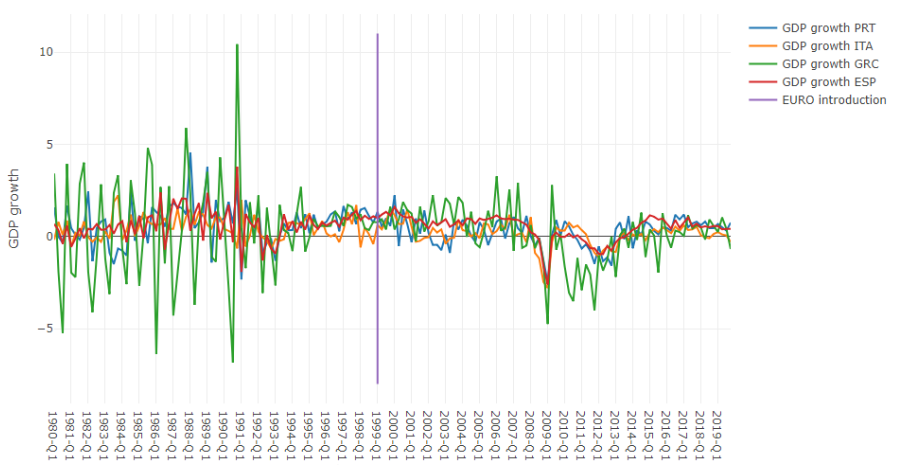
Country	Code	Optimal number of lags	BIC Value
Germany	DEU	1	430.93
Netherlands	NLD	1	351.18
Finland	FIN	1	527.17
Austria	AUT	1	290.02
Portugal	PRT	1	448.52
Italy	ITA	1	303.03
Greece	GRC	3	643.61
Spain	ESP	2	234.49



(a) General



(b) Core

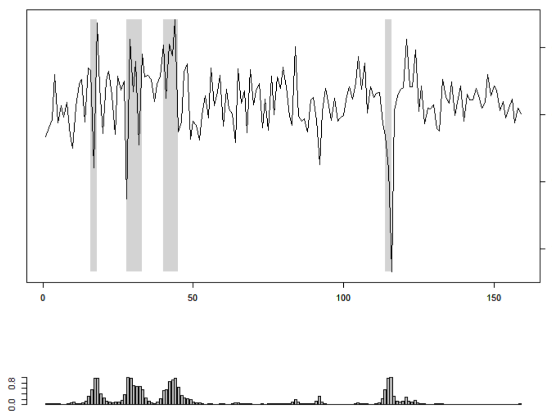


(b) Periphery

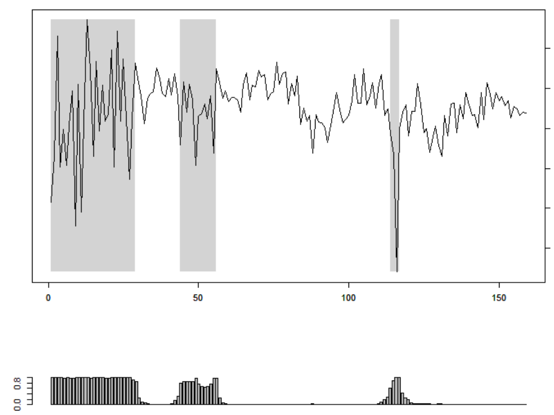
Figure 7.1: GDP growth of core versus periphery euro area countries

Table 7.3: Descriptive estimation results, data from 1990

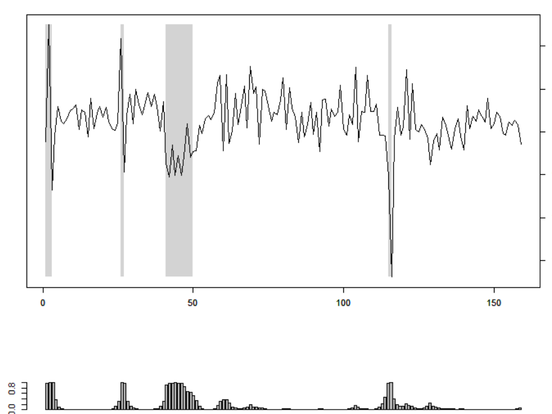
	Dependent variable: GDP growth				
	Periph	PRT	ITA	GRC	ESP
	(1)	(2)	(3)	(4)	(5)
T99	−0.164	−0.313	−0.299**	−0.015	−0.027
	(0.179)	(0.199)	(0.132)	(0.491)	(0.173)
CORE	0.746***	0.731***	0.386**	1.161**	0.703***
	(0.206)	(0.230)	(0.152)	(0.567)	(0.199)
T99:CORE	−0.022	−0.081	0.389**	−0.374	−0.020
	(0.229)	(0.255)	(0.169)	(0.629)	(0.221)
Constant	0.108	0.297*	0.099	−0.192	0.227
	(0.160)	(0.178)	(0.118)	(0.439)	(0.154)
Observations	120	120	120	120	120
R^2	0.384	0.326	0.518	0.106	0.361
Adjusted R^2	0.368	0.308	0.505	0.082	0.344
F Statistic (df = 3; 116)	24.131***	18.674***	41.474***	4.562***	21.814***
Note:					*p<0.1; **p<0.05; ***p<0.01



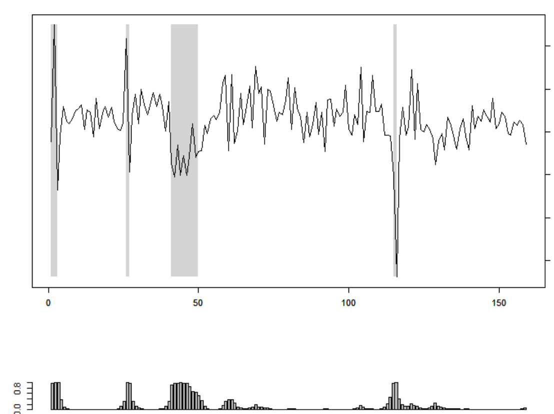
(a) Germany



(b) Netherlands

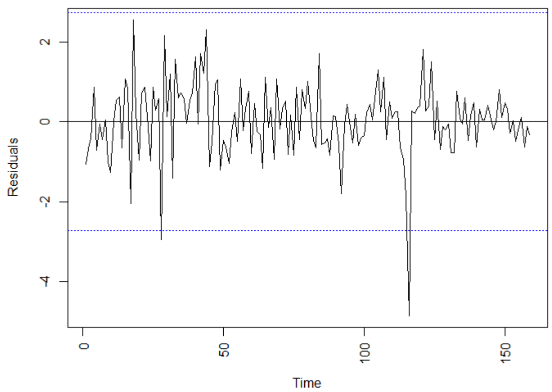


(c) Finland

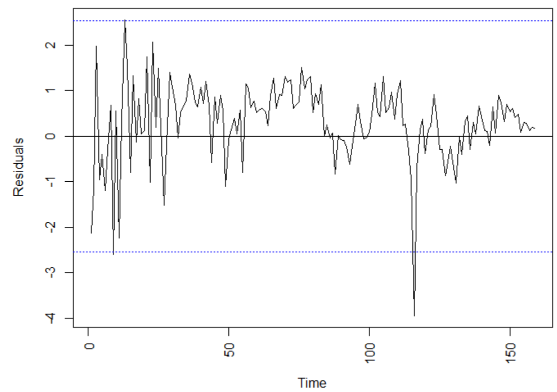


(d) Austria

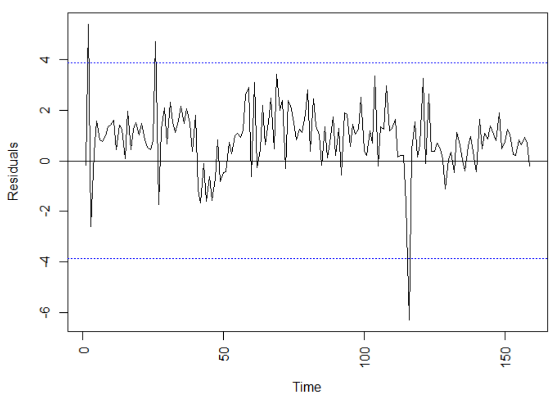
Figure 7.2: GDP Growth and Smoothed Probabilities of slow-growth state, core countries



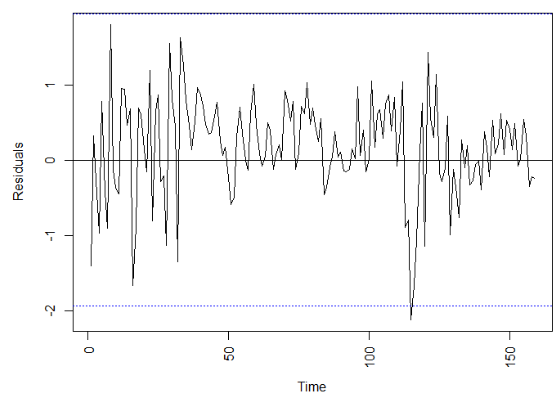
(a) Germany



(b) Netherlands

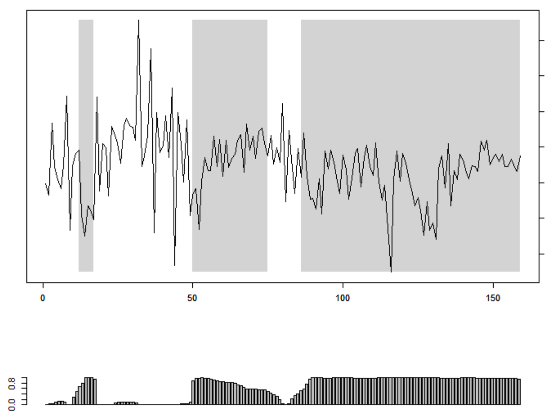


(c) Finland

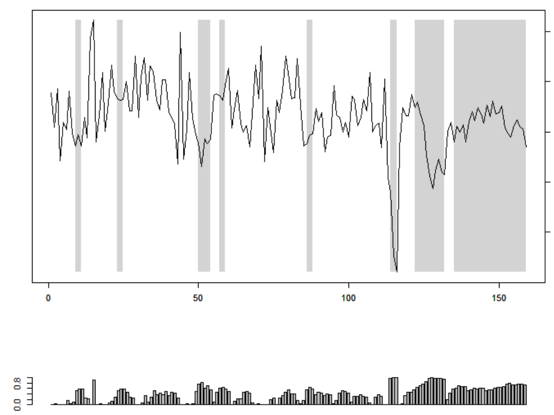


(d) Austria

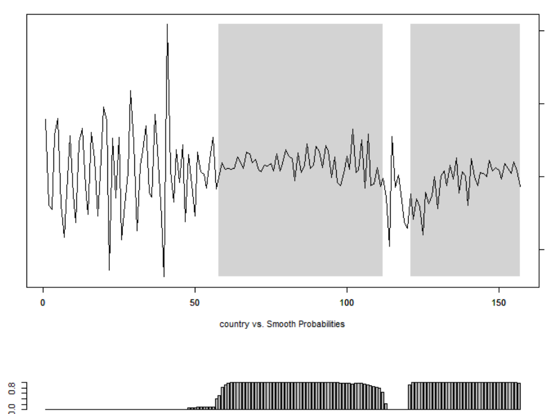
Figure 7.3: Residuals from the MS-AR models, core countries



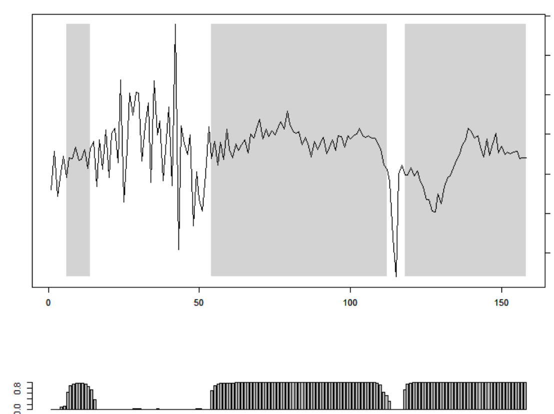
(a) Portugal



(b) Italy

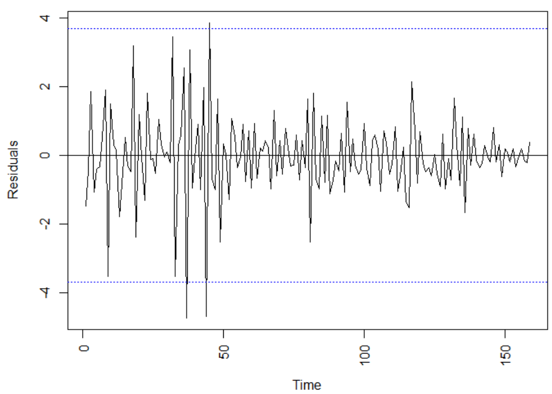


(c) Greece

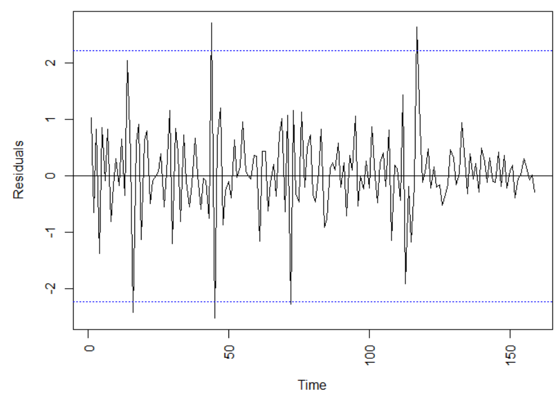


(d) Spain

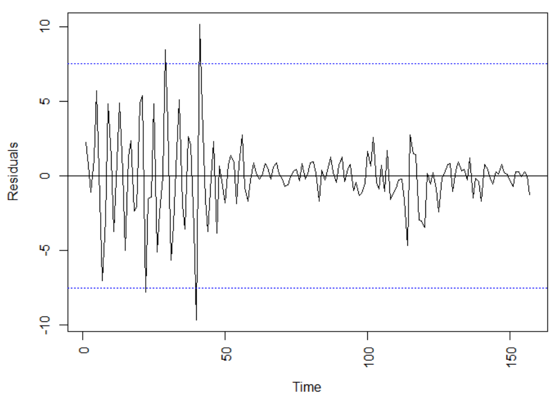
Figure 7.4: GDP Growth and Smoothed Probabilities of slow-growth state, periphery countries



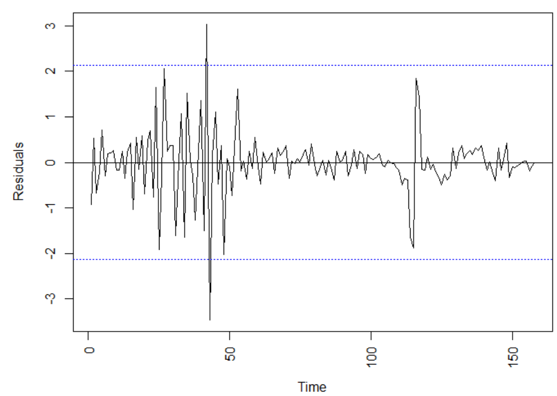
(a) Portugal



(b) Italy



(c) Greece



(d) Spain

Figure 7.5: Residuals from the MS-AR models, periphery countries

Table 7.4: Estimation results for probability of recession based on the MS-AR models, France included in the core group

	Dependent variable: probability of recession				
	Periph	PRT	ITA	GRC	ESP
	(1)	(2)	(3)	(4)	(5)
T99	0.496***	0.539***	0.279***	0.685***	0.535***
	(0.048)	(0.068)	(0.052)	(0.072)	(0.073)
CORE	0.030	−0.035	−0.052	0.126*	0.140*
	(0.050)	(0.069)	(0.053)	(0.075)	(0.074)
T99:CORE	−0.016	−0.064	−0.141**	0.015	0.065
	(0.062)	(0.088)	(0.068)	(0.094)	(0.094)
Constant	0.300***	0.385***	0.300***	0.149**	0.312***
	(0.039)	(0.054)	(0.041)	(0.058)	(0.058)
Observations	157	159	159	157	158
R^2	0.551	0.404	0.268	0.519	0.419
Adjusted R^2	0.542	0.393	0.254	0.510	0.408
F Statistic	63.031***	35.254***	19.086***	55.458***	37.257***

Note: *p<0.1; **p<0.05; ***p<0.01

Table 7.5: Estimation results for probability of recession based on the MS-AR models, impact of the financial crisis

	Dependent variable:				
	Periph	PRT	ITA	GRC	ESP
	(1)	(2)	(3)	(4)	(5)
T09	0.093**	0.122*	0.225***	−0.053	0.079
	(0.040)	(0.062)	(0.057)	(0.075)	(0.053)
CORE	0.005	−0.171***	−0.201***	0.148*	0.243***
	(0.042)	(0.065)	(0.060)	(0.078)	(0.055)
T09:CORE	0.033	0.169**	0.093	−0.050	−0.082
	(0.050)	(0.078)	(0.072)	(0.094)	(0.066)
Constant	0.746***	0.865***	0.453***	0.865***	0.801***
	(0.032)	(0.050)	(0.046)	(0.061)	(0.043)
Observations	84	84	84	84	84
R^2	0.128	0.243	0.442	0.116	0.326
Adjusted R^2	0.095	0.214	0.421	0.083	0.301
F Statistic (df = 3; 80)	3.910**	8.555***	21.113***	3.488**	12.905***

Note: *p<0.1; **p<0.05; ***p<0.01

Table 7.6: Time-dependent transition matrix, two periods

Country	Transition matrix before Euro introduction		Transition matrix after Euro introduction	
DEU	0.9045	0.0955	0.9522	0.0478
	0.2073	0.7927	0.5433	0.4567
NLD	0.9969	0.0037	0.9591	0.0409
	0.0394	0.9606	0.2866	0.7134
FIN	0.9325	0.0675	0.9685	0.0315
	0.2138	0.7862	0.4685	0.5315
AUT	0.9958	0.0042	0.9751	0.0249
	0.0318	0.9682	0.0601	0.9399
PRT	0.9909	0.0091	0.9025	0.0975
	0.0218	0.9782	0.1478	0.8522
ITA	0.9974	0.0026	0.9678	0.0322
	0.7527	0.2473	0.1915	0.8085
GRC	0.9936	0.0064	0.9784	0.0216
	0.0210	0.9790	0.0610	0.9390
ESP	0.9838	0.0162	0.9793	0.0207
	0.0235	0.8765	0.0466	0.9534
Core	0.9973	0.0027	0.9835	0.0165
	0.5020	0.4980	0.3639	0.6361
Periph	0.9928	0.0072	0.9794	0.0206
	0.0215	0.9785	0.0539	0.9461

Table 7.7: Time dependent transition probabilities, four periods

Country	Period 1 ('80s)		Period 2 ('90s)		Period 3 (Euro intro)		Period 4 (after crisis)	
	p_{12}	p_{22}	p_{12}	p_{22}	p_{12}	p_{22}	p_{12}	p_{22}
DEU	0.2651	0.6814	0.1065	0.9959	0.7875	0.8364	0.3684	0.9948
NLD	0.0101	0.9632	0.1226	0.0576	0.1007	0.5262	0.0403	0.8122
FIN	0.0545	0.7104	0.4004	0.9281	0.3484	0.0311	0.0885	0.5715
AUT	0.8978	0.9363	0.0065	0.2327	0.0317	0.9667	0.0045	0.9424
PRT	0.6977	0.9475	0.0039	0.9292	0.2728	0.7942	0.0087	0.9443
ITA	0.2561	0.1219	0.3930	0.3459	0.1041	0.9179	0.1991	0.9610
GRC	0.6310	0.9974	0.0038	0.9276	0.0951	0.1027	0.0036	0.9416
ESP	0.9505	0.7541	0.0115	0.9219	0.0295	0.9701	0.0032	0.9513
Core	0.0036	0.4988	0.0022	0.4520	0.0280	0.9118	0.0019	0.5746
Periph	0.8415	0.9850	0.0043	0.9247	0.0298	0.9684	0.0032	0.9456

Table 7.8: Estimated Business Cycle Synchronisation in euro area, before crisis

	Concordance 1999Q1 - 2008Q4									
	DEU	NLD	FIN	AUT	PRT	ITA	GRC	ESP	Core	Periph
DEU	1.00	1.00	0.98	0.93	0.30	0.88	0.03	0.00	1.00	0.05
NLD		1.00	0.98	0.93	0.30	0.88	0.03	0.00	1.00	0.05
FIN			1.00	0.90	0.28	0.85	0.00	0.03	0.98	0.03
AUT				1.00	0.38	0.80	0.10	0.08	0.93	0.13
PRT					1.00	0.38	0.73	0.70	0.30	0.75
ITA						1.00	0.15	0.13	0.88	0.18
GRC							1.00	0.98	0.03	0.98
ESP								1.00	0.00	0.95
Core									1.00	0.05
Periph										1.00

Table 7.9: Estimated Business Cycle Synchronisation in euro area, after crisis

	Concordance after 2009Q1									
	DEU	NLD	FIN	AUT	PRT	ITA	GRC	ESP	Core	Periph
DEU	1.00	0.98	1.00	0.64	0.02	0.18	0.13	0.05	0.97	0.05
NLD		1.00	0.98	0.66	0.05	0.16	0.11	0.02	1.00	0.02
FIN			1.00	0.64	0.02	0.18	0.13	0.05	0.98	0.05
AUT				1.00	0.39	0.32	0.23	0.32	0.66	0.32
PRT					1.00	0.84	0.84	0.93	0.05	0.93
ITA						1.00	0.91	0.86	0.16	0.86
GRC							1.00	0.91	0.11	0.91
ESP								1.00	0.02	1.00
Core									1.00	0.02
Periph										1.00

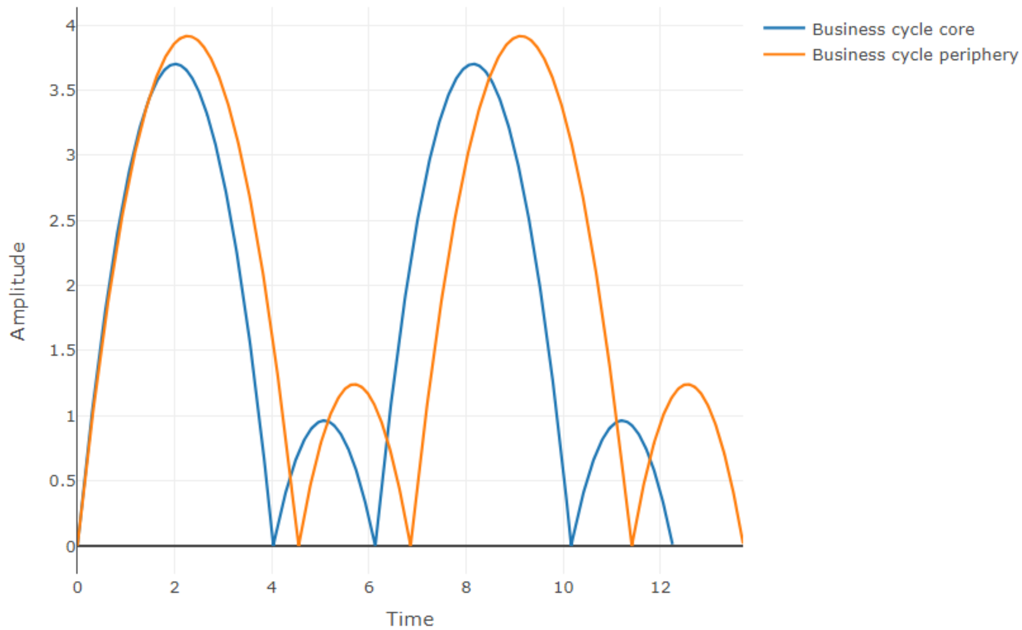


Figure 7.6: Simulated business cycles core and periphery, before Euro introduction

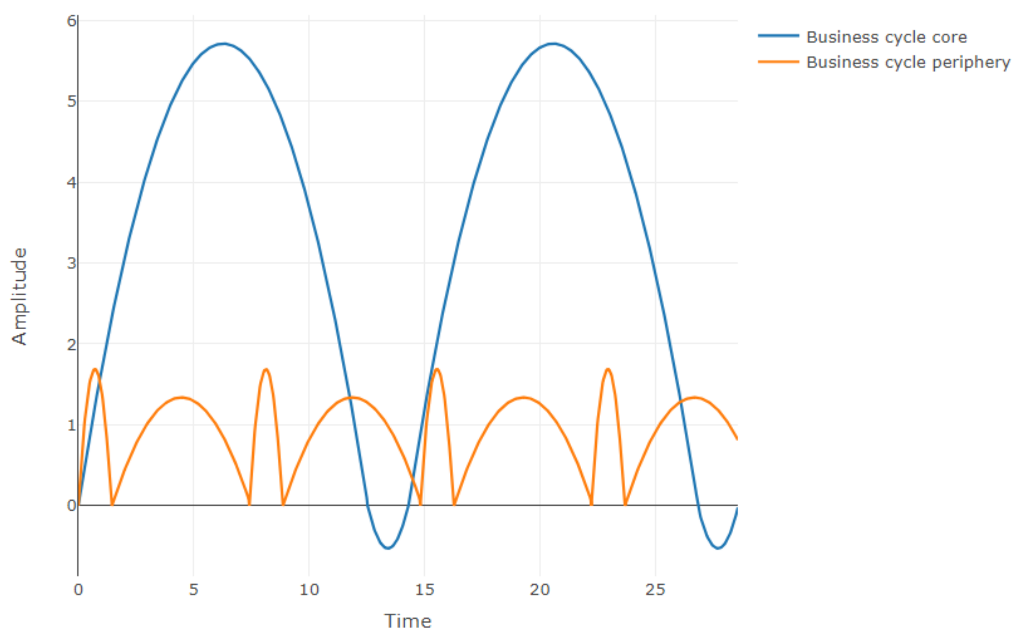


Figure 7.7: Simulated business cycles core and periphery, after Euro introduction

8 | Appendix B: R-code

```
rm(list=ls())
#Installing the packages required for the analysis
library(MSwM)
library(plotly)
library(stargazer)
library(dynlm)
library(tidyr)

#Loading data to R
mydata<-read.csv("data.csv")

#Creating dummy for Euro introduction
mydata$T99<-c(0)
mydata$T99[mydata$time>=77]<-1

#Creating average of percentage GDP growth for the core countries
mydata$CORE<-c(NA)
mydata$CORE<-rowMeans(mydata[c("DEU","NLD","FIN","AUT")])

#Creating average of percentage GDP growth for the periphery countries
mydata$Periph<-c(NA)
mydata$Periph<-rowMeans(mydata[c("PRT","ITA","GRC","ESP")])

#Performing the preliminary analysis
#mydata<-mydata[mydata$time>=41,] #For focusing on data after 1990

#Average periphery
checkPeriph<-lm(Periph~T99+CORE+T99:CORE,data=mydata)
summary(checkPeriph)

#Specific EMU periphery countries
checkPortugal<-lm(PRT~T99+CORE+T99:CORE,data=mydata)
summary(checkPortugal)

checkItaly<-lm(ITA~T99+CORE+T99:CORE,data=mydata)
summary(checkItaly)

checkGreece<-lm(GRC~T99+CORE+T99:CORE,data=mydata)
summary(checkGreece)

checkSpain<-lm(ESP~T99+CORE+T99:CORE,data=mydata)
summary(checkSpain)

#Exporting the parameter estimates to tabel in latex format
stargazer(checkPeriph,checkPortugal,checkItaly,checkGreece,checkSpain,t.auto=F, p.auto=F, title="Descriptive estimation
     results", align=TRUE,dep.var.labels=c("Periph"), no.space=TRUE,single.row=FALSE,omit.stat=c("ser"))

#Creating graph for core countries GDP growth
graphGDPcore<-plot_ly(mydata,x= ~quarter,y= ~DEU,type='scatter',mode = 'line', name="GDP growth DEU")%>%
  layout(xaxis = list(title = 'Observation quarter'),yaxis = list (title = 'GDP growth'))%>%
  add_trace(y=~NLD,type='scatter',mode = 'line', name="GDP growth NLD")%>%
  add_trace(y=~FIN,type='scatter',mode = 'line', name="GDP growth FIN")%>%
  add_trace(y=~AUT,type='scatter',mode = 'line', name="GDP growth AUT")%>%
  add_segments(x = "1999-Q1", xend = "1999-Q1", y = -8, yend = 7,name="EURO introduction")
graphGDPcore

#Creating graph for periphery countries GDP growth
graphGDPperiph<-plot_ly(mydata,x= ~quarter,y= ~PRT,type='scatter',mode = 'line', name="GDP growth PRT")%>%
  layout(xaxis = list(title = 'Observation quarter'),yaxis = list (title = 'GDP growth'))%>%
  add_trace(y=~ITA,type='scatter',mode = 'line', name="GDP growth ITA")%>%
  add_trace(y=~GRC,type='scatter',mode = 'line', name="GDP growth GRC")%>%
  add_trace(y=~ESP,type='scatter',mode = 'line', name="GDP growth ESP")%>%
  add_segments(x = "1999-Q1", xend = "1999-Q1", y = -8, yend = 11,name="EURO introduction")
graphGDPperiph

#Creating graph for core versus periphery average GDP grouth
graphGDPgeneral<-plot_ly(mydata,x= ~quarter,y= ~CORE,type='scatter',mode = 'line', name="GDP growth Core")%>%
  layout(xaxis = list(title = 'Observation quarter'),yaxis = list (title = 'GDP growth'))%>%
  add_trace(y=~Periph,type='scatter',mode = 'line', name="GDP growth Periphery")%>%
  add_segments(x = "1999-Q1", xend = "1999-Q1", y = -5, yend = 8,name="EURO introduction")
graphGDPgeneral



##################################
#Markov-switching model analysis  #
##################################


set.seed(100)
#Lag length selection based on BIC and AIC information criterion
nr_lags <- 1:8
```

```
BICdata<-data.frame(matrix(NA, nrow = 8, ncol = 13))
AICdata<-data.frame(matrix(NA, nrow = 8, ncol = 13))
colnames(BICdata)<-names(mydata[,3:15])
colnames(AICdata)<-names(mydata[,3:15])
minBIClag<-rep(0,13)
minAIClag<-rep(0,13)
for (i in 3:15){ #run for 14 and 15 separately too
  country<-mydata[,i]
  model<- lm(country~1)
  for (lags in 1:8){
    model_ms<-msmFit(model,k=2,p=lags,sw=rep(TRUE,lags+2))
    swi   <- model_ms@switch[-length(model_ms@switch)]
    np    <- model_ms["k"]*sum(swi)+sum(!swi)
    BICvalue=2*model_ms["Fit"]["logLikel"]+2*np*log(nrow(model_ms@model$model))
    AICvalue=AIC(model_ms,k=2)
    BICdata[lags,i-2]<-BICvalue
    AICdata[lags,i-2]<-AICvalue}
  #Checking for which number of lags is the BIC at its minimum
  minBIClag[i-2]<-which.min(BICdata[,i-2])
  minAIClag[i-2]<-which.min(AICdata[,i-2])
}
countries<-names(mydata[,3:15])
ARlags<-cbind(countries,minBIClag,minAIClag)
ARlags[12,2:3]<-c(1,1)
ARlags[13,2:3]<-c(1,1)

#Preparing input for the Markov-switching AR model (6 for PRT, 7 ITA, 9 GRC, 10 ESP)
country<-mydata[,ARlags[1,1]]
lags<-extract_numeric(ARlags[1,2])
model<- lm(country~1)
#Estimating the Markov-switching model with p being the optimal number of lags established above
model_ms<-msmFit(model,k=2,p=lags,sw=rep(TRUE,lags+2))
summary(model_ms)
model_ms@Fit@smoProb

#Analyzing the model fit
plotProb(model_ms,which=1) #For smoothed and filtered probabilities
plotProb(model_ms,which=2) #For when state 1 is the recession state
plotProb(model_ms,which=3) #For when state 2 is the recession state

#Analyzing model fit diagnostics
plotDiag(model_ms, regime=1, which=1) #For residuals against fitted values
plotDiag(model_ms, regime=1, which=2) #For Normal Q-Q plot
plotDiag(model_ms, regime=1, which=3) #For ACF/PACF of residuals

#Declaring a function that creates a data-set with country-specific smoothed probabilities of being in a recession based
     on the MS-AR models
recession_prob<-data.frame(matrix(NA, nrow = 160, ncol = 15))
colnames(recession_prob)<-names(mydata[,1:15])
recession_prob$time<-mydata$time
recession_prob$quarter<-mydata$quarter
for (i in 1:13){
  country<-mydata[,ARlags[i,1]]
  lags<-extract_numeric(ARlags[i,2])
  model<- lm(country~1)
  model_ms<-msmFit(model,k=2,p=lags,sw=rep(TRUE,lags+2))
  summary(model_ms)
  state_mean<-c(extract_numeric(model_ms@Coef[1,1]),extract_numeric(model_ms@Coef[2,1]))
  recession_state<-which.min(state_mean)
  probabilities<-as.data.frame(model_ms@Fit@smoProb)[,recession_state]
  recession_prob[lags:160,i+2]<-probabilities
}

#Estimating the models for the periphery countries using the probability of recession as dependent variable

#Computing the average probability of being in the recession state for the periphery countries
recession_prob$Periph<-rowMeans(recession_prob[c("PRT","ITA","GRC","ESP")])
#Adding the dummy variable for Euro introduction
recession_prob$T99<-c(0)
recession_prob$T99[recession_prob$time>=77]<-1
#Adding the data on average GDP growth for the Core countries
recession_prob$CORE<-mydata$CORE

#Estimating the models for recession probability
#Average periphery
modelPeriph <- lm(Periph~T99+CORE+T99:CORE, data=recession_prob)
summary(modelPeriph)

#Specific EMU periphery countries
modelPortugal <- lm(PRT~T99+CORE+T99:CORE, data=recession_prob)
summary(modelPortugal)

modelItaly <- lm(ITA~T99+CORE+T99:CORE, data=recession_prob)
summary(modelItaly)

modelGreece <- lm(GRC~T99+CORE+T99:CORE, data=recession_prob)
summary(modelGreece)

modelSpain<- lm(ESP~T99+CORE+T99:CORE, data=recession_prob)
summary(modelSpain)

#Exporting the parameter estimates to tabel in latex format
```

```
stargazer(modelPeriph,modelPortugal,modelItaly,modelGreece,modelSpain,t.auto=F, p.auto=F, title="Estimation results for probability of recession based on the MS-AR models", align=TRUE,dep.var.labels=c("Periph"), no.space=TRUE,single.row=FALSE,omit.stat=c("ser"))


#Analyzing the period after the financial crisis

#Adding dummy for crisis
recession_prob$T09<-c(0)
recession_prob$T09[recession_prob$time>=117]<-1

#Selecing data only after Euro introduction
recession_prob_eur<-recession_prob[77:160,]

#Estimating the models for recession probability
#Average periphery
modelPeriph <- lm(Periph~T09+CORE+T09:CORE, data=recession_prob_eur)
summary(modelPeriph)

#Specific EMU periphery countries
modelPortugal <- lm(PRT~T09+CORE+T09:CORE, data=recession_prob_eur)
summary(modelPortugal)

modelItaly <- lm(ITA~T09+CORE+T09:CORE, data=recession_prob_eur)
summary(modelItaly)

modelGreece <- lm(GRC~T09+CORE+T09:CORE, data=recession_prob_eur)
summary(modelGreece)

modelSpain<- lm(ESP~T09+CORE+T09:CORE, data=recession_prob_eur)
summary(modelSpain)

#Exporting the parameter estimates to tabel in latex format
stargazer(modelPeriph,modelPortugal,modelItaly,modelGreece,modelSpain,t.auto=F, p.auto=F, title="Estimation results for probability of recession based on the MS-AR models, impact of the financial crisis", align=TRUE,dep.var.labels=c("Periph"), no.space=TRUE,single.row=FALSE,omit.stat=c("ser"))


##############################################################################
#Analysing the properties of the business cycles identified by the MS-AR models #
##############################################################################

#Computing the average probability of recession for the periphery versus core countries
recession_prob$T99<-NULL
recession_prob$Periph<-rowMeans(recession_prob[c("PRT","ITA","GRC","ESP")])
recession_prob$CORE<-rowMeans(recession_prob[c("DEU","NLD","FIN","AUT")])
#Saving recession probabilities externally
write.csv2(recession_prob,"recession_prob.csv")

#Keeping only the probabilities for the countries of interest
recession_prob$FRA<-NULL
recession_prob$IRL<-NULL
recession_prob$IRL<-NULL
recession_prob$DNK<-NULL
recession_prob$CHE<-NULL
recession_prob$SWE<-NULL

#Changing probability of recession to probability of expansion
expansion<-recession_prob
expansion[,3:12]<-1-recession_prob[,3:12]
expansion$FIN[expansion$FIN<0]<-0

#Computing the business cycle characteristics before the euro-introduction
cycle_measures<-data.frame(matrix(NA, nrow = 6, ncol = 10))
colnames(cycle_measures)<-colnames(expansion)[3:12]
expansion<-expansion[expansion$time<77&expansion$time>3,]
mydatabefore99<-mydata[mydata$time<77&mydata$time>3,]
row.names(cycle_measures)<-c("duration_exp","duration_rec","amplitude_exp","amplitude_rec","steepness_exp","steepness_rec")
for (i in 1:10){
  denominator_exp<-0
  denominator_rec<-0
  for (j in 1:72){
    denominator_exp<-denominator_exp+((1-expansion[j+1,i+2])*expansion[j,i+2])
    denominator_rec<-denominator_rec+((1-expansion[j,i+2])*expansion[j+1,i+2])
  }
  cycle_measures[1,i]<-(sum(expansion[,i+2]))/denominator_exp
  cycle_measures[2,i]<-(sum(1-expansion[,i+2]))/denominator_rec
  colnamecheck<-colnames(expansion)[i+2]
  cycle_measures[3,i]<-(sum(mydatabefore99[,colnames(mydatabefore99)==colnamecheck]))/denominator_exp
  cycle_measures[4,i]<-(sum((1-expansion[,i+2])*mydatabefore99[,colnames(mydatabefore99)==colnamecheck]))/denominator_rec
  cycle_measures[5,i]<-cycle_measures[3,i]/cycle_measures[1,i]
  cycle_measures[6,i]<-cycle_measures[4,i]/cycle_measures[2,i]
}

#Computing the business cycle characteristics after the euro-introduction
expansion<-recession_prob
expansion[,3:12]<-1-recession_prob[,3:12]
expansion$FIN[expansion$FIN<0]<-0
cycle_measuresT99<-data.frame(matrix(NA, nrow = 6, ncol = 10))
colnames(cycle_measuresT99)<-names(expansion)[3:12]
expansion<-expansion[expansion$time>=77,]
```

```
mydataafter99<-mydata[mydata$time>=77,]
row.names(cycle_measuresT99)<-c("duration_expT99","duration_recT99","amplitude_expT99","amplitude_recT99","steepness_expT99","steepness_recT99")
for (i in 1:10){
  denominator_exp<-0
  denominator_rec<-0
  for (j in 1:83){
    denominator_exp<-denominator_exp+((1-expansion[j+1,i+2])*expansion[j,i+2])
    denominator_rec<-denominator_rec+((1-expansion[j,i+2])*expansion[j+1,i+2])
  }
  cycle_measuresT99[1,i]<-(sum(expansion[,i+2]))/denominator_exp
  cycle_measuresT99[2,i]<-(sum(1-expansion[,i+2]))/denominator_rec
  colnamecheck<-colnames(expansion)[i+2]
  cycle_measuresT99[3,i]<-(sum(mydataafter99[,colnames(mydataafter99)==colnamecheck]))/denominator_exp
  cycle_measuresT99[4,i]<-(sum((1-expansion[,i+2])*mydataafter99[,colnames(mydataafter99)==colnamecheck]))/denominator_rec
  cycle_measuresT99[5,i]<-cycle_measuresT99[3,i]/cycle_measuresT99[1,i]
  cycle_measuresT99[6,i]<-cycle_measuresT99[4,i]/cycle_measuresT99[2,i]
}
#Combining the business cycle characteristics in one data-set
cycle_measures_compared<-rbind(cycle_measures,cycle_measuresT99)

#Creating graphs for the simulated business cycles of the core vs periphery country groups, before Euro introduction
#For the core countries
time<-seq(0, 13.7, length.out = 1000)
time_exp<-time[time<=4.03]
time_rec<-time[time<=2.09]
value_exp<--0.91*time_exp*time_exp+3.67*time_exp
value_rec<--0.88*time_rec*time_rec+1.84*time_rec
value_core<-c(value_exp,value_rec,value_exp,value_rec)
diflength<-1000-length(value_core)
value_core<-c(value_core,rep(NA,diflength))

#For the periphery countries
time_exp<-time[time<=4.55]
time_rec<-time[time<=2.30]
value_exp<--0.76*time_exp*time_exp+3.45*time_exp
value_rec<--0.94*time_rec*time_rec+2.16*time_rec
value_periph<-c(value_exp,value_rec,value_exp,value_rec)
diflength<-1000-length(value_periph)
value_periph<-c(value_periph,rep(NA,diflength))

cycleplot<-as.data.frame(cbind(time,value_core,value_periph))

graphcycleplot<-plot_ly(cycleplot,x= ~time,y= ~value_core,type='scatter',mode = 'line', name="Business cycle core")%>%
  layout(xaxis = list(title = 'Time'),yaxis = list (title = 'Amplitude'))%>%
 add_trace(y=~value_periph,type='scatter',mode = 'line', name="Business cycle periphery")
graphcycleplot

#Creating graphs for the simulated business cycles of the core vs periphery country groups, after Euro introduction
#For the core countries
time<-seq(0, 28.58, length.out = 1000)
time_exp<-time[time<=12.53]
time_rec<-time[time<=1.76]
value_exp<--0.145*time_exp*time_exp+1.82*time_exp
value_rec<-0.68*time_rec*time_rec-1.20*time_rec
value_core<-c(value_exp,value_rec,value_exp,value_rec)
diflength<-1000-length(value_core)
value_core<-c(value_core,rep(NA,diflength))

#For the periphery countries
time_exp<-time[time<=1.44]
time_rec<-time[time<=5.95]
value_exp<--3.26*time_exp* time_exp+4.69*time_exp
value_rec<--0.148*time_rec*time_rec+0.89*time_rec
value_periph<-c(value_exp,value_rec,value_exp,value_rec,value_exp,value_rec,value_exp,value_rec)
value_periph<-c(value_periph[1:1000])

cycleplot<-as.data.frame(cbind(time,value_core,value_periph))

graphcycleplot<-plot_ly(cycleplot,x= ~time,y= ~value_core,type='scatter',mode = 'line', name="Business cycle core")%>%
  layout(xaxis = list(title = 'Time'),yaxis = list (title = 'Amplitude'))%>%
  add_trace(y=~value_periph,type='scatter',mode = 'line', name="Business cycle periphery")
graphcycleplot

######################################################################
#Analysing business cycle synchronisation using concordance measures #
######################################################################

#Computing the concordance measure for recessions for the whole time-period
recession<-recession_prob
recession$time<-NULL
recession$quarter<-NULL
for (i in 1:10){
  recessionvector<-rep(0,160)
  recessionvector[recession[,i]>0.5]<-1
  recession[,i]<-recessionvector
}

#Computing the matrix of concordance values for the whole time-period
concordance<-data.frame(matrix(NA, nrow = 10, ncol = 10))
colnames(concordance)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
row.names(concordance)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
```

```
for (j in 1:10){
  for (i in 1:10){
    sum=0
    for (t in 3:160){
      sum=sum+recession[t,j]*recession[t,i]+(1-recession[t,j])*(1-recession[t,i])
    }
    concordance[j,i]<-sum*(1/158)
  }
}

#Computing the matrix of concordance values for the period before the Euro introduction
concordancebefore99<-data.frame(matrix(NA, nrow = 10, ncol = 10))
colnames(concordancebefore99)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
row.names(concordancebefore99)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
for (j in 1:10){
  for (i in 1:10){
    sum=0
    for (t in 3:76){
      sum=sum+recession[t,j]*recession[t,i]+(1-recession[t,j])*(1-recession[t,i])
    }
    concordancebefore99[j,i]<-sum*(1/74)
  }
}

#Computing the matrix of concordance values for the period after the Euro introduction
concordanceafter99<-data.frame(matrix(NA, nrow = 10, ncol = 10))
colnames(concordanceafter99)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
row.names(concordanceafter99)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
for (j in 1:10){
  for (i in 1:10){
    sum=0
    for (t in 77:160){
      sum=sum+recession[t,j]*recession[t,i]+(1-recession[t,j])*(1-recession[t,i])
    }
    concordanceafter99[j,i]<-sum*(1/84)
  }
}

#Computing the matrix of concordance values for the period after the Euro introduction and before the crisis
concordanceafter99before09<-data.frame(matrix(NA, nrow = 10, ncol = 10))
colnames(concordanceafter99before09)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
row.names(concordanceafter99before09)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
for (j in 1:10){
  for (i in 1:10){
    sum=0
    for (t in 77:116){
      sum=sum+recession[t,j]*recession[t,i]+(1-recession[t,j])*(1-recession[t,i])
    }
    concordanceafter99before09[j,i]<-sum*(1/40)
  }
}

#Computing the matrix of concordance values for the period after the Euro introduction and after the crisis
concordanceafter99after09<-data.frame(matrix(NA, nrow = 10, ncol = 10))
colnames(concordanceafter99after09)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
row.names(concordanceafter99after09)<-c("DEU","NLD","FIN","AUT","PRT","ITA","GRC","ESP","Periph","CORE")
for (j in 1:10){
  for (i in 1:10){
    sum=0
    for (t in 117:160){
      sum=sum+recession[t,j]*recession[t,i]+(1-recession[t,j])*(1-recession[t,i])
    }
    concordanceafter99after09[j,i]<-sum*(1/44)
  }
}

#################################
#Data preparation for LatentGold #
#################################

rm(list=ls())
#Loading data to R
mydataLG<-read.csv("dataLG.csv")
#Saving data in latentgold format (spps dataset)
library(haven)
write_sav(mydataLG, "dataLG.sav")
```