HELLENIC REPUBLIC
UNIVERSITY OF MACEDONIA

DEPARTMENT OF ECONOMICS

Interdepartmental Program of Postgraduate studies in Economics

Master's thesis

Testing for Inflation Convergence Among European Union Countries: A Panel Approach

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Thessaloniki, Greece, March 2017

Acknowledgments

This master thesis ends a Master's degree in Economics at the University of Macedonia. First and foremost, I would like to express my immense gratitude to my thesis supervisor, Professor Stilianos Founta for his patience, motivation and considerable knowledge. His guidance assisted me throughout my research and writing of this thesis as his willingness to provide constant support enabled me to overcome difficult circumstances and solve challenging questions concerning my research. Without his valuable guidance, I would not have been able to complete this work.

Besides my advisor, I would like to thank the rest of my Economics Department colleagues for their valuable contribution to the knowledge I gained throughout the period of my postgraduate studies there.

Last but not the least; I am deeply appreciative of my family, especially my husband for supporting me with patience and persistency throughout my writing this thesis. I would also like to thank my best friends for their useful advice and vital comments.

ABSTRACT

One of the principal economic challenges in the European Union is entering the euro area by the candidate countries. The aim of this study is twofold. First, based mainly on the theoretical framework about the economic integration in Europe, issues related to this process are presented. Furthermore, the importance of the Maastricht convergence criteria is discussed, as nominal convergence criteria are underlined in connection to successful catching up. Broadly speaking, in order for any EUC to join the Euro area, it is important for them to satisfy these pre-accession criteria. It is obvious from the beginning that the Euro area would need far more convergence than other currency unions. In order to be stable, the Euro area needs price stability in the form of small inflation differentials. In the light of the achievement of small inflation differentials, this thesis also tries to empirically identify whether inflation convergence exists in a sample of twenty-four European Union countries. To tackle this issue, first and second generation panel unit root and stationarity tests are employed so as to provide evidence of inflation convergence before and after the launch of the single currency, the euro. The methodology of the influential studies by Spiru (2008) and Gregoriou et al. (2011) is used. In general, the findings reveal that conditional inflation convergence exists for all panels under study.

Keywords: Inflation Convergence, EUCs, Maastricht Criteria, Panel testing

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Acronyms

List of Abbreviations

Abbreviations of member states

Austria	**AT**
Belgium	**BE**
Bulgaria	**BG**
Cyprus	**CY**
Czech Republic	**CZ**
Germany	DE
Estonia	**EE**
Spain	**ES**
Finland	**FI**
France	**FR**
Greece	**GR**
Ireland	**IE**
Italy	**IT**
Luxembourg	**LU**
Hungary	**HU**
Lithuania	**LT**
Latvia	**LV**
Netherlands	**NL**
Poland	**PL**
Portugal	**PT**
Romania	**RO**
Slovakia	**SK**
Slovenia	**SI**

Other Abbreviations

Balassa–Samuelson	**BS**
Eastern European Countries	**EECs**
Central and Eastern European Countries	**CEECs**
Consumer Price Index	**CPI**
East European Countries	**EECs**
Economic and Monetary Union	**EMU**
Euro Area	**EA**
European Central Bank	**ECB**
European Coal and Steel Community	**ECSC**
European Economic Community	**EEC**
European Union	**EU**
Exchange Rate Mechanism II	**ERM II**
Inflation Differentials from Germany	$\boldsymbol{D_{Ger}}$
Inflation Differentials from PRV	$\boldsymbol{D_{prv}}$
New Member States	**NMS**
Optimal Currency Areas	**OCAs**
Old Member States	**OMS**
Policy Reference Value	**PRV**
Treaty on European Union	**TEU**

1 Introduction

Fifty years ago, after Robert Schuman's historic contribution as father of European unification, the expectations in economic integration in Europe have been largely fulfilled. The European integration has completed various stages so far; Free trade Area, Customs Union, Common Market, Internal Single Market, Economic and Monetary Union and full economic integration through political union. The successful formula of the European Integration depends on nominal convergence criteria. The historic Maastricht Treaty influenced by the Delor's report is the most important achievement in the history of the creation of a monetary union. One of the fundamental objectives of this treaty is price stability through the achievement of low inflation. However, on the basis of rich literature, consumption and institutional factors and factors related to structural differences play a significant role to determine inflation differentials among countries in a monetary union. For instance, in the case that inflation differentials among economies exhibit large deviations, which are related to non-tradable price goods, the Balassa-Samuelson model is able to explain why there is no convergence in prices.

A European country joining the Euro area has a considerable number of benefits, such as transaction cost and interest rate reduction, price stability and microeconomic efficiency. However, as this monetary union cannot be characterized as an Optimum Currency Area (Mundell, 1961), costs of membership in the EMU, such as loss of an adjustment instrument for asymmetric shocks, also exist. For this reason the EMU needed far more convergence than other currency unions. At this point, the Maastricht Treaty played a significant role in achieving convergence among EUCs. In the light of convergence achievement, one of the Maastricht criteria is inflation convergence among the member states. The importance of this criterion is twofold. First, the interest rates, set by the ECB, are based on the average inflation rate and second, to avoid inflationary bias among countries. In the large literature, inflation convergence among several European countries has been examined (Figuet and Nenovsky, 2006; Holmes, 2008; Spiru, 2008; Gregoriou et al., 2011; Lopez and Papell, 2012; Cuestas et al., 2012; Simionescu, 2015; Karanasos et al. 2016; Caporale and Pittis, 1993; Thom, 1996). From a methodological standpoint, some of the above studies employ univariate or panel unit root testing, while others employ cointegration techniques.

In this thesis, in order to examine inflation convergence among EUCs, inflation differentials of the selected countries with respect to two benchmarks are calculated by applying first and second generation panel unit root tests. In addition, the mean reverting behavior of inflation differentials, in a period of forty-three years is examined under univariate and panel approach. The innovation of this study is that in order to conduct the analysis, two benchmarks are utilized: Germany and Policy Reference Value (PRV), which is referred to in the first Maastricht criterion. In addition, this study examines twenty-four European countries for the period from 1974 to 2016, while other studies examine a shorter period of time and sample of countries. In this study the sample splits into five groups of countries and four periods of time. The main characteristic is the

comparability between countries that joined the euro in 1999, economies that joined afterwards and countries that are still in transition. The results reveal conditional convergence among EUCs. An interesting finding is that transitional economies exhibit convergence, although these economies have gained separate identities recently. In particular, the transition process by these countries presents some common features, related mainly to institutional reforms, price liberalization, the choice of an appropriate exchange rate regime, and attempts to contain corrective inflation. At the same time these economies have established an international trade relationship which helps them to strengthen the process of convergence (Spiru, 2008). Additionally, the fundamental EUCs show weaker evidence of convergence before the launch of the euro, but stronger after the introduction of the common currency.

The structure of the thesis is as follows. Part 2 presents the history of the EMU, while Part 3 is devoted to the evolution of inflation differentials among European countries and the possible sources that determine them. The theoretical framework of convergence, as well as a selective review of studies on inflation convergence is presented in Part 4. Part 5 is devoted to the data and methodology used, while the empirical findings are discussed in Part 6. Finally, Part 7 concludes.

2 The history of EMU

2.1 Historical perspective about economic integration in Europe.

"We must build a kind of United States of Europe.
In this way only, will hundreds of millions of toilers
be able to regain the simple joys and hopes which make
Life worth living".

Winston Churchill

European Monetary Union is part of a broader process of integration that finds its roots in European thinking. This process started in the aftermath of World War II where the main reason was the achievement of lasting peace in Europe. However, political and economic motivations were also contributing factors. Indeed, the multinational integration process legally started in 1951 under Schuman's plan, the main founding father of European economic integration. The plan foresaw the establishment of a European Coal and Steel Community (ECSC), which first consisted of six European countries. In particular, the economies that were part of the ECSC were Belgium, Germany, France, Italy, Luxembourg and the Netherlands. With the ratification of the treaty of Rome, the European Economic Community (EEC) and the European Atomic Energy Community (Euratom) in 1958, the next step was economic integration. Under the treaty of Rome, these same countries extended the operation of the Customs Union with the creation of the common market.

By the 1970s, it was obvious that the EEC was needed for institutional strengthening, since monetary issues were concerned. The result was to bring political leaders such as Pierre Werner who designed the plan for the creation of the EMU. This achievement by Werner started in 1970 and was completed in 1980. In the same period, three countries Denmark, Ireland, and the UK joined the EEC. The main characteristic of these economies was the fact that they cooperated inside a Free Trade Area (FTA) before being members of the EEC. During the 1980s, the Single European Act (SEA) contributed to the creation of the internal single market. Another important consideration is the Delors (1989) report which contains the three stages of the EMU. In 1992, the member states became twelve. At the same time, work was completed on that stage of their integration on the basis of the SEA. Thereafter, members would sign the Treaty for the European Union, popularly known as the historic Maastricht Treaty. With this treaty, the EUCs were led to the next step of their integration. This was the last but not the least important stage of the Economic and Monetary Union (EMU). EMU is a significant stage of multinational integration which means common monetary policy, a single currency, sufficient coordination of the economic policies of the member states, full liberalization of the capital flow, an effective institutional system for the monetary policy coordination and control. The following Table 1 summarizes the basic elements which characterized the organizations of economic integration in Europe which are presented in this part.

Table 1:Basic elements of the Stages of Economic Integration in Europe

Integration Form	**Basic Elements**
Free Trade Area (FTAs)	Elimination internal duty between member countries and import quotas.
Customs Union (CU)	Common external tariff plus the characteristic of FTAs.
Common Market (CM)	Free movement of capital and labour plus the characteristics of CU.
Internal Single Market (EU)	Common economic policies and institutions plus the characteristics of CM.
European Monetary Union (EMU)	Single currency among member states plus the characteristics of EU.

As regards the successive functioning of this form of integration, the Maastricht Treaty foresaw the convergence criteria among EUCs. Specifically, this treaty set the minimal requirements to be met by an EU member state to enter the euro area. Participating in the euro area implies that any European economy must withdraw their national currency and their national monetary policy and, equally, adopt both the single European currency and the common monetary policy, formulated and coordinated by the European Central Bank. Ten years after the Maastricht treaty, the ˝miracle˝ of the EU was a reality as the circulation of the single currency was achieved. In these days, the EU consisted of twenty eight countries where nineteen of them had launched the euro. In the following part of this chapter the Delor's report and the historical binding agreement of the Treaty of Maastricht are presented in more detail.

2.2 The Delor's Report: The three stages of the EMU

At the Hanover Summit of June 1988, the European Council agreed that the Monetary Integration was one of the main tasks. This task was assigned to the Jacques Delor's Committee. Their analysis of this Committee is known as the Delors Report which defined the principal features of the Economic Union (EU) as the Single Market. The Delors Report was submitted in April 1989 in Madrid and it stressed that the creation of the EMU must be seen as a single process in three major stages. The three stages towards EMU could be described as follows:

First stage from 1990 to 1994. The main characteristics of this stage are the lifting of barriers to the transaction of capital, closer cooperation and coordination among the EUCs. Furthermore, in this stage of the Delors Report the issue of the non-participating member states in the ERM of the EMS were addressed and the expansion of the role of the Committee of the Central Bank (Paraskevopoulos C. C., 1998).

Second stage from 1994 to 1999. During this phase the basic institutions which played a vital role in the smooth functioning of the Eurozone were defined. For instance, the transition to the euro, the future governance of the euro area (the Stability and the Growth Pact) and the way that a European country could achieve economic convergence among Member States (European Commission) were planned.

Third stage from 1999 onwards. In this phase the ECB and ESCB was established with independent monetary policy-making. In addition, binding budgetary rules in Member States were implemented. More characteristics of the three stages could be illustrated in the figure 1.

First stage : 1 July 1990	Second Stage: 1 January 1994	Third Stage: 1 January 1999
Complete freedom for capital transactions. Increased co-operation among central banks. Improvement of economic convergence. The Maastricht Treaty gets binding.	Establishment of the European Monetary Institute (EMI). Increased co-ordination of monetary policies. Strengthening of economic convergence Gradually independence of national central Banks before establishing the European System of Central Banks Preparation for transition to Stage III	Irrevocable fixing of conversion rates. The introduction of the euro in the 11 EU member states. Strengthened the fiscal discipline. Entry into effectiveness of the new exchange rate mechanism ERM II. Conduct of a single monetary policy of the ESCB.

Figure 1. Source: ECB

2.3 The road to the euro: The Maastricht convergence criteria

The historic Maastricht Treaty, known as the Treaty on European Union (TEU) was signed in December 1991 in the Dutch city of Maastricht. This Treaty sets the framework of transition to the Economic and Monetary Union (EMU) among member countries of the European Union (EU). In particular, it contains important macro-economic requirements in order for any European country to participate in the EMU. Its basic philosophy was influenced by the Delor's report as mentioned earlier.

According to the Maastricht Treaty, the transition to the final stage of monetary union was conditional on a number of convergence criteria. These criteria are also called nominal convergence criteria that prepare a member state to adopt the euro. In this way, sustained economic convergence efforts by individual member states were significant for the creation of an environment of price stability in Europe after the introduction of the single currency. The four stipulations of the MCC stressed price stability, fiscal developments, durability of convergence, and exchange rate stability. Table 2 summarizes the four entry criteria.

Table 2 : The Maastricht convergence criteria

	Price Developments	**Long-Term Interest Rates Developments**	**Fiscal Developments**	**Exchange Rate Developments**
What is measured	Price stability.	Durability of convergence.	Steadiness and sustainability of fiscal status.	Exchange rate stability.
How it is Measured	Harmonized Consumer price inflation rate.	Long-term interest rate.	Government deficit and debt as % of GDP.	Deviation from the central rate.
Convergence criteria	Inflation rate should not be higher than 1.5% above the rate of the three best performing Member States.	Should not be higher than 2% above the rate of the three best performing Member States.	Deficit should not be higher than 3% and debt should not be higher than 60%.	Joining in the ERM II for at least two years without significant deviations from the ERM II central rate (± 15%).

Source: European Commission

According to the above, if any EU member states cannot meet these convergence criteria, they should take the required actions in order to catch up. These member states are usually referred to as states with a ˝derogation˝. In the case that a candidate country complies with the above stipulations, the derogation is abrogated by the Council´s decision and this economy is able to adopt the euro.

2.4 Theoretical framework about the Optimum Currency Area

The theory of the Optimum Currency Areas (OCAs) is most often used to analyze the Monetary Union. This theory attempts to define the domain of the single currency (Tavlas 1993). Initially, Lerner (1944) analyzed this issue and concentrated on the importance of free factor mobility as significant property to set up a currency area. Nevertheless, at the beginning of 1960 the seminal contributions by Mundell (19610), McKinnon (1963) and Kenen (1969) laid the foundations for the theory of Optimum Currency Areas. Generally, the theory of OCAs can be defined as the optimal geographical area for a single currency, or for several currencies, whose exchange rates are irrevocably pegged. In addition, this theory defines the structural properties that would delineate an optimal currency area. The main criteria which are comprised in the OCAs theory are illustrated in the Table 3 below.

Table 3: Properties of the theory of the Optimum Currency Areas

Author	Criteria	Argument
Mundell 1961	Wage flexibility and Mobility of Labor	The free factor mobility acts as absorber when a monetary union faces an asymmetric shock.
McKinnon 1963	The degree of economic openness.	When the economies of the monetary union are open to trade then the single currency among its trade partners would contribute to the stabilization of prices.
Kenen 1969	Diversification in Production and Consumption	When any economy of MU is characterized by high diversity of production then, this economy is better equipped to absorb external shocks.
Kenen 1969	Fiscal Integration	Fiscal policy at the federal level can serve as an alternative choice to the use of monetary policy to foster asymmetric shocks.

In the above table, the main conditions which are necessary in order to design a monetary union are observed. However, the contribution of the traditional OCA theory has played only a modest role in the preparation of the Delors Report and hence the Maastricht Treaty. Under these circumstances, the OCA theory could not deliver clear policy guidance and normative implications. The lack of a high degree of factor mobility, a system of flexible exchange rate (Mundell 1961, Krugman 2012) would be more effective in this argument. In addition, the lack of structural cohesion in some countries is an obstacle to meeting the criteria of the OCAs. Having said that, the OCAs theory has had a great contribution to the economic theory all these years.

2.5The costs and benefits of a monetary union: The case of EMU

Under the theory of the OCAs, a monetary area is formed when there is the prospect of a positive balance between benefits and costs. EMU is also a monetary union where its members are equally affected by the advantages as well as the disadvantages by their participation in it. Under the line of the single currency such as the euro, there are several direct and indirect benefits which have a crucial impact both at a microeconomic and a macroeconomic level. Particularly, the most notable pros from a single currency are associated with the elimination of the transaction costs among EU currencies for individuals and firms. Thus, forex-related costs would be completely abolished by using a

single currency. In addition, a reduction in exchange rate volatility and uncertainty, more price transparency and a better functioning of the internal market are observed. However, there are some costs which accompany a monetary union. In the following Table 4 the Costs and benefits of the EMU are represented, grouped into four major categories.

Table 4 : Costs and Benefits of EMU

		Benefits		Costs
Categories of Economy that effect	The Final impact	Direct	Indirect	
Microeconomic efficiency	Steady state level of output and income in the Community	Savings in transaction costs. Eliminate the exchange rate uncertainty and instability costs.	The internal market is Strengthen. Integration of goods and capital markets. Lower uncertainty and riskiness of investments.	Effects on taxation and provision of public goods in some countries. Loss of revenue for some Member States.
Macroeconomic stability.	Steady state rate of inflation. Improving of welfare.	Disappearance of non-cooperative exchange rate policies. Greater availability of external financing.	Price stability. Coordinated fiscal policies.	Loss of an adjustment instrument for asymmetric shocks.
Regional equity	Distributional effects among EU members.	Spatial distribution of direct micro and macro benefits.	Differentiated impacts of EMU depending on initial macroeconomic conditions and economic policy strategies.	
External effects	Both micro and macro effects for the	Additional savings due to reduction in transaction	Better coordination internationally.	Changes in the international monetary

	Community.	costs, revenues from international seigniorage and decreasing reliance on exchange reserve.		system.
Transitional effects	Changes in the macroeconomic transition path towards EMU.		Diminishing in real interest rates.	Disinflation costs. Costs of fiscal discipline. Effects on the dollar/euro exchange rate.

Source: European Community Commission, ˝One Market, One Money˝, 1990

In conclusion, as mentioned above, it is essential that any EU member states cannot obtain the full gains from the Single Market without a single currency. Likewise, the costs associated with the creation of the EMU could be eliminated. For instance, after an asymmetric shock, if prices and wages are more flexible or mobility of labor is significantly high then this disturbance could be absorbed by the system (Mundell 1961).

2.6 The importance of the convergence criteria

The future of the EMU is strongly believed to be dependent on a degree of nominal convergence attained from specific macroeconomic indexes such as the inflation and other macroeconomic indicators that were referred to earlier. The sustainability of Eurozone is a crucial issue and it has been discussed by numerous economists. In practice, these criteria also mean that all EUCs will be similar to reduce the possibility of destabilizing specific economies. Broadly speaking, the need for convergence in the euro area is more important than in other currency unions. According to the literature the reasons which play a crucial role are the following;

1. The Euro area does not have adjustment mechanisms which are capable of correcting imbalances among member states.
2. The Euro area is characterized by a single market but it is far from full economic integration.
3. The European Central Bank (ECB) sets the single interest rate which is based on the average inflation rate. In this way, when the inflation rate differs across countries, this single interest rate is not appropriate for all countries. After all, ˝one size fits none˝.

4. Moreover, according to Buti and Sapir, (1998), nominal convergence gradually leads to real convergence thanks to the advantages of the macroeconomic stability.
5. These criteria exist in order not to characterize the monetary union as an inflationary bias, explained in the Barro-Gordon model (1983). Specifically, if country A has the least inflation of all the other countries, then the ECB should have the same preferences as the central bank of country A. In order to prevent this bias, European countries have to go through the same disinflationary process. In other words, they need convergence, shown in Figure 2. For the same reason, budgetary convergence is required among countries. As regards the exchange rate, the transition countries are prohibited from devaluating their currency in the last two years before entering the EMU. This requirement presents an obstacle for countries which manipulate their exchange rate in order to obtain a more favourable one. In addition, interest rate convergence is required so as to avoid disturbances in a capital market.

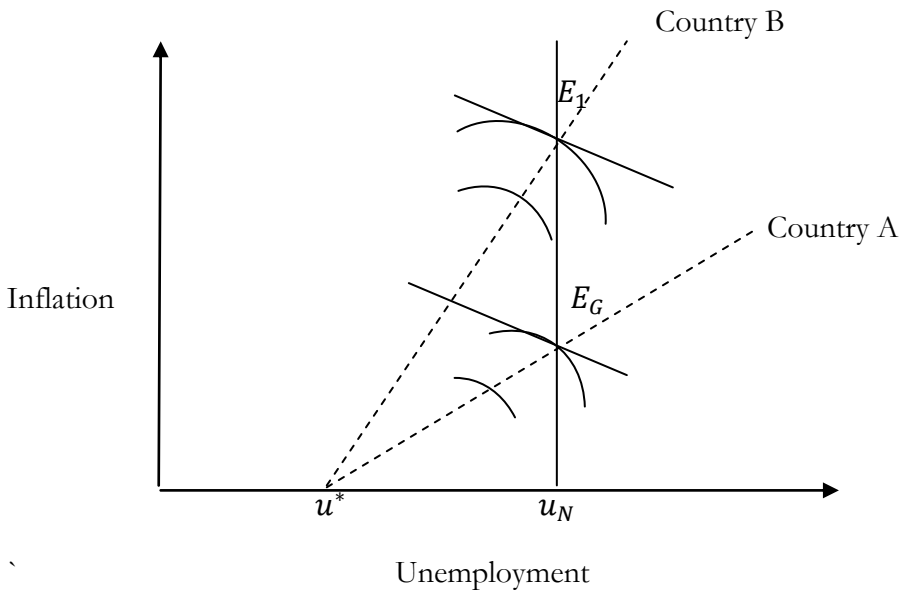


Figure 2. The inflation bias in a monetary union.

For all these reasons, there is greater need for more nominal convergence than other monetary unions. The existence of the Eurozone relies on the Maastricht Criteria. The Euro area needs price stability in the form of small inflation differentials, competitive member states that can maintain both a balance between wage growth and productivity rates, and a balanced external position.

2.7 The members of the Eurozone and the candidate countries

In general, the Eurozone is the area which consists of the EU member states that have adopted the single currency, the euro. In practice, the euro was launched on 1 January 1999 as a virtual currency for accounting purposes. After two years, on 1 January 2002 the circulation of the euro was a fact as the single currency was introduced in physical form (banknotes, coins).

In particularly, the euro (€) is the official currency of 19 out of the 28 EU member countries, widely known as the Eurozone. Particularly the first members that constituted the Euroland were Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain (AT, BE, FI, FR, DE, IE, IT, LU, NL, PT, ES). These 11 EU countries in 1999 inaugurated the start of the EMU and were joined by Greece in 2001, Slovenia (SL) in 2007, Malta and Cyprus (CY) in 2008, Slovakia (SK) in 2009, Estonia and Latvia in 2014, and by Lithuania in 2015 as the 19th member of the Eurozone. Bulgaria (BG), the Czech Republic (CZ), Hungary (HU), Poland (PL) and Romania (RO) are transition economies that are at the pre-stage of adopting the euro. The first four of these economies have not set a deadline for adopting the euro, while RO has committed to doing so in 2019. The above description of countries are illustrated in the following Tables 5 and 6 respectively. For more details see appendix 1.

Table 5: 19 countries of the Eurozone

States	Euro since
Austria	1999
Belgium	1999
Finland	1999
France	1999
Germany	1999
Ireland	1999
Italy	1999
luxembourg	1999
Netherlands	1999
Portugal	1999
Spain	1999
Greece	2001

Slovenia	2007
Cyprus	2008
Malta	2008
Slovakia	2009
Estonia	2011
Latvia	2014
Lithuania	2015

Source: ECB

Table 6: Transition countries of the Eurozone

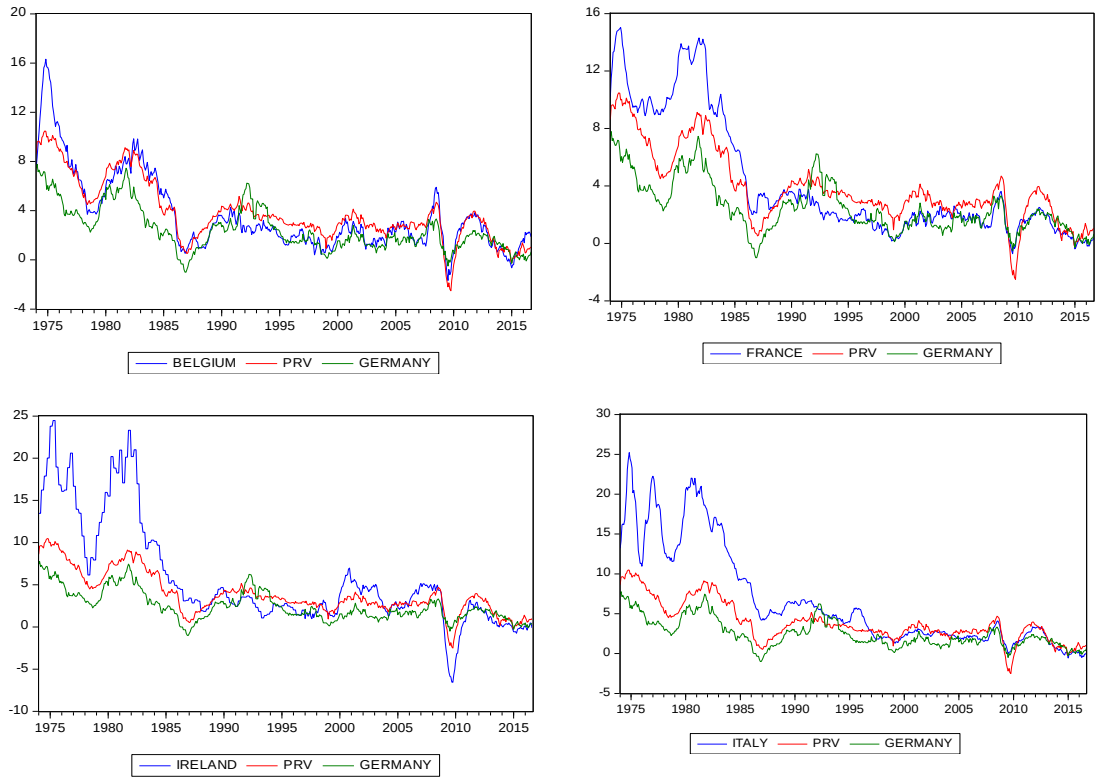
Bulgaria	-
Czech	-
Hungary	-
Poland	-
Romania	-

Source: ECB

3 Inflation differentials among European Countries

3.1 The evolution of inflation differentials among European Countries

In recent years, it is widely known that the examination of inflation differentials across the EU countries is a crucial issue. A EUC entering the euro area implies that it satisfies the Maastricht Convergence Criteria. In practice, according to this criterion inflation rate should not be higher than 1.5% above the rate of the three best performing member states. Testing inflation convergence involves studying the dynamic properties of the inflation differential between two economies. The following graphs depict developments in inflation dispersion for each examined country from the inflation rate of Germany and from the PRV.



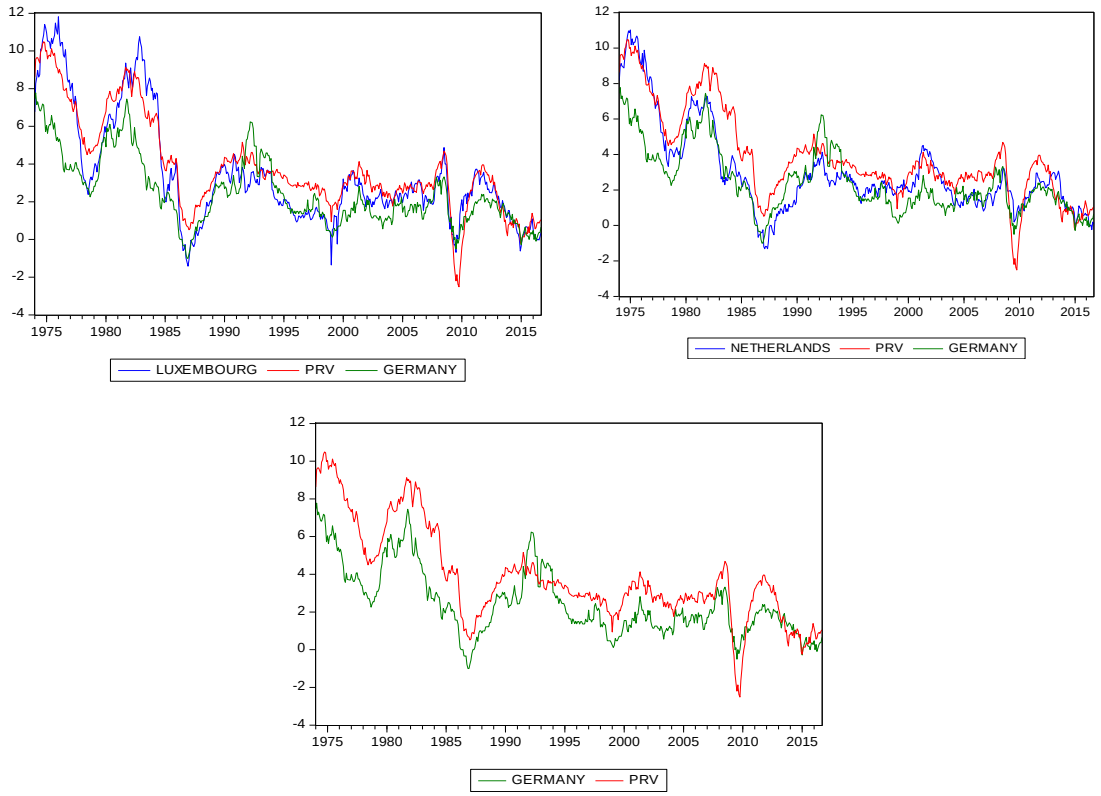
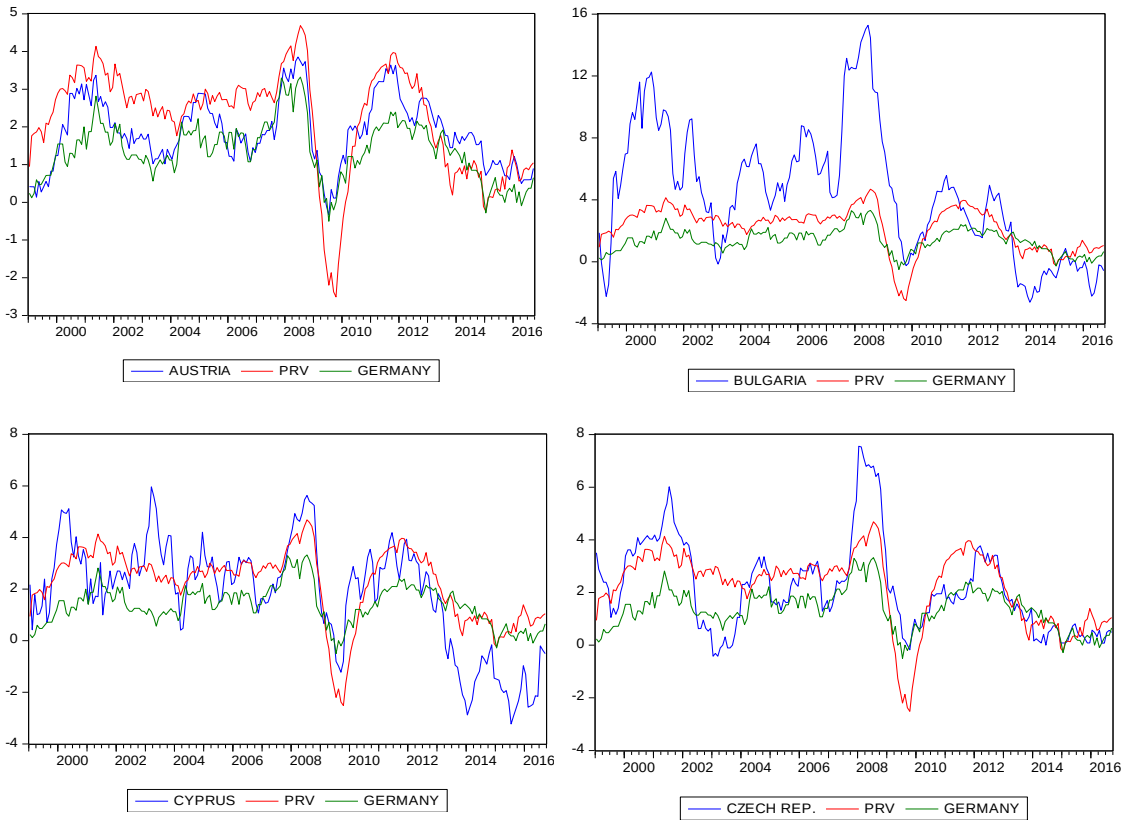
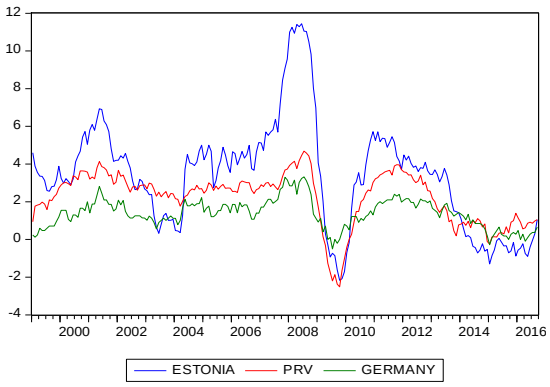
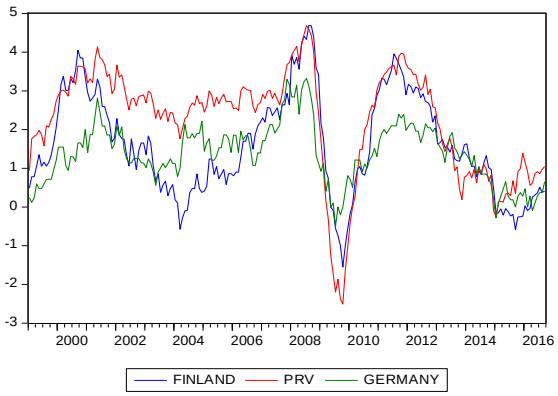
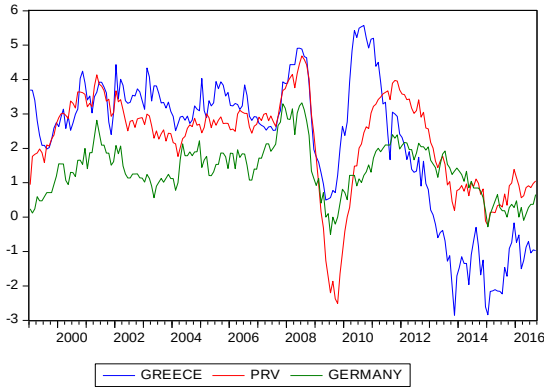


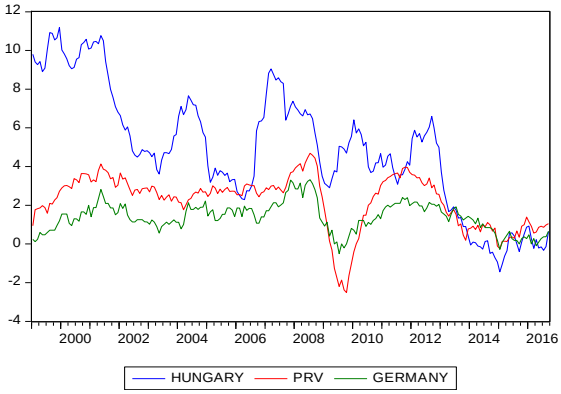
Figure 3: Inflation rates of 7 first countries 1974-2016.

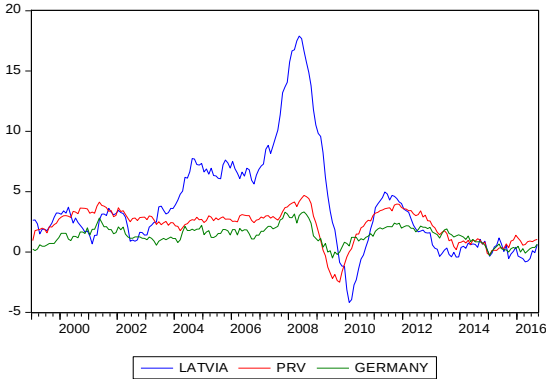



ESTONIA
PRV
GERMANY


FINLAND
PRV
GERMANY


GREECE
PRV
GERMANY


HUNGARY
PRV
GERMANY


LATVIA
PRV
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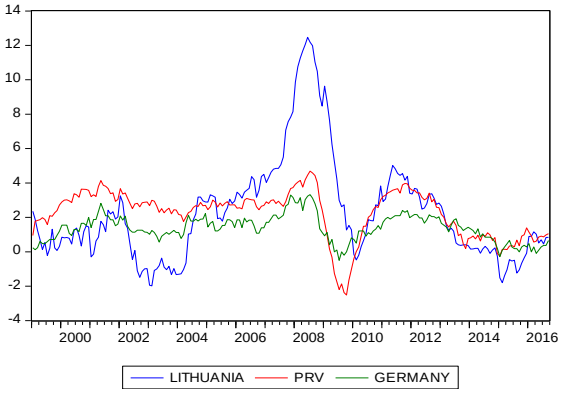
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PRV
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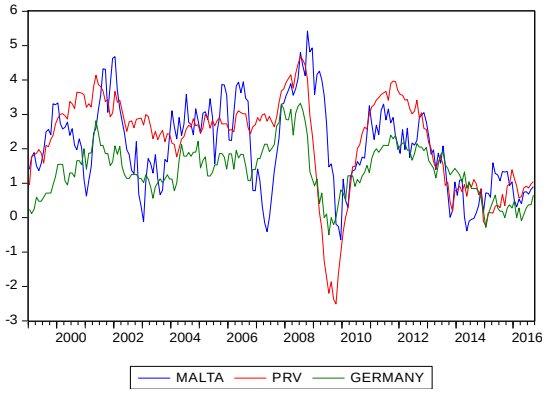
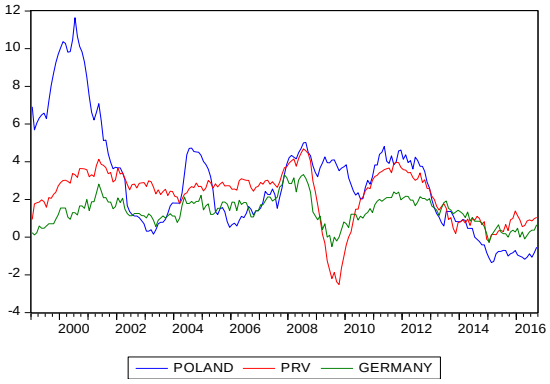

MALTA
PRV
GERMANY


POLAND
PRV
GERMANY

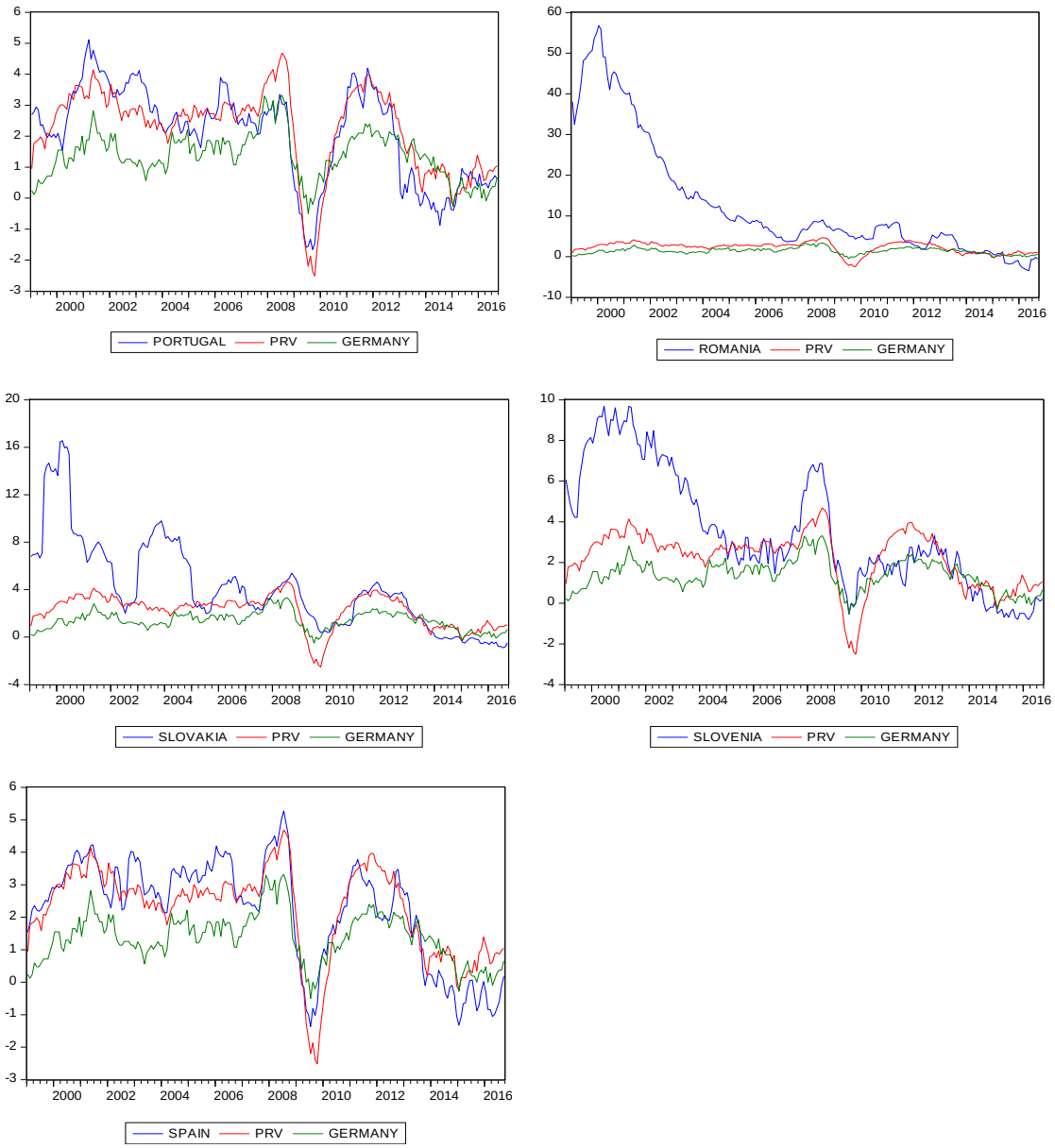


Figure 4: Inflation rates of 17 countries 1999-2016.

In the following figures 5 and 6 the inflation differentials are presented with respect to the first requirement criterion of the Maastricht Treaty (PRV) and the inflation of Germany.

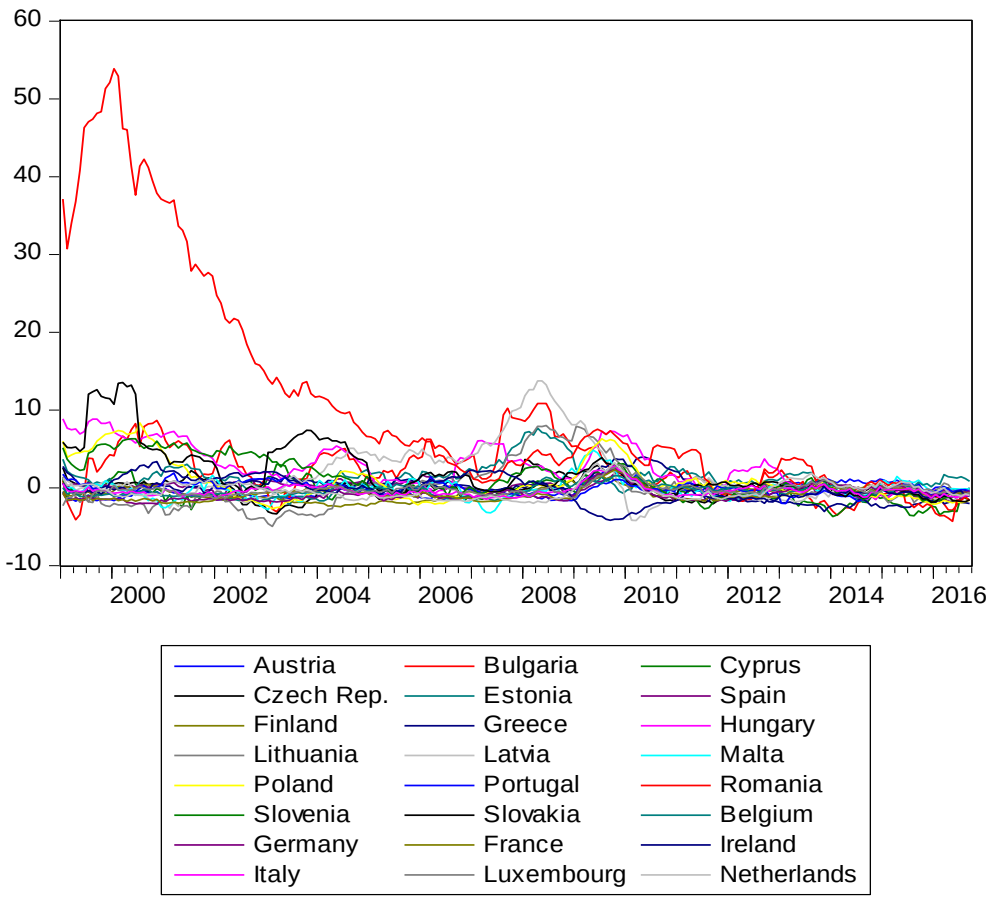


Figure 5: Inflation differentials from PRV for all countries: 1999-2016.

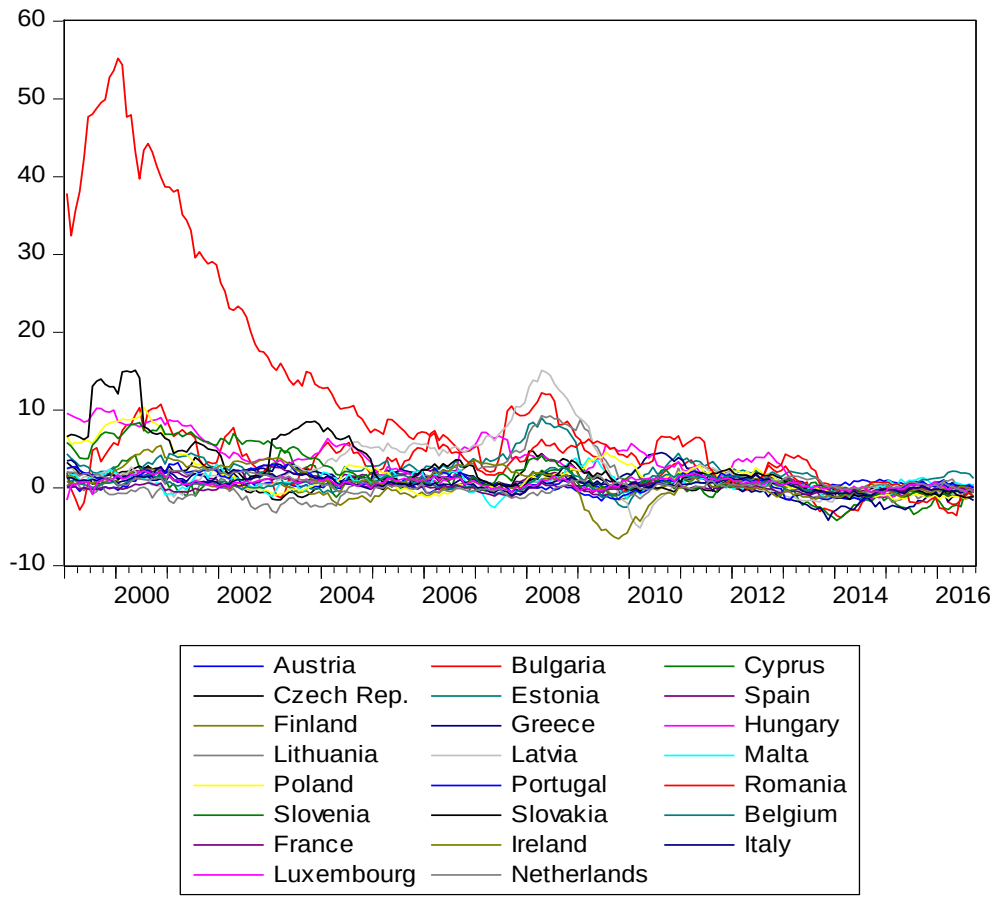


Figure 6: Inflation differentials from Germany for all countries: 1999-2016.

3.2 The determinants of inflation differentials in the EACs

The potential causes of inflation differentials is a major issue as their implications across different countries in a monetary union may differ widely. The potential sources that observed inflation differentials within a currency area concentrate on consumption and institutional factors and factors related to structural differences.

3.2.1 Consumption and institutional factors

According to the ECB (2003) inflation differentials are observed partly from a composition effect. This means differences in price developments of individual consumer goods and services across countries and differences in the shares of these items in national consumption. Moreover, reasons by different fiscal policy reflect differences in indirect taxes and in wages, examples of fiscal policy.

3.2.2 Structural factors

The inflation differentials mainly reflect structural effects. In this case, structural differences such as different levels of rigidities in the wage or different exposure to external shocks can amplify inflation differentials. Specifically, structural effects relate to

external effects, convergence in the tradable and non-tradable goods sectors and market rigidities. These factors could explain inflation differentials.

External effects

The divergent path of inflation across countries should also have an external dimension of structural character, associated with oil price shocks and the exchange rate pass-through. This means that if the Eurozone countries have a different degree of oil dependency and different pass-through patterns, then the impact of oil prices and the exchange rate changes on domestic prices might also differ. Other possible reasons are associated with the degree of dependence of a euro area country with foreign trade, the geographical trade structure and the composition of imports from non-euro area countries.

The prices of tradable and non-tradable goods

It is widely known, that purchasing power parity holds for tradable goods. In other words, the prices of homogeneous products expressed in the same currency remain the same in different locations. However, differences between tradable goods price levels exist across euro area countries and are influenced by the level of national and international competition. According to the study of the European Commission (2002a), indirect taxation, the structure of distribution networks, market power competition and inefficient service sectors are the main factors for the differences in the prices of tradable foods. As regards the differences in non-tradable goods prices across countries the Balassa Samuelson model is the main implement which explains this phenomenon. According to this model, differences in productivity growth between tradable and non-tradable goods explain the divergent inflation rate across countries. In practice, the sector of tradable goods is capital-intensive and more susceptible to competition than the non-tradable goods sector, which is labour-intensive. In the case where the productivity growth increases in the tradable goods, the wages increases without leading to higher prices. Owing to labour mobility, the wages in the non-tradable goods sector also increases which leads to higher inflation. This situation reflects inflation differentials due to differences in non-tradable goods prices among countries in a monetary union.

Market rigidities and structural reform

The level and the persistence of national inflation differentials within the euro area are also partly related to different rigidities in market (wage and price-setting). Those rigidities amplify the inflationary effects of demand pressures. Structural reform is a way to avoid this inflationary situation. However, structural reform in individual countries could also have temporary negative effects on wage and price formation and inflation differentials.

Cyclical factors

Inflation differentials in a monetary union may also partly stem from differences in the cyclical position, as measured for example by the output gap. This gap is the difference between actual and potential production. Recent studies such as Alberola (2000) and the European Commission (2002) found that there is a positive relationship between measures of the relative cyclical positions of euro area countries and their relative

inflation rates. The following Table 7 shows the above underling reasons for inflation differentials.

Table 7: Underling factors for inflation differentials.

Consumption factors	Institutional factors	Structural factors
Different national weights for calculation of CPI.	**Fiscal policy** ✓ Indirect taxation. ✓ The wages of public sector.	**External effects** ✓ Different oil independency.
		Price level convergence ✓ Tradable goods price convergence ✓ Non-tradable goods price convergence
		Market rigidities and structural reform ✓ Rigidities in wages
		Business cyclical factors ✓ Inflation differentials due to output gap.

4 Theoretical framework and empirical findings on convergence

4.1 Theoretical and methodological aspects about convergence

4.1.1 A concise analysis to convergence theory

Convergence is one of the most important issues that is analyzed in economic theory. In the large literature of economic theory the term of convergence could be defined in different ways, the first one interprets the process in which economies of different countries tend to reach a similar level of development and wealth. Another definition is the way of an economy catching up to the reference value so as to decline the inequalities. In particular, the above definitions find their roots in the economic growth theory. Therefore, definitions and methodological approaches to convergence are rooted in the empirical growth literature, pioneered by Baumol (1986), Barro (1991) and Barro and Sala-i-Martin (1992). According to this literature two types of convergence are defined:

- Absolute or unconditional convergence.
- Conditional convergence.

The examination of absolute or unconditional convergence is conducted to the standard exogenous Solow-Swan model (Solow and Swan, 1956), which predicts real convergence across countries. In general, this type of convergence implies that, independent of their characteristics, different economies will eventually converge to the same long-term level. Specifically, they claim that poorer regions and countries will catch up with richer ones. The importance of this assumption is the diminishing return to capital.

Three decades later, Romer (1990) introduced the endogenous growth theory of conditional convergence. In this case, conditional convergence ought to help explain why countries with similar conditions like savings or growth rates can converge to the same steady state. In other words, this type of convergence implies that all countries grow to their own steady state, which depends on underlying, country-specific, economic factors. In addition, under the umbrella of the economic theory two general types of convergence are also distinguished:

- Real convergence.
- Nominal convergence.

Real Convergence means that living standard becomes more similar. Nominal convergence is referred to converging of nominal macroeconomic indicators such as

inflation rates and interest rate. Following the literature, economists determined also two other complimentary types of convergence, beta and sigma convergence (Barro and Sala-I-Martin, 1992 and Sala-I- Martin, 1996). Beta convergence is synonymous with catching up. In other words, countries with lower GDP per capita tend to grow faster than the richer countries. Sigma convergence implies convergence to a common level. Table 8 shows the different kinds of convergence.

Table 8: Different dimensions of Convergence

	Beta	Sigma
Real	Catching up in living standards. e.g. poor countries achieve same living standards as rich ones.	Smaller differentials in living standards across countries. e.g. poor and rich countries become similar.
Nominal	Catching up in economic indicators. e.g. inflation differentials among EU economies to common levels.	Smaller differentials in economic indicators. e.g. inflation differentials among EU economies become smaller.

4.1.2 Measuring convergence

The estimation of convergence is a complicated process as it depends on regions, countries, groups of countries, the time period and different kinds of models which take part in estimating convergence process. That is why the results are quite mixed as they rely on the specific methodological and econometric approach. In practice, under the definitions which were referred earlier, the concept of measuring convergence could be applied with:

- Cross section tests
- Time series tests
- Panel testing

On the one hand, cross section analysis is conducted by Boumol (1986), De Long (1988), Barro and Sala-I-Martin(1991), who examined the linear relationship between the economy's average growth and initial income. This is the concept of beta convergence.

According to Sala-I-Martin (1994) the concept of beta convergence is more suitable among different economies. With this approach we could examine the speed of convergence, whether the convergence is conditional or unconditional and whether the convergence is partial or total. In this case, the regression is given by:

$$y_{i,T} = a + \beta y_{i,o} + \varepsilon_{i,T}$$

where T is fixed horizon. Empirical work using this regression reveals evidence of convergence when β coefficient in cross section regression is less than zero ($\beta < 0$).

On the other hand, time series approach is conducted with the concept of sigma convergence which is based on coefficient of variation. At the same time, Durluaf (1996) develops the concept of stochastic convergence. In this case, in terms of economic variables, differences between two countries are examined so as to provide evidence of convergence. Consequently, under the time series framework, univariate properties of the inflation differential using unit root or stationarity tests are examined to provide evidence of convergence. The regression is given by:

$$y_{i,t} - y_{j,t} = a_{i,j} + \sum_{r=0}^{\infty} \pi_{i,j,r}\ \varepsilon_{i,j,t-r}$$

where $a_{i,j} = 0$ and $\pi_{i,j,r}$ is square summable.

Panel testing is a new generation analysis, which takes place in order to provide evidence of convergence. This can be done by either panel unit root or panel stationarity tests. In this case the typical regression is given by:

$$\Delta y_{i,t} = a + (\rho - 1) y_{i,t-1} + \varepsilon_{i,t}$$

where ρ captures the rate of convergence. On the basis of growth theory that is discussed earlier, there are two types of convergence that may occur. On the one side, absolute convergence, that implies that $\rho < 1\ and\ a = 0$. This result means that the stationary difference of the two variables is on average 0. On the other side conditional or relative convergence holds when $\rho < 1\ and\ a \neq 0$ (Karanasos et al., 2015).

Using panel data in comparison with time series and cross-section analysis is more beneficial for several reasons (Baltagi, 2008). Firstly, panel analysis can control the individual heterogeneity, while time series and cross-section studies are not able to control this heterogeneity with the risk to obtain unbiased results. Secondly, panel data improve the power of the tests as they offer more informative data, more variability, less collinearity among the variables, more degrees of freedom, which means better sufficiency. In addition, panel data are better able to identify and measure effects that are simply not detectable in pure cross-section or pure time series data. Finally, due to the complexity of macroeconomic environment, panel data provide tests more appropriate than cross-section or time series data, since the models present more complicated behavior than others.

In this study, findings of inflation convergence among EUCs are revealed under the panel approach. These results are obtained by testing of first and second generation

panel unit root and stationarity tests. These tests are developed with more information in the next part.

4.2 Empirical findings in the literature

In the light of the achievement of one of the Maastricht criteria in order for the European economies to adopt the single currency, most empirical studies have addressed the issue of inflation convergence in these European countries. From this point of view, a range of econometric techniques such as time series and panel approaches take place so as to indicate evidence of convergence. While the first approach has dominated in most surveys, the second has started to gain popularity as it improves the power of the tests. Furthermore, the importance of non-linear econometric modeling in accounting for convergence is referred to in the literature.

In particular, Caporale and Pittis (1993), by applying univariate unit root and Johansen cointegration tests, discovered partial convergence of inflation differences in a sample of six EMS countries for the period of 1986 to 1990 but they do not find the same results for 1979 to 1990 and for three non-EMS countries. Similar findings are provided by Thom (1995), who finds partial convergence of inflation rates from 1983 to 1992 as well as from 1986 to 1990 for the same countries that Caporale and Pittis (1993) examined. Thus, in their letters, they confirm that the coordination of the exchange rate policies helped the convergence processes.

Similar results are reported by Kocenda and Papell (1997). In their paper the authors focus on whether the Exchange Rate Mechanism (ERM) has played a vital role in inflation convergence. Using quarterly observations from 1959 to 1994 and dividing this sample into two time periods, from the second quarter of 1959 to the first of 1979 and the second quarter of 1979 until the end of 1994, they examined a group of 10 EU countries participating in ERM and 8 non-ERM EU countries. For this reason, they applied panel unit root econometric analysis. Overall, their results showed that evidence exists in favour of inflation convergence and especially confirmed that the inflation convergence accelerates for countries that belonged to the narrow ERM.

Another survey that indicates similar findings is mentioned by Holmes (2002). His econometric analysis is based on panel data unit root and cointegration tests such as ADF unit root, IPS panel unit root and Pedroni panel cointegration tests. Taking 6 major EU economies for the period from 1972 to 1999, he found evidence of stronger convergence before 1990, which is the period that ERM took place. Likewise, Mentz and Sebastian (2003) apply univariate unit root and Johansen cointegration tests for two periods from 1993 to 1998 and 1993 to 2002 with monthly observations; they find partial convergence for the former period and no convergence for the latter. Kutan and Yigit, (2004), by investigating the convergence of the new 10 EU members, showed that strong evidence of real stochastic convergence for all new members exists. For this scope, the authors used panel unit root techniques such as IPS, Hadri and SUR-ADF, covering the period from 1993 to 2003. For their tests, they used monthly observations and took Germany as a benchmark to represent core EU countries and Greece to represent new members. Taking quarterly data of inflation differentials for Bulgaria, Romania, Czech Republic and Hungary from the EU inflation for the period of 1997 to 2005, Figuet and

Nenovsky (2006) found evidence of convergence in all transition countries except Romania. The reason for this is that Bulgaria, for example, adopted a currency board regime which provides a significantly more efficient nominal convergence when compared to Romania's discretionary monetary regime. Evidence of convergence is found by applying panel cointegration tests. Thereafter, these researchers assessed impulse responses in order to observe the shock reactions of Bulgaria and Romania. The base line results showed that Bulgaria was more flexible in its reaction to the shocks from the EU. Likewise, by applying stationarity tests, such as KPSS, on monthly inflation data for 11 EU countries, and by splitting the sample into two subsamples, 1980 to 1997 and 1998 to 2004, Busetti et al. (2007) found evidence of convergence only for the former period, while in the latter there was some kind of divergence.

A significant contribution to this thesis is the study of Spiru (2008), who examines the inflation convergence in Central and Eastern European (CEE) countries. The main characteristic of these economies is that they are all transition economies. The author used monthly CPI data commencing 1993 to 2004 and calculate inflation differentials of all countries with respect to four leaders; Germany, Greece, the EU and their group average. Thereafter, six panels of countries are constructed which comprise potential combinations of these economies. For instance, a group that consists only of former transition economies comprise Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, the Slovak Republic and Slovenia. The tests which are used in this analysis are ADF unit root, IPS, SUR-ADF panel unit root and ESTAR non-linear tests. Overall, the regression results indicate inflation convergence for some countries and for some groups of countries. Additionally, evidence of inflation convergence is provided by Holmes (2008) in a sample of 15 EU countries. The results are based on the application of principal components analysis and unit root testing for the period from 1999 to 2007.

Other important research was conducted by Gregoriou et al. (2011). Unlike the above studies, the authors concentrated on inflation deviations from the target defined by the Maastricht reference value and the ECB target. In particular, so as to estimate the inflation misalignment, they used HCPI inflation differentials from the policy reference value for 12 EMU countries, covering a period of 1996 to 2005. Their analysis relies on the linear approach such as ADF and Ng-Perron unit root tests and non-linear modeling like ESTAR unit root test. The highlight of this study is the results as the authors find strong evidence of unit root behaviour in the deviations of EMU countries' inflation rates from the policy reference value under the linear approach. However, the results differ under the non-linear one as the findings show that inflation deviations follow a stationary process.

Lopez and Papell (2012), in order to increase the power of panel unit root tests, attempted to use group-wise convergence. Regressions are estimated using annual inflation rates for the EU11 and EU10 groups of countries (which include the twelve countries excluding Greece and Ireland, respectively) from the period of 1979 to 2010. In addition, the analysis relies on rolling estimation in the entire sample. By applying ADF-SUR tests, they find a strong degree of inflation convergence for the entire period. However, their results for the EU12 group showed a weaker degree of inflation convergence, and even weaker after the financial crisis of 2007 to 2008. Another survey that follows similar econometric techniques to Gregoriou et al. (2011) is conducted by

Cuestas et.al (2012). The sample consists of seven CEE countries for the period of 1997 to 2011. The empirical results reveal mixed evidence of inflation convergence among CEE countries and the Eurozone. Arestis et al. (2014) attempted to discover whether or not countries with different monetary regimes (i.e. inflation and non-inflation-targeting) show inflation convergence. Their dataset consists of quarterly data from 1990 to 2011 for 11 OECD inflation-targeting countries and 11 OECD non-inflation-targeting countries. By employing univariate and panel unit root tests, they show that convergence in inflation rates occurred in both groups regardless of their monetary policy orientation.

More recent studies, like Simionescu (2015), aim to assess the convergence rate in 28 EU countries and check if there was a decline in the convergence process due to the economic crisis. Taking HCPI inflation differentials from the average inflation for the period of 2002 to 2013 and splitting the sample into two parts, from 2002 to 2007 and 2008 to 2013, she finds inflation convergence in the whole period, but a decline in convergence in the second sub-sample. The above results were obtained under the panel approach.

Lastly, a significant contribution is the research of Karanasos et. al (2016), who study inflation convergence in the 12 EMU countries and the link between inflation differentials and their uncertainty. Covering a period of 1980 to 2013 and separating their sample into two periods, from 1980 to 1997 and 1998 to 2013, they apply univariate and panel econometric techniques. They found convergence under the panel approach and obtained mixed evidence in favour of convergence using the univariate unit root testing procedures. The above empirical findings are illustrated in the following table.

Table 9. Empirical studies on inflation convergence.

Author(s)	Data and sample period	Econometric methodology	Main findings
Caporale and Pittis 1993	CPI inflation rates and inflation differentials vis-à-vis Germany in 6 EMS countries and 3 non-EMS countries. 1979m3-1990m12	PP unit root and Johansen cointegration tests.	Evidence of convergence between Germany and EMS countries only.
Thom 1996	CPI inflation rates vis-à-vis Germany in 7 ERM countries. 1983m4-1992m6 and 1986m5-1990m12	PP unit root and Johansen cointegration tests.	Evidence of convergence between inflation rates in ERM countries.
Kocenda and Papell 1997	CPI inflation differentials from the average inflation for 18 EU countries. 1959q2-1994q4	ADF panel unit root test.	Evidence of convergence.
Holmes 2002	CPI inflation differentials vis-à-vis Germany for 6 major EU economies. 1972m4-1999m4 and five sub-samples.	ADF unit root, IPS panel unit root and Pedroni panel cointegration tests.	Evidence of stronger convergence before 1990.
Mentz and Sebastian 2003	CPI inflation rates for 8 EC 1993m1-1998m12 and 1993m1-2002	ADF, PP, Ng-Perron unit root, KPSS stationarity and Johansen cointegration tests.	Evidence of partial convergence for the first period only.
Kutan and Yigit 2004	CPI and PPI inflation in 10 EU countries. 1993m1-2003m12	IPS and SUR-ADF panel unit root and Hadri panel stationarity tests.	Evidence of real stochastic convergence.
Figuet and Nenovsky	Inflation differentials for Bulgaria, Romania, Czech Republic and Hungary	Estimation of a panel cointegrating	Evidence of convergence in all countries except

2006	from the EU inflation. 1997q3-2005q3	relation.	Romania.
Busetti et al. 2007	Pair-wise CPI inflation differentials for 11 euro-area countries. 1980m1-1997m12 and 1998m1-2004m12	ADF unit root and KPSS stationarity tests.	Evidence of convergence only in the first sample.
Holmes 2008	HCPI inflation differentials from the EU average inflation for 15 EU countries. 1999m1-2007m10	ADF and GLS unit root, IPS and LLC panel unit root and Hadri panel stationarity tests.	Evidence of convergence.
Spiru 2008	CPI inflation differentials for 11 central and east European countries from Germany, Greece, the Euro Area and their group average. 1993m1-2004m12	ADF unit root, IPS SUR-ADF panel unit root and ESTAR tests.	Evidence of convergence for some countries under the linear and non-linear approach.
Gregoriou et al. 2011	HCPI inflation differentials from the policy reference value for 12 EMU countries. 1996m1-2005m4	ADF and Ng-Perron unit root and ESTAR non-linear unit root tests.	Evidence of divergence under the linear approach and decline of divergence under the non-linear approach.
Lopez and Papell 2012	CPI inflation differentials from the average inflation for 12 EU countries. 1979m1-2010m4	Rolling estimation. ADF-SUR panel unit root test.	Evidence of convergence in all sample period except of financial crisis (2008).
Cuestas et.al 2012	HCPI inflation differentials from the EMU inflation for 7 central and east European countries. 1997m1-2011m7	ADF and ESTAR unit root tests.	Evidence of convergence for most countries.
Arestis et al. 2014	Pair-wise CPI inflation differentials for 11 OECD inflation-targeting countries and 11 OECD non-inflation-targeting countries. 1990q1-2011q4	ADF and cross-sectional ADF unit root tests, IPS and cross-sectional IPS panel unit root tests.	Evidence of convergence within both groups of countries.
Simionescu 2015	HCPI inflation differentials from the average inflation for EU-28 countries. 2002-2013 and two sub-samples 2002-2007 and 2008-2013	Haris-Tzavalis and Fisher–type panel unit root tests.	Evidence of convergence in the whole period, decline of convergence in the second sub-sample.
Karanasos et al. 2016	CPI inflation rates for 12 EMU countries. 1980q1-1997q4 and 1998q1-2013q4	ADF, ZA, LP unit root and KPSS stationarity tests. IPS, LLC, HT, BD, CADF, KT14 and KT15 panel unit root tests.	Evidence of partial and absolute convergence under the panel approach and divergence under the univariate approach.

In this thesis, a panel approach is used so as to examine inflation convergence among the European Union countries (EUCs).

5 Data and methodology

5.1 Data description

The dataset consists of historical monthly observations on inflation, based on consumer price index (CPI) for twenty-four EU countries. The data are obtained from the Bank of International Settlements (BIS). The countries under study are Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia and Spain. The twenty-four countries are divided in five groups: the Old Member States (OMS) group comprises the first seven EU countries, namely Belgium, France, Germany, Ireland, Italy, Luxembourg and Netherlands; the Core Countries (CCs) group consists of twelve countries, namely Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain; the New Member States (NMS) group comprises five countries, namely Cyprus, Estonia, Malta, Slovakia and Slovenia; the Central and East European Countries (CEECs) group consists of seven countries, namely Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland and Romania; finally, the East European Countries (EECs) group comprises five countries, namely Bulgaria, Czech Republic, Hungary, Poland and Romania.

The sample spans from January 1974 to September 2016. Taking the advantage of the third stage of the EMU, that is 1999 being a benchmark due to the introduction of the euro, this interval splits into four sub-periods. Therefore, the OMS group is studied for the period from 1974 to 1998, known as pre-euro period, and from 1999 to 2016, known as post-euro period. The CCs group is also examined for the post-euro period. The NMS group is studied for the period from 1999 to 2006, since in January 2007 Slovenia enters the EMU. The CEECs group is analyzed for the period from 1999 to 2013, since Latvia introduces the euro in January 2014. Finally, the EECs group is examined for the period from 1999 to 2016, since these countries are transitional economies towards the EMU. Table 10 presents the above grouping of countries and the corresponding periods.

Table 10: Groups of countries.

Group	Countries	Period
Old Member States (OMS)	Belgium, France, Germany, Ireland, Italy, Luxembourg and Netherlands.	1974m1 – 1998m12 1999m1 – 2016m9
Core Countries (CCs)	Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain.	1999m1 – 2016m9
New Member States (NMS)	Cyprus, Estonia, Malta, Slovakia and Slovenia.	1999m1 – 2006m12
Central and East European Countries (CEECs)	Bulgaria, Czech Republic, Hungary, Latvia, Lithuania, Poland and Romania.	1999m1 – 2013m12
East European Countries (EECs)	Bulgaria, Czech Republic, Hungary, Poland and Romania.	1999m1 – 2016m9

The following graphs depict the evolution of inflation of the above group of countries, during the corresponding periods.

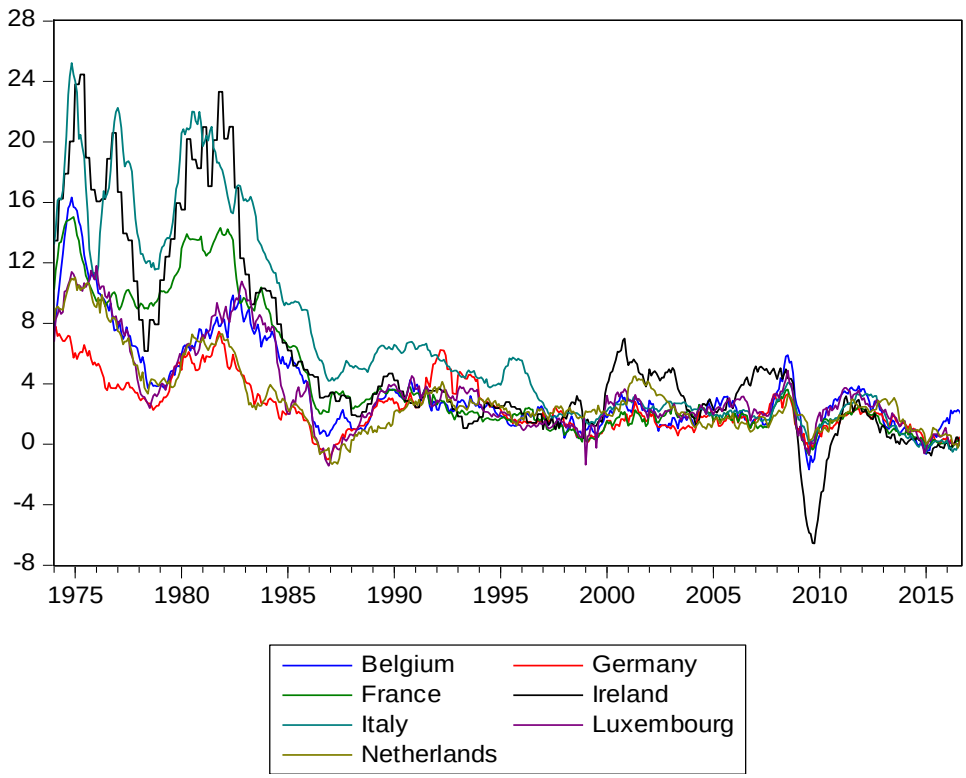


Figure 7. Inflation rates of OMS group.

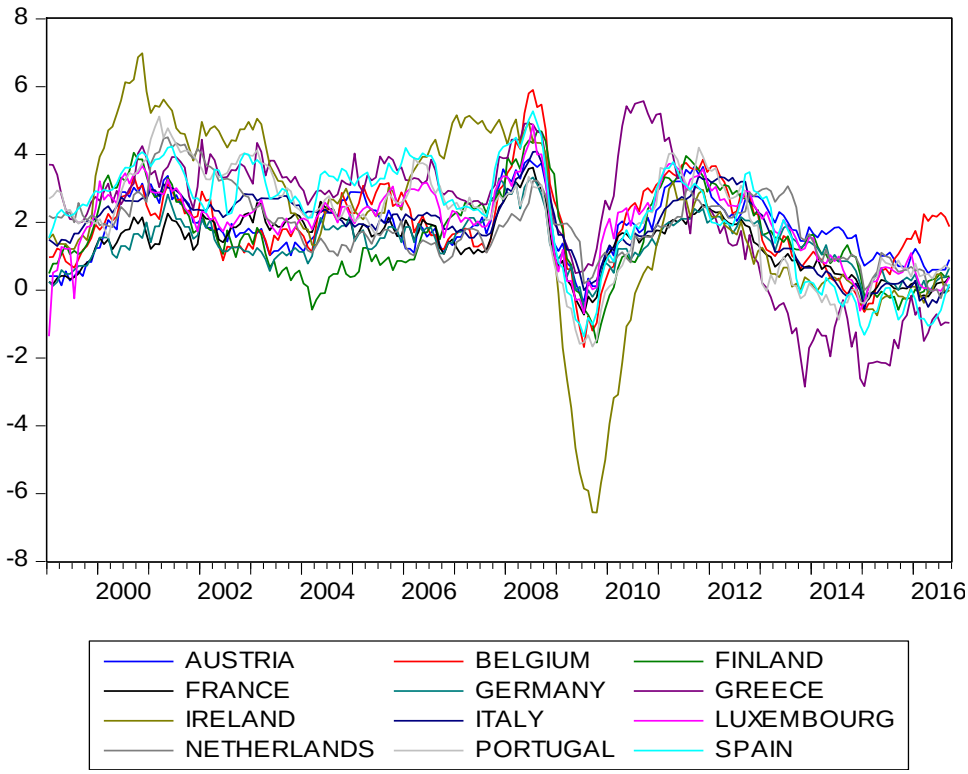


Figure 8. Inflation rates of CCs group.

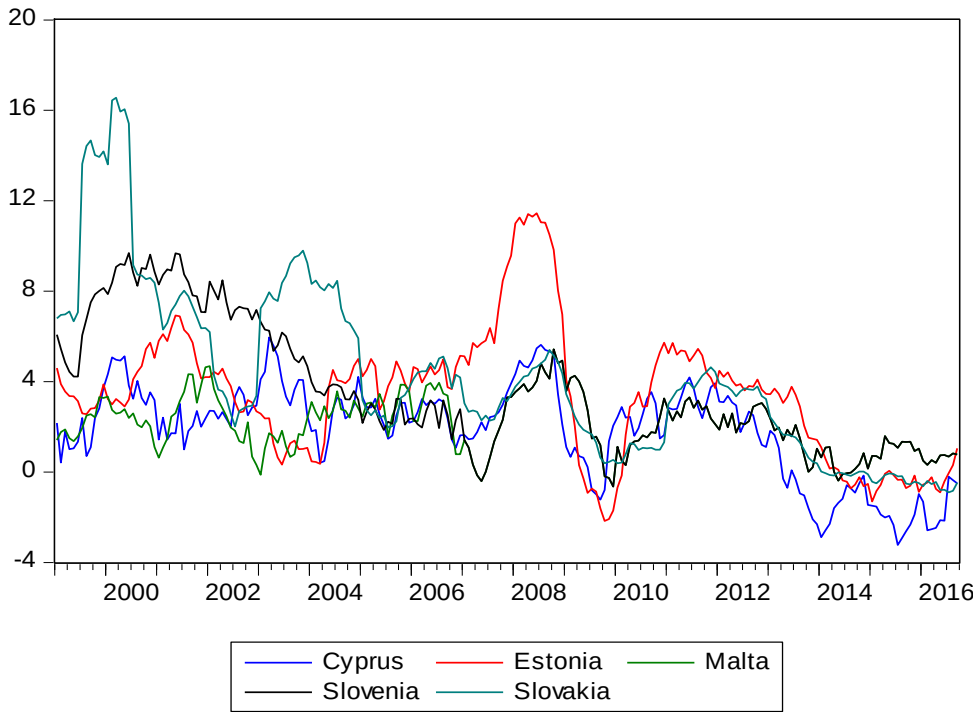


Figure 9. Inflation rates of NMS group.

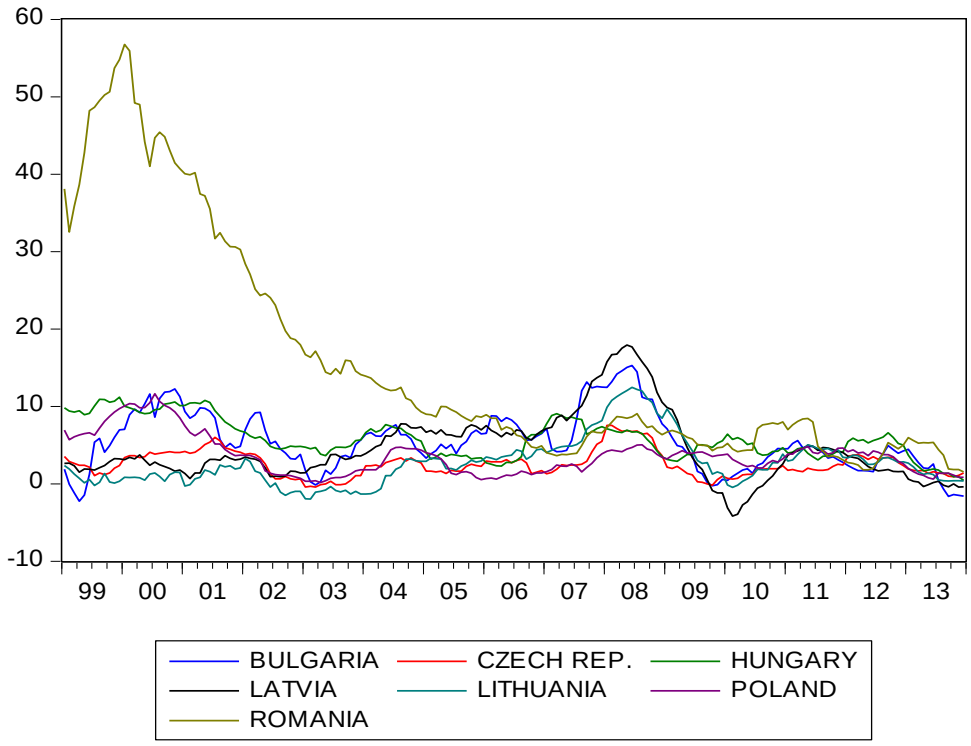


Figure 10. Inflation rates of CEECs group.

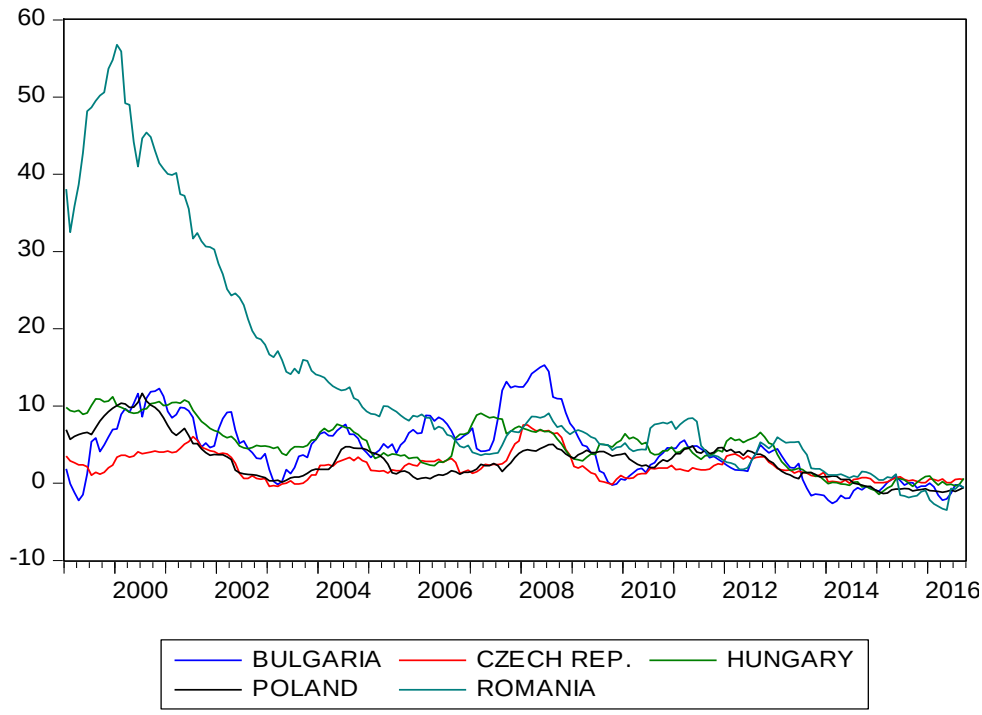


Figure 11. Inflation rates of EECs group.

5.2 Econometric methodology

In order to examine inflation convergence among EU countries, inflation differentials of the countries under study are calculated, with respect to two benchmarks, inflation of Germany and the Policy Reference Value (PRV). Germany is considered to represent the core EU standards, since it has low inflation during the whole period of the EMU. PRV is defined as 1.5% plus the average inflation of the best three performing European countries in terms of inflation control. Therefore, PRV is associated with the Maastricht convergence criterion and the ECB target. According to Gregoriou et al. (2011), PRV is a more appropriate approach to model inflation differentials, since national inflation rates are bounded by the Maastricht Treaty and the ECB target of 2%. Inflation differentials are calculated as follows.

$$D_{ger} = \pi_{it} - \pi_{ger,t} \quad (1)$$

$$D_{prv} = \pi_{it} - PRV \quad (2)$$

where π_{it} denotes inflation rate of country i at time t, $\pi_{Ger,t}$ denotes inflation rate of Germany at time t , and D_{Ger} and D_{prv} denote inflation differentials from Germany and PRV, respectively.

The following graphs depict the evolution of inflation differentials from PRV and from Germany for all groups of countries under study during the corresponding periods. Specifically, the differentials for the OMS countries in the pre-euro period seem to be

large, while after the introduction of the euro, these differentials reduce. This conclusion holds both for the differential from PRV and from Germany. In addition, it is clear from the graphs that the largest differential in the post-euro period belongs to Ireland, with the largest deviation from the other countries existing in the period of the financial crisis. As far as the other countries are concerned, when the PRV is utilized as benchmark, the differentials are larger than the differentials from Germany.

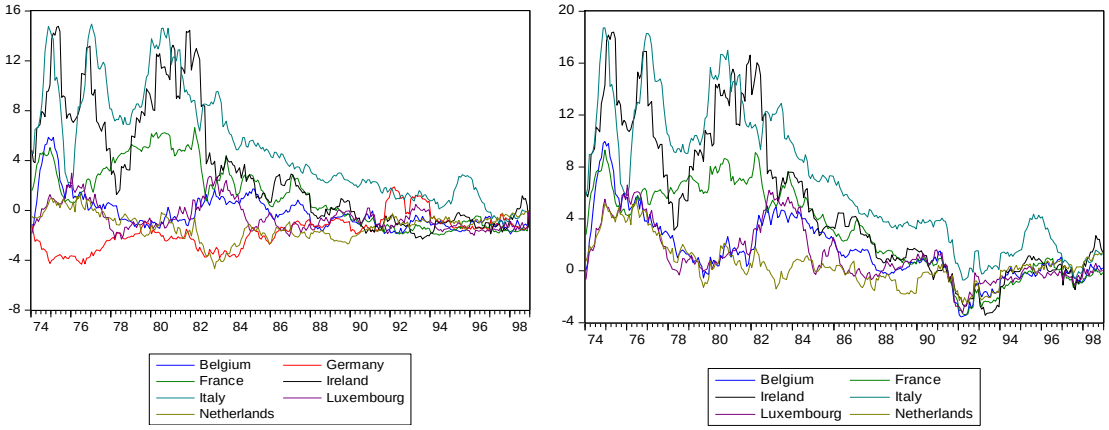


Figure 12. Inflation differentials from PRV and from Germany for OMS group for the pre-euro period.

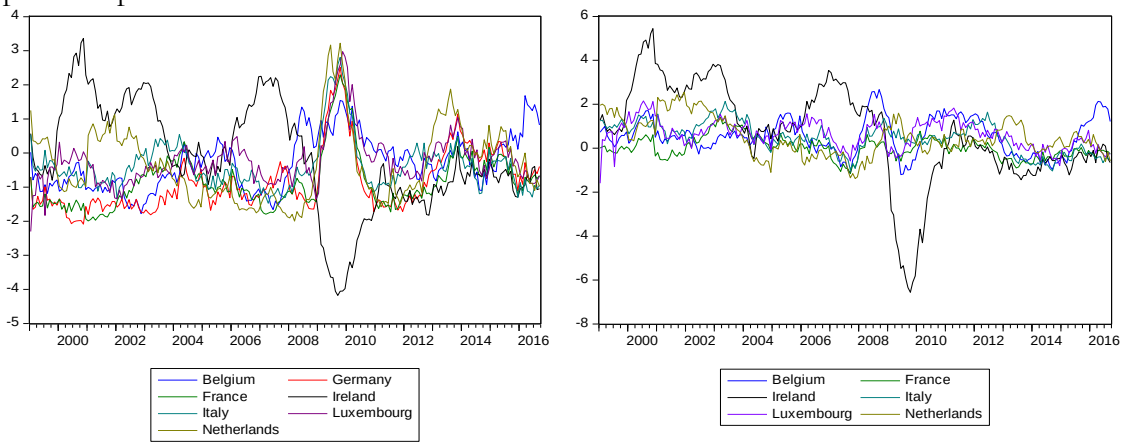


Figure 13. Inflation differentials from PRV and from Germany for OMS group for the post-euro period.

As regards the CCs group, which comprises the seven countries of the OMS group plus five more countries, a similar behavior as before is witnessed, with the largest differentials belonging to Ireland and Greece.

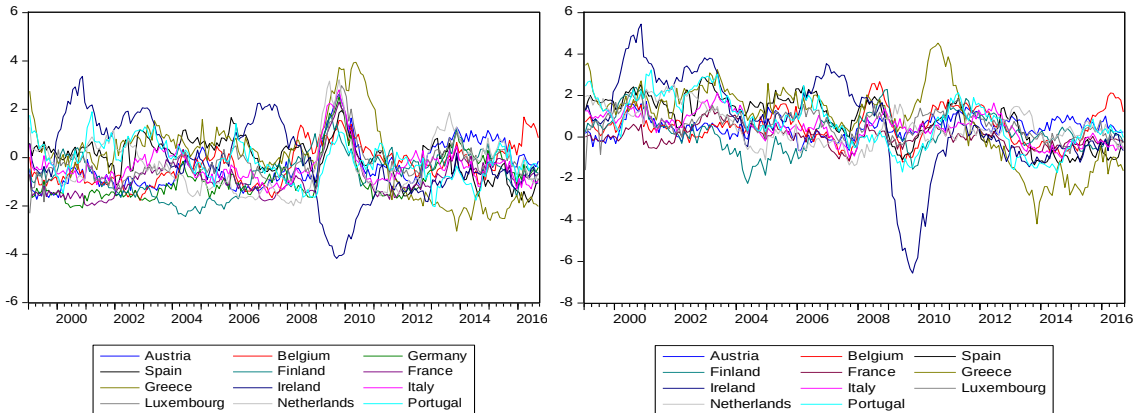


Figure 14. Inflation differentials from PRV and from Germany for CCs group.

On the other hand, larger differentials are seen in the NMS group, with Slovenia and Slovakia showing the largest misalignments. However, it is obvious that the differentials in the rest three countries are smaller and follow a similar behavior for the whole period, with respect to both benchmarks.

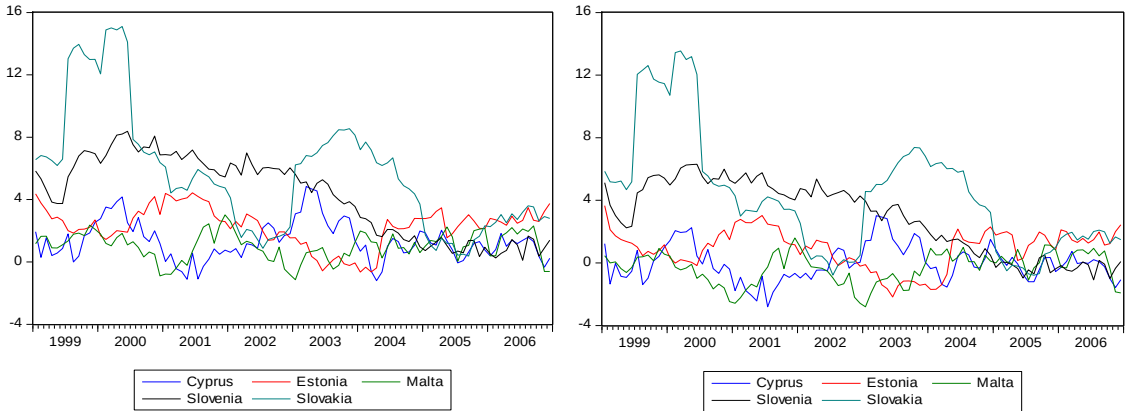


Figure 15. Inflation differentials from PRV and from Germany for NMS group.

Similar behavior in the differentials is also seen in the case of the CEECs group, with the exception of Romania, which exhibits the largest deviation from the other countries. However, this deviation reduces in the mid 2000s.

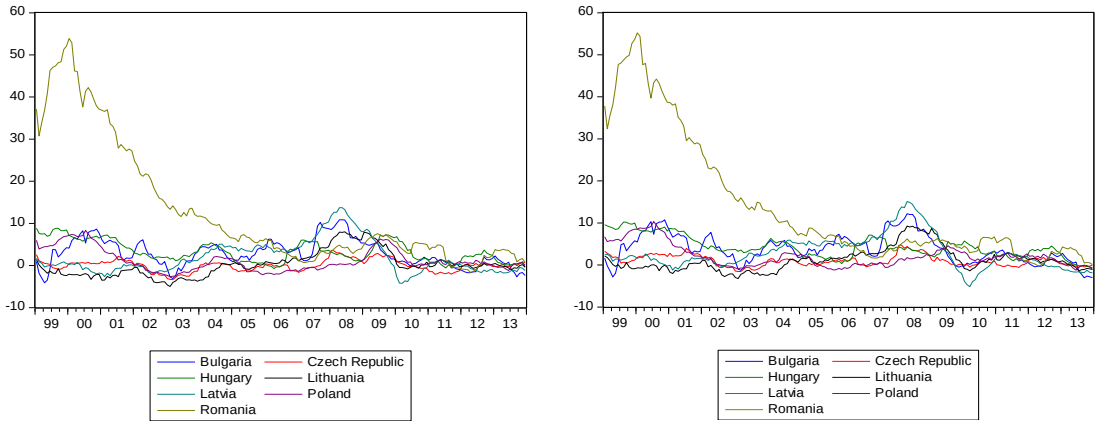


Figure 16. Inflation differentials from PRV and from Germany for CEECs group.

Finally, with the exclusion of Lithuania and Latvia, which adopted the euro in 2014 and 2015, respectively, the EECs group depicts a similar behavior as the CEECs group.

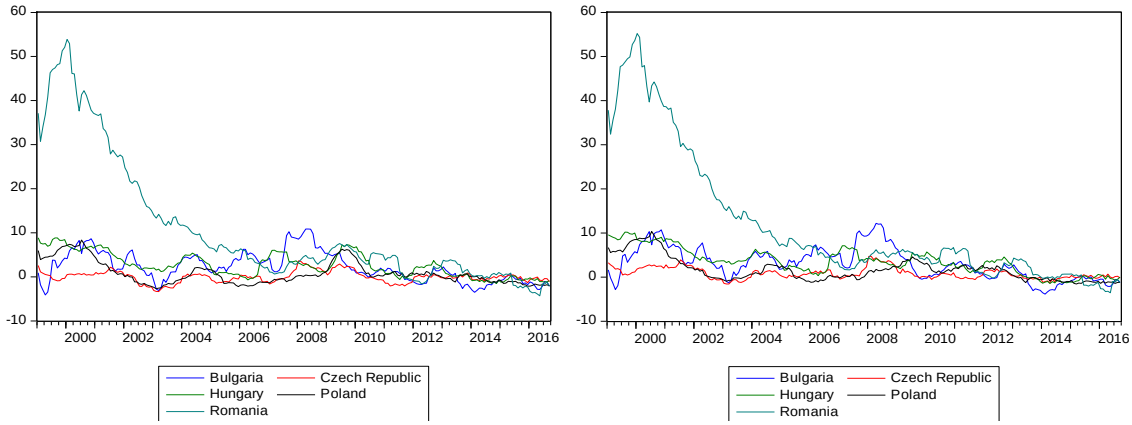


Figure 17. Inflation differentials from PRV and from Germany for EECs group .

5.2.1 First generation panel unit root tests

Two panel unit root tests and a panel stationarity test are employed in order to examine inflation convergence among EU countries. In addition, conditional variant of convergence examined which implies that the intercept included in more tests. This process is more appropriate as the more group of countries are in the pre-accession stage to the EU. The tests used are briefly described below.

Levin, Lin and Chu Test

Levin et al. (2002) (LLC) suggest a panel unit root test where the null hypothesis is that each individual time series contains a unit root against the alternative that each series is stationary. The estimated equation is

$$\Delta y_{it} = \psi y_{i,t-1} + \sum_{L=1}^{p_i} \theta_{iL} \Delta y_{i,t-L} + a_i + \varepsilon_{it}, \qquad (3)$$

where Δy_{it} is the (D_{ger}, D_{prv}), α_i is a constant term, ε_{it} is the disturbance term, which is i.i.d, $i = 1, \dots, N$ individuals and $t = 1, \dots, T$ time periods. The null hypothesis is:

$$H_0: \psi_i = 0 \; for \; all \; i$$

Against the alternative,

$$H_1: \psi_i < 0 \; for \; all \; i$$

If N and T are fixed, Levin et al. (2002) propose an adjusted t-statistic, which is calculated in a manner similar to the calculation of the normal t-statistic and follow asymptotically the standard normal distribution:

$$t_{\rho}^{*} = \frac{t_{\rho} - N\tilde{T}\hat{S}_{N}\hat{\sigma}_{\tilde{\varepsilon}}^{-2}\hat{\sigma}(\hat{\rho})\mu_{m\tilde{T}}^{*}}{\sigma_{m\tilde{T}}^{*}}$$

Im, Pesaran and Shin Test

The LLC test is restrictive, since ψ is homogeneous across i. Im et al. (2003) (IPS) improve this test by allowing ψ to be heterogeneous across cross-sectional units. The null hypothesis is that each series in the panel contains a unit root, while the alternative allows for some series to have unit roots. The estimated equation is

$$\Delta y_{it} = \alpha_i + \psi_i y_{i,t-1} + \sum_{j=1}^{p} \beta_{ij}\, \Delta y_{it} + \varepsilon_{it} \quad (4)$$

where Δy_{it} is the first difference of inflation differentials, either from Germany or from $PRV(D_{ger}, D_{prv})$, α_i is a constant term, $\varepsilon_{i,t}$ is the disturbance term, which is i.i.d, $i = 1, \dots, N$ individuals and $t = 1, \dots, T$ time periods. The null hypothesis is:

$$H_0: \psi_i = 0 \; for \; all \; i$$

Against the alternatives,

$$H_1: \psi_i < 0 \; for \quad i = 1,2, \dots, N_1$$

$$H_1: \psi_i = 0 \; for \quad i = N_1 + 1, \dots, N$$

Im. et al. (2003), compute the t-statistic as the average for all the individual test statistics t_{ψ_i} obtained from the model (1) is calculated:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{\psi_i}$$

In the general case where the lag order of equation (4) may be non-zero for some cross-sections, IPS shows that a properly standardized $\overline{t_{NT}}$ has an asymptotic normal distribution:

$$W_{\overline{t_{NT}}} = \frac{\sqrt{N}\,[\overline{t_{NT}} - N^{-1}\sum_{i=1}^{N} E(\overline{t_{iT}}(p_i))]}{\sqrt{N^{-1}\sum_{i=1}^{N} Var(\overline{t_{iT}}(p_i))}} \rightarrow N(0,1)$$

Hadri Test

The Hadri (2000) test is a panel stationarity test and has a null hypothesis of no unit root in any of the series in the panel against the alternative of a unit root in the panel. It is based on the residuals of the individual OLS regressions:

$$y_{it} = r_{it} + \varepsilon_{it} \quad (5)$$

where y_{it} is inflation differential of country i from Germany or PRV (D_{ger}, D_{prv}), $r_{it} = r_{i,t-1} + u_{it}$ is a random walk. ε_{it} and u_{it} are i.i.d., $i = 1, \dots, N$ individuals and $t = 1, \dots, T$ time periods. Equation (5) becomes

$$y_{it} = r_{i0} + \sum_{s=1}^{t} u_{is} + \varepsilon_{it} = r_{i0} + v_{it} \quad (6)$$

with $v_{it} = \sum_{s=1}^{t} u_{is} + \varepsilon_{it}$, r_{i0} being initial values that play the role of heterogeneous intercepts. The null hypothesis of stationarity is:

$$H_0: \sigma_u^2 = 0$$

Against the alternative,

$$H_1: \sigma_u^2 > 0$$

The LM statistic is given by

$$LM = \frac{1}{N}\left(\sum_{i=1}^{N} \frac{1}{T^2} \sum_{t=1}^{T} s_{it}^2\right) / \hat{\sigma}_\varepsilon^2$$

5.2.2 Tests for cross sectional dependence

During the EMU process, it is observed an increasing economic integration of the EU countries, which may lead to cross-sectional dependence due to the presence of common shocks and unobserved components. These cross-sectional dependencies should be taken into account when estimating a panel data model. In the standard panel data model

$$y_{it} = a_i + \beta' x_{it} + u_{it} \quad (7)$$

where $i = 1, \dots, N$ individuals, $t = 1, \dots, T$ time periods, x_{it} is a Kx1 vector of regressors, β is a Kx1 vector of parameters to be estimated and a_i represent time-invariant individual nuisance parameters. Under the null hypothesis u_{it} is assumed to be i.i.d. Thus, the null hypothesis is

$$H_0: \rho_{ij} = \rho_{ji} = corr(u_{it}, u_{jt}) = 0 \; for \; i \neq j$$

Against the alternative,

$$H_1: \rho_{ij} = \rho_{ji} \neq 0 \; for \; some \; i \neq j$$

In particular, in this study the presence of cross-sectional dependence across EU countries is examined, using two methods, namely the Breusch and Pagan (1980) LM test and the Pesaran (2004) test of error cross-section dependence (CD).

Breusch and Pagan LM test

Breusch and Pagan (1980) proposed a Lagrange Multiplier (LM) statistic, which is valid for fixed N as T → ∞ and is given by

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{i,j}^2$$

Pesaran's CD test

Pesaran (2004) proposes an alternative test for the presence of cross-sectional dependence, which is given by

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{i,j}^2 \right)$$

When the time dimension (T) is larger than the cross-sectional dimension (N) the LM test is appropriate, while the CD test is more appropriate when N is larger. However, the CD test is also used in cases where $T > N$ (for example Aslanidis and Fountas, 2014). For this reason in this study both tests are used, in order to examine the presence of cross-sectional dependence across the EU countries. In addition, the appropriate lag length is chosen with the help of Scwartz criterion. Likewise, none of the panel data should have a trend. Following Aslanidis and Fountas (2014), an equation with no lags and with one lag is estimated in each case, in order to conduct the test.

5.2.3 Second generation panel unit root tests

Pesaran (2007) suggests a simple unit root test in heterogeneous panels with cross-sectional dependence. The test is based on the mean of individual DF (or ADF) t-statistics of each unit in the panel. The null hypothesis assumes that all series are non-stationary. To eliminate the cross dependence, the standard DF (or ADF) regressions are augmented with the cross section averages of lagged levels and first-differences of the individual series (CADF statistics).

$$\Delta y_{it} = \alpha_i + \psi_i y_{i,t-1} + d_0 \bar{y}_{t-1} + \sum_{j=0}^{p} d_{j+1} \Delta \bar{y}_{t-j} + \sum_{k=1}^{p} c_k \Delta y_{i,t-k} + \varepsilon_{it} \quad (8)$$

where y_{it} is inflation differential of country i from Germany or PRV (D_{ger}, D_{prv}), $\bar{y}_{t-1} = (1/N) \sum_{i=1}^{N} y_{i,t-1}$ and $\Delta \bar{y}_t = (1/N) \sum_{i=1}^{N} \Delta y_{i,t}$

The CIPS statistic is given by

$$\text{CIPS} = \frac{1}{N} \sum_{i=1}^{N} \text{CADF}_\text{i}.$$

The null hypothesis is:

$$H_0: \psi_i = 0 \; for \; all \; i$$

Against the alternatives,

$$H_1: \psi_i < 0 \; for \quad i = 1,2, \dots, N_1$$

$$H_1: \psi_i = 0 \; for \quad i = N_1 + 1, \dots, N$$

5.2.4 Half-lives in univariate and panel approach

Under the univariate approach persistence is investigated by looking at the univariate time series representation of inflation (Spiru, 2008; Marques, 2004). Mean-reverting behavior (beta convergence) in inflation differentials is examined by estimating AR(1) models[1].

$$y_t = \alpha + \rho y_{t-1} + u_t \quad (9)$$

where ρ is the speed of convergence and y_t denotes inflation differential for each country from either Germany or PRV (D_{ger}, D_{prv}), respectively.

Half-lives are calculated for each country using the following formula:

[1] Unit root tests for the individual countries have been conducted using the ADF test, prior to the estimation of the AR(1) models, and the null hypothesis has been rejected for all countries.

$$HL = \frac{\ln(0.5)}{ln(\widehat{\rho})}$$

The half-life is defined as the number of periods for which the effect of a unit shock to inflation remains above 0.5. Thereafter, the average half-life for all countries has been calculated. Moreover, following Choi et al. (2004), AR(1) models for all the panels have been estimated using the fixed effects procedure and the panel half-lives have been calculated. The panel regressions are of the form:

$$y_{it} = \alpha + \rho y_{i,t-1} + \mu_i + v_{it}$$

where y_{it} denotes inflation differential for country $i = 1, \dots, N$ from either Germany or PRV (D_{ger}, D_{prv}), for time $t = 1, \dots, T$, α is the intercept term, ρ is a Kx1 vector of autoregressive coefficients, μ_i denotes the unobservable individual specific effect and v_{it} denotes the remainder disturbance.

6 Empirical results

This section presents the results of the empirical testing. The findings of the first generation panel unit root and stationarity tests are shown in Tables 11a and 11b. Tables 12a and 12b present the results of the cross-sectional dependence tests, while Tables 13a and 13b show the findings of the second generation panel unit root tests. In the last part the half-lives of the individual countries and the panels of countries are presented.

6.1 Panel unit root and stationarity tests

Tables 11a and 11b show the results of the IPS, LLC and Hadri tests for the five groups of countries for the two variables under study.

In the first group of countries, namely OMS, studied for the pre-euro period, there is no evidence of convergence under any of the three tests, when the differential from Germany is used. On the other hand, when the differential from PRV is examined, evidence of convergence is seen with the IPS test at 5% significance level. However, in the post-euro period, the OMS group reveals strong evidence of convergence under both benchmarks with the IPS test at 1% level of significance. When the CCs group of countries is examined, the results show that there is evidence of convergence only with the IPS test, for both differentials at 1% significance level. Similar results are given for the NMS group, since the IPS test only rejects the null hypothesis of unit root at 5% significance level. Stronger evidence of convergence is seen in the case of the CEECs group of countries, where both IPS and LLC tests reject the unit root at all levels of significance, when both differentials are examined. Finally, the last group of countries, namely EECs, also shows evidence of convergence in both differentials. In particular, in the case of Dger, the unit root null is rejected at all significance levels, while in the case of Dprv, the null is rejected at all levels of significance under the IPS test and at 10% level under the LLC test.

Summing up, the IPS test provides stronger evidence of convergence than the other two tests. Moreover, the strongest evidence is shown for the CEECs and EECs groups, since it is supported by both IPS and LLC tests. Finally, the Hadri test fails to provide evidence of convergence in any case, as, according to Hlouskova and Wagner (2006), the Hadri test performs very poorly. The empirical findings are present below.

Table 11a: Panel unit root and stationarity tests on inflation differential from Germany

Country panel	IPS	LLC	Hadri
OMS	-0.138	1.726	24.233***
1974-1998	(0.445)	(0.958)	(0.000)
OMS	-3.196***	1.277	9.750***
1999-2016	(0.000)	(0.899)	(0.000)
CCs	-3.879***	1.262	15.525***
1999-2016	(0.000)	(0.897)	(0.000)
NMS	-1.677**	0.156	7.874***
1999-2006	(0.047)	(0.561)	(0.000)
CEECs	-3.185***	-4.232***	17.543***
1999-2013	(0.000)	(0.000)	(0.000)
EECs	-3.799***	-5.356***	17.098***
1999-2016	(0.000)	(0.000)	(0.000)

Notes: IPS denotes the Im, Pesaran, and Shin (2003) and LLC denotes Levin, Lin, and Chu (2002) panel unit root tests. In both tests the null hypothesis is unit root. Hadri (2000) is a stationarity panel unit root test. The null hypothesis is stationarity. Lags are based on SBIC. P-values are in parentheses. *, **, *** denote statistical significance at 10%, 5% and 1% significance levels, respectively.

Table 11b: Panel unit root and stationarity tests on inflation differential from PRV

Country panel	IPS	LLC	Hadri
OMS	-1.725**	1.271	24.961***
1974-1998	(0.042)	(0.898)	(0.000)
OMS	-3.515***	0.381	6.752***
1999-2016	(0.000)	(0.648)	(0.000)
CCs	-4.653***	-0.494	10.183***
1999-2016	(0.000)	(0.310)	(0.000)
NMS	-1.784**	0.242	7.100***
1999-2006	(0.037)	(0.596)	(0.000)
CEECs	-3.577***	-4.041***	16.915***

1999-2013	(0.000)	(0.000)	(0.000)
EECs	-2.389***	-1.412*	16.446***
1999-2016	(0.008)	(0.079)	(0.000)

Notes: IPS denotes the Im, Pesaran, and Shin (2003) and LLC denotes Levin, Lin, and Chu (2002) panel unit root tests. In both tests the null hypothesis is unit root. Hadri (2000) is a stationarity panel unit root test. The null hypothesis is stationarity. Lags are based on SBIC. P-values are in parentheses. *, **, *** denote statistical significance at 10%, 5% and 1% significance levels, respectively.

6.2 Testing for cross-sectional dependence

In this part, the results of the cross-sectional dependence tests are given. Table 12a gives the results for the differentials from Germany, while Table 12b shows the results for the differentials from PRV.

It is obvious from Table 12a, that all panels of countries in all cases have cross-sectional dependence in inflation differential from Germany, since the null hypothesis of independence is rejected with no lags and one lag by both CD and LM tests. Similar results are given in the case of inflation differential from PRV (Table 12b). With the exception of the CD test without lags in the case of NMS group of countries, all tests provide evidence of cross-sectional dependence.

Table 12a: Cross-sectional dependence tests on inflation differential from Germany

Country panel	CD test		LM test	
	No lags	One lag	No lags	One lag
OMS	49.729***	24.479***	2521.278***	670.571***
1974-1998	(0.000)	(0.000)	(0.000)	(0.000)
OMS	19.732***	22.297***	517.128***	546.553***
1999-2016	(0.000)	(0.000)	(0.000)	(0.000)
CCs	40.036***	42.012***	2146.534***	1870.580***
1999-2016	(0.000)	(0.000)	(0.000)	(0.000)
NMS	1.900*	4.585***	75.142***	42.273***
1999-2006	(0.057)	(0.000)	(0.000)	(0.000)
CEECs	19.355***	12.804***	851.591***	234.201***
1999-2013	(0.000)	(0.000)	(0.000)	(0.000)
EECs	26.764***	8.248***	771.425***	90.808***

1999-2016	(0.000)	(0.000)	(0.000)	(0.000)

Notes: CD is the Pesaran's (2004) test for cross-sectional dependence which follows the standard normal distribution. LM is the Breusch-Pagan (1980) test for cross-sectional dependence. In both tests the null hypothesis is independence. A constant term is included in the test regression. P-values are reported in parentheses. *, **, *** denote statistical significance at 10%, 5% and 1% significance levels, respectively.

Table 12b: Cross-sectional dependence tests on inflation differential from PRV

Country panel	CD test		LM test	
	No lags	One lag	No lags	One lag
OMS	9.587***	7.156***	1609.096***	158.267***
1974-1998	(0.000)	(0.000)	(0.000)	(0.000)
OMS	16.948***	20.370***	1671.630***	620.791***
1999-2016	(0.000)	(0.000)	(0.000)	(0.000)
CCs	26.004***	31.747***	3038.204***	1436.276***
1999-2016	(0.000)	(0.000)	(0.000)	(0.000)
NMS	-0.673	4.243***	83.549***	36.721***
1999-2006	(0.501)	(0.000)	(0.000)	(0.000)
CEECs	16.910***	12.653***	757.522***	181.913***
1999-2013	(0.000)	(0.000)	(0.000)	(0.000)
EECs	21.565***	9.557***	548.039***	87.989***
1999-2016	(0.000)	(0.000)	(0.000)	(0.000)

Notes: CD is the Pesaran's (2004) test for cross-sectional dependence which follows the standard normal distribution. LM is the Breusch-Pagan (1980) test for cross-sectional dependence. In both tests the null hypothesis is independence. A constant term is included in the test regression. P-values are reported in parentheses. *, **, *** denote statistical significance at 10%, 5% and 1% significance levels, respectively.

Owing to these findings, panel unit root tests with cross-sectional dependence are employed in the next part. Tables 13a and 13b illustrate the results of the CIPS test for the inflation differentials from Germany and PRV, respectively. Each panel is estimated with lags based on Schwartz criterion. In Table 13a it can be seen that all panels show strong evidence of convergence, since the null hypothesis of unit root is rejected. As far

as the inflation differential from PRV is concerned, all groups of countries show evidence of convergence, except for the NMS group. These results are illustrated below.

Table 13a: CIPS test on inflation differential from Germany

Country panel	t-bar statistic	Lags
OMS	-2.527**	0
1974-1998	(0.022)	
OMS	-2.907***	1
1999-2016	(0.000)	
CCs	-3.068***	0
1999-2016	(0.000)	
NMS	-2.594**	7
1999-2006	(0.023)	
CEECs	-3.406***	8
1999-2013	(0.000)	
EECs	-3.616***	8
1999-2016	(0.000)	

Notes: CIPS is the Pesaran's (2007) cross-sectional augmented panel unit root IPS test. A constant term is included in the test regression. P-values are reported in parentheses. Lags are based on SBIC. -2.210, -2.320 and -2.530 are critical values at 10%, 5% and 1% significance levels, respectively. *, **, *** denote statistical significance at 10%, 5% and 1% significance levels, respectively.

Table 13b: CIPS test on inflation differential from PRV

Country panel	t-bar statistic	Lags
OMS	-2.851***	0
1974-1998	(0.001)	
OMS	-2.969***	0
1999-2016	(0.000)	
CCs	-2.610***	0
1999-2016	(0.001)	
NMS	-2.201	1
1999-2006	(0.150)	

CEECs	-3.298***	8
1999-2013	(0.000)	
EECs	-3.662***	8
1999-2016	(0.000)	

Notes: CIPS is the Pesaran's (2007) cross-sectional augmented panel unit root IPS test. A constant term is included in the test regression. PRV refers to Policy Reference Value. P-values are reported in parentheses. Lags are based on SBIC. -2.210, -2.320 and -2.530 are critical values at 10%, 5% and 1% significance levels, respectively. *, **, *** denote statistical significance at 10%, 5% and 1% significance levels, respectively.

6.3 Half-Lives

In the final part of this section, the speed of convergence and the half-lives of the individual countries, as well as these of the groups of countries, are given, in Tables B.2 and B.3, respectively. These findings are presented in Appendix B.

Table B.2 shows the speed of convergence and the half-lives for the twenty-four countries for both inflation differentials. It should be noted that in the case of differential from Germany, the countries under study are twenty-three, since Germany is excluded. According to the economic theory, small variations in ρ lead to disproportionately large variations in the half-life, especially for ρ in the region near unity. In other words, the closer coefficient ρ is to 1 ($\rho \rightarrow 1$), then the convergence process is lower. This implies that in terms of half-lives, convergence is faster when the value of the half life is smaller, which means that the impact of a shock causing a deviation from equilibrium will die out rapidly. In the case of Germany being the inflation benchmark, convergence is faster in Austria, Luxembourg, Malta, France and Cyprus. It is obvious that convergence is definitely slower in the cases of Ireland, Latvia and Romania. When PRV is the benchmark, the findings differentiate, as Portugal, Cyprus Luxembourg and Malta have the smallest half-lives. Romania still has the largest half-life. In addition, the average value of half-lives of all countries is given in this table, where it is shown that inflation differentials from PRV have smaller half-life average.

Table B.3 (see Appendix B) reports half-life estimation from panel data for the six panels examined in this study and a new panel consisting of all the examined countries. It is obvious that in the case of the OMS group the speed of convergence is lower in the pre-euro period than in the post-euro period, since the half-life reduces dramatically after the introduction of the euro under both benchmarks.

Regardless of the inflation benchmark considered, convergence is the fastest in the case of the NMS countries, followed by CCs and OMS, for the period from 1999 to 2016. The panels CEECs and EECs are characterized by the lowest speed of convergence for both benchmarks. Finally, the half-lives of the 24EUCs show that when the panel approach is utilized, the convergence process is weaker than in the case of the average half-life under the univariate approach.

6.4 Discussion

These results show evidence of conditional convergence among the twenty-four European countries. In particular, when Germany is used as a benchmark, it is observed that the fundamental countries of the EU (OMS group) do not reveal evidence of convergence before the launch of the euro, while when PRV is used, the results provide evidence of convergence even in the pre-euro period. A possible explanation for this deviation before the euro include factors related to determine inflation, such as different national weights for calculation of CPI, and institutional and structural factors. After the introduction of the euro, though, all groups of countries indicate evidence of convergence, with respect to both benchmarks. Moreover, when cross-sectional dependence is taken into account, the evidence of convergence is even stronger, in almost all groups of countries, even before the launch of the euro. An interesting finding is that transitional economies exhibit convergence, although, these economies have gained separate identities recently. As far as the half-life estimation is concerned, the results among the countries are quite different, with Austria, Belgium, Cyprus, Czech Republic, Italy, Luxembourg, Malta and Portugal showing the fastest speed of convergence and Ireland, Latvia, Lithuania, Poland, Romania and Slovenia showing the slowest.

These results are consistent with the majority of the relevant literature, since many authors find similar results (for instance Figuet and Nenovsky, 2006; Holmes, 2008; Spiru, 2008; Gregoriou et al., 2011; Lopez and Papell, 2012; Cuestas et al., 2012; Simionescu, 2015; Karanasos et al. 2016).

As presented earlier, in this thesis first and second generation tests are used, such as the IPS, LLC, Hadri and CIPS tests. These tests have also been used by other authors who study inflation convergence (Kutan and Yigit, 2004; Spiru, 2008; Holmes, 2008; Arestis et al., 2014; Karanasos et al., 2016). Kutan and Yigit (2004) use the IPS and Hadri tests in a panel of 10 EU countries in the period of 1993 to 2003, and find evidence of convergence only under the IPS test. Spiru (2008) examines six panels of EU countries from 1993 to 2004 using the IPS test and also finds evidence of conditional convergence. Using first generation panel unit root tests, that is the IPS, LLC and Hadri tests, Holmes (2008) provides evidence of convergence under the three tests, when studying fifteen EU countries from 1999 to 2007. However, Holmes (2002), by applying the IPS test from 1972 to 1999 in a panel of six EU countries, finds evidence of convergence only in three sub-periods. Arestis et al. (2014) use both the IPS and CIPS tests in four panels of OECD countries from 1990 to 2011 and find convergence under both tests for all panels. Similar results are provided by Karanasos et al. (2016) who find that the stationarity hypothesis holds for both the pre-euro and the post-euro periods in a panel of 12 EMU countries. To sum up, on the basis of the above literature, these authors provide similar findings to this thesis.

Other authors use cointegration techniques under the univariate and panel approach, in order to examine inflation convergence. Caporale and Pittis (1993), Thom (1996) and Mentz and Sebastian (2003) provide evidence of convergence using the Johansen cointegration test. The convergence analysis in panel data is applied by Holmes (2002) and Figuet and Nenovsky (2006) in a panel of EU countries. Other techniques, such as univariate unit root tests, unit root tests with breaks, SUR-ADF analysis, non-

linear approach and rolling estimation, are also used by several authors. Under the above techniques, evidence of convergence is provided in some cases.

As far as the half-life estimation is concerned, the results can only be compared to few studies. In particular, using the univariate approach and taking into account the same sample of countries that Spiru (2008) examines, she finds similar results for the half-lives. When Germany is used as benchmark, her findings suggest that Cyprus and Malta reveal the lowest half-life in the examined countries, a finding which is consistent to the present thesis. On the other hand, she finds the largest half-life in the case of Hungary, while in the present study the largest half-life is given by Latvia. The possible reason for this difference is the different sample period that she examines, which is from 1993 to 2004. Kutan and Yigit (2005) also calculate half-lives for ten transition countries vis-à-vis Germany for the period 1993-2004 under the SUR-ADF approach and report only the lowest, which exist for Malta and Cyprus. This finding is also supported by the present study, although the technique and the sample period are different. Finally, Lopez and Papell (2012), by applying the SUR-ADF approach, calculate the half-life of the median autoregressive coefficient for 12 EUCs, which are the same as the CCs group of the present study. Their half-life is close to the CCs group half-life, although their sample period is shorter and spans from 1999 to 2006.

7 Conclusions

One of the principal economic challenges in the European Union is entering the euro area by the candidate countries. For this scope, pre-accession criteria, namely the Maastricht convergence criteria, must be satisfied by the member states. The successful formula of European Integration depends on these nominal convergence criteria. In this thesis one of these criteria is examined, in order to study the process of convergence. In particular, inflation differentials among the EUCs are examined, so as to study inflation convergence. It is obvious that the Euro area needs price stability in the form of small inflation differentials in order to be stable, since one of the fundamental objectives of the Maastricht Treaty is price stability through the achievement of low inflation. At this point, inflation convergence is an aspect of convergence that plays a key role in the reform of the EMU, since the euro area is a special case of monetary union because it does not have adjustment mechanisms to correct imbalances.

In the light of the achievement of small inflation differentials, the present thesis tries to empirically identify whether inflation convergence exists in a sample of European Union countries. The study examines twenty-four European countries for the period of 1974 to 2016 and the sample splits into five groups of countries and four periods of time. The main characteristic is the comparability between countries that joined the euro in 1999, economies that joined afterwards and countries that are still in transition. To tackle this issue, first and second generation panel unit root and stationarity tests are employed so as to provide evidence of inflation convergence before and after the launch of the single currency, the euro. The methodology of the influential studies by Spiru (2008) and Gregoriou et al. (2011) is used. In particular, inflation differentials of the selected countries with respect to two benchmarks are calculated. In addition, the mean reverting behavior of inflation differentials, in a period of seventeen years, is examined under univariate and panel approach. The innovation of this study is that in order to conduct the analysis, two benchmarks are utilized: Germany and Policy Reference Value (PRV), which is referred to in the first Maastricht criterion. Moreover, both the number of countries and the sample period are greater than other studies.

The empirical results show evidence of conditional convergence among the twenty-four European countries. In particular, when Germany is used as a benchmark, it is observed that the fundamental countries of the EU do not reveal evidence of convergence only before the launch of the euro, while when PRV is used, the results provide evidence of convergence even in the pre-euro period. After the introduction of the euro, though, all groups of countries indicate evidence of convergence, with respect to both benchmarks. Moreover, when cross-sectional dependence is taken into account, the evidence of convergence is even stronger, in almost all groups of countries, even before the launch of the euro. In other words, under the baseline of second generation panel unit root tests, the findings are more supportive of convergence. As far as the half-life estimation is concerned, the results among the countries are quite different, with Austria, Belgium, Cyprus, Czech Republic, Italy, Luxembourg, Malta and Portugal showing the fastest speed of convergence and Ireland, Latvia, Lithuania, Poland, Romania and Slovenia showing the slowest. In addition, regardless of the inflation benchmark considered, the half-life estimation from panel data show that convergence is faster in the case of the NMS countries, followed by CCs and OMS groups, in the post-euro period. On the other hand, CEECs and EECs groups show the slowest convergence than the other groups, under both benchmarks. Moreover, when the panel

of OMS countries is taken into account, the half-lives reduce dramatically after the launch of the euro.

In conclusion, inflation convergence is supported by the panel unit root tests, with the second generation one being more supportive. Moreover, an interesting finding is that transitional economies exhibit convergence, although these economies have gained separate identities recently. Additionally, the fundamental EUCs show weaker evidence of convergence before the launch of the euro, but stronger after the introduction of the common currency.

Bibliography

Alberola, E., (2000), ˝Interpreting Inflation Differentials in the Euro Area˝, *Economic Bulletin,* 61-70.

Arestis, P., Chortareas, G., Magkonis, G., and Moschos, D., (2014), ˝Inflation Targeting and Inflation Convergence: International Evidence˝, *Journal of International Financial Markets, Institutions and Money,* Vol. 31, 285-295.

Aslanidis, N. and Fountas S., (2014), ˝Is real GDP Stationary? Evidence from a Panel Unit Root Test with Cross-sectional Dependence and Historical Data˝, *Empirical Economics*, Vol. 46, (1), 101-108.

Baltagi, B., H., (2008), ***˝Econometric analysis of panel data˝,*** Fourth edition, Wiley, New York.

Barro, R., J. (1991), ˝Economic Growth in a Cross Section of Countries˝, *The Quarterly Journal of Economics*, Vol. 106, (2), 407-413.

Barro, R., J. and Sala-i-Martin X., X., (1992),˝Convergence˝, *Journal of Political Economy* Vol 100, (2), 223–251.

Baumol, W., J., (1986), ˝Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show˝, *The American Economic Review*, Vol. 76, (5), 1072-1085.

Breusch, T. S., and Pagan, A. R., (1980), ˝The Lagrange Multiplier Test and its Application to model Specifications in Econometrics˝, *Review of Economic Studies*, Vol. 47, (1), 239-253.

Busetti, F., L. Forni, A. C. Harvey, and F. Venditti., (2007), ˝Inflation Convergence and Divergence Within the European Monetary Union˝, ECB Working Paper No. 574.

Buti M., Sapir A., (eds) (1998), ***Economic Policy in EMU***, Oxford, Clarendon Press.

Caporale, G. and Pittis, N., (1993), ˝Common Stochastic Trends and Inflation Convergence in the ERM˝, *Weltwirtschaftliches Archiv*, 207-215.

Choi, Chi-Young, Mark Nelson C., Sul, D., (2004), ˝Unbiased Estimation of the Half-Life to PPP Convergence in Panel Data˝, *National Bureau of Economic Research*, Working Paper No. 10614.

Crawford, M., (1996), ***One Money for Europe: The Economics and Politics of EMU***, St. Martin Press, New York.

Cuestas, Juan C., Gil-Alana, Luis A., Taylor, K., (2012), ˝Inflation Convergence in Central and Eastern Europe with a View to Adopting the Euro˝, Working Paper, University of Sheffield, available at:
http://eprints.whiterose.ac.uk/

De Grauwe, P., (2016), **Economics of Monetary Union**, Eleventh edn, Oxford Univercity Press, United Kingdom.

Durlauf, S., N. and Bernard, A., B., (1996), ˝Interpreting Tests of the Convergence Hypothesis˝, *Journal of Econometrics*, Vol. 71, 161-173.

El-Agraa, Ali M., (2007), ***The European Union: Economics and Policies***, Eighth edn, Cambridge University Press, United Kingdom.

Eijffinger, Sylvester, C. W., and Haan, J., (2000), ***European Monetary and Fiscal Policy***, Oxford University Press, New York.

European Central Bank, (2003), ˝Inflation Differentials in the Euro Area: Potential causes and Policy Implications˝, Report by Monetary Policy Committee.

European Central Bank, (2015), ˝ Real Convergence in the Euro Area: Evidence, Theory and Policy Implications˝, *Economic Bulletin Issue*, no. 5, 30–45.

European Commission, (2002a), Economic Reform: Report on the Functioning of Community Product and Capital Markets, COM 743, Brussels.

Figuet, Jean-M., Nenovsky, N., (2006), ˝Convergence and Socks in the road to EU: Empirical Investigation for Bulgaria and Romania ˝, Working Paper, University of Michigan, available at:
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.424.4900&rep=rep1&type=pdf

Galor, O., (1996), ˝Convergence? Inferences from theoretical models˝, *Economic journal,* Vol. 106, (437), 1056-1069.

Gregoriou, A., Kontonikas, A., Montagnoli, A., (2011), ˝Euro Area Inflation Differentials˝, Unit roots and Non-linear Adjustment˝, *Journal of Common Market Studies,* Vol. 49 (3), 525–540.

Hadri, K., (2000), ˝Testing for Stationarity in Heterogeneous Panel Data˝, *Econometrics Journal*, Vol.3 (2), 148-161.

Hlouskova J. and Wagner, M., (2006), ˝The Performance of Panel Unit Root and Stationarity Tests: Results from a Large Scale Simulation Study˝, *Econometric Reviews*, Vol. 25 (1), 85-116.

Holmes, M., (2002), ˝Panel Data Evidence on Inflation Convergence in the European Union˝, *Applied Economics Letters*, Vol. 9 (3), 155-158.

Holmes, M., (2008), ˝Has the Euro Area Facilitated Inflation Convergence*?˝, Journal of International and Global Economic Studies*, Vol. 1 (1), 27-41.

Hosli, M., O., (2005), ***The Euro: A Concise Introduction to European Monetary Integration***, Lynne Rienner, Inc., London.

Im, K., M. H. Pesaran, and Y. Shin., (2003), ˝Testing for Unit Roots in Heterogeneous Panels˝, *Journal of Econometrics*, Vol. 115, 53-74.

Karanasos, M., Koutroumpis, P., Karavias, Y., Kartsaklas, A., Arakelian, V., (2016), ˝Inflation Convergence in the EMU˝, *Journal of Empirical Finance*, forthcoming, available at: http://dx.doi.org/10.1016/j.jempfin.2016.07.004

Kenen, Peter B., (1969) ˝The theory of Optimum Currency Areas : An eclectic view˝, in R.A. Mundell and A.K. Swoboda (eds), ˝Monetary Problems of the International Economy˝, University of Chicago Press, 42-60.

Kocenda, E., and D. Papell., (1997), ˝Inflation Convergence Within the European Union: A Panel Data Analysis˝, *International Journal of Finance and Economics,* Vol. 2 (3), 189−98.

Krugman, P., (2012), ˝Revenge of the Optimum Currency Area˝, *NBER Macroeconomics Annual*, Volume 27, 439-448.

Kutan, Ali M., Yigit, Taner M., (2004),˝Nominal and Real Stochastic Convergence of Transition Economies˝, *Journal of Comparative Economics*, Vol. 32, 23–36.

Lerner, Abba P., (1944), ˝The economics of Control˝, New York: Macmillan.

Levin, A., C. Lin, and C-S Chu., (2002), ˝Unit Root Tests in Panel Data: Asymptotic and Finite Sample Properties˝, *Journal of Econometrics*, Vol. 108, 1-24.

Lopez, C., Papell, D.H., (2012), ˝Convergence of Euro Area Inflation Rates˝, *Journal of International Money and Finance*, Vol. 31 (6), 1440-1458.

Mareli E. Signorelli M., (2010), ˝Institutional, nominal and real convergence in Europe˝, *Banks and Bank Systems*, Vol. 5 (2).

Marques, Carlos R., (2004), ˝Inflation Persistence: Facts or Artefacts? ECB, Working Paper, No.371.

McKinnon, Ronald I., (1963), ˝Optimum Currency Areas ˝, *The American Economic Review,* Vol. 53, (4), 717-725.

Mentz, M.,. Sebastian, Steffen P., (2003)**,** ˝Inflation Convergence after the Introduction of the Euro˝, Working Paper, Center of Financial studies, available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=451760

Mundell, R.A., (1961), ˝A theory of Optimum Currency Areas˝, *American Economic Review,* Vol. 51, (4), 657-665.

Păun, C. and Ungureanu, S., (2015), ˝The Nominal and Real Convergence: A Real Problem for a Single Currency Area˝, *The Review of Social and Economic Issue*, Vol. 1, (2), 29-49.

Pesaran, M.H., (2004), ˝General Diagnostic Tests for Cross Section Dependence in Panels˝, Cambridge Working Papers in Economics No. 0435, Faculty of Economics, University of Cambridge.

Pesaran, M.H., (2007), ˝A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence˝, *Journal of Applied Econometrics*, Vol. 22 (2), 265-312.

Simionescu, M., (2015), ˝The impact of Economic Crisis on Inflation Convergence in the European Union. A Panel Data Approach˝, *CEA Journal of Economics,* Vol. 10 (1), 37-46.

Romer, P., (1990), ˝Endogenous Technological Change˝, *Journal of Political Economy*, Vol. 98, (5), 71-102.

Sala-i-Martin X., X., ˝The Classical Approach to Convergence Analysis˝, *The Economic Journal,* Vol. 106, No. (437), 1019-1036.

Solow, R., M., (1956), ˝A Contribution to the Theory of Economic Growth˝, *The Quarterly Journal of Economics*, Vol. 70, (1), 65-94.

Spiru, A., (2008), ˝Inflation convergence in Central and Eastern European countries˝, *Romanian Economic and Business Review*, Vol. 3 (4), 14-34.

Tavlas, George S., (1993), ˝The 'New' Theory of Optimum Currency Areas˝, *World Economy*, Vol. 6, 663-685.

Thom, R., (1995), ˝Inflation Convergence in the EMS: Some Additional Evidence. A Comment˝, *Review of International Economics*, Vol. 131 (3), 577-586.

Appendix A

Table A.1. Overview about 24 European Countries

States	EU member since	Euro since
Austria	1995	1999 (cash since 2002)
Belgium	1957(EU founding member)	1999 (cash since 2002)
France	1957(EU founding member)	1999 (cash since 2002)
Germany	1957(EU founding member)	1999 (cash since 2002)
Italy	1957(EU founding member)	1999 (cash since 2002)
Luxembourg	1957(EU founding member)	1999 (cash since 2002)
Netherlands	1957(EU founding member)	1999 (cash since 2002)
Finland	1995	1999 (cash since 2002)
Ireland	1973	1999 (cash since 2002)
Portugal	1986	1999 (cash since 2002)
Spain	1986	1999 (cash since 2002)
Greece	1981	2001
Slovenia	2004	2007
Cyprus	2004	2008
Malta	2004	2008
Slovakia	2004	2009
Estonia	2004	2011
Latvia	2004	2014
Lithuania	2004	2015
Bulgaria	2007	-
Czech	2004	-
Hungary	2004	-
Poland	2004	-
Romania	2007	-

Appendix B

Table B.1. Panel Unit Root Tests

First Generation	**Cross-sectional independence**
1. Non-stationarity tests	Levin, Lin and Chu (2002) Im, Pesaran and Shin (1997, 2002, 2003)
2. Stationarity tests	Hadri (2000)

Second Generation	**Cross-sectional dependencies**
Factor structure	Pesaran (2007)

Table B.2. Half Lives

Country	$\widehat{\rho}_{Ger}$	**Half-lives**	$\widehat{\rho}_{prv}$	**Half-lives**
Austria	0.783	2.8	0.950	13.6
Belgium	0.935	10.5	0.930	9.5
Bulgaria	0.966	20.2	0.959	16.6
Cyprus	0.920	8.3	0.887	5.8
Czech Rep.	0.924	8.8	0.929	9.5
Estonia	0.965	19.5	0.954	14.7
Finland	0.933	10.1	0.954	14.8
France	0.893	6.2	0.950	13.4
Germany	-	-	0.948	12.9
Greece	0.966	20.2	0.966	20.3
Hungary	0.976	29	0.970	23.1
Ireland	0.982	38.9	0.979	32.4
Italy	0.927	9.2	0.924	8.8
Latvia	0.989	60.7	0.989	60.8
Lithuania	0.976	28.7	0.980	33.2
Luxembourg	0.807	3.2	0.890	6
Malta	0.848	4.2	0.900	6.6
Netherlands	0.929	9.4	0.952	14.4

Poland	0.981	36	0.978	30
Portugal	0.952	14	0.877	5.3
Romania	0.990	72	0.990	65.5
Slovakia	0.975	27.3	0.968	21.6
Slovenia	0.980	34.3	0.972	24.4
Spain	0.962	17.7	0.917	8
average		21.4		19.6

Notes: The sample period for all counties is 1999-2016. $\hat{\rho}_{Ger}$ and $\hat{\rho}_{prv}$ is the speed of convergence, while HL represents the half-life of shocks. The half-lives are expressed in months and indicate how many months it takes for a shock to D_{Ger} and D_{prv} respectively to dissipate by a half.

Table B.3. Panel Half Lives

Country panel	$\hat{\rho}_{Ger}$	**Half-lives**	$\hat{\rho}_{prv}$	**Half-lives**
OMS 1974-1998	0.988	57.75	0.985	46.2
OMS 1999-2016	0.957	15.75	0.952	14.14
CCs 1999-2016	0.955	14.97	0.949	13.34
NMS 1999-2006	0.942	11.58	0.935	10.38
CEECs 1999-2013	0.988	58.73	0.986	50.99
EECs 1999-2016	0.988	56.91	0.987	52.18
24EUCs 1999-2016	0.984	42.49	0.982	38.88

Notes: $\hat{\rho}_{Ger}$ and $\hat{\rho}_{prv}$ is the speed of convergence, while HL represents the half-life of shocks. The half-lives are expressed in months and indicate how many months it takes for a shock to the D_{Ger} and D_{prv} respectively to dissipate by a half.

Appendix C

Table C1. Summary statistics of inflation differentials from Germany.						
Country	**Mean**	**Median**	**Maximum**	**Minimum**	**Std**	**Period**
Austria	0.483	0.460	1.721	-0.639	0.464	1999-2016
Belgium	1.140	0.637	9.965	-3.546	2.027	1974-2016
Bulgaria	3.065	2.723	12.197	-3.851	3.677	1999-2016
Cyprus	1.350	1.198	4.834	-1.200	1.257	1999-2006
Czech Rep.	0.821	0.459	4.700	-1.556	1.273	1999-2016
Estonia	2.289	2.568	4.440	-0.649	1.251	1999-2006
Finland	0.232	0.202	2.397	-2.230	0.902	1999-2016
France	1.772	0.432	9.036	-3.380	2.300	1974-2016
Greece	0.822	1.288	4.529	-4.190	1.782	1999-2016
Hungary	3.540	3.450	10.214	-1.440	2.972	1999-2016
Ireland	3.200	1.527	18.392	-6.562	5.040	1974-2016
Italy	4.197	1.453	18.717	-1.038	5.085	1974-2016
Latvia	2.892	2.062	15.099	-5.160	3.949	1999-2013
Lithuania	1.160	0.775	9.276	-3.222	2.756	1999-2013
Luxembourg	0.975	0.589	6.618	-3.244	1.720	1974-2016
Malta	1.033	1.094	3.019	-1.140	0.907	1999-2006
Netherlands	0.522	0.320	5.426	-2.520	1.405	1974-2016
Poland	1.622	1.226	10.348	-1.564	2.678	1999-2016
Portugal	0.707	0.767	3.240	-1.721	1.216	1999-2016
Romania	11.500	5.586	55.22	-3.556	14.706	1999-2016
Slovakia	5.651	5.337	15.098	0.375	3.864	1999-2006
Slovenia	4.228	5.052	8.381	0.106	2.550	1999-2016
Spain	0.855	1.136	2.885	-1.343	1.134	1999-2016

Table C2. Summary statistics of inflation differentials from PRV.						
Country	**Mean**	**Median**	**Maximum**	**Minimum**	**Std**	**Period**
Austria	0.367	-0.565	2.622	-1.729	0.909	1999-2016
Belgium	-0.238	-0.534	5.869	-1.904	1.201	1974-2016
Bulgaria	2.215	1.657	10.846	-4.106	3.380	1999-2016
Cyprus	-0.007	-0.065	3.021	-2.806	1.164	1999-2006
Czech Rep.	-0.029	0.000	3.622	-3.358	1.285	1999-2016
Estonia	0.932	1.233	3.659	-2.178	1.253	1999-2006
Finland	-0.618	-0.483	1.648	-2.438	0.880	1999-2016
France	0.394	-5.45	6.637	-1.994	2.240	1974-2016
Germany	-1.378	-1.366	2.510	-4.328	1.231	1974-2016
Greece	-0.029	0.124	3.942	-3.043	1.548	1999-2016
Hungary	2.690	2.136	8.863	-1.530	2.766	1999-2016
Ireland	1.822	0.317	14.770	-4.176	4.119	1974-2016
Italy	2.820	1.152	14.941	-1.474	4.274	1974-2016
Latvia	1.923	0.557	13.738	-4.225	3.904	1999-2013
Lithuania	0.191	-0.238	8.015	-4.974	2.983	1999-2013
Luxembourg	-0.403	-0.563	2.981	-2.317	0.993	1974-2016
Malta	-0.325	-0.259	1.593	-2.807	1.006	1999-2006
Netherlands	-0.856	-0.923	3.220	-4.663	1.157	1974-2016
Poland	0.772	0.172	8.332	-2.680	2.602	1999-2016
Portugal	-0.143	-0.197	1.900	-2.034	0.759	1999-2016
Romania	10.650	4.887	53.871	-4.324	14.321	1999-2016
Slovakia	4.294	3.995	13.541	-0.791	3.796	1999-2006
Slovenia	2.871	3.316	6.308	-1.078	2.312	1999-2016
Spain	0.005	0.174	1.944	-1.849	0.788	1999-2016