Sigma Convergence Interest for European Countries

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ABSTRACT

Over the several past years, economists have wondered if poor countries grow faster than rich ones in order to catch up the rich countries, that is if there is a convergence in GDP per capital values. Later, this convergence test included tests on other macroeconomic variables; and moreover beta vs sigma convergence tests emerged. The objective of this research is to determine whether there is any sigma-convergence among 31 European Countries, such as sigma convergence on per capita GDP, sigma convergence on inflation rate, and sigma convergence in interest rate. We carry the test for: (i) 31 European countries, (ii) West European countries only, and (iii) the 12 original Eurozone countries that adopted the euro before or at the start of circulation of euro banknotes. This research project analyzes panel data to examine sigma convergence using statistical tools including OLS and Coefficient Variance between 1998 and 2020. The findings indicate that there is no sigma convergence in the interest rate variable but that there is statistically significant and a negative coefficient estimate that supports the sigma convergence for the GDP per capita variable and CPI-based inflation rate among the 31 European Countries. Similarly, there is statistically significant sigma convergence for the inflation rate variable in Western European countries but no sigma convergence for the interest rate variable in Western European and Eurozone countries.

Keywords: Sigma Convergence, Sigma Convergence per GDP, Inflation Rate, Interest Rate, European Countries

ÖZ

Geçtiğimiz on yıllar boyunca, ekonomistler, gelir seviyesi düşük ülkelerin daha hızlı büyüyerek, gelir seviyesi yüksek ülkelerin refah seviyesini yakalayabilirler mi diye düşündüler. Bir başka değişle, kişibaşı GSYH açısından ülkelerarası bir yakınsama (convergence) olup olmadığını araştırdılar. Daha sonraları, bu yakınsama testleri sigma ve beta yakınsama testleri olarak 2 şekilde kendini gösterdi ve diğer makroekonomik değerleri de kapsadı. Bu tez de 31 Avrupa ülkesinden veriler kullanarak, kişibaşı GSYH, enflayson ve faiz oranları açısından ülkelerarası bir sigma yakınsama (convergence) olup olmadığını araştırıyor. Bu testleri, 3 değişik ülke grupları icin uyguluyoruz: (i) 31 Avrupa ülkesi, (ii) Batı Avrupa ülkeleri ve (iii) Euro banknoteların kullanıma sürüldüğü 2002 ve öncesinde Eurozone katılan ülkeler. Bu araştırma 1998 ile 2020 yıllarını kapsayan bir panel data verisi kullanmakta, ve sigma convergence test için de OLS tahmin ve varyasyon katsayısı (Coefficient of Variation) yöntemlerini kullanmaktadır. Sonuçlar genel olarak, 31 Avrupaülkesi için kişibaşı GSYH ve enflasyon oranları için yakınsama yani convergence olduğunu göstermektedir. Faizoranları için ise 3 ülke grubu icin ayrı ayrı yapılan testlerde ise böyle bir bulgu bulunamamıştır.

Anahtar Kelimeler: Sigma Yakınsama (Convergence) Testleri, Kişibaşı GSYH, Faiz Oranı, Enflasyon, Avrupa Ülkeleri

DEDICATION

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CAP	Common Agriculture Policy
CV	Coefficient of Variations
EEC	European Economic Community
EMS	European Monitory System
EMU	Economic Monitory Union
ERM	European Exchange Rate Mechanism
EU	European Union
GDP	Gross Domestic Product
GDPPC	Gross Domestic Product Per Capita
IMF	International Monetary Fund
OLS	Ordinary Least Squares Regression
UK	United Kingdom

Chapter 1

INTRODUCTION

Today**,** European Union is the most advanced form of economic integration. It was formally formed as European Economic Community in the year 1957 with 6 members, namely France, Federal Republic of Germany, Italy, the Netherlands, Belgium and Luxembourg. Subsequently, it expanded to include the United Kingdom, Ireland and Denmark in 1973. Greece joined in 1981, while Spain and Portugal joined in 1986; increasing the number of members to 12. In 1993, it adopted deeper integration policies and changed its name as European Union. In 1995, it expanded further to include Austria, Finland and Sweden. In 2004 it did its largest ever expansion to include 8 Eastern European Countries (Poland, Czechia, Slovakia, Slovenia, Hungary, Estonia, Latvia and Lithuania) as well as island countries of Cyprus and Malta. In 2007 and 2013 Bulgaria, Romania and Croatia also joined, increasing the total number of members to 28. Note that in 2021, the UK formally exited the EU so that there are now 27 member Countries(Sander & Kleimeier, 2006).

In addition, the EU has formed the European Economic Area or signed other bilateral trade and economic coordination agreements with Norway, Iceland, Switzerland and the UK.

As a result of the EU and its extended agreements, there is an increasing trade, financial integration and growing economic policy coordination among the Countries

mentioned above. One then wonders if there is convergence in Macroeconomic variables of these European countries due to such economic integration(Mulabdic et al., 2017).

In line with the above question, this thesis attempts to investigate if there is a convergence between (i) the GDP per capita values, (ii) inflation rates and (iii) interest rates of these European countries. In Economics, there are 2 types of convergence tests: (i) Beta and (ii) Sigma Convergence Tests. This thesis adopts the second one, which simply looks the variance (more correctly coefficient of variation) among the macroeconomic variables over the years.

The thesis uses a panel data for the all 27 EU member Countries as well as the other partner countries, the UK, Switzerland, Norway and Iceland for the time period from 1998 to 2020. Thus, the purpose of this study is to use sigma convergence test to determine if there is a convergence in the in the sampled European countries for the given time period in all there macroeconomic variables (interest rates, inflation rates and GDP per capita).

The outline of this thesis is presented as following: Chapter 1 is the introduction part. Chapter 2 outlines a brief information about the European Union. Chapter 3 highlights the types of Convergence Theories, while Chapter 4 presents the literature review on the concept of sigma convergence, and it does so for mostly European Union countries. Chapter 5 describes data and methodology. Chapter 6 introduces the results while Chapter 7 makes the conclusions where we summarized all the work done and the main findings of the study.

Chapter 2

THE EUROPEAN UNION

2.1 The Overview

In 1945 after the World War II, there was a need for several western European countries to come together and establish closer relationship in economic, social and political ties to achieve economic growth and military security.

In 1957, France, West Germany, Italy, the Netherlands, Belgium and Luxemburg signed the Treaty of Rome, and formed the European Economic Community (EEC). In1973, Denmark, Ireland and the United Kingdom joined the European Economic Community. In 1981, Greece and in 1986, Spain and Portugal joined the community.

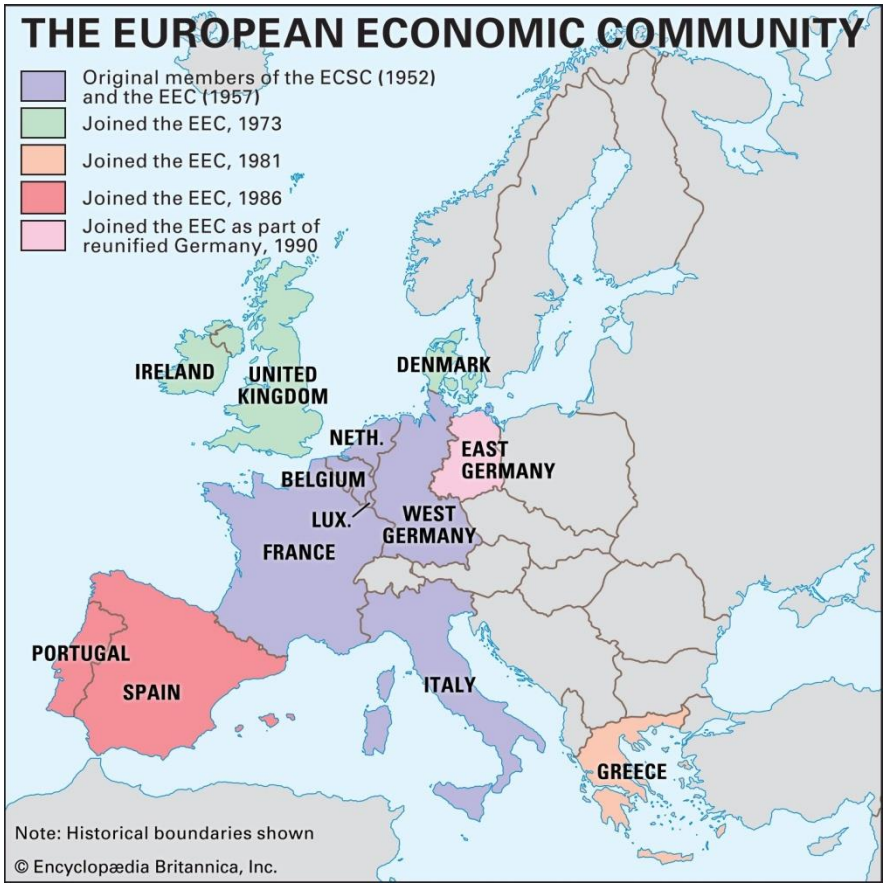

Figure 1: Enlargement of the European Union by 1990

In 1993, the EEC countries signed the Maastricht Treaty and adopted deeper integration policies. The name was formally changed to the European Union (the EU). In 1995, Austria, Finland and Sweden joined the EU, making the total number of member countries 15. In 2004, the EU made its largest ever expansion to include 10 new members. There were 8 new Central and Eastern European countries (the Czech Republic, Poland, Hungary, Estonia, Latvia, Lithuania, Slovakia and Slovenia) as well as 2 Mediterranean island Nations (Cyprus and Malta). In 2007, Bulgaria and Romania entered to the EU community, and this was followed by Croatia in 2013. In the meantime, in 2009 Lisbon Treaty came into effect, reforming and changing the legal structure of the EU.

In 2016, the British people voted in a national referendum to leave the EU, and this exit was formalized in 2021. As a result, the number of member countries in the EU dropped to 27.

The EU has faced a wave of different crises over the last decade such as debt-induced euro crisis, immigration crisis, and Brexit challenges.

However, the EU is a unique global example of integration of many different states, which now includes about 450 million people in 27 countries. The combined EU GDP is $17.1 trillion in 2020, making it the second largest economy in the world. This dynamic integration involved the establishment of supranational EU structures covering areas in economics, agriculture, energy, monetary policies and technology.

The European Union is the world's biggest trader. The EU exports 40% of world trade. The majority of the EU trade is within Europe, and more specifically within itself. The EU is primarily an exporter of manufactured goods, while it mainly imports semi-manufactured goods and raw-materials. These imports mainly come from Africa, Middle East and Latin America.

Today, the EU policies are founded on the guarantee of freedom of movement in three forms: freedom of movement of (i) people, (ii) goods, and services and (iii) capital in the internal market. It carries legislation in justice and home affairs, and maintains common policies on trade, agriculture and regional development. Moreover, the EU has established a passport-free travel zone within itself. This is known as Schengen zone. In other words, the passport controls have been abolished for travel within in the

Schengen area which includes all EU countries except for Ireland, Cyprus, Bulgaria, Romania and Croatia.

Moreover, 19 EU countries have started to use a common currency, the Euro, which came into effect as an accounting unit in 1999. In 2002, the actual coins and banknotes started to circulate. The countries which adopted the euro are known as the “Euro zone”. The 8 countries which have not “yet” adopted the euro are: Denmark, Sweden, Poland, Czech, Hungary, Croatia, Bulgaria and Romania. However, Croatia is to join the euro-zone in 2023, while Bulgaria is expected to join before 2025.

The EU functioning is distributed over several institutions: (i)The European Commission, (ii) The European Council, (iii) The Council of the EU, (iv) The European Parliament(v) The Court of Justice and (vi) The European Central Bank. The Commission and the two Councils take seat mainly in Brussels, while the Parliament mainly meets in Strasbourg. The Court of Justice is stationed in Luxembourg while the European Central Bank is in Frankfurt.

The members of the Parliament are elected directly by the EU citizens and they represent the citizens. The Council of the EU represents the National governments of the member states while the European Council is the gathering of Heads of the member states. The European Council does not make laws but it does set the political direction of the EU. The Commission, The Council of the EU and the Parliamenttogether make the policies in the EU. In general, the Commission proposes new legislation and the Council and the Parliament take a role in adaptation of the laws.

2.1.1 The Commission

The European Commission sits in Brussels and is the main executive body in the EU. Its main responsibilities are to design community policies, monitor compliance with community decisions, and oversee the enforcement of community law. The leader of the Commission is chosen by the heads of state or government of the organization's members. The leader picks the heads of the Directorate-Generals, which oversee specialized areas like as agriculture, competition, the environment, and regional policy, after consulting with member countries.

2.1.2 The European Council

The European Council is made up of the representative of all EU member nations. The European Council is led by a head president, whose position rotates among the heads of the governments of organization's state members at least twice a year. The European Council meets at least twice a year to set the long-term agenda for European political and economic unification. After the Lisbon Treaty was signed in 2009, the presidency was made permanent, with the officeholder being selected by European Council members. The leader of the European Council is elected for a time period of two and a half years which can be renewed once more, and the leader acts as the main representative person of the EU in policy matters.

2.2 The Common Currency “Euro”

The euro is the European Union's monetary unit and currency, denoted by the sign €. It was first introduced as a noncash monetary unit in 1999, and then as currency notes and coins in 2002. The member countries which adopt the “euro” form the Eurozone within the EU. Eleven European Union member states met the euro convergence criteria in 1998, and the Eurozone was established on January 1, 1999, with the formal launch of the euro (alongside national currencies). These countries are: Germany,

France, Italy, Spain, The Netherlands, Belgium, Luxembourg, Ireland, Portugal, Austria and Finland.

Greece met the convergence criteria in 2001, just before the actual circulation of banknotes and coins in 2002. In 2007, Slovenia joined the Eurozone, while Cyprus and Malta did so in 2008. In 2009, Slovakia; in 2011 Estonia; in 2014 Latvia and in 2015 Lithuania joined the Eurozone. Recently Croatia has also met the convergence criteria and will start to use euro in 2023. Bulgaria is already in ERM II (European Exchange Rate Mechanism), and is also expected to join Eurozone by 2025.

2.2.1 Euro Convergence Criteria

For EU countries to join euro, there are a number of convergence criteria that need to be met. These rules are there to ensure the stability of the euro. The Euro Convergence Criteria, also known as the Maastricht Criteria, are the criteria that European Union member states must meet in order to join Stage Three of Economic and Monetary Union, or EMU, and adopt the euro as their currency. There are criteria rules in four main areas:

1- **Price stability**:

   The inflation rate of the respective EU member country must not exceed price stability by more than 1.5 percentage points.

2- **Government finances:**

   A- The annual budget deficit should be within 3% of GDP.

   B- National debt must not be more than 60% of GDP

3- **Exchange Rates:**

Before Member States join the euro, they must have kept their currencies in ERM-II for at least the last two years prior to the examination period. That is, the currency

should be within normal margins of fluctuation allowed by the exchange rate mechanism of the European Monetary System (EMS).

4-Long-term interest rates:

Despite the convergence conditions outlined above, inclusion of diverse economies in the Eurozone without much fiscal coordination turns out to be challenging for both Member Countries as well as for the European Central Bank. It would undoubtedly be more stable situation if the countries involved shared similar political and economic characteristics before Eurozone membership.

Indeed, the euro's long-term viability was easier to achieve in a smaller zone made up of a smaller number of countries with a more cohesive set of economic and political policies.

Therefore, some economists argue that for a monetary union to survive it must be coupled with a fiscal union as well. Nevertheless, the euro has managed to survive a number of crises, and thus, each time established itself as a currency which is able to survive crises. The biggest existence challenge for euro took place in 2009, right after Global Financial Crises.

2.2.2 European Sovereign Debt Crises and Euro in 2010-2012

The European debt crisis or also known as European sovereign debt crises was a financial crisis which affected the Eurozone countries and took place around 2010-2012, right after Global Financial Crises. This crises made it difficult, if not impossible, for some countries in the euro area to repay or re-finance their government debt without the assistance of foreign countries or international institutions.

The European sovereign debt crisis resulted from the structural problem of the Eurozone as well as from 2008 Global Financial Crises which was itself a result of several complex factors such as the globalization of finance, easy credit conditions during the 2002–2008 period, international trade imbalances and real-estate bubbles.

The crisis began in 2009, when the world first realized that Greece could not service its debt. Greece was quickly followed by a number of other Eurozone countries, mainly in the Mediterranean region. These Eurozone member states were Greece, Portugal, Italy, Ireland, and Spain. Eventually, financial guarantees from European countries and the International Monetary Fund (IMF) eventually brought the euro crisis under control.

In 2009, the Eurozone crisis originated in Greece due to its budget deficit. In early 2010, the EU found numerous irregularities in the Greek accounting system. This was followed by Portugal, Italy, Ireland and Spain. Each of these countries had similar accounting problems due to a lack of discipline. Investors were concerned about the growing public debt of several EU members. As they assigned a higher risk premium to the region, sovereign debt increased, putting pressure on government budgets and making re-pay or re-finance much more difficult. As the economy declined, countries struggled to repay their debts with interest, and thus the Eurozone debt crises emerged.

The European Central Bank and the International Monetary Fund had to be involved for financial help. Contractionary fiscal policies were to be brought about in order to balance the budgets and bring down the interest rates. These measures as well as financial guarantees from European countries and the IMF eventually brought the euro crisis under control.

2.3 European Common Policies

European Union has a number of common policy areas. We believe that these policies may contribute to the convergence in macroeconomic variables. This section highlights some of these EU common policies. Most of the policies made by the EU related to internal issues that influenced our daily lives. They are also called common policies because they touch all the EU member states of the EU. The common EU policies cover these areas: agriculture, competition, regional policy, trade, transport, telecommunications, social affairs, energy and industry.

Let us now present below the most important EU common policy "Common Agriculture Policy (CAP)":

2.3.1 Common Agricultural Policy (CAP)

The common agricultural policy's aim is to increase the income in the rural EU. The CAP accounts for approximately half the EU budget. It supports farmers and improves agricultural productivity in order to have affordable food. The Common Agricultural Policy started its work in 1962.

The CAP is one of the largest programmers in the EU. There are currently 10 million farmers in the EU, and about 40 million jobs in food processing and food services depend on agriculture. As a result, the CAP has very important role in the EU development.

The common agricultural policy has three principles:

a. An unlimited market where agricultural products are freely traded with a common price within the EU.
b. Product preference on the internal market.
c. Financial solidarity through joint financing of agricultural programs.The CAP is a common policy for all EU countries. It is managed at the European level and financed from the EU budget.

Chapter 3

CONVERGENCE THEORY

One of the conclusion of Solow Growth Theory and many others is that there is a catch-up effect for developing countries. In other words, countries which have initially lower GDP per capita values tend to grow faster and catch up to richer countries, that is they converge to the level of rich countries. The basic economic intuition behind this "convergence" is that there is a diminishing marginal products for physical capital. In other words, saving and accumulating physical capital can increase the output but at a decreasing rate. Thus, for high-income countries which already have a lot of capital, buying some more capital increases output only by a small amount, whereas in developing countries which are not so much rich in capital, buying some more capital can increase output substantially. Hence countries which have initially lower GDP per capita tend to grow faster, and this is known as "Convergence Theory" in growth literature.

In Chapter 3, we present the types of convergence in economics and highlight a comparison between the different types of convergence. In general, Convergence can be studied either as (1) a Sigma-Convergence or (2) a Beta-Convergence. Furthermore, the beta-convergence has different versions such as: (a) absolute convergence, (b) conditional convergence and (c) club-convergence. We will look at the details of these in coming paragraphs below.

Some of the early studies on cross-sectional dispersion-based Sigma-Convergence are Easterlin (1960), Borts and Stein (1964), Streissler (1979), Barro (1984) and Baumol (1986). On the other hand, the early studies on Beta-Convergence include Barro (1984), Baumol (1986), DeLong (1988), Barro (1991), Barro and Sala-i Martin (1991, 1992a, 1992b), [Barro and Sala-I Martin (1995), "Economic Growth"] (cited by Simionescu, 2014).

3.1 Sigma Convergence

According to sigma convergence, there is convergence among the countries for a specific macroeconomic variable if the dispersion of that variable for different countries tends to decrease over the years. One needs to be careful, though, about the measurement of dispersion. Dispersion can be measured by range, interquartile range, variance, or standard deviation.

However, the variance or the standard deviation would not produce robust results if the countries are not of similar size. Similarly, range and interquartile range would not be optimal choices given that they are calculated based on 2 measurements only rather than the measurements of the whole countries and thus they can be affected by extreme values.

The previous literature in sigma convergence tests, therefore, have mostly used the coefficient of variation. The Coefficient of Variation is simply measured as the standard deviation divided by the mean. In this study too, we mostly use this measurement to carry out our sigma-convergence test.

However, there is also a simpler, albeit a less robust method which we will also carry out. In this method, one can find out the maximum, minimum points as well as Interquartile points Q1 and Q3; and then simply find out the ratios of these numbers to the mean. Declining ratios over the time also imply sigma-convergence.

Sigma convergence informs us whether the cross-sectional variation of the GDP per capita or other macroeconomic variables of interest among a group of countries decrease over time or not. As said, to measure sigma convergence usually coefficient of variation is commonly used, but there is another way of analyzing it. It is to compare the ratio of the minimums and maximums of GDP per capita in the sampled countries to the average GDP per capita.

Testing sigma convergence shows a clear image about the changes in economic data, taking into consideration the distribution of the variable. Friedman in 1992 indicated that sigma convergence is of greater interest because it speaks directly as to whether the distribution of income across economic is becoming more equitable(Friedman, 1992).

It is critical to assess the achievement of the sigma criterion of convergence in a timely manner so that appropriate adjustments can be made to improve the degree of convergence. In 2009, Iancu used sigma convergence to evaluate the evolution of real convergence across EU countries with the coefficient of variation reflecting a divergence increase of the economies between 1995 and 2006 (Iancu, 2009; Simionescu, 2014). Similarly, Mihuţ & Luţas (2013) compared the sigma convergences of the European Union's new members.

3.2 Beta Convergence

Beta (β) convergence tests have been mostly applied on GDP per capita values for testing an income convergence. Beta convergence occurs when less developed economic (with lower GDP per capita) tend to grow faster than more developed ones (with higher GDP per capita). Thus, a beta-convergence test mainly involves the regression of the economic growth rate on the initial value of GDP per capita (GDPPC). For convergence to be concluded, the sign of the coefficient estimate of the initial GDPPC variable is to be negative.

The coefficient estimate on the initial GDPPC during a Beta (β) convergence test shows the speed how fast the convergence is taking place. That is, the β coefficient estimate gives us information what percentage of the distance towards the steady state economy is covering during specific period.

Moreover, Gachter and Theur (2011) indicate that Beta-convergence is necessary but not sufficient condition for sigma convergence. Beta convergence tests if poorer countries grow faster than rich ones in order to catch-up the living standards of richer countries, while sigma convergence simply implies a decrease of variation among regions over the time. However, the two concepts are of course closely related; and as said the Beta – convergence is necessary but not sufficient condition for sigma – convergence.

To put it in a simple sentence, Beta-convergence tests whether poorer countries grow faster than richer countries. Hence the beta-convergence is also known as "catch-up effect". These studies became quickly popular by the publication of Barro (1984), Baumol (1986), and DeLong (1988) papers (Cited by Barro and Sala, 1992).There are

two type of beta conversion: (i) Absolute (or Unconditional) Convergence and (ii) Conditional Convergence. Let us now see how these two compares with.

3.2.1 Absolute Convergence

Absolute convergence states that Countries converge to the same income per capita values in the steady state regardless of the initial conditions. Thus, in these tests, the Countries may have different initial GDP per capita values, different technology levels, population growth rates or saving rates. Yet, the countries converge to the same income per capita in the steady state. This implies that a significant and negative coefficient estimate for the initial GDPPC variable when the dependent variable "Growth" is regressed on a number of explanatory and control variables. It also implies that convergence takes place no matter how different the countries are in terms of their explanatory or control variables such as saving rates. An important conclusion is then that all countries converge to the same income per person values regardless of policy choices and indeed regardless of existent of external aid or not.

3.2.2 Conditional Convergence

On the other hand, conditional convergence implies that countries may or may not converge to the same income per capita in the steady state depending on a number of conditions. That is, the convergence is on the condition that the countries have the same economic conditions (structures) such as saving rates, technology and population growth rates. This implies that when one regresses the economic growth rate on the initial GDPPC and on the other explanatory or control variables, not only the coefficient estimate for initial GDPPC turns out to be statistically significant and of negative sign, but also some or all of other variables also turn out to be statistically significant. This implies that other explanatory variables do affect the growth trajectory, leading to different income per person values in the steady state if the

countries are not the same in terms of their economic structures. On the other hand, if the countries have similar economic structures such as in terms of their saving rates, population growth rates and technology, then these countries converge to the same income per capita in the steady state.

The implication of this is that economic and social policies do matter. External aid does matter. Poorer Countries can catch up with the richer countries provided that they adopt the right policies affecting the economic structures which in turn affect the growth trajectories.

3.2.3 Club Convergence

Although not frequently mentioned, Club Convergence is another type of Beta-Convergence. While unconditional convergence theory states that convergence takes place no matter what, conditional convergence theory states that convergence takes place only if the condition of having similar economic structures (such as same saving rates) is met. On the other hand, club convergence takes place if the condition of having similar initial GDPPC is met, rather than the condition of having similar economic structures.

According to this theory, economic structures such as saving rates, population growth rates and technology levels as well as the policies affecting them would not matter; but the initial GDP per capita would matter in terms of where the countries end up in their steady states. The countries initially having similar and high income per capita values would converge to the same GDP per capita values in the steady state. Similarly, the countries initially having similar and lower income per capita values would converge to the same GDP per capita values in the steady state but that this steady state value would be lower than that of the high-income countries.

According to this theory, indeed, countries can be categorized based on educational levels, income per capita and other measurable factors. For example, countries are grouped as "poor" tend to converge towards one another and create a convergence club at a poor level of per-capita wealth, while rich countries are grouped into a higher-income per-capita convergence level.

The group of wealthy countries is characterized by upward convergence, in which the poorest members of the group catch up to the richer ones. The group of extremely poor countries is experiencing downward convergence, or a narrowing of income disparities, as a result of almost zero, or even negative, growth among the group's 'richer' members.

Chapter 4

LITERATURE REVIEW

In this chapter, we present some literature review on convergence. Since this study is about sigma convergence test on GDP per capita, interest rates and inflation rates, we follow the same order and present some recent papers on these topics. Moreover, since this study is focusing on European Union countries, we attempt to select papers mostly from the same geographic area.

Let us now start presenting first the sigma convergence tests on GDP per capita values.

4.1 Sigma Convergence for GDP per Capita in Europe

This research study describes beta and sigma convergence in 28 EU countries in the EU based on panel data analysis. Sigma convergence describes the decrease in income over time or in other words GDP per capita (Janekalne, 2016).

Beta convergence indicates that there is a negative relationship between income growth and the initial income level. In this Sigma convergence applies to the 28 EU countries over the period 2000-2008.Another study also has been done to analyze convergence in the 28 EU countries over the period 2000-2011.Sigma and beta are used for convergence analysis, which examines the degree of convergence of GDP per capita. The GDP indicator is highly controversial. This study clearly shows that the convergence process is faster and more clearly defined for countries than for regions beta convergence is used to test the dynamics and the elimination of disparities, sigma convergence is used.

A research study shows the economic growth paths in the transition countries of Eastern-Central Europe in the period 1990-2005. According to the sigma-convergence, these countries show both convergence and divergence. Panel data were used to determine the convergence in the EU transition countries.

Sigma test was used to determine the result. Lancu used sigma convergence in 2009 to measure the evolution of the real convergence process among EU countries. He found a divergence of economic growth in 2006-2009 (Iancu, 2009). Lancu in 2009 applied sigma convergence to quantify the evolution of real convergence between EU countries divided into three groups: EU-25, EU-15, and EU-10 (Iancu, 2009).

The results show that the divergence process has decreased in 1998 but there is still insufficient evidence that an adequate degree of convergence has been achieved. Sigma convergence, determined by variation indicators, is the best known and most commonly used method.

4.2 Sigma convergence for the interest rate in Europe

Koukouritakis & Michelis (2008) empirically examined interest rates in the 12 EU countries from 1990 to 2007. Granger causality and Johansen co-integration tests were applied in this study. This study consists of monthly data with different time periods for different EU countries.

The results show that the long-term interest rate is exogenous on a weekly basis. The short-term interest rate, on the other hand, is exogenous on a weekly basis and is most commonly used (Koukouritakis & Michelis, 2008).

In Eastern Europe and the 12 newest EU countries, both short-term and long-term interest rates apply (Koukouritakis & Michelis, 2008).Recently, the interest rate has

increased sharply and is growing. Many econometric methods have been used for the study (Koukouritakis & Michelis, 2008).

On the other hand, Frömmel & Kruse (2015) analyzed the convergence of interest rates in the European monetary system (EMU) using the 1998 framework data. Recently, interest rates have risen sharply due to the financial crisis in the EU. In this research study, time series panel data was used for data analysis, and sigma convergence was used to obtain the results. The main factor driving the convergence of interest rates between the respective countries was the coordination of fiscal and monetary policies to stabilize the exchange rate in the EU. The study shows that in 2009 there was a gradual convergence of interest rates in the EU for the accession of new EU member states, it is better that convergence with the euro area is achieved before joining the euro system (Alcidi, 2019).

Kocenda & Papell (2016) wrote about the inflation convergence in the 28 EU countries over the period 1999-2017. Inflation in the EU has attracted the attention of many people. Panel data series were used for data collection. According to Kocenda & Papell (2016), inflation in countries using the euro is stronger than in countries with exchange rates Inflation cries had a very large impact on the GDP of EU countries. The report also shows that inflation convergence among EU countries has increased after the global financial crisis. Sigma convergence is used for this research (Kocenda & Papell, 2016).

Another study conducted by Holmes (2002) examined inflation in the EU. This paper uses panel data to examine inflation convergence in the EU over the period 1972-1999. During this period, the EU experienced many changes such as crises and exchange rate

mechanisms. According to the panel data, convergence was stronger in 1999. According to Sigma, inflation convergence increased after the introduction of the euro(Holmes, 2002).

Similarly a study undertaken by Cavallero (2011) and that paper examines the convergence process of euro area inflation rates over the period 1990-2006 in the 12 EU countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain). This study is based on annual time series data. The results show that there has always been inflation convergence over the past 25 years, but the convergence process has not always been constant.

To sum up, in literature review of this thesis, there are many studies of convergence, including sigma convergence on inflation rates, and sigma convergence of interest rates which have been all examined. This study used the earlier studies by Barro and Sala (1992) with a review of research convergence the first empirical studies on convergence started with sigma convergence to understand GDP per capita. The GDP per capita indicator is very controversial because it implies that poor countries grow faster than rich countries. Sigma convergence has been used to describe or test for convergence in income over the time. This study also focuses on the convergence of interest rates. The main factor behind our desire to test for convergence of interest rates among the respective countries was the coordination of fiscal and monetary policies to stabilize the exchange rate in the EU.

This article also analyzes inflation convergence in the 28 EU countries over the period 1999-2017.Inflation in the EU has attracted the attention of many people. Panel data series were used for data collection. According to Kocenda and Papell, inflation in

countries using the euro is stronger than in countries with exchange rates (Kocenda & Papell, 2016).

Chapter 5

METHODOLOGY AND DATA

As mentioned before, the purpose of this thesis is to employ sigma convergence test on the European GDP per capita values, interest rates and inflation rates in order to decide if there is a convergence in the above-mentioned series within the Europe. In this Chapter, we present the methodologies we used for this study. Then, we present the information about the data. Let us first start with the methodology.

5.1 The Methodology

We attempt to decide whether there are convergences in European macroeconomic variables by employing the sigma convergence test which essentially looks at the dispersion numbers for each variable over the selected years.

To this end, we could employ 3 different but similar methods to measure the dispersion:

1. Coefficient of variation (std dev/mean)
2. Maximum as percent of the average (max/mean ratio)
3. Minimum as percent of the average (min/mean ratio).

For the first method, for each year, we calculate the standard deviation and the year-average from the sampled countries' data. Then the coefficient of variation (CV) is simply calculated as standard deviation divided by the mean. Thus, for each year we calculate the CV, and then we can plot the CV values against the years in order to see

if there is a downward trajectory in the graph, which would imply a sigma convergence.

For the second and third methods, we could simply replace the standard deviation with the maximum and minimum values respectively; and then plot these values against the years. Again declining plots over the years would imply that dispersions are decreasing, and thus convergence is taking place. However, one needs to note that the second and the third methods are less robust because these ratios are affected from the extreme values of the maximum and the minimum. Hence, we decide to use only the first method.

Thus we calculate the coefficient of variation (CV) for (i) GDPPC values, (ii) for cpi-based inflation rates, and (iii) for interest rates. Then we plot the CVs against the Years. Downward sloping graphs would seemingly imply a sigma-convergence for the given macroeconomic variable.

However, at the end of each plot, we also run a simple OLS estimation, where we regress the CVs on the years:

$$CV = \beta_0 + \beta_1 \text{ “Year”}$$

Here, statistically significant “negative” coefficient estimation for the explanatory variable “Year” would imply that dispersion is declining over the passing years, and thus would imply a sigma convergence.

5.2 Data

To study the sigma convergence within European countries, we use a panel data of 27 EU member states as well as 4 other European countries which are economically linked to the EU through EEA (European Economic Area) and other bilateral trade

agreements. The data span from the year 1998 to 2020. Thus, we have 22 years of observations for the following countries:"Germany", "France", "Italy", "Spain", " The Netherlands", "Ireland", "Austria","Portugal", "Greece", "Cyprus", "Malta", "Denmark", "Sweden", "Finland", "Belgium", "Luxembourg", "Poland", "Hungary", "Romania", "Bulgaria", "Czech Republic", "Slovak Republic", "Slovenia", "Croatia", "Estonia", "Latvia", "Lithuania", as well as "United Kingdom", "Switzerland", "Norway", and "Iceland".

As said earlier, the last 4 countries listed above are not EU member countries, but are closely related to EU economies.

For this thesis, we attempt to investigate sigma-convergence for GDP per capita values, for inflation rates and for interest rates. To this end, we employ data for GDPPC values in constant US dollars; we employ CPI (consumer price indices) for inflation rate study; and we employ 10-year-bond yields for interest rates. The GDPPC and CPI data come from World Bank database while the 10-year bond yields come from Eurostat database.

Chapter 6

RESULTS

We run the sigma convergence tests on 3 sets of countries: (i) The 27 EU members plus 4 related countries, and (ii) West European countries which have had both economic and/or political cooperation for the past 40 years, if not longer, and (iii) on Eurozone-12 countries which were the original countries which adopted euro before the circulation of euro currencies in 2002. Thus we present plots separately for each of the samples described above. Let us now present our results.

6.1 Full Sample (31 European Countries)

6.1.1 The Graph for GDPPC

The graph in Figure 1 show the relationship for the coefficient of variation (CV) of GDPPC values for the years from 1998 to 2020. As we can see from this plot, there is a continuous decrease in the CVs with a minor exemption in the years 2009, 2010 and 2013. These are the years corresponding to Global Financial Years and European Debt Crises. Nevertheless, the graph markedly shows a decreasing plot over the years and very clearly indicates a sigma convergence among the 31 European Countries.

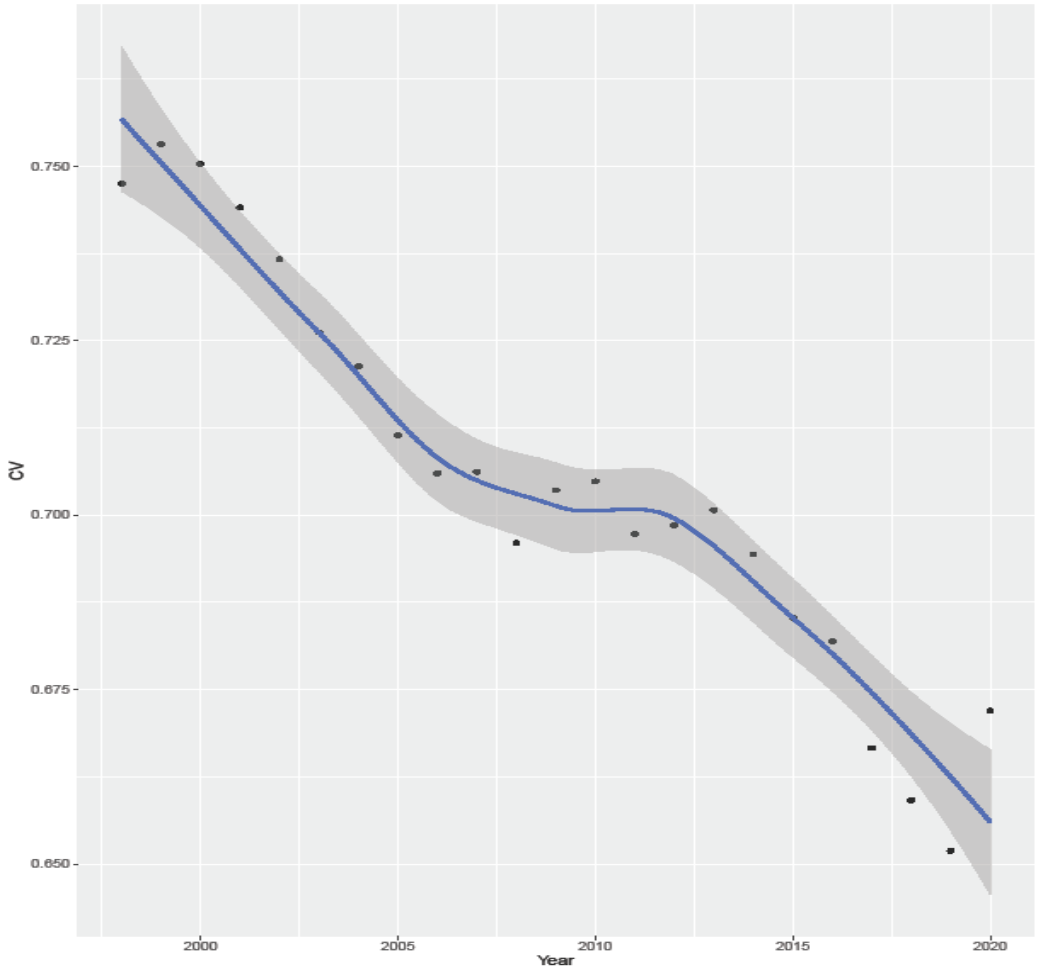

Figure 2: GDPPC Graph for 31 European Countries.

Table 1: OLS Estimation for GDPPC

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.8857668	0.5170334	17.19	7.60e-14 ***
DF$Year	-0.0040721	0.0002574	-15.82	3.83e-13 ***

Further investigation by looking at the results in Table 1, shows that the coefficient estimation for the "Year" is statistically significant at 1% significance level, and it has a negative sign as theoretically expected. This supports the sigma convergence for GDPPC variable among the 31 European Countries. However, here we should also

note the limitation of this study in the sense that the OLS estimation is based on a sample size of 23 years of observation, a rather small sample.

6.1.2 The Graph for Inflation Rates

The graph in Figure 2 show the relationship for the coefficient of variation (CV) of CPI values for the years from 1998 to 2020.

As we can see from Figure 2, the CVs of CPI are decreasing from the year 1998 to 2010, after which it starts to increase. Thus this graph clearly highlights that there is a sigma-convergence for the European inflation rates until the Global Financial Crises; but after that year this relationship disappears.

However, an OLS estimation results, presented in Table 2, clearly shows a statistically significant and negative coefficient estimate for the “Year”. This again supports that there is a sigma convergence for CPI values among the 31 European Countries for the given years.

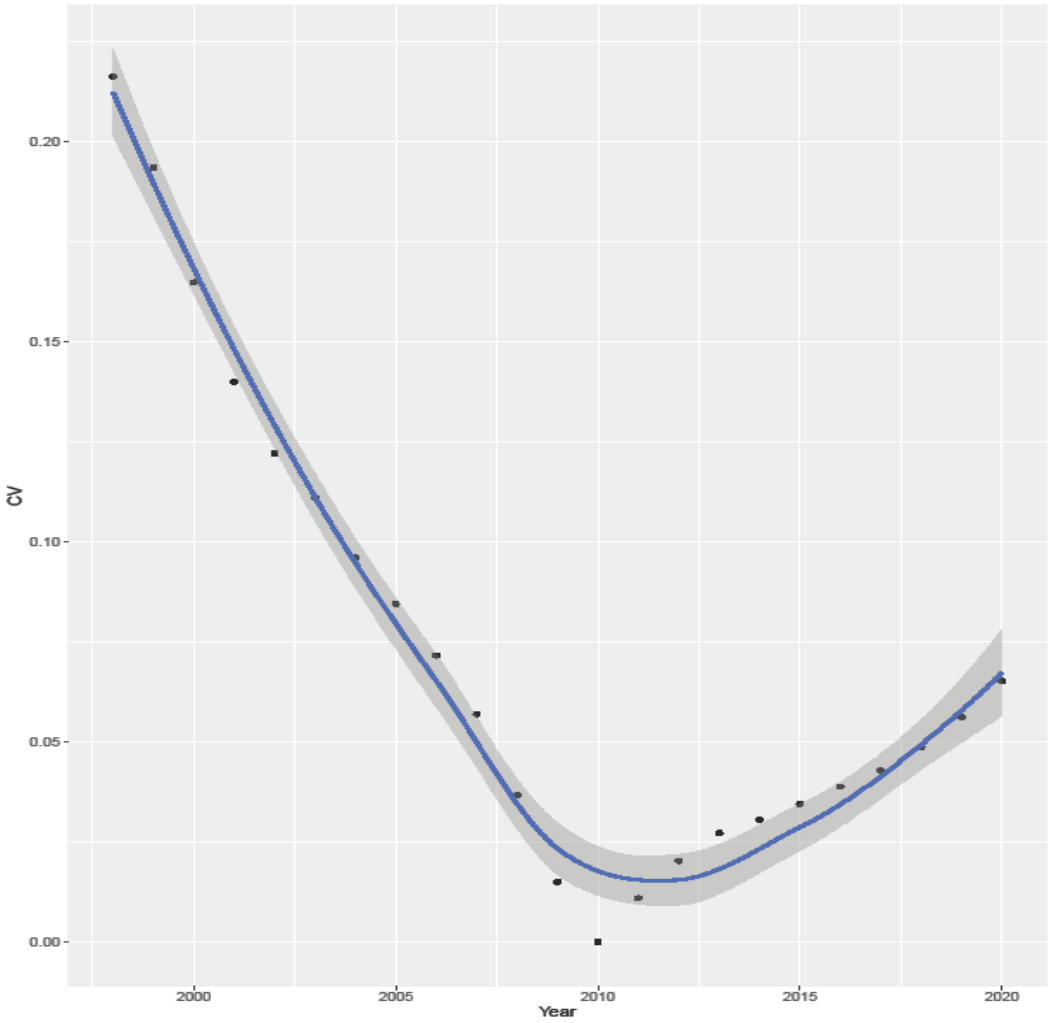

Figure 3: CPI Graph for 31 European Countries.

Table 2: OLS Estimation for CPI (31 European Countries)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	13.452440	2.500849	5.379	2.46e-05 ***
DF$Year	-0.006660	0.001245	-5.350	2.64e-05 ***

6.1.3 The Graph for Interest Rates

The graph in Figure 3 shows the relationship for the coefficient of variation (CV) of Interest Rates (bond-yields) values for the years from 1998 to 2020.

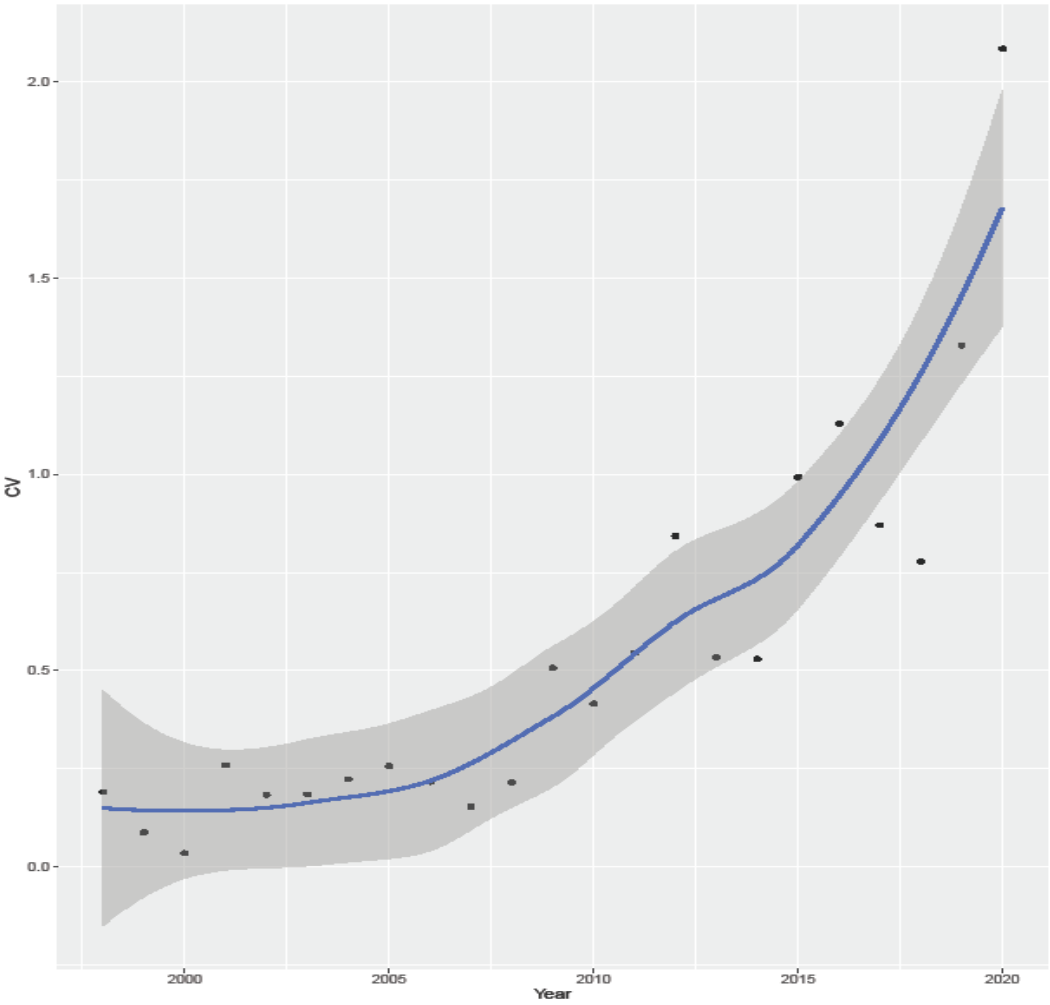

Figure 4: Interest Rates (Bond-yields) Graph for 31 European Countries

As we can see from the graph above, the CVs are not declining over the years. On the contrary, the CVs are more or less constant until 2008-09, that is until the start of Global Financial Crises, after which the CVs for interest rates start to increase, implying increasing dispersions. Thus overall this graph implies that there has been no sigma convergence for the European Interest rates for any given time period.

Table 3: OLS Estimation for the interest rates (31 European Countries)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.221e+02	1.695e+01	-7.203	4.25e-07 ***
DF$Year	6.104e-02	8.438e-03	7.235	3.97e-07 ***

As we can see from Table 3, the coefficient estimate for the “Year” is statistically significant but of positive sign. This provides counter evidence for sigma convergence for the interest rates among the 31 European Countries.

Given the non-supportive results for CPI and interest rates, we decide to carry these tests for the reduced samples. As mentioned before, we first restrict the sample to include only West European Countries which have been cooperating at least since 1980s; then secondly we restrict the sample to include the original Eurozone countries which have adopted euro since 2002.

6.2 The Sample Excluding East European Countries

6.2.1 The Graph for CPI (Inflation Rates) (West European Countries)

The graph in Figure 4 show the relationship for the coefficient of variation (CV) of CPI values for the years from 1998 to 2020 when we exclude the East European countries from the sample.

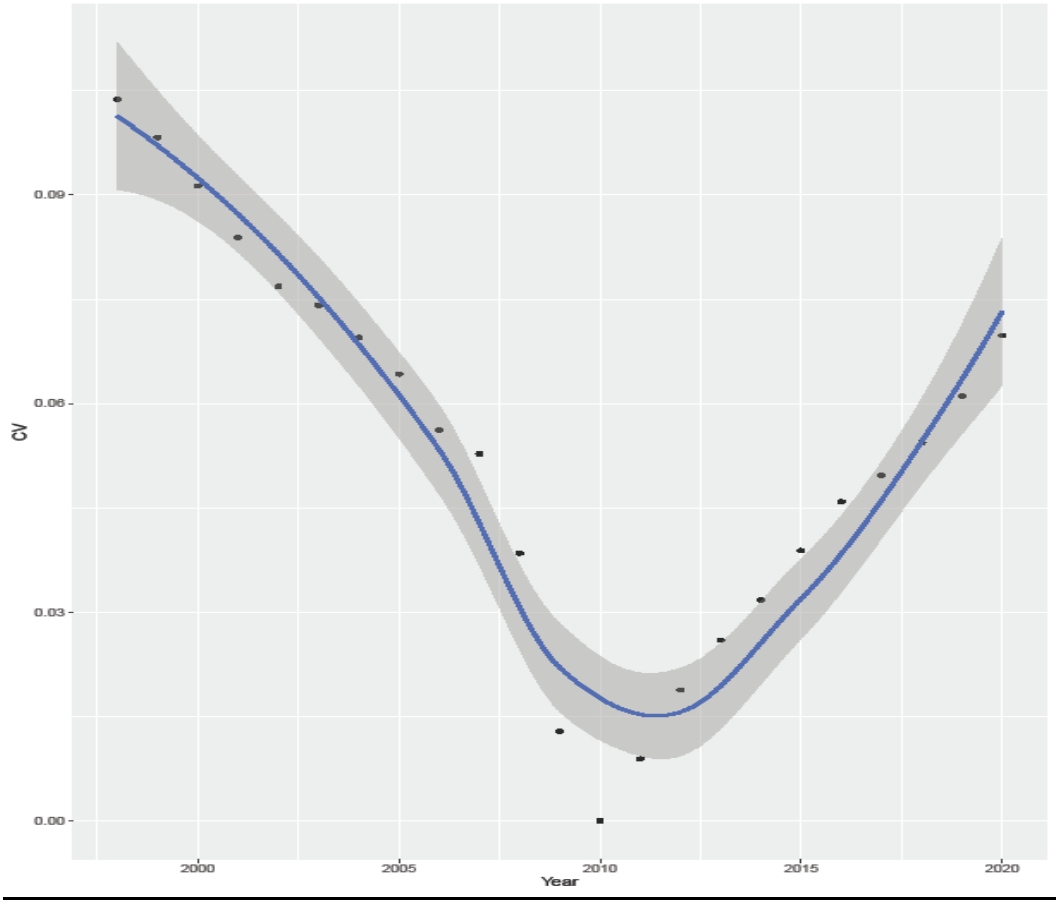

Figure 5: The Graph for CPI (Inflation Rates) (West European Countries)

Once again, the graph in Figure 4 looks very similar to that in Figure 2. This also implies that there seems to be a sigma convergence for the inflation rates among the West European countries up until 2010, and after this year, the convergence relationship disappeared.

Furthermore, and once again, when one closely looks at the CV numbers, one also realizes that there has been less dispersion for CPI values among the West European Countries than the full sample of 31 countries.

When we investigate the Table 4, where the OLS estimate results are presented, we see that the coefficient estimate for the "Year" is statistically significant at 1%

significance level and is of negative sign. This supports the sigma-convergence for CPI values among the West European Countries.

Table 4: OLS Estimation for CPI (West European Countries)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	4.7390375	1.5415296	3.074	0.00575 **
DF$Year	-0.0023323	0.0007673	-3.040	0.00623 **

Next, we do the same analysis for the Interest rates for West European Countries.

6.2.2 The Graph for Interest Rates (Bond-yields) (West European Countries)

The graph in Figure 5 show the relationship for the coefficient of variation (CV) of bond-yields for the years from 1998 to 2020 when we exclude the East European countries from the sample.

Figure 5 below, similar to Figure 3, show that there has not been a sigma convergence even for West European Countries for any of the time period studied.

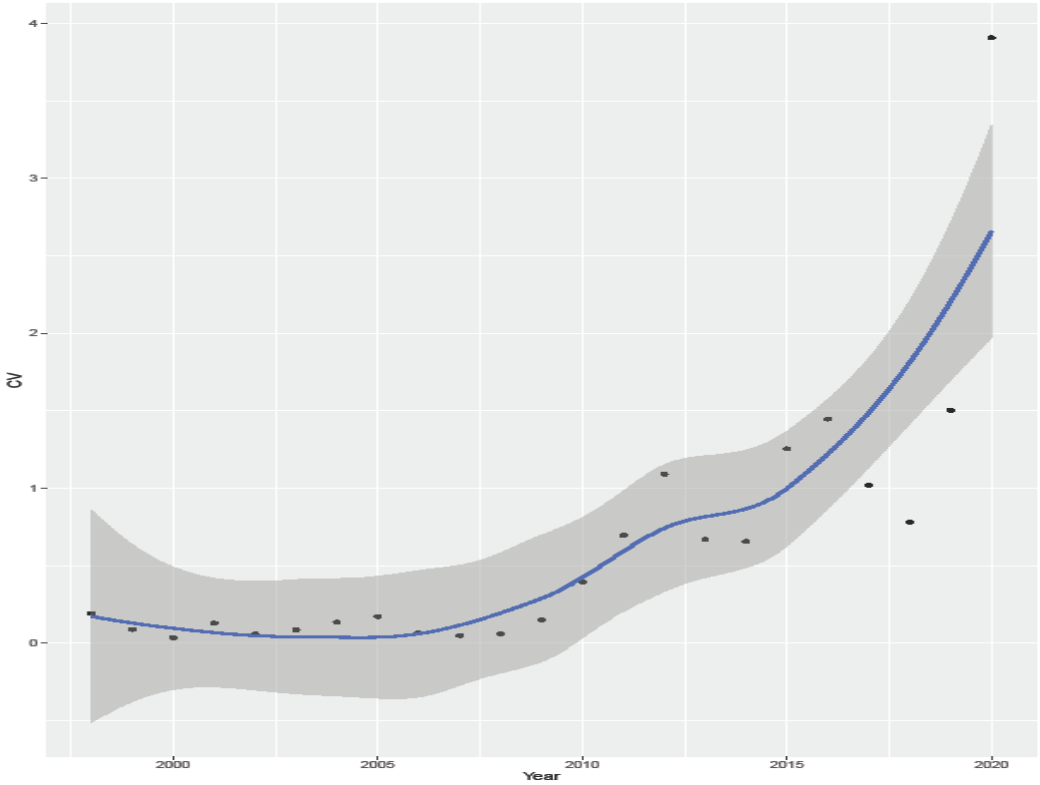

Figure 6: The Graph for Interest Rates (Bond-yields) (West European Countries).

Table 5: OLS Estimation for Interest Rates (West European Countries)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-187.74207	37.73088	-4.976	6.35e-05 ***
DF$Year	0.09377	0.01878	4.993	6.10e-05 ***

Furthermore, the OLS estimation results presented in Table 5, clearly shows that there is no support for concluding sigma convergence for the interest rates among the West European Countries.

Thus, we decide to further restrict the sample to original euro-12 countries and test if there is a sigma convergence for the interest rates among the Euro-12 Countries.

6.3 Original Eurozone-12 Countries

6.3.1 The Graph for Interest Rates (Bond-yields)

The graph in Figure 6 below is upward sloping. Hence it does not seem to support the idea of sigma convergence even for the restricted sample of 12 Eurozone countries which have adopted euro before 2002.

Furthermore, the OLS estimation results in Table 6 also do not support the sigma convergence for the interest rates among the Euro-12 Countries, as the coefficient estimate for the “Year” turns out to be statistically significant but of wrong sign.

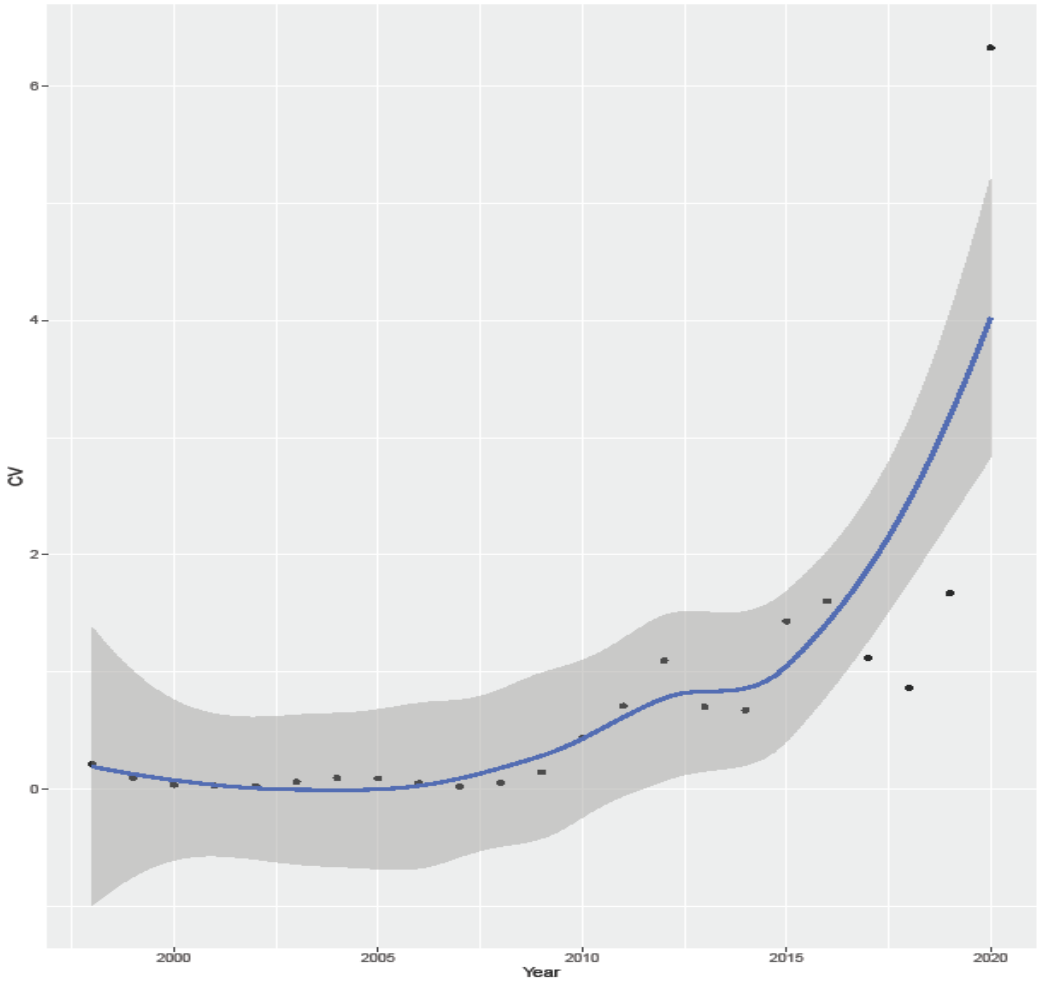

Figure 7: The Graph for Interest Rates (Euro-12 Countries)

Table 6: OLS Estimation for the Interest Rates (Euro-12 Countries)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-254.71880	65.58951	-3.884	0.000858 ***
DF$Year	0.12717	0.03265	3.895	0.000834 ***

Chapter 7

CONCLUSION

The objective of this thesis is to apply the Sigma convergence test to European per capita GDP values, interest rates and inflation rates over the period 1998-2020 to determine whether or not there is convergence between (i) the per capita GDP values, (ii) the inflation rates and (iii) the interest rates of these European countries. To this end, we used the sigma convergence test to understand the convergence between 1998-2020.From the results of the aggregate models, we can derive some important findings of this study.According to the sigma convergence test, there is convergence between countries in terms of GDP per capita values. This is concluded based on both the OLS results and the plot of CVs over the time.

Our result in this thesis according to the graph for GDPPC (Figure 2), shows a decreasing curve over the years and clearly indicates a sigma convergence among the 31 European Countries.

The test results in Table 1 show that the estimated coefficient for "year" is statistically significant at the 1% significance level and has a negative sign as theoretically expected. This confirms the sigma convergence for the GDPPC variable among the 31 European countries.

The graph for inflation rates (Figure 3) shows that the inflation rate or CPI has been declining from 1998 to 2010. This graph also clearly shows that there is a sigma

convergence for European inflation rates until the global financial crisis, but after that year this relationship disappears. The OLS estimation results presented in Table 2 clearly show a statistically significant and negative estimation coefficient for the "year". Again, this suggests that there is a sigma convergence for the CPI values among the 31 European countries for the years indicated.

The graph for interest rates shows that interest rates begin to rise in 2008-09 following the global financial crisis. The Table 3 shows that the estimated coefficient for the "year" has a positive sign, which indicate that there is no sigma convergence for 31 European Union countries.

We also examine the chart for CPI (inflation rates) of Western European countries (Figure 5). The graph shows that there appears to be sigma convergence for inflation rates among Western European countries until 2010, and after that year the convergence relationship disappeared.

The OLS estimation results in Table 4 show that the estimated coefficient for "year" is statistically significant at the 1% significance level and has a negative sign. This speaks to the sigma convergence of CPI values among Western European countries. The graph for interest rates (bond yields) for the Western European countries (Figure 6) shows that there has been no sigma convergence for the Western European countries in any of the periods studied. Moreover, the OLS estimation results presented in Table 5 clearly show that there is no support for the conclusion of sigma convergence for interest rates among Western European countries.

Finally, we decide to further restrict the sample to the original Euro-12 countries and test whether there is sigma convergence for interest rates between Euro-12 countries. From the chart (Figure 8), we find that there is no convergence among euro area countries. And the results of the OLS estimation in table 6 do not support a sigma convergence of interest rates among the euro-12 countries either.

With such results, we have to conclude that our study produced a mixed set of results, and that these are mostly in line with the previous literature review. In other words, previous studies have not produced a clear cut conclusion about the convergence of the economies in terms of the mentioned macro-economic variables, and our study also suggests so. While the results support a clear-cut conclusion for the GDPPC variable, the results are mixed for the inflation and interest rate variables.

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