A Contribution to the Empirics of Convergence: the Case of the European State Members

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Abstract

This study aims to examine the absolute and conditional convergence across the 27 EU Member States. To examine the absolute β convergence was used Baumol model (1986) estimated by OLS and Panel Data, and to examine the absolute σ convergence the Quah model (1993) by graphical analysis. Subsequently, we analyzed the conditional convergence, also estimated by OLS regressions and Panel Data. Finally, we performed a cluster analysis with the aim to understand the differences between different schools of economic growth thought. With this work we conclude that there is absolute β convergence in general, but the absolute convergence σ occurs only in the 12 most recent member states. The conditional convergence is verified in general and with a top speed of convergence β absolute. Finally we conclude that the neoclassical school, since 1980, proves to be important for economic growth and convergence of the EU as the school Neo Schumpeterian just proves to be important since 1991.

Keywords: Convergence, absolute convergence, conditional convergence, economic growth

JEL Codes: F15, F43, O40, O11

1 Introduction

Over the recent decades, the countries over the world have realized the impact of the economic growth on wealth and living standards of their citizens. Thus, the importance to study this area has led the researchers to investigate the economic growth of countries and regions.

The increasing level of globalization in recent decades leads countries to concern themselves not only with their level of economic growth, but also with comparing their own economic level with other countries. The way to compare the different levels of wealth is to realize if the countries are close to each other, or converge, or if on the other hand they turn away, or diverge. In order to examine these two situations several authors presenting different ways to check the setting in which countries are.

The analysis of convergence or divergence of countries can be highlighted by three major forms, beginning with an analysis of absolute convergence (the countries are close to all of the same steady state) based on the model of Baumol (1986) or in the model of Quah (1993). Another approach is the analysis of conditional convergence, through which the countries are close to forming steady states for different groups of convergence, analyzed with the model of Baumol (1986), but augmented with other explanatory variables that represent apparent differences in the structure of countries.

Convergence became a much-studied economic concept not only because of the importance in comparing the wealth of countries, but also because its analysis allows inferring about the validity of different economic growth models.

Although, some studies analyze the convergence based on its different forms, as such Silva and Silva (2000), Benos and Karagiannis (2008), and Cho (1996), our study aims to analyze the convergence based on two different schools of economic growth, on the one hand the neoclassic approach based on the Solow model (1956) and, secondly, the Neo-Schumpeterian approach, based on the Schumpeter model (1934). Thus the study investigates which of these approaches is more important for economic growth and to the convergence of the 27 European Union State-Members, based on the period of 1980-2006.

In addition to this main objective, it is relevant to test the theory of Fagerberg (1991). This theory argues that expenditures in research and development (R&D) lead countries to converge, since it corresponds to the expenses of the poorest countries to copy the technology of the richest, while the number of patents promotes divergence, because it prevents the most poor countries from copying the technology of the richest.

In order to answer the proposed questions, this paper is structured as follows. It begins in section 2 with a brief literature review about convergence and the various research methodologies used, continuing in section 3 with the analysis of the disparities in the European Union. Section 4 exposes the methodology to obtain our results and section 5 the data. Finally, we present and discuss the results on section 6 and section 7 concludes.

2 Literature Review

The growing interest in comparing economic growth of countries, in order to measure whether they would also achieve the same steady state in the long run, takes to the concept of convergence[1]. This concept was firstly based on the neoclassical growth model of Solow-Swan.

The neoclassical growth theory (Ramsey, 1928; Solow, 1956; Cass, 1965; Koopmans, 1965) postulates that the per capita output growth rate is inversely related to the initial level of the variable. This implies that in the economies that have the same steady state but differ in relation to initial conditions, the less developed countries (poor countries) will grow faster than rich ones (Barro and Sala-i-Martin, 1992; Heijdra and der Ploeg, 2002). This is referred to the so-called absolute convergence. Convergence in terms of both growth rate and income level is called beta-convergence, which is tested by regressing the growth rate of GDP per capita on the initial relative value across the cross section of countries. The type of convergence derived from the coefficient of the initial income value variable in the regressions gives to the beta (β). Barro and Sala-i-Martin (1992) distinguish the β-convergence, in conditional β-convergence when there is a negative correlation between initial values of real GDP per capita and its average annual growth rate,

[1] In economic growth literature it is possible to find several definitions about the concept of convergence (Barro and Sala-i-Martin (1992), Sala-i-Martin (1996), Mankiw *et al.* (1992).

under certain conditions for control variables; and absolute or unconditional β-convergence when there are no conditions and the poor economies grow faster than the wealthy ones.

With the β-convergence, Barro and Sala-i-Martin (1992) introduce the complementary concept of σ-convergence, which refers to the reduction of the dispersion of a given indicator (for example, the real GDP per capita) for a relative group of geographical economic units (regions, countries, etc) over the time, measured by means of standard deviation or related measures.

The convergence theoretically postulated in the Solow-Swan model, was for the first time empirically verify with Baumol (1986), which was followed by other authors such as Barro and Sala-i-Martin (1991) and, recently, Battisti and Vaio (2008).

Although this model is still widely used in empirical studies on this topic, it has particular problems for studies that cover periods after 1980, because of the low speed of convergence (Dobson, Ramlongan and Strobl, 2006; Fuente, 2002; Battisti and Vaio, 2008; Marelli, 2007; Duncan and Fuentes, 2006). Therefore, and since, as stated by Lusigi, Piesse and Thirtle (1998), Benos and Karagiannis (2008) and Quah (1993), the speed of convergence has a cyclic behavior similar to that of economic growth, convergence over time could not be analyzed because they were only taken into account the beginning and end, since the growth rate being given by the difference between initial and final GDP moments.

To overcome this problem, and understand which are the periods of convergence and divergence, Quah (1993) marked the beginning of another form of convergence, called σ convergence, which analyzes the variance of GDP *per capita* between countries or regions. To test this type of convergence he analyzed graphically the variance of GDP *per capita*, obtaining convergence where this variance has a decreasing behavior. This model is often used in conjunction with the model of Baumol (1986), which makes possible a better understanding of the behavior of convergence over time, allowing some authors to argue that convergence follows a cyclic behavior, such as economic growth.

Another alternative to solve the problems of the model of Baumol (1986) mentioned earlier, was the emergence of the endogenous growth models. These models, initially developed by Romer (1986) and Lucas (1988) took the technology, previously handled by Solow (1956, 1957) as being exogenous as endogenous. In addition, they assumed that the accumulation of capital externalities presented, with no diminishing returns to scale, and thus the richest countries, with more accumulated capital continue to grow faster than richer.

The last way to solve the problem was the so-called conditional convergence. With the analysis of the Solow model it was stated that countries would converge to the same steady state in the long run, but only if they have a similar structure, something that was not taken into account in the Baumol model (1986), because all countries were within the same group, despite being very different. Thus, the conditional convergence assumes that instead of all countries converge to the same steady state, small groups of countries converge each to the same steady state. The speed, with which this convergence occurs, according to Dobson, Ramlongan and Strobl (2006), is presented as homogeneous, while according to Lee, Pesaran and Smith (1997) this is different from group to group.

3 Analysis of disparities in the EU

The economic growth of countries and regions and the standards of living, has been one of the major concerns of governments in industrialized countries (Romer, 2006). Many studies has been done in an attempting to understand why some countries grow faster than others, which variables influence these differences, what to do for the country grow faster, among many others. In recent decades, the main concern of policy makers has focused on the attempt to bring the different regions or countries to a similar level of economic development. Thus, the results investigation done takes to evaluation of policies for convergence, not only based on GDP but also on other variables.

This concern also occurs in the European Union (EU), where the disparities are quite pronounced, especially after the accession of the ten new member states to the EU in 2004, which had low levels of income *per capita*. With the current 27 member states, the differences between the richest country, Luxembourg, and the poorest, Romania, is more than 38 times (Eurostat, 2008). These disparities are also observed when we have 50% of EU GDP concentrated in just five countries (France, Italy, UK, Spain and Poland) (Eurostat, 2008). Regionally these disparities also exist, as stated by Battisti and Vaio (2008), the richest region has a GDP equal to 189% of

EU 25 average and poorest GDP equal to 36%. In addition, these authors say that 90% of the population lives in regions with a GDP below 75% of the EU average.

With all this background the EU has long been concerned with the approach of GDP in regions or countries. Thus, several funds have been created for this purpose, especially during the period 2007-2013 for which there are three funds, namely: the European Regional Development Fund (ERDF), which concerns itself primarily with economic and social cohesion, promoting structural adjustment of regional economies, the Cohesion Fund, which helps Member States with a GNI (gross national income *per capita*) of less than 90% of EU average, and the European Social Fund (ESF), is concerned with the strengthening social cohesion, increase productivity and competitiveness.

4 Methodology

The empirical analysis of convergence made in this study is focused in the absolute convergence and conditional convergence.

To test the absolute β-convergence will be used the traditional model of Baumol (1986) and Battisti and Vaio (2008), estimated by the following regression:

$$Log\ (\Delta GDP) = \beta_0 + \beta_1 Log\ (GDP_{initial}) \quad (1)$$

in which ΔGDP is obtained by GDP growth between the final and initial sample and $GDP_{initial}$ is the initial value of GDP at the sample. To estimate this regression will be used the methods most used in literature, according Islam (2003) and Dobson, Ramlongan and Strobl (2006), the OLS (Ordinary Least Squares) and the Panel Data.

Thereafter calculated the speed of convergence given the following formula:

$$\beta_1 = -(1 - e^{-\beta T}) \quad (2)$$

where T is the number of time periods in the sample, and β the speed of convergence.

To study the absolute σ-convergence will be used the methodology introduced by Quah(1993), the graphical analysis of the standard deviation of GDP per capita.

The study of conditional β-convergence will be done by the estimation of the regression model of Baumol (1986), but adding explanatory variables. Also as in the analysis of absolute β-convergence will be calculated the speed of convergence, which is expected to be higher than the founded value in the second absolute convergence Dobson, Ramlongan and Strobl (2006). The OLS and Panel Data will be used, once again for the estimation of the regression.

To conclude the empirical analysis, will be performed a cluster analysis in order to separate the poor and rich countries and, thus, understand which variables influence more the economic growth, being the most important for convergence and divergence as in Maasoumig and Wang (2008) and Cappelen *et al.* (2003).

5 Data

The data used for the analysis are mainly data provided from Eurostat, which data base contains information for the 27 member states of the European Union (EU)[2].

There was selected data for the 1980-2006 period, however the human capital variable only had data for the period 1991 to 2006. Thus, the estimates will be made for a broader period (1980-2006) and for a subperiod (1991-2006), not only because of the restriction of human capital data, but also to test a period to consider the aid to the 12 Member States that joined the EU most recently. The variables had some flaws, which were completed by personal estimates, based on the trend line that best fit the data.

In addition, estimations were also performed for all countries in the sample and then for two subgroups, the first 15 EU member states and the last 12 member states. This is based on the justification of countries that acceded more recently to EU had been described, mostly, as poor countries, so there is expected that they have a different convergence speed than the first 15 EU member states.

The economic growth, as explained variable, and some of the explanatory variables are used as growth rates. To turn them into growth rates was used the difference between the logarithms of these variables.

[2] The 27 member states of the EU are: Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Italy, Cyprus, Latvia, Lithuania, Luxembourg , Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden and the United Kingdom.

In addition to the variables GDP growth *per capita*, as explained variable, and initial GDP, as an explanatory variable, to test conditional convergence and perform cluster analysis has been introduced more variables. These are:

- Physical capital as a growth rate of Gross Physical Capital *per capita* at constant prices;
- Human capital as a growth rate of expenditure on education as percentage of GDP;
- R&D as a growth rate of R&D *per capita;*
- Patents as a growth rate of patent applications per million inhabitants.

The introduction of physical capital and human capital on the one hand, and R&D and patents, on the other hand, aims to gather and compare the theories of economic growth. That is, on one hand the economic growth model of Solow (1956) and the Neoclassical school, with variables such as physical capital and human capital, increased by Mankiw, Romer and Weil (1992), argued that they are a driving of economic growth. Moreover, the economic growth model of Schumpeter (1934) and Neo Schumpeterian school (Fagerberg 1991, Fagerberg and Verspagen 2003 and Cappelen *et al.* 2003) who advocated the variable innovation (here measured by R&D and patents) as the great promoter of economic growth.

Besides this objective, the inclusion of two variables to consider innovation also aims to test the theory of Fagerberg (1991), cited in the literature review. According to this author, the variable R&D promotes convergence, since it serves to the poorest countries to copy the technology of the richest and thus grow more quickly, on the other hand, the variable number of patents would allow divergence as lead rich countries to avoid having the poorest countries the copy them, leaving them only with the growing technology and thus more quickly. Therefore, the expected sign of these two variables will be good for poor countries and negative for richer countries in the case of variable R&D and the reverse situation where the variable patents.

6 Results and Discussion

We begin our empirical investigation by analyzing the absolute β-convergence. Table 1 presents the results, either by using OLS either the Panel Data for different groups of countries in the period 1980-2006.

Table 1: Test the absolute β-convergence for the period 1980 to 2006.

Variables	OLS (1)	OLS (2)	OLS (3)	Panel (1)	Panel (2)	Panel (3)
Constant	-44.227 (-0.0003)	0.00079 (0.4779)	0.0487 (1.325)	0.523*** (12.496)	0.235*** (6.653)	0.200*** (13.92)
GDP 1980	-0.0312*** (-20.424)	0.0036*** (3.5012)	-0.0322*** (-11.537)			
GDP (-1)				-0.108*** (-11.664)	-0.076*** (-6.340)	-0.113** (-12.593)
AR (1)	0.9999*** (5.9579)	-0.7715*** (-3.5806)	0.906*** (10.24)	0.176*** (5.255)	0.331*** (9.147)	0.155*** (4.611)
MA (1)	-1.0037*** (-28.3177)	0.626** (2.163)				
MA (2)	0.936*** (24.694)					
R^2	0.912	0.41	0.819	0.436	0.357	0.473
R^2 Ajust.	0.895	0.326	0.803	0.412	0.329	0.450
D-W	1.664	1.882	1.967	2.250	2.047	2.264
β	0.12%	Divergence	0.12%	0.44%	0.29%	0.44%
Pooled Fixed				3.39***	3.209***	6.039***
Fixed Random				91.06***	123.9***	257.58***

Source: own elaboration.

Note: * Statistically significant for a 10% level, ** for a 5% level and *** 1% level. The figures in brackets are statistics of t. Equation (1) refers to all members of the EU. Equation (2) refers to the first 15 EU members. Equation (3) is on the remaining 12 EU members. Pooled fixed in line is the F statistic in the fixed line is a random chi-square statistic.

As can be seen in Table 1, for all the panel estimations, the model that there is most suitable for this study is the fixed effects model because when we counterpose the Fixed effects to the Pooled we reject H0, i.e. the coefficients of dummies are different and when we counterpose Fixed effects to Random we reject again H0, thus, there was empirical evidence to assert that the individual effects are correlated with explanatory purposes. Soon, we proved that, as stated Islan (2003) and Dobson, Ramlongan and Strobl (2006), the method that best fits the study of convergence when used Panel Data, is the Fixed effects model.

Looking at the estimations made by OLS, we can see that convergence is studied when all countries together, as in Silva and Silva (2000), Battisti and Vaio (2008) and Barro and (1991). When these are separated, the member states have older divergence, while the newer member states have a convergence rate equal to that of all countries together. These results were expected, because the first 15 countries to join the EU were in a very similar situation, i.e., their convergence would be reduced, while the latter member states had become very poor, except a few that showed a GDP very similar to those already owned, thereby converging very quickly to the richest member states.

Regarding to the Panel Data study, the results are similar to OLS, but in this case the convergence speed are higher and the older member states have the same convergence, and this occurs at a smaller speed than the other two study groups.

The results in panel should be taken more into account, since Islam (2003) asserts that with this methodology we have more trustable results.

The convergence rate is quite low, even lower than reported by Dobson, Ramlongan and Strobl (2006) as the average rate in studies analyzed by him and defined as 2%. However, was in the expected values near the results of the study for the EU regions of Battisti and Vaio (2008) that also found a very low speed of convergence. Thus, this study shows that, as stated by Dobson, Ramlongan and Strobl (2006), Islam (2003), and Benos and Karagiannis (2008), the smaller aggregates are examined the greater the speed of convergence. Thus, this study found speeds not exceeding 0.44%, while Battisti and Vaio (2008) found a rate of 0.6 and 0.8%.

The coefficient of determination has been reduced especially for Panel Data, which proves the stated per Islam (2003) for the estimation of absolute β-convergence has only one explanatory variable (in this case more than one because they are used variables to correct autocorrelation) and thus cannot prove a very significant model.

The results of the estimations presented in Table 2 are very similar to previous ones, especially for the OLS regressions carried out. The Panel Data show a superior convergence speed to those in Table. In this case, when we analyze all countries together, the speed is lower than the other two groups. Also, unlike the earlier speed of convergence is higher in the older member states than in the latest ones, which was not expected, because this time we are near the entry of 12 new member states. However this can be explained because this period was responsible for the convergence of some countries of the Group of 15member states, such as Ireland and Spain, as stated by Martin (2001).

Thus, from the analysis of Table 1 and Table 2, we conclude that there exists absolute β-convergence in the two periods analyzed for the 27 EU member states.

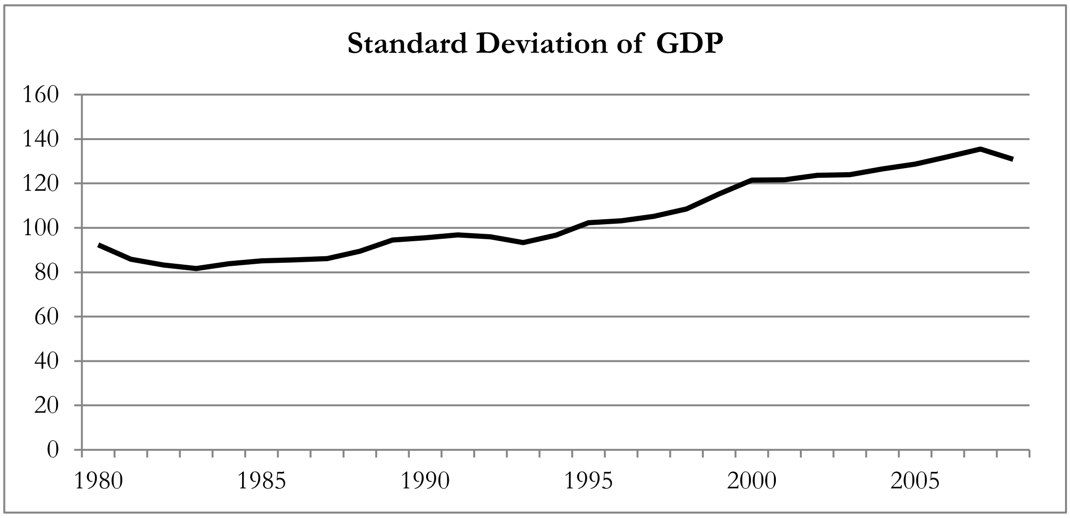
Table 2: Test the absolute β-convergence for the period 1991 to 2006

Variables	OLS (1)	OLS (2)	OLS (3)	Panel (1)	Panel (2)	Panel (3)
Constant	0.052*** (6.808)	-0.0002 (-0.601)	0.021 (1.171)	0.472*** (5.418)	0.324*** (4.315)	0.190*** (6.008)
GDP 1980	-0.0197*** (-5.09)	0.0041*** (14.392)	-0.007 (-1.227)			
GDP (-1)				-0.094*** (-5.013)	-0.104*** (-4.158)	-0.099*** (-5.269)
AR (1)		0.469* (2.038)	0.422* (2.050)		0.189*** (3.347)	
AR (2)			0.404* (2.028)			
MA (1)		-0.997*** (-6.341)				
R^2	0.51	0.68	0.431	0.177	0.239	0.232
R^2 Ajust.	0.489	0.633	0.350	0.118	0.178	0.177
D-W	1.90	2.332	1.957	2.076	2.08	2.138
β	0.12%	Divergence	0.04%	0.58%	0.65%	0.61%
Pooled Fixed				1.829***	1.763**	3.397***
Fixed Random				13.807***	13.688***	34.09***

Source: own elaboration.
Note: * Statistically significant for a 10% level, ** for a 5% level and *** 1% level. The figures in brackets are statistics of t. Equation (1) refers to all members of the EU. Equation (2) refers to the first 15 EU members. Equation (3) is on the remaining 12 EU members. Pooled fixed in line is the F statistic in the fixed line is a random chi-square statistic.

The next step in our research is the analysis of absolute σ-convergence. So, to begin with, we will analyze, in graphic form, the standard deviation of GDP *per capita*.

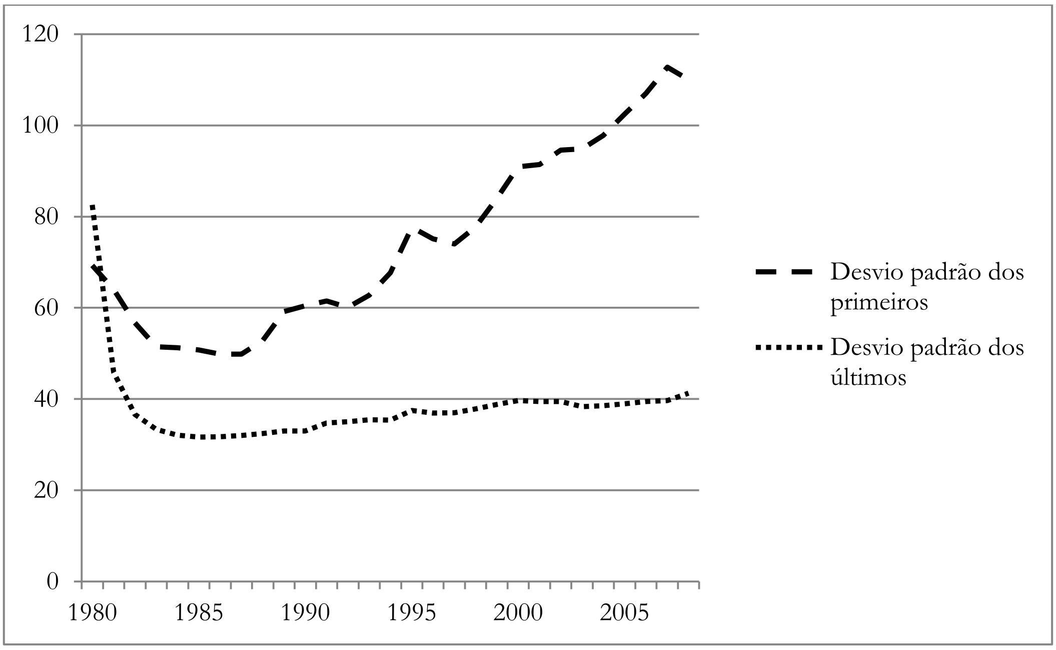
Figure 1: Standard deviation of per capita GDP at constant prices for all member states



Source: own elaboration (Data taken from Eurostat)

Analyzing the Figure 1, we conclude that there is absolute σ-convergence, especially between 1984 and 2007. However, by mid 1984, have been a slight decrease in standard deviation of GDP, but after this period there was an increasing trend, although in some periods had a small decrease. So we can say that, notwithstanding there is absolute β-convergence, there may be no absolute σ-convergence, as claimed by Sala-i-Martin (2000).

Figure 2: Standard deviation of per capita GDP constant prices, separating countries by date of entry



Source: own elaboration (Data taken from Eurostat).

Analyzing the Figure 2 it can be said that only countries that joined more recently the EU verify convergence. Although, after 1984 there is a slight increase in the standard deviation of GDP for these countries, they had, in the previous period, a remarkable decrease, which offsets this increase.

The older EU member states also show a decrease by mid-1984, but slightest. Once that occurs a large increase, which leads to reach a final value much higher than the original, than can be concluded that there is convergence.

So, we can conclude that the fact that there is absolute β-convergence is a necessary but not sufficient to guarantee the existence of absolute σ-convergence, as stated Sala-i-Martin (2000) and verified by Yao and Zhang (2001). This can be based on the fact that the three groups of analyzed countries only one finds the two forms of convergence.

Our investigation proceeds with the analysis of conditional convergence. The following tables show the estimates for the study of this type of convergence.

Based on these results we can see in Table 3 that in almost all situations, especially with Panel Data that are defended as the more truthful for Islan (2003), the speed of conditional convergence is higher than the absolute convergence for the same period, which is defended by Dobson, Ramlongan and Strobl (2006) and supported by Duncan and Fuentes (2006).

Table 3: Tests for conditional convergence for the 1980-2006 period

Variables	OLS (1)	OLS (2)	OLS (3)	Panel (1)	Panel (2)	Panel (3)
Constant	-0.355 (-0.0319)	0.0004 (0.284)	0.000001 (0.3667)	0.314*** (5.048)	0.196*** (5.804)	0.150*** (5.467)
GDP 1980	-0.033*** (-17.148)	0.002 (1.022)	-0.011*** (-6.859)			
GDP (-1)				-0.112*** (-6.625)	-0.110*** (-7.270)	-0.135*** (-7.006)
Log (GFCF/GFCF(-1))	0.000009 (0.009)	0.0105** (2.531)	0.0174*** (9.185)	0.478*** (21.077)	0.356*** (21.003)	0.503*** (21.303)
Log (R&D)	0.009*** (2.996)	-0.0178 (-1.087)	-0.0027 (-1.103)	0.042*** (4.405)	0.065*** (7.869)	0.050*** (4.681)
Log (patents)	-0.0013 (-0.7133)	0.0172 (1.4886)	0.007*** (5.051)	0.0072 (1.014)	-0.030*** (-4.753)	0.014* (1.868)
AR (1)	0.996*** (9.426)	-0.750** (-2.855)	1.302*** (9.409)	0.191*** (4.546)	0.361*** (11.232)	0.209*** (4.859)
AR (2)			-0.924*** (-6.369)	0.162*** (5.155)		0.186*** (5.893)
MA (1)	-1.367*** (-33.362)	0.6957** (2.168)	-1.877*** (-4.0411)			
MA (2)	0.995*** (22.231)					
R^2	0.941	0.641	0.986	0.630	0.671	0.654
R^2 Ajust.	0.918	0.527	0.980	0.610	0.655	0.636
D-W	1.85	2.098	2.22	2.298	2.268	2.287
β	0.124%	NS	0.04%	0.44%	0.43%	0.54%
Pooled Fixed				2.31***	2.068***	3.002***
Fixed Random				44.77***	116.85***	187.45***

Source: own elaboration

Note: * Statistically significant for a 10% level, ** for a 5% level and *** 1% level. The figures in brackets are statistics of t. Equation (1) refers to all members of the EU. Equation (2) refers to the first 15 EU members. Equation (3) is on the remaining 12 EU members. Pooled fixed in line is the F statistic in the fixed line is a random chi-square statistic.

As in the absolute convergence, the estimates for OLS do not have convergence to the EU member states and the oldest Panel Data show a convergence rate smaller than for the other two groups of countries.

As for the explanatory variables, and analyzing the Panel Data, physical capital and expenditure on R&D have been very important for economic growth of all groups of countries. The patents have minimizes with economic growth in the older member states and is non-significant for the other two groups of countries. Thus, we conclude for both of the variables advocated by Solow (1956) such as Schumpeter (1934), as promoters of economic growth, are presented in this investigation and effectively support the economic growth.

As done for Table 3, it will be given more importance to the implementation of Panel Data (Islam, 2003). Also on Table 4 the speed of conditional convergence is higher than the absolute convergence, and the older member states have a convergence speed than the other two groups of countries under study.

Table 4: Tests for conditional convergence for the period 1991-2006

Variables	OLS (1)	OLS (2)	OLS (3)	Panel (1)	Panel (2)	Panel (3)
Constant	-0.0062 (-0.536)	0.00002 (0.029)	-0.0009 (-0.422)	0.447*** (4.342)	0.328*** (5.990)	0.172*** (3.758)
GDP 1980	0.002 (0.529)	0.0005 (0.820)	-0.0043* (-1.897)			
GDP (-1)				-0.176*** (-7.584)	-0.172*** (-7.133)	-0.179*** (-7.586)
Log (GFCF/GFCF(-1))	0.030*** (4.350)	0.0246*** (7.421)	0.0176*** (5.166)	0.403*** (14.387)	0.366*** (16.584)	0.409*** (13.839)
Log (R&D)	0.008 (1.676)	0.0225*** (6.8703)	0.016*** (4.227)	0.068*** (4.455)	0.084*** (6.025)	0.067*** (4.095)
Log (patents)	0.004 (0.9802)	-0.012*** (-4.8239)	0.0093*** (3.168)	0.003 (0.358)	-0.020** (-2.458)	0.008 (0.777)
Log (Human_cap)	-0.025* (-1.849)	-0.0164** (-2.687)	-0.062*** (-6.917)	0.039 (1.075)	-0.033 (-1.488)	0.055 (1.212)
MA (1)		0.997** (2.808)	0.935*** (17.063)			
R^2	0.84	0.934	0.946	0.540	0.684	0.553
	0.800	0.913	0.930	0.502	0.658	0.516
D-W	1.73	1.57	1.75	2.17	2.036	2.192
β	NS	NS	0.03%	1.139%	1.11%	1.16%
Pooled Fixed				2.73***	2.65***	2.109***
Fixed Random				52.46***	54.77***	35.07***

Source: own elaboration

Note: * Statistically significant for a 10% level, ** for a 5% level and *** 1% level.

The figures in brackets are statistics of t. Equation (1) refers to all members of the EU. Equation (2) refers to the first 15 EU members. Equation (3) is on the remaining 12 EU members. Pooled fixed in line is the F statistic in the fixed line is a random chi-square statistic.

The speed of convergence found in these estimates is closer to that advocated by Dobson, Ramlongan and Strobl (2006) and Barro and Sala-i-Martin (1991).

As analyzed in the period 1980-2006, the variables physical capital and R&D have been very important for economic growth. The variable patents is again minimizing economic growth for the older EU member states, unlike the study of Silva and Silva (2000). The added variable human capital does not seem very important for economic growth, since it is not significant for all groups, as found in studies by Raiser (1998), Duncan and Fuentes (2006), Austin and Schmidt (1998) and Arena, Button and Lall (2000). Therefore, and as in previous regressions, the growth models of Solow-Swan and Schumpeter (1934) are important for economic growth.

Thus, we conclude that, in general, there is conditional convergence and this has a top speed of absolute convergence, as suggested by Dobson, Ramlongan and Strobl (2006), especially for the subperiod 1991-2006.

To complete the research will be performed a cluster analysis. As stated above, this analysis aims to test which variables most important for convergence among the variables that Schumpeter (1934) and Solow (1956) claimed to be the driving economic growth. This analysis also aims to test the theory of Fagerberg (1991), that the variable R&D would be a variable that measures the costs of the poorest countries to copy the technology of the richest and thus promote convergence, while variable patents would be a variable promoter of divergence because it measures the innovations that the richest countries prevent poorer countries from copying.

Table 5: Analysis of *Clusters* in the period 1980-2006

		Clusters				Significance
		Rich	Poor	Extreme 1	Extreme 2	
Variables	Economic Growth	0.178	0.815	-0.108	-0.630	0.025
	GDP 1980	161.43	50.297	340.90	263.186	0.000
	Physical Capital	0.279	1.641	0.158	0.942	0.038
	R&D	0.824	1.134	0.826	0.308	0.460
	Patents	0.883	1.776	0.745	0.870	0.070

Source: own elaboration

Table 6: Countries in each *Clusters* of the Analysis of *Clusters* in the period 1980-2006

Source: own elaboration

	Clusters			
	Rich	Poor	Extreme 1	Extreme 2
Countries	Denmark Germany Ireland Greece Spain France Italy Cyprus Luxembourg Netherlands Austria Slovakia Finland Sweden United Kingdom	Bulgaria Czech Republic Estonia Latvia Lithuania Hungary Malta Portugal Romania Slovenia	Belgium	Poland

Source: own elaboration

Looking at Table 6 can be observed that in this cluster analysis there are two groups that have only one country, because these two extremes have negative economic growth.

Table 7: Cluster Analysis 1991-2006

		Clusters		Significance
		Rich	Poor	
Variables	Economic Growth	0.132	0.308	0.037
	GDP 1980	224.64	53.923	0.000
	Physical Capital	0.0987	0.427	0.009
	Human Capital	-0.020	0.023	0.344
	R&D	0.369	0.768	0.008
	Patents	0.358	1.010	0.000

Source: own elaboration

The last three variables used to demonstrate the structural differences between countries; only physical capital is presented as between different groups, ranks only to have a different significance level of 7%, while the R&D is clearly not significant (Table7). Thus, analyzing physical capital, this presents itself as not only important for economic growth, but also to convergence, since it is much higher in poor countries than in rich countries.

Table 8: Countries in each *Clusters* of the Analysis of *Clusters* 1991-2006

	Clusters	
	Rich	Poor
Countries	Belgium Denmark Germany Ireland France Italy Luxembourg Netherlands Austria Finland Sweden United Kingdom	Bulgaria Czech Republic Estonia Greece Spain Cyprus Latvia Lithuania Hungary Malta Poland Portugal Romania Slovenia Slovakia

Source: own elaboration

In this cluster analysis are presented only two groups, having been abolished two extremes, this is because the two countries had negative rates of economic growth fail to submit it.

For this case, and with such accomplished in the analysis of conditional convergence, introduced the variable human capital, however this does not appear different between the two groups. The other three variables listed in Table 7 show that the analysis is different between the two groups, and they all present themselves as beneficial to the convergence. Thus, both the Solow model (1956) such as Schumpeter (1934) presenting important for economic growth.

Thus we conclude that both models of economic growth are important for economic growth in the EU countries, i.e. whether the variables physical capital and human capital (Solow, 1956) or the variables R&D and patents (Schumpeter, 1934) are important for economic growth in the 27 EU member states. However, only in the most recent period (1991-2006) the model of Schumpeter (1934) presents important for convergence, which is derived from the importance due to the the innovation nowadays. While the Solow-Swan was throughout the period under review, important not only for economic growth, but also for convergence.

Finally, according Fagerberg (1991) the results should demonstrate that the variable R&D promotes the convergence and the divergence would be caused by the patent variable. By analysis of the estimates, the results obtained cannot tell the difference between the impact of variables for the group of poorer countries and for the group of the rich ones, because these are not separate. However, the clusters analysis can clearly refute this hypothesis, since both variables promote convergence among EU member states. The result, in part confirmed by Cappelen *et al.* (2003), had found that the variable R&D is a driving force of economic growth in richer countries, but nothing saying about the patent variable.

7 Conclusions

Here we review the absolute and the conditional convergence for the 27 EU member states over the period of 1980-2006. The results show the existence of absolute β-convergence and conditional convergence, while σ-convergence is not verified.

With the separation of countries into two groups, according to their date of accession, it is possible that the 12 member states have a convergence speed superior to the other group, whether absolute or conditional. Even in absolute σ-convergence they present it while the others follow the trend of global and feature differences.

We check which of the two schools of economic growth, Neoclassical or Neo-Schumpeterian, was more important both for economic growth as for the convergence of these countries. We therefore conclude that none of them beats the other, but one can say that the Neoclassic presenting important throughout the period, while Neo-Schumpeterian are important to a more recent period, 1991-2006.

Finally, as stated by Fagerberg (1991), the results should demonstrate that the R&D variable would promote convergence while the patents variable would promote divergence. Although, the estimations to test the theory of Fagerberg (1991), based on the differences between the impact of the variables in poor and rich countries, are not in line with the results obtained by him. However, if we use a clusters analysis we can easily refute this hypothesis because both variables promote convergence within the EU countries. The obtained result is partially confirmed by Cappelen *et al.* (2003), who had already found that R&D would promote economic growth in rich countries, but he hadn't concluded anything about the patents variable.

In the future it may be further study of the theory of Fagerberg (1991) with inclusion of variables reflecting innovation, something that is very seldom performed in the literature. In addition, the research-based innovation variables, as well other variables, such as productivity, it would be pertinent to apply to the study of convergence as important contributions for national economic growth.

References

Arena, P., Button, K. and Lall, S. (2000), 'Do regional economies converge?', *International Advances in Economic Research*, 6-1, 1-15.

Austin, J. S. and Schmidt, J. R. (1998), 'Convergence amid divergence in a region', *Growth & Change* 29-1, 67-89.

Barro, R. and Sala-i-Martin, X. (1991), 'Convergence across states and regions, in brooking papers on economic activity', *Brainard et. al. (editores), Brooking Institutions*, 1, Washington D.C..

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

Barro, R. J. and Sala-i-Martin, X. (1995), *Economic Growth*, New York: McGraw-Hill.

Battisti, M. and Vaio, G. D. (2008), 'A spatially filtered mixture of β-convergence regressions for EU regions, 1980-2002', *Empirical Economics*, 34, 105-121.

Baumol, W. J. (1986), 'Productivity growth, convergence and Welfare: what the long-run data show?', *American Economic Review,* 76-5, 1072-1085.

Benos, N. and Karagiannis, S. (2008), 'Convergence and economic performance in Greece: evidence at regional and prefecture level', *RURDS*, 20-1, 52-69.

Cappelen, A., Castellacci, F., Fagerberg, J. and Verspagen, B. (2003), 'The impact of EU regional support on growth and convergence in the European Union', *Journal of Common Market Studies,* 41-4, 621-644.

CASS, D. (1965), 'Optimum growth in an aggregative model of capital accumulation', *Review of Economic Studies*, 32, 233–240.

Dobson, S., Ramlongan, C. and Strobl, E. (2006), 'Why do rates of β-convergence differ?. A meta-regression analysis', *Scottish Journal of Political Economy,* 53-2, 153-173.

Duncan, R. and Fuentes, R. (2006), 'Regional convergence in Chile: new tests, old results', *Cuadernos de Economía,* 43-127, 81-112.

Fagerberg, J. (1991), 'Innovation, catching-up and growth', in OCDE (1991). (http://ideas.repec.org/p/tik/wparch/1989137.html às 8h 21/2/2009)

Fagerberg, J. and Verspagen, B. (2003), 'Innovation, growth and economic development: why some countries succeed and others don't', *First GLOBELICS Conference*.

(http://redesist.ie.ufrj.br/globelics/pdfs/GLOBELICS_0090_Jan%20Fagerberg.pdf às 9h 21/2/2009)

Fuente, A. de la (2002), 'Convergence across countries and regions: theory and empirics', *Instituto de Análisis Económico (csic)*. (http://ideas.repec.org/p/aub/autbar/555.02.html às 9h 18/2/2009).

Heijdra, B. J. and der Ploeg, F. V. (2002), *Foundations of Macroeconomics*, Oxford University Press.

Islam, N. (2003), 'What have we learnt from the convergence debate?', *Journal of Economic Surveys*, 17-3, 309-362.

Koopmans, T. C. (1965), 'On the concept of optimal economic growth', in *Econometric Approach to Development Planning*, chap. 4, pp. 225–87, North-Holland Publishing Co., Amsterdam.

Lee, K., Pesaran, M. and Smith, R. (1997), 'Growth and convergence in a multi-country empirical stochastic Solow model', *Journal of Applied Econometrics*, 12, 357-392.

Lucas Jr, R. E. (1988), 'On the mechanics of economic development', *Journal of Monetary Economics,* 22-1, 3-42.

Lusigi, A., Piesse, J. and Thirtle, C. (1998), 'Convergence of per capita incomes and agricultural productivity in Africa', *Journal of International Development*, 10-1, 105-115.

Maasoumi, E. and Wang, L. (2008), 'Economic reform, growth and convergence in China', *Econometrics Journal,* 11-1, 128-154.

Mankiw, N. G., Romer, D. and Weil, D. N. (1992), 'A contribution to the empirics of economic growth', *Quarterly Journal of Economics*, 107-2, 407-437.

Marelli, E. (2007), 'Specialization and convergence of European regions', *The European Journal of Comparative Economics*, 4-2, 149-178.

Martin, R. (2001), 'EMU versus the regions? Regional convergence and divergence in Euroland', *Journal of Economic Geography,* 1-1, 51-80.

Quah, D. (1993), 'Galton's fallacy and tests of the convergence hypothesis', *Scandinavian Journal of Economics,* 95-4, 427-456.

Raiser, M. (1998), 'Subsidising inequality: economic reforms, fiscal transfers and convergence across Chinese provinces', *Journal of Development Studies,* 34-3, 1-26.

Ramsey, F. P. (1928), 'A mathematical theory of saving', *Economic Journal*, Vol. 38-152, December, 543–559.

Romer, D. (2006), *Advanced Macroeconomics*, McGraw-Hill, 3rd Edition.

Romer, P. (1986), 'Increasing returns and long-run growth', *Journal of Political Economy*, 94-5, 1002-1037.

Sala-i-Martin , X. (1996), 'The classical approach to convergence analysis', *Economic Journal* 106, pp. 1019–1036.

Sala-i-Martin, X. (2000), *Apuentes de crecimiento económico*, Antoni Bosch Editor, 2th Edition.

Silva, S. e Silva, M. R. (2000), 'Crescimento económico nas regiões europeias: uma avaliação sobre a persistência das disparidades regionais no período 1980-95', *FEP Working papers*.

Solow, R. M. (1956), 'A contribution to the theory of economic growth', *Quarterly Journal of Economics*, 70-1, 65-94.

Solow, R. M. (1957), 'Technical Change and the Aggregate Production Function, Review of Economics and statistics', August, 39(3), 312-20.

Yao, S. and Zhang, Z. (2001), 'Regional growth in China under economic reforms', *Journal of Development Studies,* 38-2, 167-186.