Investigating the Catching-Up Hypothesis Using Panel Unit Root Tests: Evidence from the PIIGS

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Abstract:

The aim of this paper is to analyze the issue of income convergence for Portugal, Italy, Ireland, Greece, and Spain (PIIGS), towards France.

The empirical analysis uses per capita GDP, in PPP and 2005 constant prices and covers the period from 1950 up to the recent pre-crisis year of 2009. The methodology applied uses non-stationary panel unit root tests both without as well as with structural breaks endogenously determined.

The results clearly demonstrate the gain in power from combining structural breaks with panel data. Our findings provide evidence in favor of convergence for all the five countries with France.

Keywords: *Stochastic Convergence, Panel Uunit Root Tests, Panel LM Unit Root Tests, PIIGS.*

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1. Introduction

Over the past two decades, there has been a noticeable revival of interest in the topic of economic convergence, a fact that has been marked by new approaches and a great emphasis on empirical analysis. In this paper, convergence of Portugal, Italy, Ireland, Greece and Spain - countries for which the grouping acronym PIIGS is used - with France, is addressed over the period from 1950 up to the recent pre-crisis year of 2009. In addition to their individual economic and development disparities, all five countries are located on the periphery of the Union, while two of the five, Ireland and Greece, are geographically remote from the rest of the Union, a fact that constitutes by itself a further topic of interest. The growth experience of these countries presents dissimilarities and seems associated with differences in the technical progress, the performance of the labor market, the level of education, FDI and technology spillovers, among others (Grima and Caruana, 2017; Rupeika-Apoga and Nedovis, 2016; Thalassinos and Dafnos, 2015; Liapis *et al.,* 2013; Allegret *et al.,* 2016; Boldeanu and Tache, 2016).

To test empirically the stochastic convergence of PIIGS towards France, we applied different panel unit root tests and more specifically, the common root tests of Breitung (2000), Levin, Lin and Chu (2002) and Hadri (2000) as well as the individual root tests of Im *et al.* (2003), the ADF and PP-Fisher tests proposed by Maddala and Wu (1999), and Choi (2001). As univariate unit root tests have lower power when structural breaks are ignored, we employed the panel LM unit root test of Lee and Strazicich (2003; 2004).

The rest of the paper is organized as follows: Section 2 briefly discusses the convergence hypothesis along with relevant historical facts concerning PIIGS and, section 3 reviews empirical methodologies. Section 4 presents the data set and the results of the empirical analysis, while significant concluding comments are provided in the final section.

2. The Convergence Hypothesis and Stylized Facts

2.1 The Theory

In the relative literature, researchers define the convergence hypothesis in several ways. Sala-i-Martin (1996), among others, provides the most-widely known definition of *β*-convergence that "there is absolute *β*-convergence, if poor economies tend to grow faster than rich ones".

Traditional empirical tests of convergence broadly fall into two categories (Bernard and Durlauf, 1996). The first research efforts on convergence were cross-sectional studies with *β*-convergence to hold if the coefficient of a regression of GDP per capita growth rates on initial levels was negative. Early empirical work on convergence is based on the estimation of the following model:

$$g_{i,t+T} = a + \beta y_{i,t} + \varepsilon_{i,t} \qquad\qquad i = 1,2,\cdots,N \qquad\qquad (1)$$

where $y_{i,t}$ is the logarithm of per capita output for economy $i = 1,2,\cdots,N$ during period t, and $g_{i,t+T} = (y_{i,T} - y_{i,t})/(T - t)$ is economy i's annual growth rate of GDP between t and T. A negative value for β provides evidence in favour of absolute β-convergence, whereas $\beta \geq 0$ supports non-convergence. See, for example Baumol (1986), De Long (1988), Barro (1991), and Barro and Sala-i-Martin, (1992).

In the framework of cross-section regression, it is not possible to account of any unobservable or unmeasurable factors (Islam 1995). Moreover, only initial and final values of the sample data are used and, therefore, the resultant parameter estimates may be sensitive to the specific values of these observations. Nonetheless, as shown by Bernard and Durlauf (1991), a diminishing marginal product of capital means that short-run transitional dynamics and long-run steady state behavior will be mixed up in cross-section regressions. Finally, the cross-section procedures work with the null hypothesis that no countries are converging and the alternative hypothesis that all countries are, which leaves out a host of intermediate cases.

The second class of tests studies the long-run behavior of differences in per capita output across countries in a time series framework (Bernard and Durlauf, 1995). In this approach, economic convergence implies that per capita GDP differences between two countries cannot contain stochastic trends (the so-called "stochastic convergence"), that is per capita income disparities between economies should follow a stationary process.

In this context, Bernard and Durlauf (1995) proposed a new definition of convergence which lies on the notion of unit roots. Countries i and j converge, if the long-term forecasts of output for both countries are equal at a fixed time t.

$$\lim_{k \to \infty} E(y_{i,t+k} - y_{j,t+k} \mid I_t) = 0 \qquad\qquad (2)$$

where I_t denotes all information available at time *t*. Bernad and Durlauf (1995) state that the above definition of convergence will be satisfied if $y_{i,t} - y_{j,t}$ is a mean zero stationary process[4].

More recently, new testing procedures for the convergence hypothesis, using panel data, have been developed. Panel data analysis endows regression analysis, with both a spatial and temporal dimension. The superiority of panel data methods has been often highlighted in the empirical literature (e.g. Islam, 1995)[5]. In our analysis, we

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[4]*The time series tests find little evidence of stationarity in per capita income disparities across countries (Bernard and Durlauf, 1995, 1996; Evans and Karras, 1996).*
[5]*The main advantage of panel data methods is to address the low power issue of unit root tests, in small samples.*

adhere to Bernard and Durlauf (1995) definition of stochastic convergence. In a panel of countries, stochastic convergence occurs if the difference between the real per capita GDP of the "benchmark" country and that of each other country in the panel, follows a zero-mean stationary process. Interestingly, researchers differ in defining convergence in multi-country situations. Some have taken deviations from the sample average as the measure of convergence. Others have based their analysis of convergence on deviations from a reference economy or, a leading economy (Islam, 2003). The group leader can be the country or the group of countries, with the best per capita economic performance. Therefore, the other countries should converge to the leader.

In our case, France is considered as a leader (benchmark), for the following reasons. First, France is a Mediterranean country with similar natural conditions and resources with the four South Europe examined countries. Additionally, in these countries, the agricultural sector is a vital component in terms of the Gross Domestic Product share. Furthermore, Ireland and Portugal, together with Spain and Greece, form the group of 'cohesion' countries within the European Union. All five are classified, for purposes of Structural Fund aid, as lagging behind the rest of the Union in terms of development.

2.2 The Stylized Facts

The acronym "PIGS" is referred to the four 'Southern' European states, Portugal, Italy, Greece and Spain. The term, as a new context, began to be used in discussions about EU enlargement and the pending EMU, separating Portugal, Italy, Spain and Greece according to their divergent economic history, with regards to inflation and government debt and deficits (Mundell, 1997; Gros, 2000; Eichengreen and Ghironi, 2001). However, the "PIGS" first appeared in the Wall Street Journal as of November 6th, 1996 in a piece on the prospective EMU by Thomas Kamm (1996), and the term gained further traction with the widely circulated 'Bafling PIGS' acronym of countries adopting the Euro currency in 2001.

At the same period, the term was also used in an academic context, by Borzel (2001) and Rodrigo and Torreblanca (2001), suggesting that Ireland should be also included in the acronym. Inclusion of Ireland in the acronym changed the connotation to an economic meaning of 'periphery' or economic marginalization in general. At the emergence of the Euro crisis, in the late 2009, there was an enormous upsurge in the usage of the term. Academic usage of the term explodes in 2010, focusing upon the economic relationship of the PIIGS to the 2008 Euro crisis; where, PIIGS becomes synonymous with the countries involved in European debt crisis (Hallet and Jensen, 2011). Pitelis (2012) invokes the PIIGS, while discussing how the Euro crisis began with Greece itself. Also, a combination of Ireland as a peripheral EU state and its entry

into economic crisis at the same time as the 'traditional' PIGS, seem to have made Ireland an obvious candidate for PIIGS membership[6].

Most importantly and above all "semantics" upon the history of the "name", the PIIGS grouping seeks to capture significant economic vulnerability issues, in order to investigate which commonalities are the most important and which precisely vulnerabilities need examination. For example, Italy's public debt ratio had long been very high without provoking concern, and Italy was much less exposed to volatility on international markets than the other countries. As Boltho (2001) concludes, in France, economic growth was led by an alliance of "big bureaucracy" and "big business" in a broadly market-conforming country; whereas, in Italy, it was led more by individual entrepreneurs, first in state-owned enterprises, and later in private firms, often in opposition to coalition governments. In fact, over the last 50 years and more, the two countries France and Italy, evolved along lines owing more to different economic starting points (such as Italy's greater underdevelopment) and to serious external forces (such as the global oil shocks) than to policy choices (Boltho, 2001).

2.2.1 The economic performance of the Cohesion countries:
The most important problems faced include the following characteristics:
- The absence of a diversified industrial base,
- Over-reliance on the agricultural sector,
- The relatively small market in the services sector, which may be very specific, mass tourism which requires severe infrastructure and environmental constraints,
- Low levels of infrastructure in the transport, energy, water and telecommunications sectors,
- High costs of upgrading industry and infrastructure due to market bottlenecks or compliance with environmental regulations.

Because of these structural problems, the Cohesion countries were reluctant to enter a common currency because they would lose an important economic policy tool, that of devaluing the currency. We could say that all five countries have achieved, to a certain extent, the convergence with the EU-14 average, while the experience of each of them appears to be different. More specifically, for Portugal and Spain, although the

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[6]Ireland and Portugal, together with Spain and Greece, form the group of 'cohesion' countries within the European Union. This definition was established with the enlargement of the then EEC to Southern -Europe, in 1981 and 1986, and was born out of the consideration that integration into the European Communities of the peripheral countries would imply measures to take into account differentials in development levels (Lains, 2006). In terms of per capita GDP, all four were below 75% of the EU average and still contain some of the poorest regions in the Union. In addition to the economic disparities, all four are on the periphery of the Union, while two of the four, Ireland and Greece namely are geographically remote from all the rest.

countries were converging towards the EU-14 average, the gap remained very high in the late 1990s, widening even further the decade of the crisis. Ireland, whose GDP per capita at around 60% of the EU-14 average in 1960, was in the second half of the 1990s above the average and was the most successful between these five countries. Lastly, Greece's development path is lagging behind the other three countries throughout the 1980s.

The success of Ireland is an excellent example of convergence, but this country's success seems to be the result of a successful interaction of a number of factors that are difficult to meet elsewhere. Indeed, the analysis of Ireland's growth factors, in relation to those of Portugal and Spain, does not lead to clear conclusions. Comparably higher rates of capital accumulation (natural, human, R & D) have played an important role, and there is also the assumption that fiscal stability has also had a positive effect. However, an important part of Ireland's growth since 1985 is not easy to interpret, partly because of the difficulty of assessing the effects of FDI (Economic Survey of Europe, 2000).

Table 1. *Annual growth rate of per capita GDP, 1960-1913*

Country	1960-1973	1974-1986	1987-1999	2000-2007	2008-2013	1960-2013
Austria	4.5	2.3	2.3	1.9	0.3	2.5
Belgium	4.6	1.8	2.2	1.7	-0.4	2.3
Denmark	3.7	2.2	1.6	1.6	-1.2	1.9
Finland	4.5	2.5	2.0	3.2	-1.3	2.5
France	**4.5**	**1.8**	**2.0**	**1.4**	**-0.2**	**2.2**
Germany[a]	3.7	2.1	1.9	1.6	0.9	1.9
Greece	**7.5**	**0.8**	**1.3**	**3.7**	**-4.7**	**2.3**
Ireland	**3.4**[b]	**2.4**	**6.1**	**3.4**	**-1.9**	**3.1**
Italy	**4.9**	**2.6**	**1.9**	**1.1**	**-1.8**	**2.3**
Luxemburg	3.0	2.0	4.1	3.0	-1.3	2.5
Netherlands	4.5	1.3	2.5	1.8	-0.6	2.2
Portugal	**7.6**	**1.2**	**3.6**	**1.1**	**-1.1**	**3.0**
Spain	**6.3**	**1.2**	**2.9**	**2.2**	**-1.6**	**2.7**
Sweden	3.8	1.7	1.6	2.8	-0.2	2.1
U.K.	3.3	1.6	2.4	2.4	-0.5	2.1
EE-15	**4.7**	**1.8**	**2.6**	**2.2**	**-1.0**	**2.4**
EE-14[c]	**4.8**	**1.8**	**2.5**	**2.1**	**-1.0**	**2.4**

Source: *World Bank and authors' calculations*
Notes: *a: 1970-1980 (West Germany), 1990-2013 (Unified Germany), b: 1970-1973, c: Without Luxembourg.*

The "Golden Age" of Europe: 1950-1973:
The first period, 1960-1973, is characterized by the convergence of the Cohesion countries and coincides with the period of strong convergence of the EU-15 countries during the "Golden Age". In the 1950s and early 1960s, the five countries were characterized by significant barriers to trade and capital movements, as well as high

levels of state interventionism and market regulation (Ó Grada and O'Rourke, 1996; Lains, 2003). However, during this period, their growth pattern was characterized by high growth rates, which even exceeded the EU-14 average. In particular, three of the five countries (Greece, Portugal and Spain), during the European Golden Age, showed significant convergence, with real GDP per capita showing an average annual increase of around 7%. An exception is Ireland, which at this time of strong convergence in Europe failed to follow the course of other countries, growing only at 3.7% (Lains, 2006).

The Recession Period 1974-1986:
The second period, 1974-1986, was marked by the global oil crisis of 1973 and by major events in this group of countries, such as the accession of Ireland in 1973 and the restoration of the Republic in Greece, Spain and Portugal. This period, unlike the previous one, is characterized by a decline in growth rates due to the collapse of productivity growth rates in both the core and the Cohesion countries. Also, this period is distinguished by a general decline in macroeconomic policy in each of the Cohesion countries and by the decline in labor market efficiency (Barry, 2003). At the same time, the three southern countries benefited from the rehabilitation of the Republic but faced pressure to reallocate incomes that led to inflation, lower growth and balance-of-payments problems (Alogoskoufis, 1995).

The process of convergence of the Cohesion countries with the EU average until the end of the period was weak, and the course of development varies considerably from country to country. In particular, the growth of the Spanish economy was very anemic compared to the previous period, while Greece was lagging behind. On the contrary, the picture in Portugal and especially in Ireland was somewhat better. Indeed, at the end of this period, Ireland began to show the highest GDP growth rates per capita in Western Europe.

The best development in Portugal and Spain, at least in relation to Greece, has been linked, inter alia, with the greater emphasis given to the two countries in view of their accession to the European Community, in terms of institution-building, macroeconomic stability, structural changes and trade liberalization, while at the same time creating a more attractive environment for FDI (Larre and Torres, 1991).

Productivity gains in Spain and Portugal during this period remained higher than in the EU core, while Greece replaced Ireland as "paratrooper" (Barry, 2003). The most significant factor in the case of Portugal was the decline in the labor force participation rate, while in Ireland and Spain there was a fall in the employment rate (Barry, 2003). In Portugal, expansionist policies were followed without the consensus on the part of the institutions, who insisted on wage moderation in Portugal's least flexible labor market. Spain and Ireland have had the worst experience in unemployment in the EU during this period, with a decline in employment growth rates, which also contributed to the poor convergence of these countries (Barry, 2003).

The 1987-2000 Period:
Since mid-late 1980s, macroeconomic and microeconomic policies have improved considerably in all countries of the region, due to the constraints imposed by the Maastricht Treaty in most cases and the forthcoming entry into the Euro Zone. Restrictive monetary and fiscal policy has been implemented, competition policy has been strengthened, public ownership has declined, and EU aid has increased significantly. 1986 is the year of accession of Portugal and Spain to the EEC, and over the period 1987-2000, the Cohesion countries (with the exception of Ireland) appear to converge slightly again to the EU-14 average. Of particular interest is the case of Ireland, which, among the poorest Western European countries in the early 1950s, became one of the richest in the late 20th century. During the 1990s, no other EU member state managed to achieve Ireland's outstanding development.

Significant privatizations have taken place in Portugal since the mid-1980s and in Spain in the 1990s, and competition policies have been strengthened over this period (Barry, 2003). Also, there have been significant improvements in the labor market in Ireland and Spain. In fact, there was wage moderation, which was supported in Ireland by the social partners' tax reduction agreements, and in Spain, from the 1974-97 labor market reforms (Barry, 2003). In the 1990s, Portugal faced a problem of competitiveness in international markets, as real wages grew faster than labor productivity, mainly due to the rigidity of the labor market (Lains, 2008). In Ireland, an increase in per capita income by 5.6% was recorded, that was mainly driven by productivity growth, as well as an increase in the employment rate. Finally, Structural Fund inflows have greatly facilitated the government's commitment to fiscal adjustment (Saravelos, 2007), while the government's commitment to lower future spending has resulted in an increase in aggregate demand and private investment (Giavazzi and Pagano, 1990).

Greece, on the other hand, was left behind, as it used European aid to postpone rather than to promote fiscal and structural adjustment. In contrast to Ireland, public investment in Greece remained broadly stable over the period 1986-1990, proving that substitution effects of EU transfers were not so significant. Indeed, the increase in EU transfers has probably resulted in higher public spending and an increase in the size of the public sector (Georgakopoulos *et al.,* 1994).

The Period 2000-2007:
During the period 1999-2002, the five Cohesion countries joined the Eurozone and their common currency is now the Euro. By joining the EMU, these countries were no longer able to pursue a national monetary policy and should follow a monetary policy common to the entire Eurozone, although the financial conditions were significantly different from those of the other Eurozone members. Meanwhile, the countries of the European South showed high deficits, a sign that something was not working properly. Indeed, during this period, the Cohesion countries did not take the opportunity to take advantage of the low interest rates resulting from the monetary union, in order to

modernize their economies and improve their competitiveness. Instead, by 2006, these countries experienced excessive consumption levels (Burda, 2013).

Over the last decade, each one of these countries has lost its competitiveness, in terms of production costs, because their prices and wages have risen faster than the average of the Member States of the Eurozone (Katos and Katsouli, 2012). If these countries had taken the opportunity to modernize their physical capital and infrastructure, they could have been able to become more competitive in their exports. Thus, public debt in the Cohesion countries, as a share of GDP, has increased significantly and countries have been forced to impose strict austerity measures. However, reducing deficits by increasing tax rates, widening the tax base and reducing spending on goods and services, as well as household transfers while appearing to lend creditors, cannot provide a basis for economic growth in the future (Burda, 2013).

The period 2008-2013:
In the period after 2007, the European Monetary Union seems to be more a challenge than an opportunity for the Cohesion countries, as the recessionary trends are evident in all five countries. At the beginning of 2010, the debt crisis in the Eurozone was a reality, with Greece in the eye of the cyclone, and serious problems in Ireland, Portugal and Spain (Anand *et al.* 2012). On 10 May 2010, European finance ministers set up a three-year stability package of 750 billion euro, to support weaker Eurozone members.

However, according to the Economist (2010), this package does not seem to solve the deeper structural problems faced by Greece, Ireland, Portugal and Spain. This is due to the fact that the core of the three MoUs imposed on Greece, Ireland and Italy was based on quite strict austerity policies. Greece, Ireland and Portugal should first try to reduce their fiscal deficits. To achieve this, it has been necessary to increase direct and indirect taxation and make a significant cut in budget expenditure through severe wage and pension cuts. However, these proposed restrictive policies have since been criticized as they often lead to social inequalities and unrest, without reducing deficits much. This is also due to the fact that the attempt to eliminate or reduce the fiscal deficit in an economy experiencing a recession may, at least, delay its return to growth (Lipsey *et al.,* 1992)[7].

3. The Methodology

3.1 The Panel Approach

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[7]*The European financial crisis revealed that the European Monetary Union's (EMU) architectural deficiencies led to the increase of poverty, especially for the South-West Euro-Area Periphery countries Thalassinos et al. (2015). The solution can only be political starting, with the recognition that the Eurocrisis is threefold: investment crisis, banking crisis and sovereign crisis (Thalassinos and Stamatopoulos, 2015).*

To test for stochastic convergence, we apply different panel unit root tests. We consider three tests based on the cross-sectional independence hypothesis. More specifically we apply the ADF and Phillips-Perron (PP) Fisher Chi-Square test of Maddala and Wu (1999), and the Levin *et al.* (2002), and Im *et al.* (2003) tests. Furthermore, four cross-sectional dependent tests are used. These are the ADF and PP Z-tests of Choi (2001), and the tests of Breitung (2000) and the stationarity test of Hadri (2000).

Even though the above panel unit root tests offer distinct advantages, none of these tests combine panel data and structural breaks. To seek a more accurate investigation of the convergence hypothesis, in a next step, we employ the panel minimum LM unit root test without breaks and with one break developed by Lee and Strazicich (2004).

The Breitung (BU) test (2000):
Breitung (2000) considers a model with heterogeneous trends and short run dynamics. The testing procedure is one sided and develops a t-statistic (t_B), which follows a standard normal distribution. Breitung shows that the proposed statistic has low power in case of heterogeneous trend parameters across units. He tests for stationarity by estimating the persistence parameter α from the below pooled equation:

$$\Delta y_{i,t}^* = a y_{i,t-1}^* + v_{i,t} \tag{3}$$

where α is a is asymptotically distributed as a standard normal, $\Delta y_{i,t}^*$ and $y_{i,t-1}^*$ are transformed standardized proxies of $\Delta y_{i,t}$ and $y_{i,t-1}$. If t_B is lower than $Z_{critical}$, for determined level of significance and sample size, the null hypothesis of unit root is rejected in favour of stationarity.

The Levin, Lin and Chu (LLC) Test (2002):
Let us consider a variable concerning a group of N individual countries observed over T time periods and a model with individual effects, and no time trend. The LLC tests assume homogeneity of the coefficient of the lagged dependent variable across all units of the panel:

$$\Delta y_{i,t} = a_i + \rho y_{i,t-1} + \sum_{j=1}^{p_i} \theta_{i,j} \Delta y_{i,t-1} + \varepsilon_{i,t} \tag{4}$$

for $i = 1,2,\cdots,N$, $t = 1,2,\cdots,T$. Additionally, Levin Lin and Chu assume that ε_{it} are *i.i.d.* $(0,\sigma_\varepsilon^2)$ and independent, across the units of the sample. In this model, the tested null hypothesis is $H_0: \rho_i = 0$ against the alternative $H_1: \rho_i < 0$ for all $i = 1,2,\cdots,N$, with assumptions about the individual effects $(\alpha_i = 0)$ for all $i = 1,2,\cdots,N$, under H_0 . The LLC test is based on the t-statistic of the pooled fixed-effect estimator $\hat{\rho}$. However, this statistic diverges to negative infinity, in a model with individual effect. For that, Levin Lin and Chu suggest using the following adjusted t-statistic:

$$t_\rho^* = \frac{t_\rho}{\sigma_T^*} - NT\hat{S}_N \left(\frac{\hat{\sigma}_\rho}{\hat{\sigma}_\varepsilon}\right)\left(\frac{\mu_T^*}{\sigma_T^*}\right)$$

Where μ_T^* and σ_T^* are the mean and standard deviation adjustment, simulated by authors for various sample sizes T, and $\hat{S}_N$ is the average standard deviation ratio, $\hat{S}_N = N^{-1}\sum_{i=1}^{N}\hat{S}_i$. In using the LLC test, we reject the null hypothesis when the LLC test is smaller than a critical value, from the lower tail of a standard normal distribution.

3.2.2 The Im, Pesaran and Shin (IPS) Test (2003):
The major limitation of the Levin-Lin-Chu tests is that ρ is the same for all observations. Im, Pesaran and Shin, relax the homogeneity assumption concerning the lagged variable coefficient. Essentially, considering a model with a linear trend for each of the N cross-section units, they take model (4) of Levin, Lin and Chu and substitute ρ_i for ρ. The IPS test is based on the following equation:

$$\Delta y_{i,t} = a_i + \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \theta_{i,j}\Delta y_{i,t-1} + \varepsilon_{i,t} \tag{5}$$

Thus, instead of pooling the data, Levin, Lin and Chu use separate unit root tests for the N cross-section units. They cconsider the t-test for each cross-section unit based on T observations. The null hypothesis of a unit root can now be defined as $H_0: \rho_i = 0$ for all i against the alternative $H_1: \rho_i < 0$ for $i = 1,2,\cdots,N_0$, and $\rho_i = 0$ for $i = N_0 + 1,\cdots,N$ with $0 < N_0 \leq N$. The alternative hypothesis allows unit roots for some (but not all) of the individual. Therefore, the IPS test evaluates the null hypothesis that all the series contain a unit root, against the alternative that some of the series are stationary. The IPS test simply uses the average of the N ADF individual *t*-statistics. If we let t_{iT} denote the *t*-statistic for testing unit root in the *ith* country, the IPS statistic is then defined as:

$$\bar{t}_{N.t} = \frac{1}{N}\sum_{i=1}^{N} t_{i,T}$$

Under the assumption of cross-sectional independence, this statistic is shown to converge to a normal distribution. In using the IPS tests, we reject the null hypothesis when the IPS statistics are smaller than a critical value from the lower tail of a standard normal distribution.

The Maddala and Wu (MW) Tests (1999), and the Choi (CH) Tests (2001):
Maddala and Wu (1999 propose the ADF and Phillips-Perron Chi-Square. These simple tests are based on Fisher's (1932) suggestion of combining the *p*-values p_i from

the individual Augmented Dickey-Fuller (ADF) unit root test applied to cross-section unit i. Under the assumption of cross-sectional independence, the statistic proposed by Maddala and Wu (1999) defined as:

$$P = -2 \sum_{i=1}^{N} \log(p_i)$$

asymptotically, has a chi-square distribution with $2N$ degrees of freedom, when $T \rightarrow \infty$ and N is fixed. For both Fisher tests (ADF & PP-Fisher Chi-square), the exogenous variables must be defined. It is though, possible either not to include exogenous regressors or to include individual intercepts and/or trend terms.

For large N samples, Choi (2001) proposes a similar standardized statistic:

$$Z = -\frac{\sum_{i=1}^{N} \log(p_i) + N}{\sqrt{N}}$$

This statistic corresponds to the standardized cross-sectional average of individual p-values. Under the cross-sectional independence assumption, $Z \rightarrow N(0,1)$, under the unit root hypothesis. In using the Z test, we reject the null hypothesis, when the Z test is smaller than a critical value from the lower tail of a standard normal distribution. In contrast, critical values for the P test are taken from the upper tail of the chi-square distribution. Both the asymptotic chi-Square and the standard normal statistics are reported using ADF and Phillips-Perron individual unit root tests.

The Hadri (2000) Test of Stationarity:
Contrary to the previous, the test proposed by Hadri (2000) is based on the null hypothesis of stationarity. Hadri proposes a residual-based Lagrange multiplier test for the null hypothesis that the individual series $y_{i,t}$ for $i = 1,2,\cdots,N$, are stationary around a deterministic level or around a deterministic trend, against the alternative of a unit root in panel data. The tests proposed are LM tests when we assume that the disturbance terms are normally distributed instead of being only $i.d.d.$.
The LM t-statistic could be computed by:

$$LM_H = \frac{1}{N} \left(\sum_{i-1}^{N} \left(\sum_{t} S_i(t)^2 / T^2 \right) \Big/ f_0 \right)$$

where $S_i(t)$ represents the cumulative sums of the residuals and f_0 is the average of the individual estimators of the residual spectrum at frequency zero.

The Minimum LM Test of Lee and Strazicich (2003, 2004):
Perron (1989) pointed out that unit root tests perform poorly when there is a break in the constant or the deterministic trend function and proposes to allow for one known, or exogenous structural break in the augmented Dickey–Fuller (ADF) type unit root tests. However, Perron's method has been criticized claiming the break point is chosen exogenously.

Lee and Stazicich have developed methods to endogenously determine the break point from the data and have demonstrated that their tests are robust and more powerful than the Dickey and Fuller (1979) and Phillips–Perron (1988) tests. The LM unit root test considered by Lee and Strazicich (2003; 2004) develops with the estimation of two-break LM unit root test statistic. If less than two breaks are significant, the procedure is repeated using the one-break LM unit root test. If no break is significant, then the no-break LM unit root test is employed. As such, the location of breaks, the number of breaks, and the number of lagged augmentation terms are jointly determined for each country**.**

When the LM test of the relative per capita output (GDP_{it}^{R}) is found non-stationary, the LM unit root tests with one break or, with two breaks are also performed. Their LM unit root tests have some more appropriate statistical properties over the other unit root tests with structural break(s). In particular, the LM test, performed by Lee and Strazicich (2003), has the advantage of utilizing both panel data and structural breaks when testing for unit root, it can successfully take structural breaks into account without the necessity to simulate new critical values that depend on the number and location of breaks and yields unbiased results due to the assumption of endogenously determined breaks in the null hypothesis of the unit root tests. Lee and Strazicich conclude that when unit root null hypothesis assumes no break, the resulting test statistic provides divergence and significant rejections of the unit root null.

The break minimum LM unit root can be described as follows. According to the LM principle, a unit root test statistic can be obtained from the following regression equation:

$$\Delta y_t = \delta' \Delta Z_t + \varphi \, \tilde{S}_{t-1} + \sum_{1}^{k} \gamma_i \Delta \tilde{S}_{t-1} + \varepsilon_t \tag{6}$$

where, Z_t reflects the deterministic components, $\tilde{S}_t = y_t - Z_t \hat{\delta} - \widehat{\Psi}_x$ as $t = 2, 3, \cdots, T$. The estimator $\hat{\delta}$ is the vector of coefficients obtained from the regression of Δy_t on ΔZ_t, $\widehat{\Psi}_x = y_t - Z_t . \delta$. The lagged $\Delta \tilde{S}_{t-1}$, $i = 1, 2, \cdots, \kappa$, included in Equation (6) provide the correction of autocorrelation. When $Z_t = [1, t]$, we have the statistic proposed in Schmidt and Phillips (1992). If we want to account for some structural breaks, similar to Perron's (1989) model A, Z_t is described by $[1, t, D_{1t}, D_{2t}]$, where $t \geq T_{Bj} + 1$ for $D_{jt} = 1$, $j = 1$, and 0 otherwise, and T_{Bj} stands for the time period of the breaks. For the model C with two changes in level

and trend, Z_t is described by $[1, t, D_{1t}, D_{2t}, DT_{1t}^*, DT_{2t}^*]$, where $DT_{1t}^* = t - T_{Bj}$ for $t \geq T_{Bj} + 1, j = 1,2$ and 0 otherwise. The first model allows for one or two changes in level and the latter allows for one or two changes in both the level and trend. Note that test regression (6) involves ΔZ_t instead of Z_t, so that ΔZ_t becomes $[1, B_{1t}, B_{2t}, D_{1t}, D_{2t}]$ for model C, where $B_{jt} = \Delta D_{jt}$ and $D_{jt} = \Delta DT_{jt}^*, j = 1,2$. The unit root null hypothesis is described in Equation 1, by $\varphi = 0$ by and the test statistic can be defined as follows:

$\tilde{\tau} = t$ -statistic for the null hypothesis $\varphi = 0$

To endogenously determine the location of two breaks $(\lambda = T_{Bj}/T, j = 1,2)$, the minimum LM unit root test uses a grid search as follows:

$$LM_\tau = Inf_\lambda \tilde{\tau}(\lambda)$$

If the LM test statistic indicates rejection of the null, this would be a statistical confirmation of convergence for the examined country with a benchmark country or the group average**.**

The panel LM unit root test (Im *et al.* 2005) test statistic is obtained by taking into consideration the average of the optimal univariate LM unit root t test statistic which is estimated for every single country as:

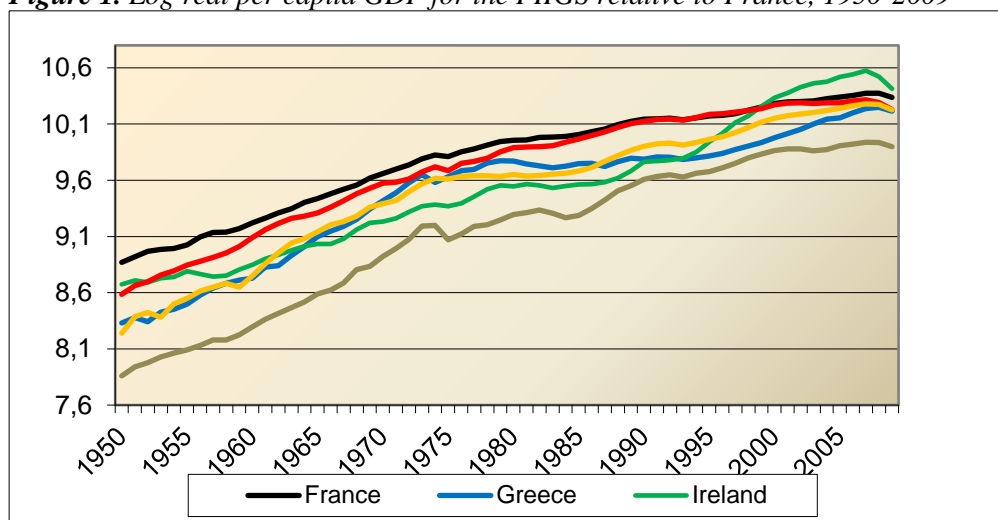$$\overline{LM}_{NT} = \frac{1}{N} \sum_{i=1}^{N} LM_i^\tau$$

4. Data and Empirical Results

4.1 The Data

Data sources that come from the Pen World Table 7 (Heston *et al.,* 2011), refer to the annual real per capita GDP in log form for France, Portugal, Italy, Ireland, Greece and Spain, from 1950 up to 2009. The five per capita GDP series are plotted in Figure 1. A cursory examination of the data suggests that, until 1990, the convergence process of the three poorer countries (Portugal, Greece and Spain) towards France was weak. Although experience of the five countries in this period was different, compared to their starting levels in 1950, it can be stated that all five countries have succeeded in catching-up, to some extent, to France. Italy, whose income level is just below that of France, is the most successful across all five countries. More specifically, during 1950 to 1973, Greece, Portugal and Spain, were the fastest growing economies in Western Europe, with real GDP per capita rising at an average annual rate close to 7%, whereas Italy's growth, although historically high, remained behind at 5.5% (Lains, 2006; Boltho, 2001). Performance, in the period after 1973, was strongly influenced by the

two oil shocks, and the countries faced pressures for income redistribution that led to inflation, slower growth and balance of payments problems during 1975-84. Also, membership in the EU didn't help all countries to catch-up. More specifically, Spain and Portugal experienced respectively a 3.6% and 5.6% increase in average growth rates, after joining the EU in 1986. On the other hand, Irish 5-year average growth rate after accession in 1973 was only 1% and Greece's growth rate, after 1981, was 3.2%, i.e. lower than that before joining the EU (Brodzicki, 2003). In the period after 1990, it is clear that all the five countries, returned to convergence, with macro and microeconomic policy-making improved, in most cases, because of the constraints imposed by the Maastricht criteria and the eventual euro entry (Barry, 2003). Notably also, Irish performance was rather better. In fact, it is in this period that Ireland started to achieve the highest per capita GDP growth in Western Europe.

Figure 1. *Log real per capita GDP for the PIIGS relative to France, 1950-2009*

Source: *Authors' calculations.*

Since the main objective of the European integration is the income convergence of countries, in relation to our research here, Figure (1) shows the evolution of per capita GDP of each PIIGS country relative to the French per capita GDP. As we can see, the widening of income inequalities shows that in times of strict economic policy coordination, the consolidation of the Single Market and the creation of the common Monetary Union, the EU's objective of EU cohesion is far from being feasible.

4.2 The Results
The Panel Unit Root Tests:
We begin our empirical analysis by examining the convergence hypothesis using different panel unit root tests. In particular, we apply the unit root tests of Breitung, the Levin *et al.* (2002), the Im, Pesaran and Shin (IPS) test, the ADF and PP-Fisher Chi-Square of Maddala and Wu (1999), the ADF and PP Z-tests of Choi (2001), and

the stationarity test of Handri (2000). These tests are carried out employing time series data for individual countries and the data for panels considering the log relative real per capita GDP for each country as in the following equation:

$$GDP_{it}^R = log\,(GDP_{it}/GDP_{France}) = logGDP_{it} - logGDP_{France}$$

where, GDP_{it}^R, $logGDP_{it}$, and $logGDP_{France}$, represent the relative per capita GDP for country i at time t, natural logarithm of the per capita GDP for country i and per capita GDP of France at time t, respectively. When the unit root test of GDP_{it}^R is found non-stationary, one may state that the per capita GDP of the country i is not converging towards that of France.

Consider the $y_{it=}\rho_i y_{it-1} + X_{it}\delta_i + \varepsilon_{it}$ AR process for panel data. There are two natural assumptions that we can make about ρ_i. First one can suppose that there is a common ρ. Alternatively, one can allow ρ_i to vary freely across cross-sections. Thus, we can classify our unit root tests on the basis of whether there are restrictions on the autoregressive process across cross-sections or series, as follows**:**

- Common root tests
    - Breitung
    - Levin, Lin & Chu (LLC)
    - Handri
- Individual root tests
    - Im, Pesaran and Shin (IPS),
    - ADF & PP-Fisher Chi-Square
    - ADF & PP-Choi Z-test

The summarized results from the unit root tests are reported in Table 2. Null hypothesis is that of a unit root for the Breitung and the LLC test. Breitung and LLC test fail to reject the null unit root hypothesis, while the test of Hadri strongly rejects the null hypothesis of stationarity supporting the non-convergence hypothesis for the PIIGS towards France.

Table 2. *Panel unit root tests (common root)*

There is a common unit root process → ρ_i is identical across cross-sections $\rightarrow \rho_i = \rho$ for all *i* $$y_{it=}\rho_i y_{it-1} + X_{it}\delta_i + \varepsilon_{it}$$		
Breitung Ho: unit root	LLC Levin, Lin & Chu Ho: unit root	Hadri Ho: no unit root ~ stationarity
0.89053	-1.07984	7.77083

(0.8134)	(0.1401)	(0.0000)

Note: The numbers in parenthesis are p-values.

Contrary, as it is shown in Table 3, all the tests, that allow ρ_i to vary across countries, fail to reject the null of a unit root that means that the series are not stationary and the countries are not converging towards France.

Table 3. *Panel unit root tests (individual root)*

There is an individual unit root process →
ρ_i may vary across cross-sections

$$y_{it=}\rho_i y_{it-1} + X_{it}\delta_i + \varepsilon_{it}$$

IPS Im, Shin	Pesaran,	ADF-Fisher Chi-Square	ADF- Choi Z- stat	PP-Fisher Square	Chi- PP-Choi Z-stat
0.32012 (0.6256)		10.6805 (0.3829)	-0.23921 (0.4055)	12.9793 (0.2248)	-0.49806 (0.3092)

Note: The numbers in parenthesis are p-values.

The Panel LM Unit Root Tests:

Even though the applied panel unit root tests offer distinct advantages, none of these tests combine panel data and structural breaks. To seek a more accurate investigation of the convergence hypothesis, we employ the panel LM unit root test without breaks and with one break developed by Lee and Strazicich (2004). We begin our empirical analysis by examining the univariate LM test, without any structural breaks. These results are reported in the following Table 4.

Table 4. *LM unit root test without structural break for the real per capita GDP*

Country	Minimum LM statistic	Lag Length
Portugal	-2.812***	1
Italy	-1.676	1
Ireland	-2.589	4
Greece	-1.282	3
Spain	-1.923	3
Panel LM test statistic	-0.412	

Note: The 1%, 5% and 10% critical values for the LM test without a break, are -3.63, -3.06, -2.77 respectively. The corresponding critical values for the panel LM test are -2.326 -1,645 and -1.282. (***) denote statistical significance at the 10% level.

The unit root null is rejected only for Portugal at the 10% level. The four countries for which the relative per capita GDP series are found to be non-stationary is Italy, Ireland, Greece and Spain. In addition to individual LM statistics, we explore the panel version of the LM test to the group of the five examined countries in our sample.

Without allowing for structural breaks, the panel LM statistic obtained is -0.412, which is higher than the critical values at the 1%, 5% and 10% level, clearly indicating that the unit root null cannot be rejected.

The failure to find stationarity in real per capita GDP series, may be due to the fact that univariate unit root tests have lower power when structural breaks are ignored. To cope with this problem, we investigate the convergence hypothesis by the LM unit root test, with one structural break (Table 5).

Table 5. *LM unit root test with one structural break for the real per capita GDP*

Country	Minimum LM statistic	Lag Length	Break Year
Portugal	-3.321***	8	1976
Italy	-2.596	7	1967
Ireland	-3.778**	5	1960
Greece	-4.031**	8	1982
Spain	-2.451	7	1965
Panel LM test statistic	-4.986*		

Note: *The 1%, 5% and 10% critical values for the LM test with one break, are -4.239, -3.566, -3.211 respectively. The corresponding critical values for the panel LM test are -2.326 -1,645 and -1.282.*
(*), (**) and (***) denote statistical significance at the 1%, 5% and 10% level respectively.

We can see that the unit root null hypothesis is rejected giving evidence in favour of convergence for Ireland and Greece at the 5% significance level and for Portugal at the 10% significance level. In contrast, the null hypothesis of a unit root test cannot be rejected for Italy and Spain and the countries are considered to diverge. For Italy, the "failure" of convergence as suggested by the test is somewhat misleading. Italy has for most of the sample period fluctuated around the mean output level. It has not needed to converge as the convergence has already occurred prior to the sample period (Figure 1).

Although the null hypothesis of a unit root test cannot be rejected for Italy and Spain, the rejection of the unit root null hypothesis for the rest of the countries provides evidence in favour of convergence towards France, as panel LM test statistic of -4.986 strongly rejects the unit root null at less than 1%.

5. Conclusions

To test for stochastic convergence of PIIGS towards France, we applied different panel unit root tests, and more specifically, the common root tests of Breitung, Levin, Lin and Chu (LLC), and Hadri, and the individual root tests of Im, Pesaran and Shin (IPS), ADF and PP-Fisher, ADF and PP-Choi. All unit root tests accept the null hypothesis of non-stationarity supporting the hypothesis of non-convergence. The

failure to find stationarity in real per capita GDP series may be because univariate unit root tests have lower power when structural breaks are ignored.

To cope with this problem, we employed the panel LM unit root test of Lee and Strazicich (2003, 2004). This test has the advantage of utilizing both panel data and structural breaks when testing for unit root. The LM test without break, fails to reject the unit root hypothesis for all examined countries except Portugal.

Allowing for one structural break, evidence in favour of convergence is found for Portugal, Ireland and Greece. Concerning the non-convergence of Spain, one suspects that it is probably the lower starting point of Portugal in comparison with Spain, in 1950, which can explain that the test reports convergence for Portugal with France but not for Spain. However, allowing for one structural break, the Panel LM test statistic of -4.986 strongly rejects the unit root null at less than 1%, supporting the hypothesis of PIIGS, as a group, towards France. This finding clearly demonstrates the gain in power from combining structural breaks with panel data.

From an economic policy point of view, the issue of convergence or divergence remains always very much important. It seems that a central factor for the catch-up process of the examined countries was the higher rates of financial assistance, under the form of structural funds during the examined time period that these countries, as members of the "cohesion" group, took advantage. Moreover, all five countries are benefited from the integration process. However, convergence is not automatic in the EU, since other forces, such as institutional quality and/or national economic policies, are much at work. The lack of convergence could be the result of a lack of commitment on the part of national governments to move sufficiently quickly in liberalizing their economies. More specifically, there is a need for significant economic policy domestic measures, such as institutional adjustments, structural reforms, etc. all necessary in order to stimulate a sustainable growth and desirable convergence.

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