Unemployment in Greece:

Evidence from Greek Regions using Panel Unit Root Tests

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Abstract

The purpose of the paper is to examine the nature of Greek regional unemployment. The paper contributes to the literature assessing the stochastic properties of Greek unemployment rate in the context of the Greek regions by relying on various univariate and panel unit root tests. In particular, recently developed and more powerful panel unit-root tests that control for structural breaks, heterogeneity and cross-sectional dependence in the panel are employed. The results show that in all cases, after taking into account the fact that regional unemployment rates in Greece are subject to a structural break, the null hypothesis of a unit root is not rejected, indicating that the Greek regional unemployment series are non-stationary with the presence of a structural break.

Keywords: Unemployment · Hysteresis · Panel Unit Root Tests · Structural Breaks · Cross-Sectional Dependence

JEL Classification: C32 · C33 · E24 · J64 · R23

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1 Introduction

The issue of unemployment clearly is one of the most pressing problems for most countries over the recent decades. Nearly five years after the worst recession that hit OECD countries since the 1930s, most of the concern of economists is that the unemployment rate in a number of OECD countries remains stubbornly high and shows no apparent tendency to return to its natural level. Moreover, recent reports suggest that job creation will remain anaemic in the near term implying tackling high and persistent unemployment and alleviating the human costs of unemployment should be at the top of the political agenda (OECD, 2012).

Even before the global financial crisis, the Greek economy was in the middle of a deep crisis, characterized mainly by large fiscal deficits, huge debt, a continued erosion of competitiveness and high unemployment rates. The crisis of 2009 amplified these negative effects and accelerated the downturn of the Greek economy (Bank of Greece, 2009). In May 2010, Greece embarked on an ambitious economic adjustment programme to deal with the chronic deficiencies of the economy by restoring sustainable public finances, competitiveness and setting the foundation for solid long-term growth.

The rate of unemployment in Greece almost tripled over the 1980s and 1990s reaching 12.1 percent in 1999 before it started its decline, but remained high for over a decade. Over that period, regional unemployment disparities were diminishing and the behaviour of unemployment has not been uniform across regions. The downward trend in unemployment was reversed after the crisis. The strong fiscal contraction which resulted from the program caused an increase unemployment rate from 11.0% in the first quarter of 2010 to 16.7% in the second quarter of 2011.

The high and highly persistent unemployment rates experienced by many countries and regions in Europe and the US have attracted a significant amount of both theoretical and empirical work and are mainly explained by the hysteresis hypothesis. Hysteresis in unemployment implies that cyclical fluctuations have permanent effects on the level of unemployment due to labour market restrictions (Blanchard and Summers, 1986). By contrast, the natural rate of unemployment hypothesis characterizes unemployment as a mean reverting process, so shocks to the series have only temporary effects. These theories can be investigated, by examining the order of integration of the unemployment rate. Level stationarity of unemployment (rejection of the unit root hypothesis) would support the natural rate of unemployment hypothesis while the presence of a unit root would imply that shocks affecting the series have permanent effects supporting the hysteresis hypothesis. In a seminal work, Blanchard and Summers (1986) use conventional unit root tests to examine the impact of hysteresis on unemployment and they provide evidence of non-stationarity of unemployment in European Union (EU) concluding that unemployment exhibits hysteresis, while, they find evidence of stationarity for the U.S.

However, it is well documented in the literature that conventional unit root tests, such the augmented Dickey-Fuller, exhibit very low power when the time span of the data is short. To address this problem, two different approaches are followed in the literature on hysteresis: first, the use of unit-root testing techniques that allow for the presence of structural breaks, such as the tests of Zivot and Andrews (1992), Lee and Strazicich (2003) and the more recent ones of Enders and Lee (2012a;b) that account for smooth structural breaks and, second, the application of panel unit root methods that help increase the power of the tests (Im *et al.*, 2003; Maddala and Wu, 1999; Christopoulos and Leon-Ledesma, 2007; Dreger and Reimers, 2009).

At the same time, most of the analysis is performed under the assumption of cross-sectional independence among regions or countries. However, cross-sectional dependence is an important characteristic in the analysis of macro and regional panel data models (Sarafidis and Wansbeek, 2012). This type of interdependence can reflect global common shocks with heterogeneous impact across countries, such as the oil crises in the 1970s or the recent financial crisis. Alternatively, it can be the result of local spillover effects between countries or regions (Banerjee *et al.*, 2010). Latest empirical evidence supports the interdependence of regional unemployment in Greece (Lolos and Papapetrou, 2012). Also, the recent and simultaneous increase in unemployment at the national level and across regions in Greece provides evidence of potentially strong cross-sectional dependence, suggesting that panel unit root tests that do not allow for cross-sectional dependence may lead to spurious results.

The two distinct directions on unit root testing have been combined recently in the development of panel unit root tests that allow for the presence of structural breaks and cross-sectional correlation. Im *et al.* (2005) extends the univariate Lagrange Multiplier (LM) unit root test of Lee and Strazicich (2003) to a panel LM test. Recently, Im *et al.* (2010) further extend the panel LM unit root test to allow for the presence of heterogeneous structural breaks in both the intercept and slope of each cross-sectional unit and cross-sectional dependence in the panel.

The purpose of this paper is to examine the nature of Greek unemployment allowing for cross-sectional dependence among Greek regions and for the presence of structural breaks. To our knowledge little work has so far addressed this problem systematically in the context of the Greek regions. Empirical evidence depicts unemployment (at the national level) in Greece as a unit root process whereas in the context of Greek regions the evidence is scarce (Katsimi, 2000; Christopoulos, 2004; Apergis, 2005; Cheng *et al.*, 2014). This paper contributes to the literature assessing the stochastic properties of Greek regional unemployment rates using various univariate and panel unit root tests as well as the recently developed and more powerful panel unit-root tests that allow for structural breaks. For that purpose, we apply the Lagrange Multiplier (LM) panel unit root test of Im *et al.* (2010) that makes use of a simple transformation in order to obtain a test statistic which is invariant to both the location and the size of breaks in the level or trend of the series in the panel. This test depends only on the number of breaks in the series and, therefore, has significantly greater power than all previous panel tests. In addition, the test corrects for the presence of cross-correlations in the innovations of the panel by applying the cross-sectionally augmented procedure of Pesaran (2007) that is found to perform robustly under various specifications of cross-sectional dependence (Baltagi *et al.*, 2007). We believe that the findings of our analysis are important as we contribute to the existing literature on regional unemployment behaviour of Greece, a country currently in the middle of a deep crisis and the investigation of unemployment behavior is of paramount importance for policy making. The findings of our analysis might be indicative of other countries sharing similar economic characteristics with Greece, such as some Southern and Eastern European countries.

The remainder of the paper is organized as follows. Section 2 provides a short theoretical and empirical review of the concept and tests for unemployment hysteresis. Section 3 presents some basic characteristics of the Greek labour market. Section 4 discusses the econometric methodology. Section 5 presents the data and reports the empirical results. Finally, in Section 6 concluding remarks are provided.

2 Theoretical and Empirical Evidence

The high levels and strong persistence of unemployment rates in Europe, especially after the first oil shock, have attracted a sufficient number of theoretical and empirical papers focused on understanding the behaviour of unemployment. Various economists suggest that major macroeconomic disturbances, such as a productivity slowdown, the steep rise in oil prices in the 1970s and changes in world interest rates could account for the rise and persistence of unemployment (Roed, 1997).

There are different hypothesis for the dynamics of aggregate unemployment rates. In their seminal work, Friedman (1968) and Phelps (1968) established the natural rate hypothesis which states that the unemployment rate tends to fluctuate around some equilibrium level associated with labour markets in equilibrium. This natural rate depends on fundamentals in the economy, which are considered as exogenous. Unemployment shocks are considered temporary, which implies that unemployment is mean reverting. However, the theory was not able to explain the high and persistent unemployment rates in Europe following the first oil shock.

Phelps (1972) suggested that the natural rate of unemployment may not be unique but path dependent so it could rise as a consequence of negative shocks resulting in prolonged departures from equilibrium unemployment rates. The structuralist hypothesis as suggested by Phelps (1994) and Phelps and Zoega (1998) explains the rise in European unemployment through the adjustment to an underlying equilibrium unemployment rate, which has increased from one time period to another in response to structural factors of the economy. They suggest that several real disturbances in the economy and the ensuing adjustment to them may shift up or tilt the path of unemployment rate (Phelps, 1994). The underlying idea is that unemployment may remain higher because some or all of the driving forces are persisting and non-neutral to the unemployment rate in the long-run and not because the volume of unemployment has some inherent persistence in the sense of sluggishness (Phelps and Zoega, 1998). According to this view, most shocks to unemployment are temporary, but infrequent large variations in these structural shocks result in shifts in the natural rate of unemployment, implying the endogenous character of unemployment.

Blanchard and Summers (1986) focusing on insider-outsider dynamics in wage formation argued that unemployment is path-dependent as its current level shows high dependence on past levels. In such a framework, temporary shocks can affect unemployment permanently. According to this argument, wage bargaining is largely dominated by the insiders and, due to training and vacancy costs of firms, insiders can demand wage premia. Outsiders, such as the long-term unemployed, cannot exert pressure on the bargaining process; thus negotiated wages are prevented from falling. The power of insiders is largely dependent in the degree of labour market regulation (Nickell *et al.*, 2005). Also, unemployed may have a difficulty in maintaining their skills. Therefore, depreciation of human capital may explain a strong degree of persistence. Hysteresis may arise if depreciation of human capital is unevenly distributed while at the same time relative wages are prevented from adjusting. Hysteresis advocates claim that the rise in unemployment should not be attributed to adverse supply disturbances or demand disturbances but rather to the way countries adjust to these shocks.

As hysteresis was formally equated to the presence of a unit root in the unemployment rate a variety of empirical tests has been developed, employing univariate unit root methods, to determine its validity (Blanchard and Summers, 1986; Roed, 1996). These studies use conventional univariate unit root tests, such as the Augmented Dickey-Fuller (ADF) test, and fail to reject the null of a unit root in European unemployment rates supporting the hysteresis hypothesis for European countries. However, the reliance on univariate unit root tests, characterized by low power when the time period under consideration is short and the unemployment variable is subject to high degree of persistence, makes the validity of the tests questionable. To address this problem, two different approaches are followed in the literature on testing the hysteresis hypothesis: first, the use of unit-root testing techniques that allow for the presence of structural breaks and, second, the application of panel unit root methods that help increase the power of the tests.

Since the pioneering work of Perron (1989), it is well known that ADF tests can fail to reject a false unit root due to misspecification of the deterministic trend. Unit root tests with structural breaks represent a powerful alternative and have been used extensively to correct for the lower-power problem when testing the hysteresis hypothesis. Arestis and Mariscal (1999) applied Lumsdaine and Papell's methodology, an extension of Zivot and Andrews's test allowing for two breaks in level and trend, in a sample of 26 OECD countries, the results pointed to a rejection of the hysteresis hypothesis for the majority of these countries. Gomes and da Silva (2009) applied more powerful unit root tests that allow for endogenous structural breaks providing evidence that the unit root null hypothesis could not be rejected for Brazil and for all metropolitan areas, but for Rio de Janeiro. Recently, Cheng *et al.* (2014) by applying the flexible Fourier unit root test, proposed by Enders and Lee (2012a), support the hysteresis hypothesis for five European countries.

The second approach increases the power in testing for unit roots by using panel unit root tests that exploit the cross-sectional dimension of the data. Several studies have employed first generation panel unit root tests to test for the hypothesis of hysteresis. Song and Wu (1998) by using the Levin and Lin test on unemployment rates for a sample of 48 US states and 15 OECD countries reject the hysteresis hypothesis for both samples, whereas Leon-Ledesma (2002) by applying the Im *et al.* test in a panel of 12 EU countries and 51 US states rejects the hysteresis hypothesis only for the

US panel.

The early panel tests that were based on the restrictive assumption of independence among the panel units suffer from serious size distortion and restricted power in the presence of cross-sectional dependence and cross-sectional cointegrating relationships (Banerjee *et al.*, 2004). Thus, more recent panel unit root tests relax the independence assumption and presuppose cross sectional dependence. Christopoulos and Leon-Ledesma (2007), by applying newly developed panel unit root tests to a panel of 12 EU countries, reject the hysteresis hypothesis. Dreger and Reimers (2009) also, by examining the hysteresis hypothesis in EU and US unemployment series provide mixed evidence.

The previous two directions have been combined recently in the development of panel unit root tests that allow for the presence of structural breaks and cross-sectional correlation. Im *et al.* (2005) extends the univariate Lagrange Multiplier (LM) unit root test of Lee and Strazicich (2003) to a panel LM test. Lanzafame (2010) consistently rejects the unit root hypothesis for a panel of Italian regions by implementing the panel LM test. Recently, Im *et al.* (2010) further extend the panel LM unit root test to allow for the presence of heterogeneous structural breaks in both the intercept and slope of each cross-sectional unit and cross-sectional dependence in the panel.

The empirical evidence for Greece is limited. There are few empirical studies (Demekas and Kontolemis, 1996; Katsimi, 2000; Apergis, 2005; Christopoulos, 2004; Mitrakos and Nicolitsas, 2006; Lolos and Papapetrou, 2012). Demekas and Kontolemis (1996) present evidence for a high degree of unemployment persistence in Greece. Katsimi (2000), confirming the results of Demekas and Kontolemis (1996), suggests that the observed nonstationarity of the rate of unemployment is due to infrequent structural shifts in the natural rate. Apergis (2005) has showed that in the Greek labour market experience, it is the insider-outsider problem (hysteresis phenomena) which contributed to an increased natural rate of unemployment. Mitrakos and Nicolitsas (2006) present evidence that the upward trend in the unemployment rate in Greece has been accompanied by a prolongation of unemployment spells. Lee (2010), using panel unit root tests in annual series, finds that unemployment in Greece displays hysteresis. Similarly, Cheng *et al.* (2014) using the flexible Fourier unit root test confirm the hysteretic behaviour of Greek unemployment. At a regional level, Christopoulos (2004) using panel data techniques, confirms that Greece's unemployment rate is nonstationary and reveals that Okun's law can be confirmed for six out of the 13 regions of Greece. Finally, Lolos and Papapetrou (2012) examine the factors responsible for the existence of regional unemployment disparities and unemployment persistence in Greece over the period 1981-2008. However, the nature of regional unemployment, controlling for structural breaks and cross-sectional dependence within the framework of panel unit root, has not been addressed for Greece. The present study bridges this gap in the literature.

3 The Labour Market in Greece: Some Basic Characteristics

The Greek labour market is characterized by low employment and low participation rates. Part-time employment in Greece is lower than that of the EU average. Greece has always had high unemployment rates, which declined from 1999 (12.1 percent) until 2008 (7.6 percent) and then started rising, due to the recent crisis, to 16.7 percent in the second quarter of 2011. Unemployment is high, particularly among first-time labour market entrants and re-entrants (i.e. young and women), and long-term unemployment is high and persistent (OECD, 2007). The unemployment compensation system is rather poor and assistance to those seeking entrance to the labour market is limited.[1]

In 2010, changes were enacted relating to the institutional features of collective bargaining and labour costs in Greece with the aim of increasing labour market flexibility and productivity. The labour market reforms were outlined in the original Memorandum of Understanding (MoU) of May 2010 and the updated Memoranda (August 2010, November/December 2010) between the Greek government and the EC-ECB-IMF (Troika) and consisted mainly of institutional changes relating to wage bargaining procedures with the aim of increasing labour market flexibility and productivity and changes with the direct impact on labour costs. These changes include among others: minimum wage falls to facilitate youth entrance in the labour market, a reduction in firing costs, a reduction in the overtime premium and in salaries paid, the extension of the use of temporary employment, the relaxation of firing restrictions for all firms subject to collective dismissal rules, the reduction of severance costs for white collar workers, that were higher than for blue-collar works, through a shortening of the notification period for dismissal.

4 Econometric Methodology

4.1 Univariate Unit Root Tests without and with Structural Breaks

Several unit root tests have been proposed to examine the order of integration of the unemployment series. The conventional test for hysteresis examines the order of integration of the unemployment series using the standard univariate augmented Dickey-Fuller (hereafter **ADF**) test based on the following equation:

$$\Delta U_t = \alpha_0 + \phi U_{t-1} + \sum_{j=1}^{k} c_j \Delta U_{t-j} + \varepsilon_t, \tag{1}$$

where U_t is the unemployment rate and ε_t is a white noise error term. Elliott *et al.* (1996) propose a simple modification of the ADF test, the Dickey-Fuller GLS (hereafter **DF-GLS**) test, that has substantially higher power than the conventional ADF unit root test.

Unit root tests that take into account structural breaks provide a powerful alternative to correct for the lower-power problem when testing the hysteresis hypothesis. The Lee and Strazicich's (2004) minimum Lagrange multiplier (hereafter **LM**) test allows for one level shift and endogenous determination of the time of the break and is unaffected by the occurrence of structural breaks under the null.

The LM test of Lee and Strazicich (2004) is obtained using the following regression:

$$\Delta U_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_{j=1}^{k} c_j \Delta \tilde{S}_{t-j} + u_t, \tag{2}$$

where Z_t is the vector describing the breaks. Specifically, the case of one structural change in the mean is formed as $Z_t = [1, t, D_t]'$, where $D_t = 1$ for $t \geq T_B + 1$, and zero otherwise. T_B is the time period of the structural break. The LM t-test statistic is given by the $\tilde{\tau}$, the t-statistic for the null hypothesis $\phi = 0$. The location of the break is determined endogenously by utilising a grid search over all possible break points. Lee and Strazicich (2004) provide simulated critical values of the minimum LM unit root test.

4.2 Univariate Unit Root Tests with a Fourier Function

The method of Lee and Strazicich's (2004) uses dummy variables in order to capture structural breaks in the level of a series. However, this approach is subjected to some drawbacks. First, the number and the location of the breaks are unknown and need to be estimated. Second, the exact form of the breaks is also unknown and has to be specified. Third, the use of dummy variables suggests a sharp break in the level of the series. To deal with these issues, Enders and Lee (2012b) extend the ADF test equation to incorporate low frequency components from a Fourier approximation to imitate structural changes. Their testing regression is given as follows:

$$\Delta U_t = \alpha_0 + \phi U_{t-1} + \alpha_1 \sin(2\pi kt/T) + \alpha_2 \cos(2\pi kt/T) + \sum_{j=1}^{k} c_j \Delta U_{t-j} + e_t, \tag{3}$$

where k is the number of frequency of the Fourier function, t is the trend term, T is the sample size and $\pi = 3.14159$. The Dickey-Fuller version of the test (hereafter **F-DF**) is given by the τ_{DF}, the t-statistic for the null hypothesis $\phi = 0$ in Equation (3). Furthermore, Enders and Lee (2012b) suggest to pretest for nonlinearity by performing the usual F-test for the null hypothesis $\alpha_1 = \alpha_2 = 0$. If the null hypothesis of linearity is not rejected, Enders and Lee (2012b) recommend to perform the usual ADF type of test. Finally, they provide simulated critical values of the Dickey-Fuller test with a Fourier function and the F-statistic.

4.3 Panel Unit Root Tests without Structural Breaks

The literature on non-stationary panels includes two distinct generations of tests. The first generation tests assume that the cross-sectional units are independent of each other. They build on a panel extension of the univariate ADF regression as follows:

$$\Delta U_{i,t} = \alpha_i + \phi_i U_{i,t-1} + \sum_{j=1}^{p_i} \theta_{i,j} \Delta U_{i,t-j} + \varepsilon_{i,t}, \tag{4}$$

where $U_{i,t}$ is the unemployment rate of region i at time t and $\varepsilon_{i,t}$ is a white noise error term. Specifically, we conduct one homogeneous unit root test (Levin *et al.*, 2002, hereafter **LLC**), three heterogeneous unit root tests (Im *et al.*, 2003, hereafter **IPS**; Maddala and Wu, 1999, hereafter **MW**; Choi, 2001, hereafter **CH**) and the stationarity panel test by Hadri (2000), hereafter **HAD**. However, if the panel units (regions) are correlated, then these tests experience severe size distortion and restricted power (Banerjee *et al.*, 2004).

To determine the existence of cross-sectional dependence among regions under investigation the general diagnostic test suggested by Pesaran (2004) is implemented. The Cross-Section Dependence (hereafter **CD**) test statistic is based on the average of pair-wise correlation coefficients ($\hat{\rho}_{ij}$) of the OLS residuals obtained from the individual ADF regressions. The CD test is given by:

$$CD = \sqrt{\frac{2T}{N(N-1)} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \right)}. \tag{5}$$

The CD statistic under the null of cross-independence is distributed as a two-tailed standard normal distribution, i.e. $CD \sim N(0,1)$ for $T_{ij} > 3$ and sufficient large N. Baltagi *et al.* (2007) present evidence that the CD test can be also used as a useful diagnostic test for various models of spatial dependence.

The second generation tests relax the independence hypothesis and assume cross-sectional dependence. They include, two unit-root tests that rely on common factor structure models (Bai and Ng, 2004, hereafter **BNG** and Moon and Perron, 2004, hereafter **MP**), the unit-root test by Pesaran (2007), hereafter **PES** and a stationarity test (Hadri and Kurozumi, 2009), hereafter **HAK** that apply a cross-sectional augmentation procedure and the multivariate unit-root test of Taylor and Sarno (1998) (hereafter **MADF**) that is based on the SUR estimation methods.[2]

4.4 Panel Unit Root Tests with Structural Breaks

Recently, there are new directions in the development of panel unit root tests that allow for the presence of structural breaks and cross-sectional dependence. Im *et al.* (2005) extends the univariate Lagrange Multiplier unit root test of Lee and Strazicich's (2003) to a panel LM test.

4.4.1 The Im et al. (2005) test

Following Im *et al.* (2005), the test statistic (hereafter **ILT**) is based on the panel extension of Lee and Strazicich's (2004) version of the test equation that allows for one shift in level and trend as follows:

$$\Delta U_{i,t} = \delta_i' \Delta Z_{i,t} + \phi_i \tilde{S}_{i,t-1} + \sum_{j=1}^{k} c_{ij} \Delta \tilde{S}_{i,t-j} + \varepsilon_{i,t}, \tag{6}$$

where $U_{i,t}$ is the unemployment rate of country i at time t, $\tilde{S}_{i,t}$ is the detrended unemployment rate series, $Z_{i,t}$ is a vector describing the breaks and $\varepsilon_{i,t}$ is a white noise error term. Specifically, $Z_{i,t} = [1, t, D_{i,t}]'$ expresses the case of a change in mean and $Z_{i,t} = [1, t, D_{i,t}, DT^*_{i,t}]'$ for the case of a break in mean and trend. $D_{i,t} = 1$ and $DT^*_{i,t} = t - T_{Bi}$ for $t \geq T_{Bi} + 1$, and both zero otherwise. T_{Bi} is the time period of the structural break for country i. The test statistic is based on the null hypothesis, $H_0 : \phi_i = 0$ for all i, against the alternative hypothesis, $H_1 : \phi_i < 0$ for some i. The panel LM statistic can be constructed as the average of univariate LM unit root t-test statistic estimated for each individual i:

$$\bar{t}^B_{N,T} = \frac{1}{N}\sum_{i=1}^{N} \tilde{\tau}_{i,T}. \tag{7}$$

Then, the standardized ILT panel LM unit root test statistic is obtained as follows:

$$\Gamma^B_{LM} = \frac{\sqrt{N}\left(\bar{t}^B_{N,T} - E(\tilde{\tau}_{i,T})\right)}{\sqrt{V(\tilde{\tau}_{i,T})}}, \tag{8}$$

where $E(\tilde{\tau}_{i,T})$ and $V(\tilde{\tau}_{i,T})$ are the expected value and variance of the individual $\tilde{\tau}_{i,T}$ statistic, respectively, and their values are listed in *Table 1* of Im *et al.* (2005). Thus, as $N, T \to \infty$ as long as $E(\tilde{\tau}_{i,T})$ and $V(\tilde{\tau}_{i,T})$ exist and $N/T \to k$, where k is any finite constant, we have $\Gamma^B_{LM} \to N(0,1)$ and the asymptotic distribution is not affected by the presence of structural breaks.

4.4.2 The Im et al. (2010) test

The panel LM test of Im *et al.* (2005) will critically depend on the nuisance parameters indicating the size and location of breaks when the series under investigation exhibits breaks in both the intercept and the slope, and thus can be subject to serious size distortions. To address this problem, Im *et al.* (2010) propose a new Lagrange multiplier (hereafter **ILT***) panel unit root test that is invariant to the nuisance parameters. Following Lee and Strazicich (2009), the dependency of the test statistic on the nuisance parameter can be removed with the following transformation:

$$\tilde{S}^*_t = \begin{cases} \frac{T}{T_B}\tilde{S}_t & \text{for } t \leq T_B \\ \frac{T}{T-T_B}\tilde{S}_t & \text{for } T_B < t \leq T. \end{cases} \tag{9}$$

Using the transformed series, Im *et al.* (2010) formulate a test equation similarly to Equation (6) by replacing $\tilde{S}_{i,t-1}$ with $\tilde{S}^*_{i,t-1}$. The transformed panel LM statistic can be obtained as the standardized statistic of the following average test statistic:

$$\bar{t}_{N,T} = \frac{1}{N}\sum_{i=1}^{N} \tilde{\tau}^*_{i,T}. \tag{10}$$

Formally, the standardized ILT* panel LM unit root test statistic is obtained as follows:

$$LM_{\tilde{t}^*} = \frac{\sqrt{N}\left(\bar{t}_{N,T} - \tilde{E}(\bar{t}_{N,T})\right)}{\sqrt{\tilde{V}(\bar{t}_{N,T})}}, \tag{11}$$

where $\tilde{E}(\bar{t}_{N,T})$ and $\tilde{V}(\bar{t}_{N,T})$ are the estimated values of the average of the means and variances of $\bar{t}$ as reported in *Table 2* of Im *et al.* (2010). Similarly, the standardized LM panel unit root test follows a standard normal distribution. Im *et al.* (2010) examine the finite-sample properties of the transformed panel LM test, and show that the test has reasonably good size even for relatively small sample sizes of N and T and that the test has greater power than other tests employed in the empirical analyses.

The previous panel LM unit root tests assumed no correlations in the innovations across the panel. To correct for the presence of cross-sectional dependence, Im *et al.* (2010) apply the cross-sectionally augmented procedure of Pesaran (2007) that is found to also be robust to the presence of other sources of cross-section dependence such as the spatial form (Baltagi *et al.*, 2007). Therefore, they formulate the transformed testing regression augmented by the cross-section averages of lagged levels and first-differences of the individual series:

$$\Delta U_{i,t} = \delta_i' \Delta Z_{i,t} + \phi_i \tilde{S}^*_{i,t-1} + g\bar{S}^*_{t-1} + h\Delta\bar{S}^*_t + \sum_{j=1}^{k} g_{ij}\Delta\bar{S}^*_{t-j} + \sum_{j=1}^{k} c_{ij}\Delta\tilde{S}_{i,t-j} + \varepsilon_{i,t}, \tag{12}$$

with $\bar{S}^*_{t-1} = N^{-1}\sum_{i=1}^{N} S^*_{i,t-1}$ and $\Delta\bar{S}^*_t = N^{-1}\sum_{i=1}^{N}\Delta S^*_{i,t} = \bar{S}^*_t - \bar{S}^*_{t-1}$. Therefore, the t-statistic on ϕ_i is used in order to construct the mean statistic $\bar{t}$ as in Equation (10), which in turn can be used to construct the ILT^*_{CA} test statistic equivalently to Equation (11), which again follows a standard normal distribution.

5 Data and Empirical Results

5.1 Data

The empirical analysis uses quarterly data for unemployment (u_t) for the national level and for the 13 NUTS-II regions over the period 1998:Q1–2011:Q2, as well as annual data over the period 1981–2011.[3,4,5] Following similar studies, such as Christopoulos and Leon-Ledesma (2007), we perform the analysis using the logarithmic form of the unemployment rate, $U_t = ln(u_t)$, as well as its logistic transformation, $U_t = ln(u_t/(1-u_t))$.[6,7] All series were obtained from the Hellenic Statistical Authority (EL.STAT.).

5.2 Empirical Results using Quarterly Data

Table 1 presents the evolution of unemployment rate at the national level and for the 13 Greek regions for the period 1998-2011 (second quarter) and Table 2 presents the summary statistics for unemployment. The unemployment rate, although high, decreased from 11.3% in the first quarter of 1998 to 7.4% in the second quarter of 2008. However, this downward trend was reversed after the crisis, and, in the second quarter of 2011, it increased to 16.7%.

[Table 1 Here]

[Table 2 Here]

Figure 1 plots the quarterly regional unemployment rate relative to the Greek national level. While there is a similar pattern in the unemployment rates of the 13 Greek regions, the evolution of unemployment in some of the peripheral regions shows a strong heterogeneity. Central Macedonia, Thessaly and Attica show a similar pattern with the national unemployment rate, while in almost all other regions there is substantial diversion from the aggregate level. Moreover, four regions show significant lower unemployment rates during various sub-periods (Attica, Peloponnese, North Aegean and Crete), while there are other regions where the level of unemployment remains substantially above the national level (West Macedonia, Epirus and Sterea Ellada). Overall, the data on unemployment in Greece and across regions show first, the presence of a significantly high and persistent rate of national unemployment both on aggregate and across regions, and second that the inter-regional disparities in unemployment dynamics remain for long periods, with clear examples the regions of West Macedonia and Epirus. Finally, the simple visual investigation supports the absence of a deterministic trend for the national and the 13 regional quarterly series.

[Figure 1 Here]

As a starting point we begin our analysis by testing the hysteresis hypothesis at the national level and for the 13 Greek regions using univariate unit root tests, without and with structural breaks, and continue by extending our analysis with the exploration of the behaviour of regional unemployment using several panel unit root tests that allow for the presence of cross sectional dependence and structural breaks across the 13 NUTS-II Greek regions.[8]

5.2.1 Univariate Unit Root Tests

Initially two conventional unit root tests are performed, the benchmark ADF test and the DF-GLS test (Elliott *et al.*, 1996). Table 3 reports the ADF and DF-GLS tests on the logarithm of the unemployment rate and its logistic transformation, at the national level (Greece) and for the 13 Greek regions.[9] The results clearly indicate that the null hypothesis of a unit root for both the logarithmic and the logistic transformations of unemployment rates cannot be rejected by the ADF test at the 5% level of significance for the national level and for all the 13 regional series. Similarly, the DF-GLS test shows that the unit root null hypothesis is neither rejected for Greece nor for the Greek regions, except for the South Aegean region. The results of the unit root tests, clearly indicate the support for the hysteresis hypothesis for the Greek data.

[Table 3 Here]

However, the development of the unemployment rates in Greece might suggest the existence of a structural break after the emergence of the crisis of 2008 and this needs further examination. Moreover, testing the unit root hypothesis under the presence of structural breaks entails two advantages. First, it increases the ability to reject a unit root when the stationary alternative is true. Second, it provides useful information to identify shocks that have affected unemployment in Greece.

Next, we implement the Lee and Strazicich's (2004) minimum LM test that allows for one level shift and the endogenous determination of the timing of the break.[10] The results in Table 4 (first four columns) show that in aggregate and at the level of the 13 regions, the unit root null hypothesis cannot be rejected, at 5% level of significance.[11] Therefore, the hysteresis hypothesis is confirmed for both Greece as a whole and for all 13 regions. The test suggests the existence of a break in the level of the series, both on aggregate and for the 13 regions, during the periods after the crisis of 2008. The timing of the break, except the case of Ionian Islands, is set between the third quarter of 2008 and the first quarter of 2010. Our findings are invariant to the different transformation (logarithmic and logistic) of the series used.

[Table 4 Here]

Finally, we employ a nonlinear unit root approach, the recently developed flexible Fourier unit root test of Enders and Lee (2012b) that accounts for multiple smooth breaks through the inclusion of a small number of low frequency components from a Fourier approximation (Table 4, last four columns). One main advantage of this F-DF type of test compared to the LM unit root test of Lee and Strazicich (2004) is that the F-DF test is able to capture the characteristics of one or more structural breaks in the series. The results in Table 4 (last four columns) support the previous evidence of the LM test with one structural break and show that in all series (both at aggregate and regional level) the unit root null hypothesis cannot be rejected, at 5% level of significance.[12] However, performing an *F*-test on the Fourier components, as presented in the sixth and eighth column of Table 4, we cannot reject the null hypothesis of a linear form in none of the series. Therefore, following Enders and Lee (2012b), we cannot support the nonlinear model of an unknown form with multiple smooth breaks and thus we rely the univariate results on the usual ADF type of test and the LM version of Lee and Strazicich (2004) that account for one level shift in the series.

To sum up, the univariate unit root results, using quarterly data, support the hypothesis of hysteresis for Greece, comforting the results provided by Apergis (2005) and more recently by Cheng *et al.* (2014), and confirming the evidence by Katsimi (2000) of a structural shift in the Greek unemployment rate.

5.2.2 Panel Unit Root Tests

We test for the hysteresis hypothesis by applying different panel unit root tests to the regional panel of the logistic and logarithmic transformation of the unemployment rate. We perform five tests based on the cross-sectional independence hypothesis (LLC, IPS, MW, CH and HAD).[13] The results from the independent panel unit root tests are reported in Table 5. The results provide evidence in favour of the hysteresis hypothesis for Greek unemployment, confirming the previous univariate evidence. Specifically, the LLC, IPS and MW panel tests soundly fail to reject the unit root null hypothesis. The only exception is the CH test that gives the opposite result of a rejection of the null hypothesis in the case of the logarithmic transformation of the data. The hysteresis hypothesis is also confirmed by the HAD stationarity test at the 5% level of significance but only in the homogeneous version of the test, while when we allow for heterogeneity in the sample the HAD test favours stationarity.

[Table 5 Here]

However, this evidence might not be reliable as these panel unit-root tests, which require cross-sectional independence, experience strong size distortions and restrictive power when the assumption of independence fails to hold (Banerjee *et al.*, 2004). Therefore, the null of cross-sectional independence is examined applying the Pesaran's (2004) CD test in Table 6. The null hypothesis of zero cross-sectional correlation among the panel members (Greek regions) is strongly rejected at the 1% level of significance, for the logistic and the logarithmic transformation of the unemployment data.

[Table 6 Here]

Panel unit root tests that that rely on cross-sectional dependence hypothesis among the Greek regions are presented in Table 7. The PES, MP, BNG and the MADF tests strongly reject the null hypothesis of a unit root at the 5% level of significance. The same conclusion is depicted by the stationarity panel test of HAK, which fails to reject the null of stationarity at the 5% level of significance in all cases except for the logistic transformation of unemployment. Overall, the results based on the panel unit root test that account for the cross-sectional dependence provide evidence to reject the null hypothesis of a unit root, contrary to the findings of the panel unit root tests based on the assumption of cross-sectional independence.

[Table 7 Here]

Nevertheless, one critical issue regarding panel based tests is that they are joint test of a unit root for all panel members and so a rejection of the joint null hypothesis could be attributed to a few stationary series (Karlsson and Lothgren, 2000). Furthermore, the rejection of the unit root hypothesis may be driven by the failure of the tests to allow for the presence of structural breaks in each cross-sectional region in the panel. Therefore, we extend our analysis by performing the recently introduced Im *et al.* (2005) panel LM test (ILT), that is an extension of the Lee and Strazicich's (2004) minimum LM test with one level shift, as well as the Im *et al.* (2010) test that allow for the presence of heterogeneous structural breaks (ILT*) and cross-sectional dependence in the data (ILT^*_{CA}).

In Table 8 we present the two versions of the panel LM test, that is with and without cross-sectional dependence, and perform the tests considering heterogeneous shifts in level.[14] The results show that in all cases, after taking into account the fact that regional unemployment rates in Greece are subject to a structural break in mean and both in mean and the slope of the series, the null hypothesis of a unit root is not rejected, indicating that the Greek regional unemployment series are not stationary with the presence of a structural break.[15] In summary, after taking into account structural changes in the regional Greek unemployment series, the hysteresis hypothesis remains to explain the behaviour of Greek unemployment rate.

[Table 8 Here]

5.3 Further Results using Annual Data

For a more complete picture of the behaviour of the Greek regional unemployment, we extend the analysis to annual data. Figure 2 plots the annual regional unemployment rate relative to the Greek national level. The visual investigation does not support the existence of a significant trend in the pattern of most of the annual series.

[Figure 2 Here]

Table 9 reports the ADF and DF-GLS tests on the logarithm of the unemployment rate and its logistic transformation, at national level (Greece) and for the 13 Greek regions using annual data. The results show that when we use annual data, the null hypothesis of a unit root cannot be rejected by the ADF test at the 5% level of significance for the national level and for 8 out of the 13 regional series, while the DF-GLS test suggests that the unit root null hypothesis is rejected only for 2 regions (Attica and North Aegean). Thus, the results of the unit root tests using annual data, partially support the hysteresis hypothesis for Greece.

[Table 9 Here]

Since the dimension of the annual data is relative short ($T = 31$), the conventional unit root tests exhibit low power with the presence of structural breaks. Therefore, as before, we proceed by applying the Lee and Strazicich's (2004) minimum LM test that allows for one level shift (Table 10, first four columns) as well as the flexible Fourier unit root test of Enders and Lee (2012b) that accounts for multiple smooth breaks (Table 10, last four columns). Accounting for structural breaks in the unemployment series, we provide evidence in favour of the hysteresis hypothesis for Greek unemployment, except for the North Aegean region when employing the F-DF test.[16] These results are in line with the univariate evidence on quarterly data.

[Table 10 Here]

Finally, we apply the two versions of the panel LM test, that is with and without cross-sectional dependence, to the regional panel of the logistic and logarithmic transformation of the annual unemployment rate.[17] Table 11 reports the results from the two versions of the panel LM test. Assuming cross-sectional independence and employing the Im *et al.* (2005) test, the null hypothesis of a unit root at the conventional level of significance is rejected. However, the tests of Im *et al.* (2010) clearly show that the null hypothesis of a unit root is not rejected at the 5% level of significance, in the version with and without cross-sectional dependence, providing qualitatively similar results with those obtained using quarterly data.

[Table 11 Here]

In short, our empirical findings, using quarterly and annual data, are in line with earlier studies, based on univariate and traditional panel unit root tests, that have found evidence for a high degree of unemployment persistence in Greece (Lee, 2010; Lolos and Papapetrou, 2012; Cheng *et al.*, 2014) and highlight the importance that policy making could have on unemployment.

6 Conclusions

This paper studies the behaviour of regional unemployment across the 13 NUTS-II regions in Greece employing quarterly and annual data. The paper applies a variety of univariate as well as panel unit root tests and particularly the recently introduced estimation method – the panel LM unit root tests with heterogeneous structural breaks as developed by Im *et al.* (2010), to assess whether regional unemployment rates are subject to hysteresis behaviour. Our results present evidence in favour of the hysteresis hypothesis for Greece's unemployment rate, while this evidence becomes weaker when we turn our analysis in the panel of the 13 Greek regions. The empirical results based on panel unit root tests that account for the cross-sectional dependence and controlling for the fact that regional unemployment rates of Greece are subject to a structural break, shows that the null hypothesis of a unit root is not rejected, indicating that the Greek regional unemployment series are not stationary with the presence of a structural break. This is very important from a policy point of view as our findings suggest that structural breaks should be taken into account when considering general models that relate unemployment to other macroeconomic variables, at the national and regional level in Greece.

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Notes

1. For an extensive discussion on various features of the Greek labour market, see *inter alia* Papapetrou (2006).
2. Baltagi *et al.* (2007) by considering spatial dependence across the panels as an alternative way of capturing cross-section dependence, show that the PES test has good size and power properties if the spatial correlation is not very high.
3. The quarterly analysis is restricted to this period, as quarterly data for unemployment prior to 1998 are not available.
4. The national unemployment rate for Greece is abbreviated as GR, while for the 13 NUTS-II regions as follows: East Macedonia and Thrace (EMT), Central Macedonia (CM), West Macedonia (WM), Epirus (EPI), Thessaly (THE), Ionian Islands (ION), West Greece (WG), Sterea Ellada (STE), Attica (ATT), Peloponnese (PEL), North Aegean (NA), South Aegean (SA), Crete (CRE).
5. We thank an anonymous referee for this suggestion.
6. The quarterly unemployment rate series are seasonally adjusted.
7. Since unemployment rate is a variable bounded between 0 and 1, the conventional unit root tests are potentially unreliable in the presence of bounds (Cavaliere and Xu, 2014). Thus, following the suggestion of Wallis (1987) we employ the logistic transformation for the unemployment rate.
8. Since the visual inspection of the data does not support the presence of a trend, we rely our analysis on the versions of the tests without a deterministic trend.
9. The lag order of the tests is selected using the Schwert information criterion (SIC), setting the maximum length of lags (k_{max}) according to the Schwert's principle. All tests are based on a specification of the test equation with drift at the 5% level of significance.
10. We employed the Lagrange Multiplier unit root test by Lee and Strazicich's (2004) that allows for one level shift and endogenous determination of the time of the break. We do not proceed to the two-breaks version of the test by Lee and Strazicich's (2003) due to the short dimension of our regional data.
11. We report the LM test with one break where the lag order of the tests is in accordance with the ADF lag length, as chosen by SIC. We also perform the LM test where the lag order is selected using the recursive t-statistic procedure with an upper bound of $k_{max} = 2$. The results are qualitatively the same and are available upon request.
12. The F-DF test is performed by choosing the lag length in accordance with the ADF lag length, provided by SIC, and by imposing the Fourier frequency component equal to one. We also performed the Fourier DF test where the lag order is selected using the recursive t-statistic procedure and a grid-search for the optimal frequency. The results are qualitatively similar.
13. The lag order selection as well as the bandwidth parameters are chosen in accordance with the univariate analysis, by using the SIC criterion. All tests are based on a specification of the test equation with individual fixed effects at the 5% level of significance.
14. We employ the one-break version of the panel LM tests of Im *et al.* (2005) and Im *et al.* (2010). The lag order selection are chosen using the recursive t-statistic procedure with an upper bound of $k_{max} = 2$, similarly to the univariate analysis, and are quantitatively similar with those based on SIC.

15. Although it could be argued that the results of panel unit root tests can be further decomposed to separate stationary from non-stationary series in the panel, using recent panel selection methods, such as the sequential panel selection method (SPSM) proposed by Chortareas and Kapetanios (2009), our findings using panel unit root tests do not provide enough evidence to perform such an analysis. This is due to the fact that the SPSM procedure stops when unit-root null is not rejected and suggesting acceptance of the non-stationarity hypothesis for the panel.
16. Similarly with the quarterly data analysis, we cannot reject the null hypothesis of a linear form in none of the series, as provided in the sixth and eighth column of Table 10.
17. We have also employed, the first and second generation panel unit root tests with quantitatively similar results with those of the quarterly data.

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Tables and Figures

Table 1: Quarterly Unemployment Rate in Greece: National and Regional Level

	1998	2000	2002	2004	2006	2008	2010	2011
Greece	11.2	11.4	10.3	10.5	8.9	7.6	12.5	16.7
East Macedonia & Thrace	10.0	9.0	10.5	13.2	11.0	8.7	14.2	20.9
Central Macedonia	10.4	11.1	11.5	12.2	9.3	8.3	13.5	18.8
West Macedonia	12.9	15.1	15.0	16.6	14.2	12.5	15.5	23.3
Epirus	14.0	11.7	11.4	11.2	9.8	9.9	12.6	16.5
Thessaly	11.8	12.9	11.5	9.9	8.2	8.3	12.1	16.4
Ionian Islands	6.8	9.6	10.3	11.0	11.4	8.6	15.0	15.2
West Greece	11.9	10.7	10.7	12.5	9.5	9.6	11.7	16.2
Sterea Ellada	12.9	14.7	10.7	12.8	9.2	8.5	12.5	17.1
Attica	12.3	12.0	9.3	9.1	8.3	6.5	12.3	16.0
Peloponnese	8.0	9.7	8.2	9.1	7.7	7.1	9.9	13.0
North Aegean	11.2	7.4	9.8	9.3	9.4	4.5	9.1	13.4
South Aegean	10.3	11.7	15.1	9.1	8.9	7.6	15.2	14.9
Crete	8.6	7.5	8.7	7.6	7.0	6.3	12.0	14.5

Table 2: Summary Statistics: Quarterly Unemployment Rate

Variable	GR	EMT	CM	WM	EPI	THE	ION	WG	STE	ATT	PEL	NA	SA	CRE
Mean	10.414	11.205	10.990	15.050	11.850	10.799	10.339	10.808	11.735	9.965	8.618	8.708	11.191	8.050
Maximum	16.678	20.902	18.840	23.258	16.466	16.428	16.947	16.179	17.089	15.994	13.019	13.448	19.062	14.488
Minimum	7.421	8.459	8.254	11.672	9.382	7.316	6.368	8.764	8.375	6.173	6.804	4.072	5.432	4.300
Std. Dev.	1.792	2.294	1.990	2.373	1.606	2.117	2.308	1.517	2.252	2.252	1.175	2.253	2.816	2.006
Skewness	0.963	1.760	1.648	0.860	0.635	0.219	0.776	1.310	0.323	0.516	1.352	-0.079	0.621	1.134
Kurtosis	4.890	7.509	7.240	4.206	2.998	2.343	3.339	5.014	1.981	2.628	5.691	2.385	2.987	4.960
Jarque-Bera	16.388	73.642	64.894	9.926	3.626	1.403	5.685	24.567	3.277	2.706	32.736	0.906	3.475	20.217
Prob	0.000	0.000	0.000	0.007	0.163	0.496	0.058	0.000	0.194	0.258	0.000	0.636	0.176	0.000

Figure 1: *Quarterly Regional and National Unemployment Rate, 1998Q1 – 2011Q2.*

Table 3: ADF and DF-GLS Unit Root Tests

	Logarithmic(U_t)			*Logistic*(U_t)		
	ADF	*Prob*$_{ADF}$	*DF-GLS*	*ADF*	*Prob*$_{ADF}$	*DF-GLS*
Greece	-0.1450 (1)	0.938	-1.1804 (2)	-0.8244 (2)	0.803	-1.1381 (2)
East Macedonia & Thrace	-0.2463 (0)	0.925	-0.4282 (0)	-0.1027 (0)	0.943	-0.3014 (0)
Central Macedonia	-0.9307 (2)	0.770	-1.2388 (2)	-0.8485 (2)	0.796	-1.1775 (2)
West Macedonia	-1.4394 (1)	0.556	-1.5322 (1)	-1.3678 (1)	0.590	-1.4691 (1)
Epirus	-1.1677 (1)	0.681	-1.0586 (1)	-1.1309 (1)	0.696	-1.0433 (1)
Thessaly	-0.1284 (0)	0.940	-0.4126 (0)	-0.0851 (0)	0.945	-0.3832 (0)
Ionian Islands	-2.6154 (0)	0.096	-1.0740 (1)	-2.5857 (0)	0.102	-1.0727 (1)
West Greece	-1.3065 (0)	0.620	-1.4197 (0)	-1.2425 (0)	0.649	-1.3730 (0)
Sterea Ellada	-1.0007 (0)	0.746	-1.1179 (0)	-0.9659 (0)	0.758	-1.0922 (0)
Attica	-2.0117 (2)	0.281	-1.8620 (2)	-1.9562 (2)	0.304	-1.8311 (2)
Peloponnese	-0.4213 (0)	0.897	-0.5163 (0)	-0.3605 (0)	0.908	-0.4602 (0)
North Aegean	-2.2782 (1)	0.182	-1.7797 (1)	-2.2574 (1)	0.189	-1.7537 (1)
South Aegean	-2.5874 (0)	0.101	-2.3467*(0)	-2.5733 (0)	0.104	-2.3323*(0)
Crete	-1.0764 (0)	0.718	-1.2017 (0)	-1.0077 (0)	0.744	-1.1516 (0)

Notes: The numbers in parentheses refers to the lag length. The ADF *5%* critical value is *-2.92*. The DF-GLS *5%* critical value is *-1.95*. * indicates rejection of the null hypothesis at *5%* significance level.

Table 4: LM and Fourier DF Unit Root Tests

	LM Test				*Fourier DF Test*			
	Logarithmic(U_t)		*Logistic(U_t)*		*Logarithmic(U_t)*		*Logistic(U_t)*	
	LM statistic	*Break date*	*LM statistic*	*Break date*	τ_{DF}	$F(\hat{k})$	τ_{DF}	$F(\hat{k})$
Greece	-1.4245 (1)	2009:Q1	-1.7799 (2)	2009:Q1	-0.0068 (1)	3.4125	-0.6216 (2)	2.2091
East Macedonia & Thrace	-1.7553 (0)	2009:Q2	-1.7132 (0)	2009:Q2	-0.2973 (0)	0.8757	-0.1638 (0)	0.9421
Central Macedonia	-1.5500 (2)	2009:Q1	-1.5304 (2)	2009:Q1	-0.5016 (2)	2.1143	-0.3814 (2)	2.1599
West Macedonia	-1.4966 (1)	2009:Q4	-1.4786 (1)	2009:Q4	-0.4563 (1)	2.2594	-0.3368 (1)	2.2986
Epirus	-1.6109 (1)	2009:Q3	-1.5846 (1)	2009:Q3	-2.1906 (1)	3.2511	-2.1438 (1)	3.2094
Thessaly	-0.9616 (0)	2009:Q4	-0.9589 (0)	2009:Q4	-1.1213 (0)	7.5008	-1.0370 (0)	7.4209
Ionian Islands	-3.0753 (0)	2004:Q2	-3.0702 (0)	2004:Q2	-2.4561 (0)	0.3896	-2.4323 (0)	0.4012
West Greece	-2.2738 (0)	2010:Q1	-2.2320 (0)	2010:Q1	-1.6751 (0)	1.3904	-1.6084 (0)	1.3898
Sterea Ellada	-1.3715 (0)	2008:Q4	-1.3548 (0)	2008:Q4	-2.0072 (0)	3.8626	-1.9669 (0)	3.8726
Attica	-2.5002 (2)	2009:Q2	-2.4684 (2)	2009:Q2	-2.7664 (2)	3.1346	-2.6776 (2)	3.0323
Peloponnese	-1.5314 (0)	2010:Q1	-1.5166 (0)	2010:Q1	-0.5180 (0)	2.2829	-0.4531 (0)	2.3210
North Aegean	-2.5134 (1)	2009:Q4	-2.4932 (1)	2009:Q4	-2.3247 (1)	0.4250	-2.2996 (1)	0.4185
South Aegean	-2.5935 (0)	2008:Q3	-2.5782 (0)	2008:Q3	-3.2724 (0)	2.6116	-3.2517 (0)	2.5882
Crete	-2.1151 (0)	2008:Q3	-2.0841 (0)	2008:Q3	-1.6183 (0)	1.6193	-1.5581 (0)	1.6304

Notes: The numbers in parentheses refers to the lag length. The number of frequency k is fixed to 1. The *5%* critical value for the *LM statistic* is *-3.57*. The *5%* critical value for τ_{DF} is *-3.81* and for $F(\hat{k})$ is *7.58*. * indicates rejection of the null hypothesis at *5%* significance level.

Table 5: First Generation Panel Unit Root Tests

	Logarithmic(U_t)		*Logistic(U_t)*	
	Statistic	*Prob*	*Statistic*	*Prob*
Null: Unit Root				
LLC	1.200	0.885	1.394	0.918
IPS	0.809	0.791	1.039	0.850
MW	20.422	0.771	19.507	0.814
CH	-1.772*	0.038	-1.554	0.060
Null: Stationarity				
HAD_{HOM}	1.817*	0.034	1.807*	0.035
HAD_{HET}	1.526	0.063	1.516	0.064

Notes: * indicates rejection of the null hypothesis at *5%* significance level.

Table 6: Cross-Sectional Dependence Test

	Logarithmic(U_t)	*Logistic(U_t)*
CD Test	36.27*	36.43*
Prob	0.000	0.000
Corr	0.559	0.561

Notes: * indicates rejection of the null hypothesis at *5%* significance level.

Table 7: Second Generation Panel Unit Root Tests

	Logarithmic(U_t)		*Logistic*(U_t)	
	Statistic	*Prob*	*Statistic*	*Prob*
Null: Unit Root				
PES	-2.851*	0.000	-2.844*	0.000
$MP_{t(a)}$	-18.240*	0.000	-18.041*	0.000
$MP_{t(b)}$	-6.691*	0.000	-6.612*	0.000
BNG_P	2.175*	0.014	2.164*	0.015
BNG_Z	41.690*	0.026	41.608*	0.026
MADF	98.800*	77.223†	98.280*	77.818†
Null: Stationarity				
$HAK_{Z_{SPC}}$	-0.676	0.750	-0.646	0.741
$HAK_{Z_{LA}}$	1.548	0.060	1.666*	0.047

Notes: * indicates rejection of the null hypothesis at 5% significance level. † indicates the 5% critical value for the MADF panel unit root test.

Table 8: Panel LM Test with One Structural Break

	Logarithmic(U_t)	*Logistic*(U_t)
C-S Independence		
ILT	-0.054	0.061
ILT*	2.116	2.428
C-S Dependence		
ILT^*_{CA}	3.576	4.301

Notes: * indicates rejection of the null hypothesis at 5% significance level, the 5% critical value for the panel unit root test is *-1.645*.

Figure 2: *Annual Regional and National Unemployment Rate, 1981 – 2011.*

Table 9: ADF and DF-GLS Unit Root Tests: Annual Data

	Logarithmic(U_t)			*Logistic(U_t)*		
	ADF	*$Prob_{ADF}$*	*DF-GLS*	*ADF*	*$Prob_{ADF}$*	*DF-GLS*
Greece	-1.0835 (1)	0.709	-0.1671 (1)	-1.0171 (1)	0.734	-0.1496 (1)
East Macedonia & Thrace	-3.3627* (0)	0.021	-1.0325 (0)	-3.0839* (0)	0.039	-0.9555 (0)
Central Macedonia	-0.1979 (1)	0.928	-0.6127 (0)	-0.1345 (1)	0.936	0.4196 (1)
West Macedonia	-1.6253 (0)	0.458	-1.2144 (0)	-1.5612 (0)	0.490	-1.1578 (0)
Epirus	-2.6788 (0)	0.089	-1.4801 (0)	-2.5919 (0)	0.106	-1.4465 (0)
Thessaly	-2.1516 (1)	0.227	-0.5964 (1)	-2.0587 (1)	0.262	-0.5958 (1)
Ionian Islands	-0.5078 (1)	0.876	0.2972 (1)	-0.4423 (1)	0.889	0.3322 (1)
West Greece	-3.3428* (0)	0.022	-0.9268 (0)	-3.1418* (0)	0.034	-0.8801 (0)
Sterea Ellada	-2.3429 (0)	0.166	-1.1352 (0)	-2.2563 (0)	0.192	-1.1224 (0)
Attica	-3.1718* (1)	0.032	-2.1112* (1)	-3.1477* (1)	0.034	-2.1203* (1)
Peloponnese	-3.5250* (0)	0.014	-0.8138 (0)	-3.3184* (0)	0.023	-0.7663 (0)
North Aegean	-3.6767* (0)	0.010	-2.9682* (0)	-3.6227* (0)	0.011	-2.9535* (0)
South Aegean	-1.8373 (0)	0.356	-1.2513 (0)	-1.7988 (0)	0.374	-1.2431 (0)
Crete	-1.8305 (0)	0.359	-1.2017 (0)	-1.7348 (0)	0.404	-0.9686 (0)

Notes: The numbers in parentheses refers to the lag length. The ADF *5%* critical value is *-2.96*. The DF-GLS *5%* critical value is *-1.95*. * indicates rejection of the null hypothesis at *5%* significance level.

Table 10: LM and Fourier DF Unit Root Tests: Annual Data

	LM Test				*Fourier DF Test*			
	Logarithmic(U_t)		*Logistic(U_t)*		*Logarithmic(U_t)*		*Logistic(U_t)*	
	LM statistic	*Break date*	*LM statistic*	*Break date*	τ_{DF}	$F(\hat{k})$	τ_{DF}	$F(\hat{k})$
Greece	-2.7961 (1)	1986	-2.8488 (1)	1986	-0.9631 (1)	0.2618	-0.8593 (1)	0.2609
East Macedonia & Thrace	-1.7722 (0)	2008	-1.7666 (0)	2008	-3.3890 (0)	1.4366	-3.0550 (0)	1.2663
Central Macedonia	-2.8203 (1)	1986	-2.8339 (1)	1986	-0.0635 (1)	0.0270	0.0551 (1)	0.0507
West Macedonia	-2.7852 (0)	1989	-2.7433 (0)	1989	-2.0230 (0)	0.9365	-1.9173 (0)	0.8330
Epirus	-2.7907 (0)	1999	-2.7731 (0)	1999	-3.5844 (0)	2.7020	-3.4467 (0)	2.5169
Thessaly	-2.2947 (1)	1991	-2.3488 (1)	1991	-2.1691 (1)	0.7178	-2.0555 (1)	0.6723
Ionian Islands	-3.3340 (1)	2009	-3.3634 (1)	2009	-2.0104 (1)	2.0721	-1.9131 (1)	1.9277
West Greece	-1.4653 (0)	1999	-1.4747 (0)	1999	-2.5864 (0)	0.2613	-2.3620 (0)	0.2250
Sterea Ellada	-1.9513 (0)	2001	-1.9690 (0)	2001	-2.0409 (0)	0.3124	-1.9355 (0)	0.2703
Attica	-2.0240 (1)	1987	-2.0493 (1)	1987	-3.0788 (1)	0.9007	-3.0159 (1)	0.8227
Peloponnese	-1.4087 (0)	2008	-1.4175 (0)	2008	-3.0809 (0)	0.9371	-2.8474 (0)	0.8523
North Aegean	-3.4281 (0)	2008	-3.4066 (0)	2008	-4.0116* (0)	1.3577	-3.9532* (0)	1.3391
South Aegean	-2.6610 (0)	1990	-2.6553 (0)	1990	-2.8459 (0)	2.3033	-2.7885 (0)	2.2257
Crete	-2.5538 (0)	2008	-2.5186 (0)	2008	-2.2155 (0)	1.0618	-2.0936 (0)	0.9921

Notes: The numbers in parentheses refers to the lag length. The number of frequency k is fixed to 1. The *5%* critical value for the *LM statistic* is *-3.57*. The *5%* critical value for τ_{DF} is *-3.81* and for $F(\hat{k})$ is *7.58*. * indicates rejection of the null hypothesis at *5%* significance level.

Table 11: Panel LM Test with One Structural Break: Annual Data

	Logarithmic(U_t)	*Logistic(U_t)*
C-S Independence		
ILT	-3.425*	-3.409*
ILT*	-1.455	-1.491
C-S Dependence		
ILT^{*}_{CA}	3.797	3.893

Notes: * indicates rejection of the null hypothesis at *5%* significance level, the *5%* critical value for the panel unit root test is *-1.645*.