Centre of Excellence
for Science and Innovation Studies

CESIS Electronic Working Paper Series

Paper No. 435

Are Unemployment Rates in OECD Countries Stationary? Evidence from Univariate and Panel Unit Root Tests

Naceur Khraief
Muhammad Shahbaz
Almas Heshmati
Muhammad Azam

April, 2016

The Royal Institute of technology
Centre of Excellence for Science and Innovation Studies (CESIS)
http://www.cesis.se

Are Unemployment Rates in OECD Countries Stationary? Evidence from Univariate and Panel Unit Root Tests

Naceur Khraief
Faculty of Economic Science and Management of Sousse,
University of Sousse, Tunisia, and
GREDEG (Research Group on Law Economics and Management)
University of Nice Sophia Antipolis, France,
E-mail: nkhraief@gmail.com

Muhammad Shahbaz
Department of Management Sciences,
COMSATS Institute of Information Technology,
Lahore, Pakistan. E-mail: shahbazmohd@live.com

Almas Heshmati
Jönköping International Business School (JIBS),
Centre of Excellence for Science and Innovation Studies (CESIS),
and Department of Economics, Sogang University, Seoul, South Korea,
E-mail: almas.heshmati@gmail.com

Muhammad Azam
School of Economics, Finance & Banking,
College of Business, Universiti Utara Malaysia.
E-mail: drazam75@yahoo.com

Abstract: This paper revisits the dynamics of unemployment rate for 29 OECD countries over the period of 1980-2013. Numerous empirical studies of the dynamics of unemployment rate are carried out within a linear framework. However, unemployment rate can show nonlinear behaviour as a result of business cycles or some idiosyncratic factors specific to labour market (Cancelo, 2007). Thus, as a testing strategy we first perform Harvey et al. (2008) linearity unit root test and then apply the newly ESTAR nonlinear unit root test suggested by Kruse (2011). This test has higher power than conventional unit root tests when time series exhibits nonlinear behaviour. Our empirical findings provide significant evidence in favour of unemployment rate stationarity for 25 countries. For robustness purpose, we have also used panel unit root tests without and with structural breaks. The results show that unemployment hysteresis hypothesis is strongly rejected when taking into account the cross-sectional and structural break assumptions. Thus, unemployment rates are expected to return back to their natural levels without executing any costly macroeconomic labour market policies by the OECD's governments.

Keywords: Unemployment; Unit root; labour market policy; OECD
JEL Classification Codes: C23; E24; J48; J64; N30

Introduction

The empirical investigation of hypothesis of hysteresis in unemployment rate is the bone of great attention among academicians, policy makers and practitioners. The hypothesis is related to the relationship between changes in unemployment and its effect on the equilibrium level of unemployment. There are two economic theories providing theoretical and empirical discussions on unemployment behaviour. For example, hysteresis in unemployment hypothesis developed by Blanchard and Summers (1986a) reveal that any changes in actual unemployment will have permanent effect on the equilibrium level of unemployment i.e. unemployment rate contains random walk process (Furuoka, 2014)[1]. In such situation, equilibrium unemployment rate depends on the path and actual unemployment rate that moves around equilibrium path slowly (Blanchard and Summers, 1986b). Secondly, it is argued by Phelps (1967) and Friedman (1968) that technological development, monetary policy changes, human resource development, and macroeconomic changes in an economy affect unemployment but keep the actual unemployment rate around equilibrium level of unemployment. This shows that unemployment rate contains a stationary process which indicates that equilibrium level of unemployment is determined by actual unemployment rate in previous periods (Blanchard and Summers, 1986a).

There is another concept termed as "persistence" in unemployment rate. A primary difference between hysteresis and persistence in unemployment rate reveals that slow speed of adjustment process towards long-run equilibrium path indicates the mean reversion of unemployment series after all. It is also called a special case of non-accelerating rate of unemployment (NAIRU). This slow speed of adjustment towards long-run equilibrium unemployment is due to introduction of wage-rigidity via efficiency wage as well as union behaviour models (Tiwari, 2014). Statistically, it is termed as near non-stationary process and in such situation, macroeconomic policy will have temporary effects on unemployment and the effects on unemployment are permanent if hysteresis hypothesis applies (Tiwari, 2014). Using time series data, Brunello (1990) for Japan, Mitchell (1993) and Røed (1996) for OECD countries, Figueiredo (2010) for Brazil, and

---

[1] This hypothesis got empirical popularity due to high unemployment rate in Europe during 1980s.

Furuoka (2014) for South Korea accepted the presence of hysteresis unemployment hypothesis. On contrarily, rejection of hysteresis unemployment hypothesis is also validated using panel data by Camarero and Tamarit (2004) and Ener and Arica (2011) for OECD countries, Chang et al. (2005) for Central and Eastern Europe, and Lee et al. (2010) for East Asian countries, etc[2].

The main purpose of this paper is to re-examine the dynamics of unemployment rate for 29 countries from OECD over the period between 1980 and 2013. The outcomes are expected to guide the policy makers of OECD countries whether they should avoid to execute or pursue costly macroeconomic stabilization polices. This paper contributes to the existing applied economics literature by five folds: (i) This paper revisits the dynamics of unemployment rates for OECD countries by applying Harvey et al. (2008) linearity test, (ii) The ESTAR nonlinear unit root test developed by Kruse (2011) is employed for testing the unit root properties of unemployment rate, (iii) The robustness of unit root analysis is tested by Lee and Strazicich (2003) unit root test with single and double unknown structural breaks, (iv) The cross-sectional dependence as well as panel unit root tests have been applied for testing either unemployment rate contains random walk process or not in the panel, and (v) The robustness of panel unit root analysis is validated by applying panel unit root by accommodating structural breaks. Our results show that the unemployment hysteresis hypothesis is rejected and unemployment rate contains stationary process.

Rest of the study is organized as follows. Section II reviews the literature on unemployment stationarity. Section III presents the econometric methodologies used. The data and empirical results are discussed in Section IV. The final Section V provides summary of the results and policy recommendations.

II. Literature Review

Numerous studies investigated the unit root properties of unemployment in case of OECD countries. Availability of data and rich labour market policies explains the large

[2] Yoon (2009) showed the presence of linearity in the US unemployment rate.

number OECD based studies. For example, Mitchell (1993) started the empirical discussion for testing unit root properties of unemployment rate by applying the Perron's (1989) unit root test. The empirical results confirmed the presence of unemployment hysteresis hypothesis in OECD labour market[3]. Røed (1996) used data of 16 OECD countries for testing the presence of unemployment hysteresis hypothesis and found that unemployment hysteresis hypothesis is strongly confirmed in Australia but rejected in the USA[4]. Song and Wu (1998) applied the ADF and PP unit root tests to re-examine the stationary properties of unemployment rate using data of 15 OECD countries. They found that unemployment rate contains unit root problem which forces to reject the hypothesis of unemployment hysteresis. Arestis and Mariscal (1999) employed the Clemente et al. (1998) unit root test by accommodating the single and double unknown structural breaks in the series. They found that unemployment rate contains stationary process at level in the presence of structural breaks. This favours to reject the hypothesis of unemployment hysteresis[5]. Later on, Arestis and Mariscal (2000) applied Perron's (1997) unit root test and rejected the hypothesis of unemployment hysteresis[6]. Everaet (2001) also used the ADF and KPSS unit root tests to corroborate the existence of unemployment hysteresis hypothesis in OECD countries and found that unemployment rate is stationary process but contains unit root problem in the presence of infrequent level-shifts. Camarero and Tamarit (2004) tested the validation of the unemployment hysteresis hypothesis in 19 OECD countries. They applied SURADF panel unit root test and found that unemployment hysteresis hypothesis is present in 7 out of 19 countries. Camarero et al. (2006) revisited the unit root properties of unemployment rate in 19 OECD countries by applying the unit root tests with and without structural breaks. They found that in the presence of cross-dependence and structural breaks, unemployment hysteresis hypothesis is rejected which implies that shock affects unemployment rate but temporarily.

Yilanci (2008) applied the linear and non-linear unit root tests developed by Kapetanios et al. (2003) to examine the stationary properties of unemployment in 17 OECD

[3] Elmskov and MacFarlan (1993) also presented the channels comprehensively on how labor markets are affected by macroeconomic shocks.

[4] Røed (2002) confirmed the presence of unemployment hysteresis in 10 OECD countries.

[5] Fève et al. (1999) also validated the presence of wage hysteresis for OECD countries.

[6] Australia, Belgium, Canada, Denmark, Finland, Germany, Luxemburg, Switzerland and the UK.

countries. The results of ADF unit root test leads to accept the hypothesis of unemployment hysteresis i.e. unemployment contains random walk process. After knowing the presence of non-linearity in unemployment, KSS unit root test is employed and found that results support to accept unemployment hysteresis hypothesis. This concludes that unemployment rate contains unit root process. Lee and Chang (2008) applied the LM unit root test developed by Lee and Strazicich (2004) to examine the presence of unemployment hysteresis hypothesis in 14 major OECD countries. The minimum LM unit root test is found suitable for investigating the unit root properties of unemployment in the presence of single unknown structural break in the series. Their results indicated that unemployment rate is stationary at level in the presence of single unknown structural break. This indicates the rejection of unemployment hysteresis hypothesis i.e. economic shocks have permanent effect on labour markets in OECD countries. Lee et al. (2009) tested the validation of hypothesis of unemployment hysteresis by applying the LM unit root test in the presence of heterogeneous structural breaks developed by Im et al. (2005). Their empirical evidence favours to reject the hypothesis of unemployment hysteresis and indicates that economic shocks occurring in labour market have temporary impact on unemployment rates in OECD countries. Lee, (2010) used the nonlinear heterogeneous panels to re-examine the unit root properties of unemployment rate in 29 OECD countries. The nonlinear unit root test developed by Ucar and Omay (2009) is applied for empirical purpose. The empirical results show that null hypothesis of unemployment rate hysteresis is rejected which indicates that unemployment rate contains stationary process at level.

Fosten and Ghashray (2011) used the regime switching unit root test developed by Leybourne et al. (2007) in examining the unit root properties of unemployment rate in OECD countries[7]. Leybourne et al. (2007) argued that regime switching such as World War I and Great Depression may cause of unit root problem in unemployment rates. Based on the empirical analysis, Fosten and Ghashray (2011) noted that hypothesis of unemployment hysteresis is validated after World War I and Great Depression due to

[7] Chang and Lee (2011) applied the threshold unit root test developed by Caner and Hansen (2001) to revisit the hypothesis of unemployment hysteresis in case of Canada, France, Germany, Italy, Japan, UK and US. They found that hysteresis in unemployment is present for France, Germany and Italy.

strong labour unions corroborating the findings of Blanchard and Summers (1986b). Huang (2011) employed the Nybolm and Harvey (2000) unit root test to re-examine the presence of "hysteresis in unemployment". His findings indicate the presence of non-stationarity in OECD countries i.e. validating the presence of hypothesis of unemployment hysteresis.

Liew et al. (2012) revisited the unemployment hysteresis hypothesis by applying parametric and non-parametric panel unit root tests in OECD countries. Their empirical evidence is in favour of accepting the unemployment hysteresis hypothesis in most of the OECD countries once country-level analysis is conducted[8]. They argued that cross-country labour market independence should be incorporated while testing the unemployment hysteresis hypothesis. Using panel unit root tests, they found the rejection of the unemployment hysteresis hypothesis in OECD countries. This shows that labour market institutions as well as stabilization in economic policies have played their important role to maintain unemployment at sustainable level in OECD countries. The quintile unit root test developed by Galvao (2009) is applied by Lee et al. (2013) to validate the hypothesis of unemployment hysteresis after knowing about asymmetries in unemployment rate in OECD countries. They exposed that unemployment rate contains stationary process. Using data of PIIGS (Portugal, Ireland, Italy, Greece and Spain), Cheng et al. (2014) tested the stationary properties of unemployment rates by applying Flexible Fourier unit root test developed by Enders and Lee (2012). Their results favoured to accept the hypothesis of "hysteresis in unemployment"[9]. A summary of the different test results found in the literature is presented in Appendix A.

III. Econometric Methodologies

[8] Using state-level data, Liu et al. (2012) reported that unemployment hysteresis hypothesis is accepted in Australia.

[9] Furuoka (2014) examined whether hypothesis of hysteresis in unemployment exists or not in case of Asia-Pacific countries by applying Fourier ADF unit root test. The empirical results indicated that unemployment rate contains stationary process for South Korea, Australia and Hong Kong but in China and Japan unemployment rate contains unit root problem.

This section presents econometric methodologies used involving individual and panel unit root tests. The first group include weighted tests for linearity/non-linearity applied to processes of different integration orders with structural breaks and functional forms. The second group include the first and second generations of panel unit root tests aimed at increasing the power of the univariate unit root tests. They differ by their treatment of cross-sectional dependency and ignore presence of structural breaks. This is accounted for in several augmented alternative tests.

III.I Individual unit root tests

Prior to the application of individual unit root tests, we begin by testing the null hypothesis of linearity against a nonlinear alternative. The linearity test can be applied to decide which of the unit root tests (linear or nonlinear) should be employed to check if the series is stationary. We utilize a recently introduced linearity test proposed by Harvey et al. (2008) which can be applied either to I(0) or I(1) processes. Moreover, when the order of integration is unknown, this test has superior finite sample size and power proprieties to Harvey and Leybourne (2007) linearity test. If the integration of series is unknown, Harvey et al. (2008) suggest constructing a weighted average Wald test statistic which can be written as follows:

$$W_\lambda = (1-\lambda)W_0 + \lambda W_1 \underset{d}{\rightarrow} \chi^2(2) \qquad (1)$$

where W_0 and W_1 denote the Wald tests when the variable is I(0) and I(1), respectively. Both tests follow the standard $\chi^2(2)$ distribution. λ is a some function that converges in probability to 1 when the variable is I(1) and to 0 when the process is I(0). According to Harvey et al. (2008), a suitable function must be chosen for λ. Thus, the authors suggested the following functional form:

$$\lambda(U,S) = exp\left(-g\left(\frac{U}{S}\right)^2\right) \qquad (2)$$

where g is some finite positive constant which has no effect on the asymptotic proprieties ofW_λ. U and S denote appropriately chosen unit root and stationarity statistics. Harvey et al. (2008) propose to use the standard Dickey-Fuller unit root statistic for U and the nonparametric stationarity statistic of Harris et al. (2003) for S. When the time series is stationary, $\left(\frac{U}{S}\right)^2$diverges and λ converges to zero, and when the time series is unit root, $\left(\frac{U}{S}\right)^2$ converges to zero resulting in λ converging to 1.

When the data generating process exhibit non-linearity, the linear unit root tests (ADF, Phillips-Perron and KPSS) may not possess good power, i.e. they tend to over accept the unit root null hypothesis. To address this concern, we perform the nonlinear unit root test recently developed by Kruse (2011). This test is based on the Kapetanios et al. (2003) approach for testing the unit root hypothesis against the alternative of a globally stationary exponential smooth transition autoregression (ESTAR) model:

$$y_t = \beta y_{t-1} + \emptyset y_{t-1} F(\theta; y_{t-1}) + \varepsilon_t \qquad (3)$$

where ε_t is $iid(0, \sigma^2)$ and $F(\theta; y_{t-1})$ is the transition function which has an exponential form:

$$F(\theta; y_{t-1}) = 1 - exp\{-\theta(y_{t-1} - c)^2\} \qquad (4)$$

with $\theta \geq 0$. The transition function, which exists between zero and one, is symmetrically U-shaped around zero. Kapetanios et al. (2003) show that the ESTAR model, under the restriction$\beta = 0$, is globally stationary if $-2 < \emptyset < 0$ is satisfied even though it is locally nonstationary in $y_{t-1} = c$. The authors assume that $c = 0$ and propose the following model:

$$\Delta y_t = \beta y_{t-1} + \emptyset y_{t-1}(1 - exp\{-\theta y_{t-1}^2\}) + \varepsilon_t \qquad (5)$$

In order to test the null hypothesis $H_0: \theta = 0$ versus the alternative $H_1: \theta > 0$, Kapetanios et al. (2003) impose the restriction $\beta = 0$. By applying a first-order Taylor approximation to the ESTAR model, around $\theta = 0$, an auxiliary regression can be obtained:

$$\Delta y_t = \delta_1 y_{t-1}^3 + \mu_t \qquad (6)$$

with μ_t being a noise term depending on ε_t, $\emptyset$ and the rest of the Taylor expansion. Kapetanios et al. (2003) suggested a Dickey-Fuller type t test, denoted as KSS, for unit root null hypothesis against globally stationary ESTAR which correspond to $H_0: \delta_1 = 0$ against the alternative $H_1: \delta_1 < 0$:

$$KSS \equiv \frac{\hat{\delta}_1}{\sqrt{v\hat{a}r(\hat{\delta}_1)}}$$

Kruse (2011) suggested that the zero location parameter c in the exponential transition function is too restrictive. Therefore, the author propose an extension of Kapetanios et al. (2003) unit root test by relaxing the zero restriction on c and considers the following modified ADF regression:

$$y_t = \beta y_{t-1} + \emptyset y_{t-1}(1 - exp\{-\theta(y_{t-1} - c)^2\}) + \varepsilon_t \qquad (7)$$

By applying the first-order Taylor approximation of the smooth transition function around $\theta = 0$, the regression model is written as follows:

$$\Delta y_t = \delta_1 y_{t-1}^3 + \delta_2 y_{t-1}^2 + \delta_3 y_{t-1} + \mu_t \qquad (8)$$

In order to improve the power of test, Kruse (2011) imposes $\delta_3 = 0$ and proceeds with:

$$\Delta y_t = \delta_1 y_{t-1}^3 + \delta_2 y_{t-1}^2 + \mu_t \qquad (9)$$

where $\delta_1 = \theta\emptyset$ and $\delta_2 = -2c\theta\emptyset$. The null hypothesis $H_0: \delta_1 = \delta_2 = 0$ is tested against the alternative $H_1: \delta_1 < 0, \delta_2 \neq 0$. Kruse, (2011) suggested to employ the methods of Abadir and Distaso (2007) to derive a modify Wald test. This modified Wald test builds upon the one-sided parameter (δ_1) and the transformed two-sided parameter, say $\delta_2^{\perp}$, that are stochastically independent by definition.

Regarding the series that exhibits linear behaviour, we employ the LM unit root tests with structural breaks developed by Lee and Strazicich (2003). They suggested the following Data Generating Process (DGP):

$$y_t = \delta' Z_t + e_t, \; e_t = \beta e_{t-1} + \varepsilon_t \qquad (10)$$

And they defined the structural breaks models C and CC as follows:

1) The Model C which can be described by $Z_t = [1, t, D_t, DT_t]'$ where $DT_t = t - TB_t$ for $t \succ T_B + 1$, zero otherwise.

2) The Model CC that contains two changes in level and trend is described by $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$ where $DT_{jt} = t - TB_{jt}$ for $t \succ T_B + 1$, *j=1,2,* zero otherwise.

The LM unit root test statistic can be estimated by regression according to the LM (score) principle as follows:

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + u_t \qquad (11)$$

where $\tilde{S}_{t-1} = y_t - \tilde{\psi}_x - Z_t \tilde{\delta}, t = 2,...,T, \tilde{\delta}$ are coefficients in the regression of Δy_t on ΔZ_t, $\tilde{\psi}_x$ is given by $y_1 - Z_1 \tilde{\delta}$. The unit root null hypothesis is described by $\phi = 0$ and the LM test statistics are given by:

$$\tilde{\rho} = T.\tilde{\phi}$$

$\tilde{\tau} =$ t-statistic testing null hypothesis $\phi = 0$.

The minimum LM unit root test determines the break points TB_{jt} endogenously by using a grid search as follows:

$$LM_\rho = \underset{\lambda}{Inf}\ \tilde{\rho}(\lambda)$$

$$LM_\tau = \underset{\lambda}{Inf}\ \tilde{\tau}(\lambda)$$

where $\lambda = T_B / T$. The break points are determined to be where the test statistic is minimized. In order to eliminate the end points, we use the trimming region $(0.15T, 0.85T)$, where T is a sample size. The critical values for one break and two breaks are given by Lee and Strazicich (2003, 2013).

III.II Panel unit root tests

In order to increase power of univariate unit root test, we also use panel unit root tests. Which are separated into "first generation panel unit root tests" including LLC test (Levin et al., 2002), IPS test (Im et al., 2003), MW test (Maddala and Wu, 1999) and Choi test (Choi, 2001) and the "second generation panel unit root tests" containing MP test (Moon and Perron, 2004), Pesaran test (Pesaran, 2007) and Choi test (Choi, 2006). First generation tests do not allow for cross-sectional dependence between units; however, second generation tests take into account the cross sectional dependency. The first and second generation tests which do not allow for the structural breaks may suffer from significant loss of power if data display possible breaks. This is why we suggest using Lagrange Multiplier (LM) panel unit root test developed by Im, Lee and Tieslau (2005). The LLC test (Levin et al., 2002), which allows for *homogeneity* of the first order autoregressive parameters and the cross sectional independence between units, suggests the following adjusted t statistic:

$$t_{\rho}^{*} = \frac{t_{\rho}}{\sigma_T^{*}} - NT\hat{S}_N \left(\frac{\hat{\sigma}_{\hat{\rho}}}{\hat{\sigma}_{\hat{\varepsilon}}^{2}} \right) \left(\frac{\mu_T^{*}}{\sigma_T^{*}} \right) \tag{12}$$

where $\hat{S}_N$ denotes the average of individual ratios of long-run towards short-run variances for individual i. $\hat{\sigma}_{\hat{\rho}}$ and $\hat{\sigma}_{\hat{\varepsilon}}^{2}$ are respectively the standards deviations of slope coefficients and error term. The mean adjustment μ_T^{*} and standard deviation adjustment σ_T^{*} are tabulated by Levin, Lin, and Chu (2002, p. 14) for various periods T .

The IPS (Im, Pesaran and Shin, 2003) test which assumes *heterogeneity* of the first order autoregressive parameters employs a standardized t_bar statistic based on the limiting distribution of individual ADF statistics:

$$Z_{tbar}\left(p;\beta\right) = \frac{\sqrt{N}\left[t\_bar_{NT} - E\left(t_{iT}\right)\right]}{\sqrt{V\left(t_{iT}\right)}} \tag{13}$$

where $E(t_{iT})$ and $V\left(t_{iT}\right)$ are respectively the expected mean and variance of t_{iT} (the *t*-statistic).

The MW test (Maddala and Wu, 1999) which uses Fisher type test (1932) is based on combined p-values p_i or P_{MW}, from unit root test-statistics for each cross-sectional unit *i*. The MW test (Maddala and Wu, 1999) proposed the statistics as: $P_{MW} = -2\sum_{i=1}^{N} \ln\left(p_i\right)$ which has a χ^2 distribution with $2N$ degrees of freedom as $T \to \infty$ and N fixed. This test was suggested by Fisher (1932). In addition, Choi (2006) suggested the following standardized statistic:

$$MW = \frac{\sqrt{N}\left\{N^{-1}P_{MW} - E\left[-2\ln\left(p_i\right)\right]\right\}}{\sqrt{V\left[-2\ln\left(p_i\right)\right]}}. \qquad (14)$$

Under the null hypothesis as $T_i \to \infty$ and $T \to \infty$, $Z_{MW} \to N\left(0,1\right)$ (Hurlin, 2004). Concerning second-generation unit root tests, which assume cross sectional dependence between units, we used MP test (Moon and Perron, 2004), Pesaran test (Pesaran, 2007) and Choi test (Choi, 2006). Further, to take into account cross-sectional dependence assumption, Moon and Perron (2004) use an *AR(1)* model with common factors in error terms:

$$y_{i,t} = \left(1-\lambda_i\right)\mu_i + \lambda_i y_{i,t} + u_{i,t} \qquad (15)$$

$$u_{i,t} = \delta_i' F_t + e_{i,t}.$$

For $i = 1,...,N$ and $t = 1,...,T$. F_t is a $\left(k \times 1\right)$ vector of commons factors, δ_i is the coefficients vector corresponding to the common factors and $e_{i,t}$ is an idiosyncratic error term which is cross-sectionally uncorrelated and follows an infinite Moving Average (MA) process. The null hypothesis corresponds to the unit root hypothesis $\mathrm{H}_0 : \lambda_i = 1$ for $i = 1,...,N$ against the heterogeneous alternative hypothesis $\mathrm{H}_1 : \lambda_i < 1$ for some *i*. For testing, the data are de-factored and then the panel unit root test statistics based on de-factored data are proposed.

To construct a unit root test, Moon and Perron (2004) considered the factors as nuisance parameters and developed two t-statistics, which are based on a pooled de-factored series. Specifically, if we let $\hat{\lambda}^*$ denote pooled least squares estimate of λ using the de-factored data, Moon and Perron (2004) suggest that the following two statistics can be used:

$$t_a^* = \frac{\sqrt{N}T\left(\hat{\lambda}^* - 1\right)}{\sqrt{\frac{2\hat{\varphi}_e^4}{\hat{\omega}_e^4}}} \xrightarrow[T,N\to\infty]{} N\left(0,1\right) \tag{16}$$

$$t_b^* = \sqrt{N}T\left(\hat{\lambda}^* - 1\right)\sqrt{\tfrac{1}{NT^2} tr\left(Y_{t-1}Q_{\hat{\Delta}}Y_{t-1}'\right)}\left(\frac{\hat{\omega}_e}{\hat{\varphi}_e^2}\right) \xrightarrow[T,N\to\infty]{} N\left(0,1\right) \tag{17}$$

where $\hat{\varphi}_e^4$ denotes cross-sectional average of $\hat{\omega}_e^4$. The statistics t_α^* and t_b^* are based on an estimator of projection matrix and estimators of long-run variances $\hat{\varphi}_e^2$. In Pesaran's test (2007), the author suggests to augment the cross-sectional unit $ADF\left(p_i\right)$ regressions by cross-sectional means of lagged levels and first-differences of the individual time series. The cross-sectionally augmented *ADF* regressions are given by:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + c_i\left[\left(1/N\right)\sum_{i=1}^{N} y_{i,t-1}\right] + d_i\left[\left(1/N\right)\sum_{i=1}^{N}\Delta y_{i,t}\right] + \varepsilon_{i,t} \tag{18}$$

Pesaran (2007) suggested the following truncated test statistics which is denoted as a *Cross-Sectional Augmented IPS (CIPS)*:

$$CIPS\left(N,T\right) = \frac{1}{N}\sum_{i=1}^{N} t_i\left(N,T\right) \tag{19}$$

where $t_i\left(N,T\right)$ the t-statistic of the OLS estimates of is ρ_i (denoted as CADF). The Pesaran test statistic is the modified IPS statistics based on average of individual CADF. The next panel unit root test is the Choi, (2006) test which combines p-values of Augmented Dickey-Fuller univariate tests. In first step, the panel unit root tests of Choi, (2006) use Elliott et al. (1996) GLS de-trending, to eliminate the cross-sectional correlations and controlling for the deterministic trends. In second step, meta-analytic panel tests are used. Choi (2006) assumes the following two-way error-component model:

$$y_{i,t} = \alpha_i + \theta_t + u_{i,t} \tag{20}$$

$$u_{i,t} = \sum_{j=1}^{p_i} d_{i,j} u_{i,t-1} + \varepsilon_{i,\mathrm{t}}$$

where $\varepsilon_{i,\mathrm{t}}$ is i.i.d$\left(0, \sigma_{\varepsilon_i}^2\right)$. Then, after having obtained the p-values of t-statistics, Choi (2006) combined these into panel test (Fisher's type) statistics as follows:

$$P_m = -\frac{1}{\sqrt{N}} \sum_{i=1}^{N} \left[\ln\left(p_i\right) + 1\right] \xrightarrow[T,N\to\infty]{} N\left(0,1\right) \tag{21}$$

$$Z = -\frac{1}{\sqrt{N}} \sum_{i=1}^{N} \phi^{-1}\left(p_i\right) \xrightarrow[T,N\to\infty]{} N\left(0,1\right) \tag{22}$$

$$L^* = -\frac{1}{\sqrt{\pi^2 N/3}} \sum_{i=1}^{N} N \ln\left(\frac{p_i}{1-p_i}\right) \xrightarrow[T,N\to\infty]{} N\left(0,1\right) \tag{23}$$

where ϕ is the standard cumulative normal distribution function and p_i is the asymptotic p-values of the Dickey-Fuller-GLS statistic for country *i*.

The first and second generation tests don't allow for structural breaks and may suffer from significant loss of power if data display possible breaks. This is why we suggest using Lagrange Multiplier (LM) panel unit root test developed by Im, Lee and Tieslau (2005). Based on univariate LM statistic (Lee and Strazicich, 2003), Im, Lee and Tieslau (2005) suggested a panel LM t-statistic. Lee and Strazicich's model can be recalled as follows:

$$\Delta Y_{i,t} = \gamma_i' \Delta Z_{i,t} + \delta_i \hat{S}_{i,t-1} + \varepsilon_{i,t} \tag{24}$$

where, Δ is the first difference operator, $\hat{S}_{i,t-1}$ is detrended variable of $Y_{i,t-1}$ and $\varepsilon_{i,t}$ denotes error term. The t-statistic (denoted t^*) for the null hypothesis $H_0 : \delta_i = 0$ can be calculated for each unit in order to compute LM test statistic:

$$\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_i^* \tag{25}$$

This in turn can be used to determine the following standardized panel LM test statistic:

$$LM(\bar{t}) = \frac{\sqrt{N}\left(\bar{t} - E(\bar{t})\right)}{\sqrt{V(\bar{t})}} \tag{26}$$

Where $E(\bar{t})$ and $V(\bar{t})$ are tabulated by Im, Lee and Tieslau (2005).

IV. Data and Empirical Results

The World Economic Outlook database (International Monetary Fund, April 2014) was the source of data on the unemployment rates in 29 OECD countries over the period 1980-2013 and summary statistics of the data are reported (see Appendix). Spain and Switzerland have the highest and the lowest average employment rates, respectively. The unemployment rate tends to be more volatile for Ireland and Spain. Jarque-Bera statistics indicate that we reject the null hypothesis of normal distribution for Chile, Greece, Korea, Iceland Portugal and Turkey. This result is consistent with Skewness and Kurtosis statistics.

The issue being investigated is whether unemployment rate in OECD countries contains a unit root. Our empirical analysis begins by conducting the nonlinearity of time series in order to decide which unit root test we should run. If the time series were to follow a non-linear path over time, the standards unit root tests become powerless by over accepting the null hypothesis (Kapetanios et al. 2003; Kruse, 2011). To test the null hypothesis of linearity against the alternative nonlinear model we use the Harvey et al. (2008) test. This test has better size control and offers substantial power gains over Harvey and Leybourne

(2007) linearity test. When the linearity hypothesis is rejected, we apply the Kruse, (2001) nonlinear unit root test, which is an extension of Kapetanios et al. (KSS, 2003) one. This test has a main advantage that it improves the power and size of KSS test by relaxing the assumption of a zero location parameter in the smooth transition function.

Table 1: Linearity Test Results

Countries	Statistics	Prob. value	Result
Australia	7.616	0.107	Linear
Austria	2.718	0.606	Linear
Belgium	11.242	0.024	Non Linear
Canada	1.753	0.781	Linear
Chile	2.709	0.608	Linear
Denmark	10.248	0.036	Non Linear
Finland	6.538	0.162	Linear
France	2.264	0.687	Linear
Germany	3.515	0.476	Linear
Greece	13.715	0.008	Non Linear
Hungary	13.893	0.008	Non Linear
Iceland	4.991	0.288	Linear
Ireland	0.553	0.968	Linear
Israel	0.766	0.943	Linear
Italy	0.600	0.963	Linear
Japan	14.217	0.007	Non Linear
Korea	6.533	0.163	Linear
Luxembourg	2.881	0.578	Linear
Mexico	22.893	0.000	Non Linear
Netherlands	3.648	0.456	Linear
New Zealand	2.203	0.699	Linear
Norway	3.181	0.528	Linear
Portugal	1.162	0.884	Linear
Spain	12.887	0.012	Non Linear
Sweden	8.454	0.076	Non Linear
Switzerland	15.112	0.004	Non Linear
Turkey	18.879	0.001	Non Linear
United Kingdom	1.830	0.767	Linear
United States	11.142	0.025	Non Linear

Note: The 1%, 5%, and 10% critical values for Harvey et al. (2008)test are respectively 7.779, 9.488, and 13.277.

The result presented in Table 1 here show that the null hypothesis of linearity is rejected in 11 cases out of 29 OECD countries. Our finding is an interesting contrast to those in previous empirical studies that used the conventional linear unit root tests (see Cross, 1995; Neudorfer et al., 1990; and Røed 2002). We have carried out the Kruse (2011) test along with LM univariate linear unit root tests. When the linearity hypothesis is rejected, results from Kruse (2011) test of Table 2 provideno evidence for the hysteresis of the unemployment rates in Belgium, Denmark, Greece, Mexico, Switzerland, Turkey and United States. This indicates that unemployment rate contains stationarity process and transitory shocks to the unemployment rate have temporary effects in these economies.

Table 2: ESTAR Unit Root Test Results

Countries	KSS	Result
Belgium	-3.349	Stationary
Denmark	-4.294	Stationary
Greece	-3.111	Stationary
Hungary	-1.262	Non stationary
Japan	-2.417	Non stationary
Mexico	-7.536	Stationary
Spain	-2.316	Non stationary
Sweden	-2.367	Non stationary
Switzerland	-2.919	Stationary
Turkey	-3.554	Stationary
United States	-3.589	Stationary
Note: The 1%, 5%, and 10% critical values, for Kruse (2011) test, are respectively -3.48, -2.93, and -2.66.		

However, in Hungary, Japan, Spain and Sweden, the nonlinear unit root test rejects stationarity process which supports the strong evidence in favour of the hysteresis hypothesis. When we consider the LM unit root test with structural breaks, the unit root null hypothesis is rejected for all 18 countries that exhibit linear behaviour (Table 3), and then any shock to unemployment rate is likely to be transitory. These results support therefore natural rate hypothesis when structural break dummies are included in regressions. The LM unit root tests result showed that there are two significant break dates in the selected countries that exhibit linear behaviour.

Table 3: LM Univariate Unit Root Test Results

Country	LM univariate test without break (Schmidt and Phillips, 1992)	k	LM univariate test with one break (Model C)	k	TB	LM univariate test with two breaks (Model CC)	k	TB_1	TB_2	Result
Australia	-0.1608 (-2.0080)	1	-0.5450*** (-4.4502)	1	1996	-1.2804*** (-5.4236)	4	1997	2008	Stationary with break
Austria	-0.3826 (-2.7599)	0	-0.4752* (-3.3904)	0	1998	-1.1835*** (-5.6526)	3	1986	1994	Stationary with break
Canada	-0.2219 (-2.6791)	1	-0.4593*** (-4.2837)	1	1996	-0.4436*** (-5.2417)	1	1996	2008	Stationary with break
Chile	-0.3246** (-3.2517)	0	-0.4351*** (-4.6163)	0	1998	-0.4886*** (-5.2052)	3	1998	2008	Stationary
Finland	-0.1774* (-2.9725)	1	-0.4300*** (-4.8683)	1	1995	-0.8735*** (-7.0389)	1	1990	1996	Stationary
France	-0.1091 (-1.6721)	1	-0.6150** (-3.6542)	3	1998	-0.6995*** (-4.5913)	3	1993	2008	Stationary with break
Germany	-0.2190 (-2.5261)	1	-0.6647** (-3.8625)	4	2008	-1.3466*** (-6.5075)	4	1988	2003	Stationary with break
Iceland	-0.4303** (-3.1886)	1	-0.5730* (-3.5281)	1	2007	-1.7403*** (-7.7935)	3	1992	2007	Stationary
Ireland	-0.0767 (-1.9661)	2	-0.2257 (-2.8126)	2	1994	-1.4408*** (-4.6883)	4	1991	2001	Stationary with break
Israel	-0.2070 (-2.0804)	1	-0.6120** (-3.9196)	1	2005	-0.5952*** (-4.5782)	1	2000	2008	Stationary with break
Italy	-0.1015 (-1.8946)	1	-0.3570* (-3.4787)	1	2003	-0.9934*** (-6.2593)	4	1992	2004	Stationary with break
Korea	-0.2803 (-2.0827)	0	-0.6327** (-3.6407)	1	1992	-2.1961*** (-9.6969)	3	1996	2003	Stationary with break
Luxembourg	-0.2610 (-2.7533)	1	-0.4808*** (-4.4243)	2	2008	-0.5625*** (-4.9943)	2	2003	2008	Stationary with break
Netherlands	-0.0940 (-1.8309)	2	-0.2565** (-3.9757)	1	1995	-0.5851*** (-6.0283)	1	1987	1997	Stationary with break
New Zealand	-0.1901 (-2.0373)	1	-0.4627* (-3.3251)	1	1992	-1.5085*** (-8.2367)	3	1989	2004	Stationary with break
Norway	-0.1931 (-2.4340)	1	-0.5352*** (-4.8938)	1	1994	-0.6388*** (-5.9534)	1	1989	1995	Stationary with break
Portugal	-0.1845* (-3.0432)	2	-0.5970*** (-6.7717)	2	2003	-1.0810*** (-11.2904)	3	1987	2004	Stationary
United Kingdom	-0.1245 (-2.5462)	1	-0.2867* (-3.3916)	1	1996	-0.7246*** (-5.1861)	3	1986	2007	Stationary with break

Notes: Numbers in the parentheses are the optimal number of lagged first-differenced terms included in the unit root test to correct for serial correlation. The 1%, 5% and 10% critical values for the LM unit root test with no break are: −3.63, −3.06, and −2.77. The 1%, 5%, and 10% critical values for the minimum LM test with one break are: −4.239, −3.566, and −3.211. The 1%, 5%, and 10% critical values for the minimum LM test with two breaks are: −4.545, −3.842, and −3.504, respectively.

These dates are 1987-88, 1997-1998 and 2007-2008 which can be associated with three crisis events (Black Monday 1987, 1997 Asian Financial crisis, and 2007-2008 Global Financial crisis). Overall, our empirical findings provide significant support for unemployment rate stationarity process in 25 out of 29 countries, and therefore there is an absence of unemployment hysteresis hypothesis in these countries. Previous empirical studies have reached mixed conclusions about whether unemployment rate in OECD countries is stationary or contains unit root process. Our results are not in line with earlier findings about unemployment hysteresis in OECD countries (Brunello, 1990; Neudorfer, Pichelmann, and Wagner, 1990; Mitchell, 1993; Jaeger and Parkinson, 1994; Røed, 1996). These empirical studies did not consider nonlinearity and structural changes when testing a unit root hypothesis. However, the nonlinear behaviour of employment rate in OECD countries is recognized in the existing applied economics literature due to business cycles or some idiosyncratic factors specific to the labour market (Cancelo, 2007).

Recently, some empirical studies used nonlinear unit root test to investigate the stationarity proprieties of unemployment. Yilanci (2008) carried out the KSS test to unemployment rates in 17 OECD countries and found evidence in favour of stationarity hypothesis for only 7 countries. This study, however, does not account for possible breaks in the series of unemployment rates. Hence, compared to these studies, our empirical findings provide more obvious evidence in favour of unemployment rate stationarity among 29 OECD countries while allowing for both nonlinearity and structural breaks in series. Turning to the panel unit root tests, we begin by applying the cross-section dependence (CD) tests developed by Pesaran (2004), Friedman (1937) and Frees (1995). Table 4 indicates that null hypothesis of cross-sectional dependence is rejected for the entire panel highlighting that unemployment rate is highly dependent across OECD countries. This finding indicates the importance of taking into account cross-sectional dependence when analysing the stationarity of OECD countries panel.

Table 4: Cross Sectional Dependence Test Results

Cross sectional dependence test	Full Panel
Frees' test of cross sectional independence (p-value)	1.653 (0.0000)
Pesaran's test of cross sectional independence (p-value)	-0.131 (0.1044)
Friedman's test of cross sectional independence (p-value)	52.918 (0.0030)

Table 5: Panel Data Unit Root Results[10]

First Generation of Panel Unit Root Tests: Full panel				
Types of test statistic	*Test statistic*	*1 % CV*	*5 % CV*	*10 % CV*
LLC test statistic	-1.1319	-2.3263	-1.6449	-1.2816
IPS test statistic	-1.0959	-2.3263	-1.6449	-1.2816
MW test statistic	90.9817	85.9502	76.7778	72.1598
Choi test statistic	1. 1524	2.3263	1.6449	1.2816
Second Generation Panel Unit Root Tests: Full panel				
Moon Perron1 statistic (ta_bar statistic)	-10.7505***	-2.3263	-1.6449	-1.2816
Moon Perron2 statistic (tb_bar statistic)	-5.4646***	-2.3263	-1.6449	-1.2816
Pesaran (2007) test statistic	-1.3881	-2.7260	-2.6077	-2.5441
Choi test statistic (P_m)	6.6531***	2.3263	1.6449	1.2816
Choi test statistic (Z)	-5.6899***	-2.3263	-1.6449	-1.2816
Choi test statistic (Lstar)	-5.5484***	-2.3263	-1.6449	-1.2816

Table 6: Panel Unit Root Test Results with Structural Breaks[11]

Panels		No break	One break	Two breaks
Full Panel		-18.135***	-35.817***	-45.381***
	Note: The 1%, 5% and 10% critical values for the panel LM unit root tests with structural breaks are -2.326, -1.645 and -1.282 respectively. * Significance at 10% level. ** Significance at 5% level. *** Significance at 1% level.			

As a starting point of panel stationarity analysis, we employ the first generation panel unit root tests which allow for cross-sectional independence between countries. As displayed in Table 5, the results suggest that the unemployment hysteresis null hypothesis cannot be rejected by all the first generation tests (LLC, IPS, MW and Choi tests). This finding of stationarity is not in line with Song and Wu (1998) who reported the absence of hysteresis in unemployment for the quarterly data of 15 countries by using Levin and

[10] We can find Matlab codes for the Panel Unit Root test on Christophe Hurlin's homepage (http://www.univ-orleans.fr/deg/masters/ESA/CH/churlin_R.htm).

[11] We can find Gauss codes for the Im, Lee and Tieslau (2005) test on Junsoo Lee's homepage (http://old.cba.ua.edu/~jlee/gauss).

Lin (1992) panel unit root test. However, the cross-sectional (CD) dependence test rejects the presence of cross-sectional independence and hence, the first generation unit root test is not applicable. Therefore, the failure of the these tests to reject the null of unemployment hysteresis is due to the fact that the first generation panel unit root tests do not allow neither for cross-sectional dependence nor for possible structural breaks. In light of these considerations, when we consider the cross-sectional dependence test, our empirical findings show that the second generation panel unit root tests (except for Pesaran test) provide evidence that unemployment rate contains stationarity process. Thus, the consideration of cross-sectional assumption gives more consistent results and rejection of hysteresis hypothesis is obtained when cross-country interdependence in unemployment rates is incorporated. This study has applied the panel unit root test of Im, Lee and Tieslau (2005) which allows for structural breaks. This test improves largely the power of the panel unit root tests and increases the amount of information in panel data. The results reported in Table 6 support evidence of unemployment rate stationarity which confirm the finding of the second generation unit root tests. This result indicates that shocks to unemployment in OECD countries are temporary and the unemployment rate will revert back to its long-run trend. Hence, the failure to reject the unit root hypothesis of OECD unemployment rates is due to the lower power of classical unit root tests which do not take into account the cross-sectional and structural break assumptions.

V. Conclusion and Policy Implications

This study retests the unit root properties of unemployment rate by using the data of OECD countries for the period of 1980-2013 to confirm either unemployment hysteresis hypothesis exists or does not. In doing so, linear and non-linear unit root tests have been applied for testing the unit root properties. Further, cross-sectional dependence as well as panel unit root tests with and without structural breaks have also been applied. The empirical analysis reveals that unemployment rate contain stationary process almost in 86% of sampled countries that seems to reject the unemployment hysteresis hypothesis. The results of panel unit root tests also show the absence of unemployment hysteresis hypothesis in the presence of cross dependence and structural breaks.

The empirical findings of the study suggest some fundamental policy implications. As the results support the non-existence of hysteresis hypothesis or stationary process, the process returns to the mean, while the mean moves over time. This indicates that shocks are transitory and produce simply impermanent changes of the unemployment rate nearby the equilibrium position. Hence, there is a resilient tendency for the unemployment rate to go back to its long-run equilibrium level following macroeconomic shocks in the OECD countries. Therefore, there is no need to execute costly macroeconomic stabilization policy, otherwise any fine-tuning is likely to disturb unemployment equilibrium level and thereby will bring macroeconomic instability instead of stability in these countries. Hence, unemployment rate in OECD countries is expected to return back to natural levels without the interferences from the OECD's governments.

The conclusion regarding the persistency of unemployment will of course depend on the flexibility of wages to attain the unemployment equilibrium levels without active public interventions in the labour market. Labour market is heavily regulated and job-market training and employment programs are natural elements of the state intervention policies. Given the alarming state of youth unemployment, mobility of capital, capital-labour substitution and technology's influence on relocation of production, it is not possible to think of a situation where state is not actively intervening to labour market. The suggested improved testing procedures, functional forms and accounting for cross-sectional dependence and structural breaks will increase the power of the unit root tests and enable more accurate inference about state interventions in labour market.

References

Abadir, K. M. and Distaso, W. (2007). Testing joint hypotheses when one of the alternatives is one-sided. *Journal of Econometrics*, 140, 695-718.

Arestis, P. and Mariscal, I. (1999). Unit roots and structural breaks in OECD unemployment. *Economics Letters*, 65, 149-156.

Arestis, P. and Mariscal, I. (2000). OECD unemployment: structural breaks and stationary. *Applied Economics*, 32, 399-403.

Blanchard, O. J. and Summers, L. H. (1986a). Hysteresis in unemployment problem. NBER Working Paper no. 2035.

Blanchard, O. J. and Summers, L. H. (1986b). Hysteresis and the European unemployment problem. NBER Working Paper no. 1950.

Bolat, A., Tiwari, A.K. and Erdayi, A.U. (2014) “Unemployment hysteresis in the Eurozone area: evidences from nonlinear heterogeneous panel unit root test”, *Applied Economics Letters*, 21(8), 536-540.

Breuer, J.B., McNown, R., Wallace, M.S., 2001. Misleading inferences from panel unit-root tests with an illustration from purchasing power parity. *Review of International Economics*, 9 (3), 482–493.

Brunello, G. (1990). Hysteresis and the Japanese experience: A preliminary investigation. *Oxford Economic Papers*, 42, 483-500.

Camarero, M. and Tamarit, C. (2004). Hysteresis vs. natural rate of unemployment: new evidence for OECD countries. *Economics Letters*, 84, 413–417.

Camarero, M., Carrión-i-Silvestre, J. L. and Tamarit, C. (2006). Testing for hysteresis in unemployment in OECD countries. New evidence using stationarity panel tests with breaks. *Oxford Bulletin of Economics and Statistics*, 68, 167-182.

Cancelo, J.R. (2007). Cyclical asymmetries in unemployment rates: international evidence. *International Advances in Economic Research*, 13, 334–346.

Caner, M. and Hansen, B. E. (2001). Threshold autoregrssion with a unit root. *Econometrica*, 69, 1555-1596.

Chang, T., Nieh, K.C., Wei, C.C., 2005. An empirical note on testing hysteresis in unemployment for ten European countries: panel SURADF approach. *Applied Economics Letters*, 12, 881–886.

Chang, T. and Lee, C-H. (2011). Hysteresis in unemployment for G-7 countries: Threshold unit root test. *Romanian Journal of Economic Forecasting*, 4, 5-14.

Chang, H.-L., Liu, D.-C. and Su, C.-W. (2012). Purchasing power parity with flexible Fourier stationary test for Central and Eastern European countries. *Applied Economics*, 44, 4249-4256.

Cheng, S-C., Wu, T., Lee, K-C. and Chang, T. (2014). Flexible Fourier unit root test of unemployment for PIIGS countries. *Economic Modeling*, 36, 142-148.

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance*, 20, 249-272.

Choi, I. (2006).Nonstationary panels. *In Palgrave Handbooks of Econometrics, Vol.* 1, MillsTC, PattersonK *(eds).* Palgrave Macmillan. Basingstoke, 511–539.

Chou, H.C. and Zhang, Y.C. (2012). "Unemployment hysteresis in G20 countries: Evidence from non-linear panel unit-root tests", *African Journal of Business Management*, 6 (49), 11887-11890.

Christopoulos, D.K. and León-Ledesma, M.A. (2007). "Unemployment hysteresis in EU countries: what do we really know about it?", *Journal of Economic Studies*, 34(2): 80-89.

Clemente, J., Montanes, A. and Reyes, M. (1998). Testing for a unit root in variables with a double change in the mean. *Economics Letters*, 59, 175–182.

Elmskov, J. and MacFarlan, M. (1993). Unemployment persistence. *OECD Economic Studies*, 21, 60–89.

Enders, W. and Lee, J. (2012). A unit root test using a Fourier series to approximate smooth breaks. *Oxford bulletin of Economics and Statistics*, 74, 574-599.

Ener, M. and Arica, F. (2011). Is there hysteresis in unemployment in OECD countries? Evidence from panel unit root test with structural breaks. *Chinese Business Review*, 10, 294–304.

Everaert, G. (2001). Infrequent large shocks to unemployment: new evidence on alternative persistence perspectives. *Labo*r, 15, 555–577.

Fève, P., Hènin, P.Y.and Jolivaldt, P. (1999). Testing for hysteresis: unemployment persistence and wage adjustment. *Empirical Economics*, 28, 535–552.

Figueiredo, E. A. (2010). Dynamics of regional unemployment rates in Brazil: Fractional behavior, structural breaks, and Markov switching. *Economic Modelling*, 27, 900-908.

Fisher, R.A. (1932). *Statistical methods for research workers*. Fourth Edition, Edinburgh, Oliver and Boyd.

Fosten, J. and Ghoshary, A. (2011). Dynamic persistence in the unemployment rate of OECD countries. *Economic Modelling*, 28, 948-954.

Frees, E. W. (1995). Assessing cross-sectional correlations in panel data. *Journal of Econometrics*, 69, 393-414.

Friedman, M. (1937). The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *Journal of the American Statistical Association*, 32, 675-701.

Furuoka, F. (2014). Are unemployment rates stationary in Asia-Pacific countries? New findings from Fourier ADF test. *Economic Research*, 27, 34-45.

Galvao, Jr. A. F. (2009). Unit root quantile autoregrssion testing using covariates. *Journal of Econometrics*, 152, 165-176.

Gray, D., 2004. Persistent regional unemployment differentials revisited. *Regional Studies*, 38, 167–176.

Harris, D., McCabe, B. P. and Leybourne, S. J. (2003). Some limit theory for autocovariances whose order depends on sample size. *Econometric Theory*, 10, 829-864.

Harvey D. I.and Leybourne. S. J. (2007). Testing for time series linearity. *Econometrics Journal*, 10, 149-65.

Harvey, D. I., Leybourne, S. J. and Xiao, B. (2008). A powerful test for linearity when the order of integration is unknown. *Studies in Nonlinear Dynamics & Econometrics*, 12, 1-24.

Hayashi, N., 2005. Structure changes and unit roots in Japan's macroeconomic time series: is real business cycle theory supported. *Japan and the World Economy*, 17, 239–259.

Huang, S-C. (2011). Testing for unit roots and persistence in EU unemployment rates. *The Empirical Economics Letters*, 10, 669-677.

Hurlin, C. (2004). Testing Granger causality in heterogeneous panel data models with fixed coefficients. Document de recherche LEO.

Im, K. S., Lee, J. and Tieslau, M. (2005). Panel LM unit root tests with level shifts. *Oxford Bulletin of Economics and Statistics*, 67, 393-419.

Im, K.S., Pesaran, M. H. and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115, 53-74.

Kapetanios, G., Shin, Y., Snell, A., 2003. Testing for a unit root in the non-linear STAR framework. *Journal of Econometrics*, 112, 359-379.

Kruse R., 2011. A new unit root test against ESTAR based on a class of modified statistics. *Statistical Papers*, 52, 71-85.

Lee, C-C. and Chang, C-P. (2008). Unemployment hysteresis in OECD countries: Centurial time series evidence with structural breaks. *Economic Modelling*, 25, 312-325.

Lee, C-F. (2010). Testing for unemployment hysteresis in nonlinear heterogeneous panels: International evidence. *Economic Modelling*, 27, 1097-1102.

Lee, C-F., Hu, T-C., Li, P-C. and Tsong, C-C. (2013). Asymmetric behavior of unemployment rates: evidence from the quantile covariate unit root test. *Japan and the World Economy*, 28, 72-84.

Lee, J. and Strazicich, M. (2003). Minimum Lagrange Multiplier unit root test with two structural breaks. *Review of Economics and Statistics,* 85(4), 1082–1089.

Lee, J. and Strazicich, M. (2004). Minimum LM unit root test with one structural break. Working Papers 04-17, Department of Economics, Appalachian State University.

Lee, J. and Strazicich, M. (2013). Minimum LM unit root test with two structural break. *Economics Bulletin*, 33, 2483-2492.

Lee, J-D., Lee, C-C. and Chang, C-P. (2009). Hysteresis in unemployment revisited: evidence from panel LM unit root tests with heterogeneous structural breaks. *Bulletin of Economic Research*, 61, 325-334.

Leon-Ledesma, M.A., McAdam, P. (2004). Unemployment, hysteresis and transition. *Scottish Journal of Political Economy*, 51 (3), 377–401.

Levin, A., Lin, C.F. and Chu, C.S.J. (2002). Unit root test in panel data: asymptotic and finite sample properties. *Journal of Econometrics*, 108, 1-24.

Leybourne, S., Kim, T. and Taylor, A. M. (2007). Detecting multiple changes in persistence. *Studies in Nonlinear Dynamics and Economics*, 11, 1-23.

Liew, V, K-S., Chia, R. C-J. and Puah, C-H. (2012). Does hysteresis unemployment occur in OECD countries? Evidence from parametric and non-parametric panel unit root tests. *International Journal of Economics and Management*, 6(2), 446-458.

Lin, C.H., Kuo, N.F. and Yuan, C.D. (2008). “Nonlinear vs. nonstationary of hysteresis in unemployment: evidence from OECD economies”, *Applied Economics Letters*, 15(11): 905-909.

Liu, D-C., Sun, C-H. and Lin, P-C. (2012). Hysteresis hypothesis in unemployment and labour force participation rates: evidence from Australian states and territories. *Australian Economic Papers*, 51, 71-84.

Maddala, G.S. and Wu, S. (1999). A comparative study of unit roots with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, 61, 63-651.

Mitchell, W. F. (1993). Testing for unit roots and persistence in OECD unemployment rates. *Applied Econometrics*, 25, 1489–1501.

Moon, H. R. and Perron, B. (2004). Testing for a unit root in panels with dynamic factors. *Journal of Econometrics*, 122, 81-126.

Nybolm, J. and Harvey, A. (2000). Tests of common stochastic trends. *Econometric Theory*, 16, 176-199.

Papell, D.H., Murray, C.J., Ghiblawi, H., 2000. The structure of unemployment. *The Review of Economics and Statistics*, 82, 309–315.

Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels*. University of Cambridge, Faculty of Economics, Cambridge Working Papers in Economics No. 0435.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22, 265-312.

Røed, K. (1996). Unemployment hysteresis – Macro evidence from 16 OECD Countries. *Empirical Economics*, 21, 589-600.

Røed, K. (2002). Unemployment hysteresis and the natural rate of vacancies. *Empirical Economics*, 27, 687–704.

Smyth, R., 2003. Unemployment hysteresis in Australian states and territories: evidence from panel data unit root tests. *The Australian Economic Review*, 36, 181–192.

Smyth, R., Inder, B., 2004. Is Chinese provincial real GDP per capita nonstationary? Evidence from multiple trend break unit root tests. *China Economic Review* 15, 1–24.

Song, F.M. and Wu, Y. (1998). Hysteresis in unemployment: evidence from OECD countries. *The Quarterly Review of Economics and Finance*, 38, 181-192.

Strazicich, M.C., Tieslau, M. and Lee, J. (2002). "Hysteresis in unemployment? Evidence from panel unit root test with structural change", University of North Texas Working Paper, No.01-08.

Tiwari, A. K. (2014). Unemployment hysteresis in Australia: Evidence using non-linear and stationarity test with breaks. *Quality & Quantity*, 48, 681-695.

Ucar, N. and Omay, T. (2009). Testing for unit root in nonlinear heterogeneous panels. *Economic Letters*, 104, 5-8.

Yamamoto, T., 1996. A simple approach to the statistical inference in linear time series models which may have some unit roots. *Hitotsubashi Journal of Economics*, 37, 87–100.

Yilanci, V. (2008). Are unemployment rates nonstationary or nonlinear? Evidence from 19 OECD countries. *Economics Bullet*in, 3, 1-5.

Yoon, G. (2009). It's all the minors' fault: On the nonlinearity in U.S. unemployment rates. *Economic Modelling*, 26, 1449-1454.

Appendix

Appendix A: Summary of Literature on Hypothesis of Hysteresis in Unemployment

Author(s)	Countries	Period	Empirical Method	Linear unit root test	Nonlinear unit root test	Structural breaks	Functional form	Regime switching	Hysteresis hypothesis
Blanchard and Summers (1986)	France, Germany, UK and U.S.	1953-1984	DF and ADF unit root tests	Yes	No	No	Linear	No	No: U.S. Yes: France, Germany, UK
Brunello (1990)	Japan	1955-1987	DF unit root	Yes	No	No	Linear	No	Yes
Mitchell (1993)	15 OECD countries	$1960Q_1$ - $1991Q_3$	PP test	Yes	No	No	Linear	No	Yes
Røed (1996)	16 OECD countries	1970Q1–1994Q4	Exact maximum likelihood stationarity test	Yes	No	No	Linear	No	No for US
Song and Wu (1998)	15 OECD countries	$1972Q_1$–$1992Q_2$	Panel unit root test	Yes	No	No	Linear	No	No
Papell et al. (2000)	16 OECD countries	1955–1997	Zivot and Andrews Unit root (one structural break)	Yes (Linear unit root test with structural break)	No	Yes	Linear regression	No	No: Belgium, Canada, Denmark, Finland, Ireland, Norway, Sweden, Spain, U.S., UK
Arestis and Mariscal (2000)	22 OECD countries	$1960Q_1$–$1997Q_2$	Perron's (1997) unit root test	Yes	No	Yes	Linear	No	No: Australia, Belgium, Canada, Denmark, Finland, Germany, Luxembourg, Switzerland and the UK
Everaert (2001)	21 OECD countries	1960–1999	Tsay's (1988) intervention model	Yes	No	No	Linear	No	No
Strazicich *et al.* (2002)	France, Germany, Italy, Spain and UK	1955-1999	- LM Test - LM test with structural breaks	Yes	No	Yes	Linear	No	Yes
Røed (2002)	10 OECD countries	1960-1995	ADF and KPSS unit root tests	Yes	No	No	Linear	No	No: US
Fève et al. (2003)	21 OECD countries	$1966Q_1$–$1999Q_1$	*ADF*, KPSS and generalization of *ADF*	Yes	No	No	Linear	No	No: Australia, Belgium, Canada, Denmark, Finland, Netherlands, Norway, U.S.

Smyth (2003)	Australian States	1983Q2–2002Q1	LL and IPS unit root tests	Yes	No	No	Linear	No	Yes
Camarero and Tamarit (2004)	19 OECD countries	1956–2001	Multivariate SURE unit root tests	Yes	No	No	Linear	No	Yes: Austria, Germany, Italy, Japan, Norway, New Zealand and Switzerland.
Leon-Ledesma and McAdam (2004)	12 Central and Eastern European Countries and 15 EU	1991M1–2001M5	Univariate and panel unit root tests with and without breaks	Yes	No	Yes	Linear	No	No
Gray (2004)	UK	1974M4–2002M12	ADF and KPSS unit root tests	Yes	No	No	Linear	No	Yes
Chang *et al.* (2005)	10 European countries	1961–1999	Panel SURADF unit root tests (Breuer et al., 2001)	Yes	No	No	Linear	No	No: Belgium and the Netherlands.
Hayashi (2005)	Japan	1955Q1–1998Q2	Augmented step-wise Chow test (Yamamoto ,1996)	Yes	No	No	Linear	No	No
Camarero *et al.* (2006)	19 OECD Countries	1956-2001	KPSS unit root test with structural breaks	Yes	No	Yes	Linear	No	No: France and UK.
Christopoulos, and León-Ledesma (2007)	12 European Union (EU) countries	1988 Q1- 1999 Q4	The second-generation panel unit root tests	Yes	No	No	Linear	No	No
Yilanci (2008)	19 OECD Countries	Different periods	Nonlinear unit root test (KSS)	No	Yes	No	Nonlinear	No	No: Belgium, Czech Republic, Korea, Netherlands, Poland, Switzerland and USA.
Lee and Chang (2008).	14 OECD countries	Different period samples	LM unit root tests without and with structural breaks	Yes	No	Yes	Linear	No	No
Lin *et al.* (2008)	16 OECD countries	1970M1-2005M4	Threshold autoregression (TAR) test	No	Yes	No	Nonlinear	No	Yes: Australia, Finland, France, Germany, Japan and the USA
Lee *et al.* (2009)	19 OECD countries	1960-2004	The panel LM unit root tests with heterogeneous structural breaks	Yes	No	Yes	Linear	No	No
Chang (2011)	17 OECD countries	1960-2009	Stationary test with a Fourier function	No	Yes	No	Nonlinear	No	No: Australia, Canada, Finland, France, Sweden and the US.
Chou and Zhang	G20 countries	1980-2008	SURADF and	Yes	No	No	Linear	No	No: Belgium, Canada,

(2012)			SURKSS tests						Denmark, Finland, France, Germany, New Zealand, Norway and Portugal
Chang and Su (2014)	Taiwan	Six educational attainment categories, between January 1978 and June 2012.	First and second generations panel unit root test + Carrion-i-Sylvester *et al.* panel unit root (2005) + KSS unit root test	Yes	Yes	Yes	Linear and Nonlinear	No	No: junior college graduates
Bolat *et al.* (2014)	17 EU countries	2000:Q_1-2013:Q_1	Nonlinear panel unit root tests	No	Yes	No	Nonlinear	No	Yes: Netherlands, Slovakia, Slovenia, Italy, Portugal and Cyprus.
Tiwari (2014).	Australia	1978M_2-2010M_{12}	Linear and Nonlinear unit root tests	Yes	Yes	Yes	Linear and Nonlinear	No	Yes

Appendix B: Descriptive statistics on unemployment rates

Country	Mean	Median	Maxi- mum	Mini- mum	Std. Dev.	Skew- ness	Kurtosis	Jarque- Bera	Proba- bility
Australia	7.0512	6.8460	10.9000	4.2750	1.8539	0.4511	2.2114	2.0341	0.3617
Austria	3.7972	3.8835	5.2000	1.6000	0.8218	-0.7361	3.1868	3.1201	0.2101
Belgium	8.5219	8.3540	11.5000	6.4420	1.3448	0.3128	2.1996	1.4622	0.4814
Canada	8.5089	7.8835	11.9250	6.0580	1.6769	0.5487	2.1037	2.8440	0.2412
Chile	9.6882	8.7585	20.9990	6.1080	3.6886	1.7209	5.4777	25.4788	0.0000
Denmark	6.2163	6.1915	9.5330	3.4750	1.5575	0.0950	2.0105	1.4381	0.4872
Finland	8.3261	7.9180	16.6060	3.2000	3.5926	0.8312	2.9686	3.9162	0.1411
France	9.6148	9.5670	11.6830	6.3490	1.2542	-0.3429	2.9113	0.6775	0.7127
Germany	7.7463	7.8630	11.2080	3.3590	1.6874	-0.3383	3.1577	0.6836	0.7105
Greece	9.8627	9.1850	26.9860	2.6630	4.7682	2.1674	8.2626	65.8533	0.0000
Hungary	5.8854	6.8000	11.2900	0.0410	4.1579	-0.3208	1.5729	3.4682	0.1766
Iceland	2.7489	1.8210	8.1320	0.3130	2.2264	1.0376	3.1346	6.1261	0.0467
Ireland	11.5706	12.9310	19.0000	3.9300	5.3420	-0.1906	1.5175	3.3192	0.1902
Israel	8.6727	8.6030	13.4000	4.5620	2.4794	0.1131	2.0053	1.4742	0.4785
Italy	8.9994	8.7080	12.0420	6.1000	1.5046	0.2315	2.1881	1.2374	0.5386
Japan	3.5252	3.3705	5.3580	2.0220	1.1050	0.1566	1.5477	3.1269	0.2094
Korea	3.5573	3.4375	6.9500	2.0580	1.0938	1.3677	5.3174	18.2079	0.0001
Luxembourg	2.9023	2.6160	6.2960	0.7230	1.5777	0.7051	2.4250	3.2861	0.1934
Mexico	3.8031	3.7080	6.2300	0.9000	1.2710	-0.0657	2.7832	0.0910	0.9555
The Netherlands	5.1351	5.1000	8.2540	2.5410	1.4734	0.2319	2.3432	0.9157	0.6326
New Zealand	6.0644	6.1955	10.6250	3.6750	1.9344	0.7073	2.9463	2.8390	0.2418
Norway	3.6744	3.4260	5.9480	1.6500	1.1669	0.3182	2.2054	1.4684	0.4799
Portugal	7.5469	7.2255	18.2500	3.8600	3.1841	1.5788	5.8865	25.9288	0.0000
Spain	17.1007	17.6200	27.0000	8.2750	5.0921	-0.1224	2.0172	1.4534	0.4835
Sweden	5.6762	5.8670	9.8830	1.5580	2.6650	-0.0867	1.6332	2.6891	0.2607
Switzerland	2.2253	2.3810	4.5050	0.1810	1.3626	-0.0938	1.5693	2.9496	0.2288
Turkey	8.7339	8.4105	14.0280	6.4970	1.6921	1.0224	4.0232	7.4070	0.0246
United Kingdom	7.8518	7.8395	11.7770	4.7880	2.1964	0.2433	1.8589	2.1799	0.3362
United States	6.4746	6.0460	9.7080	3.9670	1.6523	0.5246	2.2830	2.2879	0.3186