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Structural Break, Nonlinearity and the Hysteresis hypothesis: Evidence from new unit root tests.

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Abstract

We have checked whether there exists hysteresis hypothesis in 25 OECD countries covering the period from September, 1983 to September,2013 by using the unit root test which includes nonlinearity and structural break in their testing process. In particular, LNV test proposed by Leybourne, Newbold and Vougas (1998), EG test developed by Enders and Granger (1998), the nonlinear KSS unit root test of Kapetanios et al., (2003), Sollis' (2009) test, combined KSS-LNV test developed by Omay and Yildirim (2014), combined LNV-Sollis test by Omay et al (2017), modified unit root test with Fractional Frequency Flexible Fourier Form by Omay (2015) and EST test by Corakcı et al., (2017).

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1. Introduction

The fact that labor markets in the OECD countries have never recovered the full employment levels after the several oil price shocks occurred between 1978 and 1983. Afterward, the labor market performance declined significantly due to global financial and economic crisis in 2008 and 2009. Nowadays, the unemployment rates stay at the higher level compared to 2008- 09 crisis level in many OECD countries. Evidently, that high unemployment levels may lead to the decline of output and have a negative effect on the economic development of the country.

The main difficulty behind the high unemployment rates is whether the rise caused by cyclical factors that can be returned to its equilibrium state as the economic recovery becomes stronger or by hysteresis phenomenon that cannot be eliminated even after the full recovery of the economy. Thus, the remedy for the non-negligible labour market issues is directly related to the mentioned question.

Experts distinguish two competing hypothesis describing the unemployment behaviour: the *natural rate hypothesis (NRH)* and the *hysteresis hypothesis (HH)*.

The first hypothesis states there is a temporary effect of the cyclical factors to the unemployment rate in the short-run and the economy will converge to a unique and stable equilibrium unemployment rate in the long-run. The equilibrium unemployment rate is named as the natural rate of unemployment, which is regulated according to the structure of and frictions in the labour market. The NRH indicates that, high current unemployment rates can be caused by one of the following scenarios. When the economy exhibits a negative growth, the disturbances which are producing cyclical fluctuations of the unemployment rates may push those above its natural rate. The theory supposes that in this case the economy will turn back to its low natural rate over the long run. The second case shows that shocks that alter the structure of the labor market may increase the natural rate itself, therefore, the unemployment rate will stay at the new high level of equilibrium unemployment rate permanently. It is important to emphasize, that in accordance with the hypothesis, the long-run Phillips curve, which represents the relationship between the inflation rate and unemployment rate, is vertical, i.e. these macroeconomic variables are unrelated. Thus, the natural rate is independent of monetary policy actions.

The NRH was quite eligible theory to describe the labor market fluctuations in developed countries, however the sharp rise of the oil prices had a negative and permanent effects on the actual rate of unemployment. This circumstance leads to the necessity of the natural rate theory reconsideration.

The second hypothesis, namely *hysteresis*, is defined as a process which exhibit a dependency on past shocks, i.e. reversing the shock does not recover initial properties of the system even over the long-run. The memory is described as nonlinear, selective, and with remanence (H. Hallett, L. Piscitelli, 2002). Remanence means that the temporary shocks may cause permanent outcomes, thus moving the equilibrium rate from one level to another. According to (H. Hallett, L. Piscitelli, 2002), selectivity determines only the shocks 'which are 'not dominated' by shocks which come later'.

According to HH, cyclical unemployment would be transformed into structural one (B. Bartlett, 2013), that will cause the permanent consequences of unemployment rate rise. Various factors may contribute to structural unemployment. For example, the skills of employees no longer valuable since the industries which hired them do not exist; the human workforce is replaced by computers and automatic machinery.

NRH requires that the unemployment series are stationary or mean reverting around a unique equilibrium unemployment rate. However, the hysteresis hypothesis determines the unemployment series as nonstationary and containing a unit root, meaning that the temporary shocks result the unemployment rate to fluctuate and have no tendency for the unemployment rate to return to its equilibrium level. A following equation is used in order to review these hypotheses

$$u_t = \alpha + \beta u_{t-1} + \varepsilon_t \tag{1}$$

where the unemployment series u_t follows an autoregressive process of order 1, i.e. AR(1) and ε_t is a white noise error term. For the NRH, a unit root in u_t occurs in equation (1) when $H_0 : \beta = 1$. Thus, the natural rate hypothesis holds in its weak form when the null hypothesis is rejected against the alternative $H_0 : \beta < 1$. For the NRH to hold in its strong form the null $H_0 : \beta = 0$ should be tested since the unemployment rates are assumed not to be a function of the past unemployment rate. Otherwise, if the null $H_0 : \beta = 1$ cannot be rejected, the unemployment rates have a hysterical behavior.

2. Empirical Literature

The majority of the previous studies conducted the modelling of the unemployment hysteresis within a linear unit-root framework. Commonly used linear unit root tests, like Dickey-Fuller (ADF) test, Phillips-Perron (PP) test, KPSS test of Kwiatkowski et al. (1992) and/or the DF-GLS test of Elliott et al. (1999) were implemented to examine for the hysteresis effects in the unemployment rate series. The unemployment rates in the US and its states were detected to be non-stationary using the ADF and the PP tests (Breitung (1994), Hatanaka (1996). Song and Wu (1998) and Leon-Ledesma (2000)). Applying the classical linear univariate tests, it has been failed to reject the hysteresis hypothesis in most EU countries (Blanchard and Summers, 1986; Groenewold and Taylor, 1992; Roed, 1996; Leon-Ledesma, 2000; Camarero and Tamarit, 2004).

It should be noted that various ADF test statistics are biased towards the non-rejection of the unit root hypothesis when the structural breaks take place. There are a large number of studies considering the structural breaks. The plenty number of these studies succeeded to reject the unit root null (Camarero and Ordonez; 2006; Lee and Chang; 2008; Furuoka, 2014a), however the majority of the studies were unable to reject the hysteresis effect in the unemployment rates (Chang et al., 2007; Chang; 2011; Cuestas et al., 2011; Cheng et al., 2014; Furuoka, 2014b). Moreover, having low power in small samples, particularly when the unemployment series are near-unit root processes, the conventional univariate unit root tests are less reliable and accurate.

The mentioned studies consider the linear behaviour of the unemployment rates and believe that those demonstrate symmetric adjustment paths. However, nonlinear behaviour of the key macroeconomic variables is important from a theoretical perspective. The observations, which wages are rigid downward, have an important meaning for labour markets. Moreover, business cycles have downturns which are steeper than upturns in the main economic variables, such as output and employment. Thus, another group of scientists test hysterical unemployment behaviour within a nonlinear framework. There are some studies, which assume that the unemployment rates follow a threshold Autoregressive (TAR) process (Coakley et al., 2001; Perez-Alonso and Sanzo, 2011), smooth transition autoregressive (STAR) process (Skalin and Teräsvirta, 2002; He and Sandberg; 2012) or a Markov switching process with multiple equilibria (Bianchi and Zoega, 1998; Leon-Ledesma and Mc Adam, 2004).

Furthermore, new univariate nonlinear unit root tests have been developed. For example, TAR models have been used in order to construct new unit root test. (Enders and Granger, 1998; Caner and Hansen, 2001), also, ESTAR model have been used to establish unit root tests (Kapetanious et al.,2003). The mentioned studies have determined that most European countries are distinguished by the non-stationary unemployment rates, however for the US other studies have rejected the hysteresis hypothesis (Gustavsson and Österholm, 2006; Ghosh and Dutt, 2008; Yilanci, 2008; Lin et al., 2008; Chang and Lee; 2011; Tiwari; 2014, Tartıcı 2015).

In our study we give a brief review of different nonlinear unit root tests, in particular, LNV test proposed by Leybourne, Newbold and Vougas (1998), EG test developed by Enders and Granger (1998), the nonlinear KSS unit root test of Kapetanios et al., (2003), Sollis' (2009) test, combined KSS-LNV test developed by Omay and Yildirim (2014), combined LNV-Sollis test by Omay et al (2017), modified unit root test with Fractional Frequency Flexible Fourier Form by Omay (2015) and EST test by Corakcı et al., (2017).

The aim of our study is to apply the aforementioned models to test the hysteresis hypothesis in the unemployment rates of 25 OECD countries and compare the implementation of the unit root tests. Thus, we have improved upon the Tartıcı (2015) study by increasing the country and sample period. On the other hand, we also have also used more recent unit root test in order to increase the understanding of the stationarity properties of the unemployment data.

The paper is organized as follows: the next section outlines the theoretical framework of the developed nonlinear unit root tests. The Section 3 and 4 present data description and results of applied tests. Finally, in the last section we report the main conclusions.

3. The model and testing procedure

Equation (1) can be improved in many different ways by adding the deterministic function, allowing for structural breaks, producing asymmetric mean reversion, and assuming the serial dependence of the error terms. In this section we a short review of existing nonlinear unit root tests.

TAR threshold Autoregressive type of unit root test. EG test

Enders and Granger. (1998), have proposed the unit root test employing Tong's (1983) threshold autoregression (TAR) model. Let the unemployment rate, u_t, follow the pth order TAR model:

$$\Delta u_t = \alpha + \rho_1 I_t u_{t-1} + \rho_2 \left(1 - I_t\right) u_{t-1} + \sum_{j=1}^{p-1} \hat{\delta}_j \Delta u_{t-j} + \varepsilon_t \tag{2}$$

$t = 1. \dots . T$, where I_t is the Heaviside indicator function defined as

$$I_t = \begin{cases} 1, \text{if } u_{t-1} \geq 0 \\ 0, \text{if } u_{t-1} < 0 \end{cases}$$

ε_t are zero-mean iid error terms. The null hypothesis $H_0: \rho_1 = \rho_2 = 0$, indicates the unit root process. Under the alternative hypothesis $H_1: \rho_1 < 0 \; and \; \rho_2 < 0, \rho_1 \neq \rho_{2.}$ authors consider the stationarity with asymmetric adjustment towards a constant mean or deterministic trend.

Symmetric ESTAR test. KSS test

Kapetanios *et al.,* (2003) developed the unit root test against the nonlinear but globally stationary process. Let us consider the following model, namely an exponential smooth transition model (ESTAR)

$$u_t = \beta u_{t-1} + \gamma u_{t-1}\left[1 - e^{-\theta u_{t-d}^2}\right] + \varepsilon_t \qquad \text{for } t = 1\ldots..T. \tag{3}$$

where u_t is a stochastic process with unknown parameters γ, ε_t is a white noise disturbance. The transition function is of the exponential form, where $d \geq 1$ is the delay parameter, the slope parameter θ is positive, which defines the transition speed between the two extreme regimes, namely "upper" and "lower" regimes, which correspond to the two extreme values of the transition function.

The Equation (3) can be rewritten with the assumption that $= \beta - 1$. Thereafter, Kapetanios *et al.,* (2003) set $\phi = 0$, indicating that the process is in the middle regime, also d=1 is selected to maximize goodness of fit. The ESTAR model with aforementioned assumptions is given as follows;

$$\Delta u_t = \gamma u_{t-1}\left[1 - e^{-\theta u_{t-1}^2}\right] + \varepsilon_t. \tag{4}$$

In order to decide whether the process is linear or unit root the null hypothesis $H_0: \theta = 0$ is implemented against the alternative $H_1: \theta > 0$, meaning that the process has the nonlinear globally stationary behaviour. By using the first order Taylor approximation this test become more feasible

$$\Delta u_t = \sum_{j-1}^{p} \rho_j \Delta u_{t-j} + \delta u_{t-j}^3 + e_t \tag{5}$$

where e_t includes original shocks ε_t as well as the error term resulting from Taylor approximation. The t-statistic, namely the KSS test, for $H_0: \delta = 0$ against $H_1: \delta < 0$ is defined as

$$t_{NL} = \frac{\hat{\delta}}{s.e.\left(\hat{\delta}\right)}, \tag{6}$$

with the OLS estimate, $\hat{\delta}$ and the standard error of $\hat{\delta}$, $s.e.\left(\hat{\delta}\right)$.

Asymmetric ESTAR test

Sollis, (2009) have developed the unit root test applying an extension of the ESTAR model, which is able to produce both symmetric and asymmetric mean reversion

$$\Delta u_t = G_t\left(\gamma_1, u_{t-1}\right)\left\{S_t\left(\gamma_2, u_{t-1}\right)\rho_1 + \left(1 - S_t\left(\gamma_2, u_{t-1}\right)\right)\rho_2\right\}u_{t-1} + \varepsilon_t \tag{7}$$

where the transition functions are of the exponential and logistic forms

$$G_t\left(\gamma_1.u_{t-1}\right) = 1 - e^{-\gamma_1 u_{t-1}^2}, \qquad \gamma_1 \geq 0$$
$$S_t\left(\gamma_2.u_{t-1}\right) = \frac{1}{1 + e^{-\gamma_2 u_{t-1}}}, \qquad \gamma_2 \geq 0 \tag{8}$$

ε_t is a zero mean i.i.d. error term. The model is asymmetric, if $\rho_1 \neq \rho_2$, and symmetric otherwise. Here, we assume only asymmetric version of ESTAR.
A first order Taylor expansion for ESTAR is used since there are unknown parameters under the null hypothesis, $H_0: \gamma_1 = 0$.

$$\Delta u_t = \rho_1 \gamma_1 u_{t-1}^3 S_t\left(\gamma_2, u_{t-1}\right) + \rho_2 \gamma_1 u_{t-1}^3\left(1 - S_t\left(\gamma_2, u_{t-1}\right)\right) + \eta_t \tag{9}$$

Finally, an augmented version of ESTAR is

$$\Delta u_t = \phi_1 u_{t-1}^3 + \phi_1 u_{t-1}^4 + \grave{o}_t \tag{10}$$

The null hypothesis becomes as follows

$$H_0 : \phi_1 = \phi_2 = 0 \tag{10}$$

against the alternative hypothesis, $H_1 : \phi_1 < 0$ *and* $\phi_2 < 0, \ \phi_1 \neq \phi_2$ of stationary asymmetric nonlinear ESTAR for testing the unit root null hypothesis. Solis, (2009) derived the asymptotic distribution of an F-test and asymptotic critical values of the test statistics.

LNV test

Leybourne, Newbold and Vougas, (1998) proposed LNV test based on the following regression models with the logistic smooth transition function

$$\begin{aligned} &\textit{Model A} \qquad u_t = \alpha_1 + \alpha_2 S_t(\gamma,\tau) + \nu_t \\ &\textit{Model B} \qquad u_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma,\tau) + \nu_t \\ &\textit{Model C} \qquad u_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma,\tau) + \beta_2 t S_t(\gamma,\tau) + \nu_t \end{aligned} \tag{11}$$

where the logistic smooth transition function is defined as follows[2]

$$S_t(\gamma,\tau) = \left[1 + exp\left\{-\gamma\left(t - \tau T\right)\right\}\right]^{-1} \qquad \gamma > 0 \tag{12}$$

The test statistics is established by two steps.

First step:

$$\begin{aligned} &\textit{Model A} \qquad \hat{\upsilon}_t = u_t - \hat{\alpha}_1 - \hat{\alpha}_2 S_t(\hat{\gamma},\hat{\tau}) \\ &\textit{Model B} \qquad \hat{\upsilon}_t = u_t - \hat{\alpha}_1 t - \hat{\beta}_1 - \hat{\alpha}_2 S_t(\hat{\gamma},\hat{\tau}) \\ &\textit{Model C} \qquad \hat{\upsilon}_t = u_t - \hat{\alpha}_1 t - \hat{\beta}_1 - \hat{\alpha}_2 S_t(\hat{\gamma},\hat{\tau}) - \hat{\beta}_2 t S_t(\hat{\gamma},\hat{\tau}) \end{aligned} \tag{13}$$

At the first step the deterministic component of the selected model is estimated applying a nonlinear least squares (NLS) algorithm, the NLS residuals are obtained.
Second step: Calculate the ADF statistic

$$\Delta\hat{\nu}_t = \hat{\rho}\hat{\upsilon}_{t-1} + \sum_{i=1}^{k}\hat{\delta}_i \Delta\hat{\nu}_{t-i} + \hat{\eta}_t \tag{14}$$

The following unit root hypotheses are considered:

Null hypothesis $u_t = \mu_t,\ \mu_t = \mu_{t-1} + \varepsilon_t,\ \mu_0 = \psi$
Alternative hypothesis Model A, Model B or Model C
Null hypothesis $u_t = \mu_t,\ \mu_t = \kappa + \mu_{t-1} + \varepsilon_t,\ \mu_0 = \psi$
Alternative hypothesis Model B or Model C.

KSS-LNV test

Omay and Yildirim, (2014) proposed new nonlinear unit root test by combining aforementioned KSS test by Kapetanois et al (2003) and LNV test by Leybourne, Newbold and Vougas (1998). The expansion of the existing models is that the structural change is modeled as

[2] For the Nonlinear optimization algorithm which is used in LNV type of de-trending we have followed the suggestion which are given in Omay and Emirmahmutoğlu (2017).

a smooth transition between different regimes. while Leybourne et al. (1996) consider those as a rapid structural break. The authors establish the linear unit root null hypothesis against nonlinear stationary process around smoothly varying trend and intercept under the alternative hypothesis.
The *First Step* is similar to the first step of the LNV model.
Second Step: the KSS statistic is computed

$$\Delta\hat{\varepsilon}_t = \hat{\rho}\hat{\varepsilon}_t^3 + \sum_{j=1}^{k}\hat{\delta}_j \Delta\hat{\varepsilon}_{t-j} + \hat{\eta}_t \tag{15}$$

The null hypothesis $H_0: \rho = 0, for\ all\ i,$ holds for linear nonstationary process against the alternative, $H_a: \rho < 0, for\ some\ i,$ (Nonlinear and Stationary around nonlinear trend and intercept).

LNV-Solis test

Omay et al, (2017) proposed a test which permits for simultaneous structural change and asymmetric nonlinear adjustment towards the equilibrium level. Three aforementioned smooth transition models, see Equations (11, 12) are considered with logistic transition function which model gradual structural breaks. In order to model adjustments towards the equilibrium asymmetric ESTAR (AESTAR) nonlinearity is used, see Equations (7,8). As in Kapetanios et al., (2003) and Sollis (2009), the transition functions were replaced by their first-order Taylor series approximation, see Equations (9,10).
Omay et al., (2017) assumes a serial correlation of the error terms, assuming that those enter in a linear way as follows

$$\Delta u_t = \mathrm{G}_t(\gamma_1, u_{t-1})\left\{\mathrm{S}_t(\gamma_2, u_{t-1})\rho_1 + \left(1 - \mathrm{S}_t(\gamma_2, u_{t-1})\right)\rho_2\right\}u_{t-1} + \sum_{j-1}^{p}\delta_j \Delta u_{t-j} + \varepsilon_t \tag{16}$$

with zero mean error terms, ε_t. Therefore, the auxiliary regression equation becomes

$$\Delta u_t = \phi_1 u_{t-1}^3 + \phi_1 u_{t-1}^4 + \sum_{j-1}^{p}\delta_j \Delta u_{t-j} + \grave{o}_t \tag{17}$$

The null hypothesis $H_0: \phi_1 = \phi_2 = 0$, tests for a unit root process against the alternative hypothesis, $H_1: \phi_1 < 0\ and\ \phi_2 < 0, \phi_1 \neq \phi_2$, of globally stationary AESTAR nonlinearity.
The null hypothesis testing can be performed in two steps. First, estimate the deterministic component of the preferred model using NLS algorithm and then collect residuals $\hat{u}_t$. Second, employing these residuals estimate the auxiliary regression equation by ordinary least squares and test the null hypothesis by F-test. The critical values for the test are displayed in Omay et al., (2017).

Unit root test with FFFFF

The unit root test with Fractional Frequency Flexible Fourier Form (FFFFF) was improved by Omay, (2015) by combining the methods of Becker et al. (2004) and Enders and Lee (2012b). The Fourier approach is capable to model multiple smooth breaks when the deterministic function is of unknown form and even is not periodic.

Consider the Dickey-Fuller test

$$u_t = d(t) + \phi_1 u_{t-1} + \lambda t + \varepsilon_t \tag{18}$$

where ε_t is a stationary disturbance term with constant variance σ^2. $d(t)$ is a deterministic function of t.

Omay, (2015) claims that the deterministic function can be approximated by applying the Fourier transform

$$d(t) = \alpha_0 + \alpha\sin\left(\frac{2\pi kt}{T}\right) + \beta_k cos\left(\frac{2\pi kt}{T}\right) \tag{19}$$

where k is a particular frequency and T is the number of observations. According to the literature, the single frequency is recommended to use since it leads to an optimal approximation to a model with structural change. Fractional frequency is employed instead of integer ones, that allows to establish an appropriate nonlinear trend into the unit root test.

The testing regression for fractional single frequency is

$$\Delta u_t = \rho u_{t-1} + c_1 + c_2 \text{t} + c_3 \sin\left(\frac{2\pi k^{fr} t}{T}\right) + c_4 cos\left(\frac{2\pi k^{fr} t}{T}\right) + e_t. \tag{20}$$

The critical values for the test are tabulated in Omay, (2015).

ÇEO test

Corakcı et al., (2017) consider three regression models, see Equations (11) and employ an exponential smooth transition (EST) function which allows for temporary breaks.

$$S_t(\gamma.\tau) = 1 - exp\left[-\gamma(t-\tau)^2\right], \quad \gamma > 0 \tag{21}$$

The null hypothesis tests for linear non-stationarity against the alternative including nonlinear stationary (stationary around smoothly changing trend and intercept). The calculation of the test statistics is based on the two step procedure as in Leybourne, Newbold and Vougas (1998)[3].

[3] The panel extension of EG, Solis (2004, 2009) and LNV can be found in Çorakcı *et al* (2017) (Hereafter, ÇEO), Omay *et al* (2017) (Hereafter, OÇE), Emirmahmutoğlu and Omay (2014), Omay *et al* (2017) (Hereafter, OHS), respectively. For the further study we can use these panel unit extensions, as well.

Data description

Data includes monthly unemployment rates of 25 OECD countries. The unemployment rates in 14 countries are observed from September, 1983 to September, 2013; Chile (from January,1986), Spain (from April, 1986), Mexico (from January, 1987), Finland (from January, 1988), Norway (from January, 1989), Korea (from January, 1990), Germany (from January, 1991), Austria (from January, 1993), Hungary (from January, 1996), Poland (from January, 1997), Greece (from April, 1998).

In the following Table 1, the descriptive statistics and the number of observations for each country are observed.

Table 1. Descriptive statistics

Country	Values number	Minimum value	Maximum value	Median	Mean	Variance	Standard deviation
Australia	369	3.97	11.21	6.84	7.14	3.65	1.91
Austria	249	3.40	5.50	4.30	4.29	0.02	0.05
Belgium	369	6.30	11.00	8.30	8.41	1.57	1.25
Canada	369	5.90	12.70	7.90	8.50	2.87	1.70
Chile	333	5.44	14.54	7.99	8.31	2.80	1.67
Denmark	369	3.10	9.90	5.80	6.14	2.53	1.59
Finland	309	2.90	17.60	8.70	9.29	12.97	3.60
France	369	6.90	11.30	9.20	9.33	1.13	1.06
Germany	273	5.20	11.50	8.20	8.17	2.56	1.60
Greece	186	7.20	27.50	10.55	12.38	27.84	5.28
Hungary	213	5.50	11.30	7.60	8.14	3.86	1.97
Ireland	369	3.70	17.10	13.10	11.00	22.85	4.78
Italy	369	5.80	12.50	8.90	9.10	2.27	1.51
Japan	369	2.00	5.50	3.70	3.65	1.14	1.07
Korea	285	1.90	8.20	3.30	3.45	1.52	1.23
Luxembourg	369	1.40	6.00	2.90	3.27	1.44	1.20
Mexico	321	2.10	7.60	3.60	3.82	1.16	1.08
Netherlands	369	2.50	8.30	5.10	5.16	2.21	1.49
Norway	297	2.30	6.80	3.70	4.22	1.59	1.26
Poland	201	6.80	20.30	11.10	13.24	19.07	4.37
Portugal	369	3.90	17.60	7.20	7.76	9.28	3.05
Spain	330	7.90	26.60	15.95	15.87	23.02	4.80
Sweden	369	1.30	10.50	6.50	6.08	6.73	2.59
UK	369	4.60	11.30	7.70	7.59	4.43	2.11
USA	369	3.80	10.40	5.80	6.29	2.57	1.60

According to the Table 1, Greece and Spain display the highest unemployment rates, 27.5% and 26.6%, respectively. The unemployment rates in Finland, Poland, Ireland, Spain, and

Greece shows considerably unstable behavior while Austria, Japan, Korea, Luxembourg, Mexico, Norway are characterized by the quite balanced macroeconomic situation.

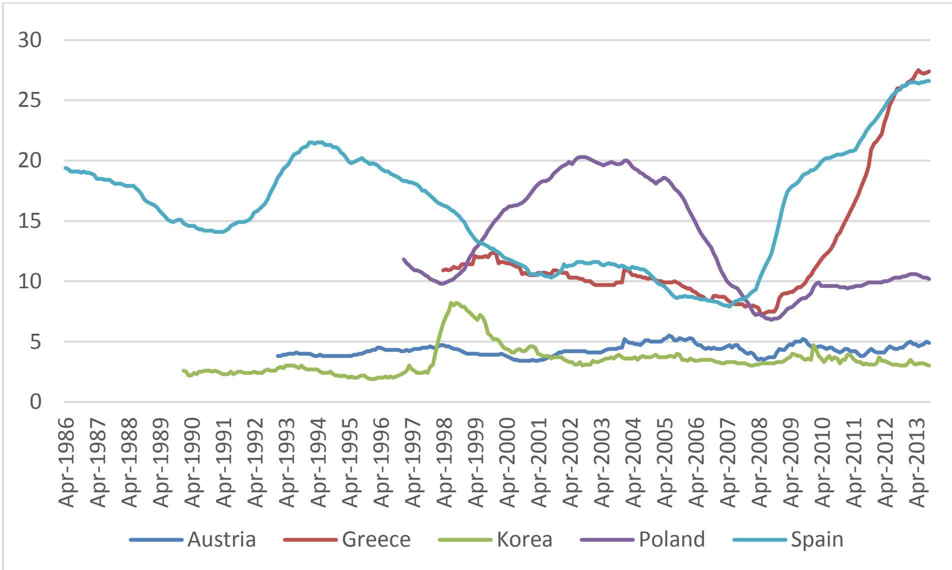

Figure 1. The unemployment rates of 5 countries: Austria, Greece, Korea, Poland, and Spain

In Figure 1. we compare the unemployment rates (in percent) of the selected countries. We observe that both Spain and Greece suffers a significant rise of the unemployment rate from 2008 until 2013, in comparison the unemployment rates of Korea and Austria are quite stable and low. The joblessness in Poland increases sharply from about 10% to over 20% between 1998 and 2003, then the decline of those follows until 2008, later the unemployment rate remains at about 10% from 2010 to 2013.

An Empirical Application

In this section we apply all the unit root tests which include the nonlinearity and structural break in their testing procedure to examine the hysteresis hypothesis in OECD countries. The empirical results of the conducted unit root tests are presented and discussed. Moreover, all applied unit root tests assume that the error terms are serially uncorrelated.

Table 2. Unit Root Test Results

Country	ADF	LNV	Sollis	KSS	EG	LNV-KSS	EST test	FFFFF test	LNV-Sollis
Australia	-1.193	-3.628	0.465	-1.629	1.287	-2.055	-1.641	**-3.740*****	5.409
Austria	-1.493	-1.198	-0.606	-1.174	2.367	-0.927	-1.439	-1.235	2.313
Belgium	-2.106	-2.452	1.364	**-3.324***	**6.643***	-1.768	-3.596	-3.467	2.747
Canada	-2.321	-2.549	-1.030	**-3.500***	**3.148****	-3.073	-2.377	-2.729	**8.508****
Chile	**-3.336****	-2.610	-0.084	**-3.025***	**3.932****	-3.392	-2.664	**-3.382****	5.231
Denmark	-1.745	-2.564	0.934	**-3.000***	2.763	-3.127	-2.531	**-4.074****	**8.352****

Finland	-1.694	-3.566	-0.337	**-4.194***	**4.238****	-3.362	-2.186	-2.904	**10.260****
France	-2.031	-2.408	2.305	**-3.489***	**5.829***	-3.368	-3.607	**-4.480***	6.530
Germany	-0.638	-1.400	0.947	**-2.063****	2.984	-1.109	-1.698	-2.242	0.234
Greece	-2.791	-1.537	-0.594	**-2.815****	2.022	-1.653	0.564	-2.456	5.177
Hungary	-0.703	-0.703	-1.276	-0.369	0.671	-0.369	-0.703	**-3.787*****	0.667
Ireland	-1.045	-2.441	-0.728	-1.774	2.101	-2.031	-2.141	-3.200	**12.183***
Italy	-0.042	-1.198	0.802	-1.673	1.264	0.073	-1.633	-2.666	5.094
Japan	-1.073	-2.888	-0.936	**-2.083****	1.044	**-3.622*****	-1.521	-3.206	**7.771*****
Korea	-1.736	-2.216	-0.387	**-3.344***	2.336	-2.376	-2.379	-2.840	3.902
Luxembourg	0.714	-2.560	0.606	-1.042	0.494	-2.191	-0.073	-2.914	**7.159*****
Mexico	-1.155	-1.819	0.436	**-3.592***	2.666	-3.083	-0.888	-2.921	**7.886*****
Netherlands	-1.647	-2.155	0.780	**-2.801****	**4.495****	-2.144	-3.209	-3.539	**9.299****
Norway	-0.498	-2.321	0.514	-1.219	0.450	-1.529	-0.842	-1.973	0.302
Poland	-1.312	-1.312	-0.076	-2.014	2.078	-2.014	-1.905	-1.960	1.410
Portugal	0.416	-2.747	-0.982	**-2.017*****	0.760	-1.896	-0.849	-3.224	4.553
Spain	-1.198	-2.134	-1.377	**-2.098*****	**3.211*****	-2.077	-2.322	**-3.686****	3.831
Sweden	-0.904	-2.900	-2.478	**-2.032*****	2.771	-3.059	-1.979	-3.255	3.884
UK	-1.558	-2.415	0.493	**-1.982*****	2.765	-2.970	-3.265	**-3.662*****	3.997
USA	-2.554	-2.592	0.310	-3.446	**3.726*****	-2.696	-3.078	**-3.712*****	**9.695****

Note 1: ADF %10 ,%5 and %1 significance level 3.09, 3.39, 3.74. LNV %10, %5 and %1 significance level -3.85, -4.16, -4.76. Sollis %10, %5 and %1 significance level 3.50, 4.30, 6.07. KSS %10, %5 and %1 significance level -1.92, -2.22, -2.82. EG %10, %5 and %1 significance level 3.10, 3.82,5.53. LNV-KSS %10, %5 and %1 significance level -3.50, -3.81, -4.42. EST test %10, %5 and %1 significance level -3.98, -4.27, -4.81. FFFFF test %10, %5 and %1 significance level for k<1 -3.60, -3.90, -4.50, for k=1.1 -3.42,-3.74,-4.39, for k=1.2 -3.33,-3.67,-4.31, for k=1.3 -3.26,-3.62,-4.29, for k=1.4 -3.20,-3.55,-4.22, for k=1.5 -3.13,-3.48,-4.14, for k=1.6 -3.07,-3.42,-4.10, for k=1.9 -2.94,-.330,-3.99. LNV-Sollis %10, %5 and %1 significance level 7.01, 8.10,10.53.
Note 2: *, **, *** indicates the %1, %5 and %10 significance levels, respectively.

In order to assess the efficiency of the nonlinear unit root test, we first demonstrate the results of the conventional ADF test. The ADF test, the linear unit root test, could reject the hysteresis hypothesis only for Chile at the %5 significance level. In other words, the unemployment rates in other 24 OECD countries show a hysterical behaviour.

The KSS test which is nonlinear and allows for state dependency and producing symmetric mean reversion displayed the most frequent rejection of the null hypothesis. The test could reject the null hypothesis for 18 OECD countries, in particular Belgium, Canada, Chile, Denmark, Finland, France, Korea, Mexico, USA at the %1 significance level; Germany, Greece, Japan, and Netherlands at the %5 significance level; UK, Sweden, Spain, and Portugal at the %10 significance level. According to the EG test, which is also nonlinear and state dependent, but allows for asymmetry adjustment, the null hypothesis is rejected only in 8 cases, including Spain, USA, Canada, Chile, Finland, Netherlands, Belgium, and France. In contrast to the KSS test, the Sollis test, which produce asymmetric mean reversion, was not able to reject the null hypothesis in any OECD country. Up to now, the symmetric adjustment assumption shows the superior results.

However, the considered tests verify only the possibility of nonlinear adjustment in the unemployment rate series. However, the unemployment rates might experience the structural breaks during the given time period. To see whether allowing for structural breaks alters the results of the unit rot tests, we implement three different tests, namely LNV test, EST test and

FFFFF test. The results of the LNV and EST unit root tests suggest that the null hypothesis of a unit root is not rejected. On the other hand, the FFFFF test rejects the null hypothesis in 8 OECD members, namely Australia, Chile, Denmark, France, Hungary, Spain, UK, and USA. The implementation of the unit root tests with structural breaks decreased considerably the number of countries which do not contain a unit root.

In the recent studies, new combined unit root tests, namely the LNV-KSS test and the LNV-Sollis test, were investigated. The tests are nonlinear, allowing state dependency and structural breaks. While the LNV-KSS test could reject the hysteresis hypothesis only for Japan at the %10 significance level, the LNV-Sollis unit root test rejects the hysteresis hypothesis in 9 cases, namely Ireland at %1 significance level; Canada, Denmark, Finland, Netherlands, USA at the %5 significance level; Japan, Luxembourg, Mexico at the %10 significance level. It worse to mention, that the LNV-Sollis test allows an asymmetric nonlinear adjustment towards the attractor in contrast to the LNV-KSS test, which assumes a symmetric adjustment.

Overall, most of the conducted unit root tests verified the hysteresis hypothesis for a majority of the OECD countries considered in our study. However, the KSS test could reject the hysteresis hypothesis in the unemployment rates for 18 OECD countries. According to this result, we suppose that the unemployment rates in those countries follow a nonlinear but globally stationary process.

Conclusion

In this study we observed the validity of the hysteresis hypothesis for 25 OECD countries. We have applied unit root tests allowing for nonlinearity and/or structural breaks. The results recommend that the assumption of more complex dynamics in the unemployment rates results in more frequent rejection of the null hypothesis. In particular, the FFFFF test that allow for structural breaks was able to reject the null hypothesis of unit root for 8 OECD countries, while the LNV-Sollis that allow for both structural break and asymmetric nonlinear adjustment towards the attractor, reject the hysteresis hypothesis in 9 OECD countries. On the other hand, the unit root test that allow only for nonlinear symmetric adjustment, namely the KSS test, shows a more frequent rejection of the null hypothesis. The test demonstrates that the unemployment rates in 18 OECD countries follow a non-hysterical process. Therefore, we suppose that the unemployment rates in those countries follow a nonlinear but globally stationary process.

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