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What do unit root tests tell us about unemployment hysteresis in transition economies?

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Abstract

Purpose – This study aims to examine the hysteresis hypothesis in unemployment using monthly data from 13 countries in transition.

Design/methodology/approach – Stationarity in the unemployment rate of selected transition economies was analyzed using four different group unit root tests, namely, linear, structural breaks, non-linear and structural breaks and non-linear.

Findings – The empirical results show that the unemployment hysteresis hypothesis is valid for the majority of transition economies, including Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, the Kyrgyz Republic, Latvia, Lithuania, Poland, Romania and Slovenia. However, the results strongly reject the null hypothesis of unemployment hysteresis for the Kazakhstan and the Slovak Republics.

Originality/value – This study revealed that, for countries in transition, advanced unit root tests exhibit greater validity when compared to standard tests

Keywords Unemployment hysteresis, Transition economies, Fourier unit root test, Non-linear unit root test

Paper type Research paper

1. Introduction

The theory of hysteresis, developed by Blanchard and Summers (1986, 1987), indicates that cyclical variations or shock effects will persist because of the rigidity of the labor market. Hysteresis can include the delayed effects of unemployment, whereby the unemployment rate continues to rise even after the economy has recovered. It can indicate a permanent

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change in the workforce from the loss of job skills making workers less employable even after a recession has ended. Hysteresis occurs when current unemployment is dependent on past values, with the sum of their coefficients equal to or very similar to unity. In other words, the authors developed a new unemployment theory that assumes the unit root process of unemployment dynamics. The theory states that unemployment shocks have lasting long-term effects on the variable, which will be well-defined as unit root process. Accordingly, after a shock, the unemployment rate will not return to its equilibrium in the long term (Bolat *et al.*, 2014). According to Carlin and Soskice (1990), unemployment hysteresis implies that the equilibrium rate of unemployment is path-dependent. Smyth (2003) asserted that, under the unemployment hysteresis theory, cyclical changes in the economy may have a lasting impact on the rates of unemployment. The validity of this hypothesis is of great importance as it impacts on policy. If unemployment is defined as a unit root process, policymakers should focus on structural reforms to mitigate adverse shocks. On the contrary, if unemployment is stationary, the goal would be to avoid short-term imbalances. As unemployment hysteresis is associated with non-stationary unemployment rates, unit root tests have been widely used since the 1980s to investigate the validity of the hysteresis effect. The results obtained are, however, highly dependent on the statistical power of the unit root tests applied. If the presence of dynamics is misspecified in standard unit root tests, all tests have lower power (Enders and Granger, 1998).

Since the seminal work of Blanchard and Summers (1986), researchers have conducted substantial empirical analyzes to evaluate the validity of the hysteresis hypothesis. The extant research has not expounded on transition economies, hence, these studies are scarce. Transition economies can be an interesting case to explore the unemployment hysteresis hypothesis because of their extensive time under one regime. These economies have also started to realize social and economic reforms to keep pace with the ever-changing international environment. Transition economies underwent a deep transformation in the social, economic and political sphere. Integration into global value chains was accompanied by high levels of unemployment, often reaching double digits (Terrell and Jurajda, 2007). Changing global human values has encouraged countries to participate in these new conditions and develop new relations between employers and employees; the labor market of former command economies underwent deep transformation. These structural changes in the labor market have motivated our study.

This study contributes to the existing literature because these transition economies are characterized by profoundly changing labor markets, warranting a thorough understanding of the hysteresis effect. It examines the validity of unemployment hysteresis for selected transition economies, namely, Bulgaria, Croatia, the Czech Republic (CzechR), Estonia, Hungary, the Kyrgyz Republic (KyrgyzR), Latvia, Lithuania, Poland, Romania, Slovenia, Kazakhstan and the Slovak Republic (SlovakR). We use various unit root tests that consider linear, non-linear structures and structural breaks to determine whether the initial specifications of the series affect the performance of unit root test results on unemployment hysteresis. The reason why these tests are used is when the transition between the regimes is a smooth one and/or there exist multiple structural breaks in time series, the advanced unit root tests provide greater power when compared with standard tests. The results of these tests support that the hysteresis hypothesis is accepted for all transition economies except Kazakhstan and SlovakR.

The study is organized as follows: Section 2 addresses unemployment in transition economies. Sections 3 and 4 present the literature and data used, respectively. In Section 5, the methodology and empirical findings are presented. Finally, Section 6 concludes the study.

2. Unemployment in transition economies

During the past decades of the 20th century, transition economies underwent profound changes throughout their economies. The transition process inevitably led to crises (Nesporova, 2002). The severity and scale of this crisis depended on many factors and had a significant impact on the economic and social development of countries in Central and Eastern Europe (CEE) and the Commonwealth of Independent States (CIS).

Transition economies witnessed major layoffs during the 1990s, primarily influenced by the inability of socialist companies to restructure and offer competitive products (Petreski, 2020). The first phase of the transition from a centrally planned to market economy resulted in a recession and a major reallocation of labor and capital; thus, it is expected that, in most post-communist economies, unemployment rates grew rapidly from their theoretically zero base to double digits (Terrell and Jurajda, 2007). Transition economies vary significantly in their economic performance, as observed in the labor market, presenting an unemployment challenge. Many countries have managed to tackle unemployment, while others continue to face severe repercussions.

In some transformation economies, unemployment can be attributed to slow economic recovery. Conversely, there is evidence that in those economies where economic growth has been achieved, unemployment continues to be a challenge. With the dissolution of the Soviet Union, open unemployment began to accelerate. Scholars and policymakers asserted that it was important to tackle economic issues first so that when the economy started to recover, which they expected to be imminent, it would automatically improve labor market outcomes. However, these expectations were unrealized (Nesporova, 1999).

Generally, the initial transformation shock resulted in decreasing employment rates, increasing unemployment, decreasing working hours and declining real wages. However, countries were affected differently by these adjustment mechanisms (Svejnar, 1999). For instance, CEE countries exhibited declining employment rates and increasing unemployment, followed by a slight decline in real wages. In contrast, the former Soviet Union experienced a considerable drop in real wages, while unemployment increased slightly with limited employment rate decreases (Boeri and Terrell, 2002). The 2008 global financial crisis also worsened labor market outcomes.

Scholars argued that persistent high unemployment in transition economies could be attributed to macroeconomic and structural reforms (Nesporova, 2002) or tight labor market regulations. Boeri and Terrell (2002) asserted that it is difficult to associate this persistent unemployment with labor market flexibility, but rather attributed it to ineffectively and inconsistently implemented unions, minimum wages and employment protection legislation. Hungary, for instance, has the most flexible employment protection legislation, while the Russian Federation and Slovenia are most restrictive (Cazes, 2002). Vocational training was given significant attention in Hungary, Croatia and CzechR, while in other countries the implementation of labor market training has been ineffective (Nesporova, 1999).

3. Literature

Hysteresis theory has drawn considerable interest from researchers from various countries since the seminal work of Blanchard and Summers (1986). The extant research indicates contradictory findings when applying various unit root and stationary tests for time series or panel data. These studies are summarized in Table 1.

As can be seen from Table 1, earlier studies used conventional unit root tests. As hysteresis is associated with non-stationary levels of unemployment, unit root tests have

Table 1. Summary of contradictions in extant hysteresis research

Author	Country	Period	Method	Validity
Khraief *et al.* (2020)	29 Organization for Economic Cooperation and Development (OECD) countries	1980–2013	Harvey *et al.* (2008) linearity unit root test and ESTAR non-linear unit root test suggested by Kruse (2011)	The hysteresis hypothesis is rejected
Yaya *et al.* (2019)	42 African countries	1991–2017	Fourier ADF test	The hysteresis hypothesis is confirmed for seven countries
Bechný (2019)	Czech Republic	1999–2016	Bayesian approach	The hysteresis hypothesis is accepted
Albulescu and Tiwari (2018)	8 European Union (EU) countries	1965–2013	Cavaliere and Xu's (2014) unit root tests	The hysteresis hypothesis is accepted
Bahmani-Oskooee et al. (2018)	USA	1976–2016	Non-linear quantile unit root test	For 19 states hysteresis hypothesis is confirmed
Meng *et al.* (2017)	14 OECD countries	1983–2013	Fourier ADF test	For 4 countries hysteresis hypothesis is confirmed
Akdogan (2017)	31 European countries, the USA and Japan		Linear and non-linear unit root tests	The hysteresis hypothesis is rejected for 60% of the countries
Furuoka (2017a)	5 European countries	1991–2015	SUR–FADF procedure	The hysteresis hypothesis is accepted (except Spain)
Furuoka (2017b)	4 Nordic countries	2000–2014	FADF–SB test	The hysteresis hypothesis is not confirmed
Guris *et al.* (2017)	Turkey	1970–2014	Non-linear unit root tests Kapetanios *et al.* (2003) and Kruse (2011)	The hysteresis hypothesis is not confirmed
Garcia-Cintado et al. (2015)	17 Spanish regions	1976–2014	Unit root tests with breaks	The hysteresis hypothesis is confirmed
Furuoka (2014)	14 regions of the Czech Republic	2005–2013	SURADF/FADF procedure	For nine regions hypothesis is confirmed. While for five regions hypothesis is rejected
Bolat *et al.* (2014)	17 Eurozone countries	2000–2013	Non-linear panel unit root test by Ucar and Omay (2009)	For six countries hysteresis effect is confirmed
Gozgor (2013)	CEE countries	1998–2012	Panel unit root test	The hysteresis hypothesis is confirmed
Cheng *et al.* (2014)	PIIGS (Portugal, Italy, Ireland, Greece and Spain) countries	1960–2011	Fourier unit root test proposed by Enders and Lee (2012)	The hysteresis in unemployment is confirmed

(*continued*)

Table 1.

Author	Country	Period	Method	Validity
Cheng *et al.* (2012)	51 US states	1976–2010	PANIC method and recursive mean adjustment (RMA) methods	The hysteresis in unemployment is confirmed
Chang (2011)	17 OECD countries	1960–2009	Becker *et al.* (2006) stationary test with a Fourier function	The hysteresis in unemployment is confirmed for 11 countries
Chang and Lee (2011)	G-7 countries	1992–2008	Caner and Hansen's (2001) threshold unit root test	The hysteresis in unemployment is confirmed for France, Germany and Italy
Lee *et al.* (2010)	9 East Asian economies.	1976–2004	Lee and Strazicich's (2003) minimum LM test	The hysteresis hypothesis is confirmed
Lee *et al.* (2009)	19 OECD countries	1960–2004	The panel LM unit root tests with heterogeneous structural breaks	The hysteresis hypothesis is not confirmed
Lin *et al.* (2008)	16 OECD countries	1970–2005	Caner and Hansen (2001) threshold unit root tests	For Denmark and Portugal the hysteresis hypothesis is accepted
Camarero *et al.* (2008)	8 transition economies	1991–2003	Panel unit root tests	The hysteresis hypothesis is not confirmed
Gomes and da Silva (2008)	Brazil and Chile	1980 2002 1982–2004	Lee and Strazicich's (2003) LM unit root test	The hysteresis hypothesis is accepted in case of both countries
Romero-Ávila and Usabiaga (2007)	Spain and USA	1976–2004	LM unit root tests	The hysteresis hypothesis for Spain is accepted. For US structuralist hypothesis is accepted
León-Ledesma and McAdam (2004)	12 CEE and 15 EU countries	1991–2001	Univariate and panel unit root tests with and without breaks	The hysteresis hypothesis is not confirmed
Camarero and Tamarit (2004)	19 OECD countries	1956–2001	ADF-type panel unit root tests in a SURE framework	The hysteresis hypothesis is valid only for seven countries
Feve et al. (2003)	17 OECD countries	1966–1999	Unit root test	For nine countries the hysteresis hypothesis is accepted
Røed (1996)	16 OECD countries	1970–1994	Exact maximum likelihood stationarity test	For 15 countries the hysteresis hypothesis is accepted (except USA)
Blanchard and Summers (1986)	France, Germany, the UK and the US	1953–1984	DF/ADF unit root tests	The hysteresis hypothesis is accepted (except USA)

been used to assess its validity (Arestis and Mariscal, 2000; Blanchard and Summers, 1986; Brunello, 1990; Røed, 1996).

It is evident from Table 1 that the number of studies dealing with the hysteresis issue in transition economies is scarce. Unemployment hysteresis in CEE countries was examined by León-Ledesma and McAdam (2004), Camarero *et al.* (2005) and Gozgor (2013), however, as far as we are aware, CIS countries have yet to be investigated.

4. Data

In this study, we used the monthly unemployment rates for the selected 13 transition economies from 2000:01 to 2017:04, except for Estonia and Kazakhstan whose data start dates were 2000:02 and 2001:01, respectively. The countries analyzed are Bulgaria, Croatia, CzechR, Estonia, Hungary, Kazakhstan, KyrgyzR, Latvia, Lithuania, Poland, Romania, SlovakR and Slovenia. Data were obtained from the International Monetary Fund database (International Financial Statistics, 2019).

The unemployment time series is generally influenced by seasonality. In the literature, it is very common for researchers to apply a seasonal adjustment to remove the influence of fluctuations in the level of the series and to observe the cyclical, underlying trend and other non-seasonal movements in the series (Akdogan, 2017; Cheng *et al.*, 2012; Garcia-Cintado *et al.*, 2015; Gustavsson and Österholm, 2006; Romero-Ávila and Usabiaga, 2007,etc.). In our empirical analysis, we use seasonally adjusted monthly data on unemployment rates for the 13 countries in transition.

5. Methodology and empirical findings

This study examines whether the hysteresis effect is valid for transition economies by considering different unit root tests. First, we used different linearity tests to detect the existence of non-linearities of the unemployment series for all selected transition economies. This is important because a failure to recognize the non-linearity of a time series can often lead to poor parameter estimates (Bisaglia and Gerolimetto, 2014). We applied different well-known linearity tests, named after McLeod and Li (1983), Keenan (1985), Tsay (1986), Harvey and Leybourne (2007) and Harvey *et al.* (2008). The results of these tests are listed in Table 2.

According to the results given above regarding the McLeod and Li (1983) linearity test, the unemployment series of all countries display non-linear characteristics. However, the other linearity test results are contradictory. This can be attributed to the differences in the mechanism of the tests. Because of the contradictory results, we investigate unemployment hysteresis in the transition economies by considering both linear and non-linear unit root tests in the study.

The performance of unit root tests depends on the specification of the series, which includes deterministic, trend, non-linear and structural breaks. By making stronger and more precise predictions, it is possible to accurately reveal the structure of the data. Alternatively, incomplete and/or misidentification of the data leads to insufficient and less sensitive predictions. Because of the contradictory results of the linearity tests, we consider four groups of unit root tests:

(1) *Linear unit root tests*: Dickey-Fuller/Augmented Dickey-Fuller (Dickey-Fuller, 1979), Phillips-Perron (Phillips and Perron, 1988), Kwiatkowski *et al.* (KPSS, 1992), Elliott *et al.* (Elliott *et al.*, 1996).

(2) *Structural breaks unit root tests*: Zivot-Andrews (ZA, 1992) and Fourier KPSS (Becker *et al.*, 2006).

$$\text{McLeod and Li Model: } y_t = \beta_0 + \Sigma_{i=1}^{p} \delta_i y_{t-p} + \Sigma_{j=1}^{q} \delta_j \varepsilon_{t-q} + \varepsilon_t$$
$$\text{Keenan Model 1: } y_t = \beta_0 + \Sigma_{i=1}^{p} \delta_i y_{t-p} + \varepsilon_t$$
$$\text{Keenan Model 2: } y_t^2 = \beta_0 + \Sigma_{i=2}^{p} \delta_i y_{t-i} + V_t$$
$$\text{Tsay Model 1: } y_t = \beta_0 + \Sigma_{i=1}^{p} \delta_i y_{t-p} + \varepsilon_t$$
Tsay Model 2:
$$y_t = \beta_0 + \Sigma_{i=1}^{p} \delta_i y_{t-p} + \Sigma_{l=1}^{p} \theta_l y_{t-l}^2 + \Sigma_{j=2}^{p} \vartheta_j y_{t-1} y_{t-j} + \Sigma_{j=3}^{p} \varnothing_j y_{t-2} y_{t-j} + \cdots + \Sigma_{j=p}^{p} \varphi_j y_{t-p-1} y_{t-p} + V_t$$
Harvey and Leybourne Model:
$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-1}^2 + \beta_3 y_{t-1}^3 + \beta_4 \Delta y_{t-1} + \beta_5 (\Delta y_{t-1})^2 + \beta_6 (\Delta y_{t-1})^3 + \varepsilon_t$$
$$\text{Harvey } et\ al. \text{ Model }^{I(0)}: y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2}^2 + \beta_3 y_{t-3}^3 + \Sigma_{i=1}^{k} \delta_i \Delta y_{t-i} + \varepsilon_t$$
$$\text{Harvey } et\ al. \text{ Model }^{I(1)}: y_t = \lambda_1 \Delta y_{t-1} + \lambda_2 (\Delta y_{t-1})^2 + \lambda_3 (\Delta y_{t-1})^3 + \Sigma_{i=1}^{k} \delta_i \Delta y_{t-i} + \varepsilon_t$$

Tests	McLeod and Li	k	Keenan	Tsay	Harvey and Leybourne			Harvey *et al.*
Bulgaria	(0.00)***	3	0.467	0.713	9.87	9.75**	9.68	5.41*
Croatia	(0.00)***	6	2.409	2.018***	15.98***	15.79	15.68	13.44***
CzechR	(0.00)***	4	0.026	1.676*	1.32	1.28	1.25	0.26
Estonia	(0.00)***	10	8.537***	1.619**	7.48	7.42	7.38	3.30
Hungary	(0.00)***	3	0.036	0.532	2.33	2.30	2.28	0.73
Kazakhstan	(0.00)***	3	1.478	7.186***	49.52***	49.00	48.71	58.96***
KyrgyzR	(0.00)***	1	0.402	0.132	10.43	10.25**	10.15	0.58
Latvia	(0.00)***	9	9.594***	0.874	7.35	7.29	7.25	3.74
Lithuania	(0.00)***	7	5.275**	1.686**	7.72	7.64	7.59	3.90
Poland	(0.00)***	2	0.003	0.967	3.44	3.31	3.23	3.29
Romania	(0.00)***	2	0.047	1.929	5.71	5.48	5.35	4.80*
SlovakR	(0.00)***	2	0.145	4.712***	5.36	5.13	5.00	2.92
Slovenia	(0.00)***	7	1.745	1.107	2.40	2.37	2.35	0.43

Notes: McLeod and Li (1983) test statistics are obtained using the squares of residuals obtained from the ARMA model in the Ljung and Box (1978) statistic; in the Tsay (1986) test, residuals obtained from Models 1 and 2 equations are regressed and F test statistics are obtained from this equation; in the Keenan (1985) test, residuals obtained from Models 1 and 2 equations are regressed and F test statistics are obtained from two equations; χ_4^2 Table critical values of and the χ_2^2 table critical values of Harvey *et al.* (2008) test are 9.21, 5.99, 4.60, respectively; ***, ** and *simply rejection of the linearity at the 1%, 5% and 10% levels, respectively; values in parentheses indicate prob. values

Table 2.
Results of linearity tests

(3) *Non-linear unit root tests*: Kapetanios *et al.* (KSS, 2003), Sollis (2009), Cuestas and Garratt (CG, 2011) and Kruse (2011).

(4) *Structural breaks and non-linear unit root tests*: Guris (FKruse, 2019).

These different tests show how the initial specifications of the series affect the performance of unit root results.

5.1 First group: linear unit root tests

The first approach used to determine the stationary properties of the series is Dickey and Fuller (1979), which is one of the linear unit root tests. In the following studies, there have been important developments in the unit root testing process. Following this test, many other tests, such as Phillips and Perron (1988), Kwiatkowski *et al.* (1992) and Elliott *et al.* (1996) constitute the basis of unit root literature. Since linear unit root tests such as DF (1979) and PP (1988) do not take into account structural breaks in the model, it has a lower power to reject the null hypothesis that indicates the existence of the unit root and is known to cause deviation (Perron, 1989). With respect to the unit root test process, Elliott *et al.* (1996) developed a test procedure based on the generalized least square (GLS) detrending to increase the power of the test process of Dickey and Fuller (1979). Moreover, KPSS and DF-GLS are also linear unit root tests. The ADF, PP, KPSS and DF-GLS unit root test equations and their results, are summarized in Table 3.

From Table 3, it is evident that the null hypothesis of unit root is not rejected for all countries for ADF, PP and DF-GLS. However, the null hypothesis of unit root is rejected at the first difference for ADF and PP. These findings support that the unemployment hysteresis is valid for all countries. According to the KPSS test, the null hypothesis of unit root is not rejected for Bulgaria, Croatia, CzechR, Hungary, Kazakhstan and Slovenia. These findings highlight that the unemployment hysteresis is not valid for Bulgaria, Croatia, CzechR, Hungary, Kazakhstan and Slovenia.

5.2 Second group: structural breaks unit root tests

Zivot and Andrews (1992, ZA) suggested that the history of structural breaks should be intrinsic by criticizing Perron's (1989) external breakpoint hypothesis. The ZA test allows for one structural break and determines the time of structural breaks endogenously. Lumsdaine and Papell (1997) developed the ZA test, which considers two breaking structures, an endogenous one and/or two breaking unit root tests that were developed by Lee and Strazicich (2003, 2004). The breaks are generally included in the model using dummy variables. However, in this approach, the exact number and time of structural breaks should be known. This causes an unwanted pre-selection bias and weakens the test's strength (Enders and Lee, 2012; Maddala and Kim, 1998). However, these tests are criticized as the number of breaks and the structural forms should be known in advance.

Becker *et al.* (2006) suggested a new unit root test with a Fourier function and used a modified version of the KPSS framework to accommodate non-linear breaks under both the null and the alternative. This test is called the Fourier KPSS (FKPSS, 2006) test and captures smooth and sharp breaks. The power of the test is not affected by smooth or sharp breaks, structural break dates or the number of breaks. The ZA and FKPSS unit root test equations, and their results, are presented in Table 4.

According to the results of ZA, Model A is valid for Bulgaria, Croatia, CzechR, Estonia, KyrgyzR, Latvia, Lithuania, Poland, SlovakR, Slovenia, Model B for Hungary and Romania and Model C for Kazakhstan. In addition, the null hypotheses were rejected for Estonia, KyrgyzR, Latvia, Lithuania and the trend stationary with the structural break was found. The findings of the ZA test show that the unemployment hysteresis is valid for all countries except Estonia, KyrgyzR, Latvia and Lithuania. According to the consequences of the FKPSS, the null hypothesis of the unit root is not rejected for only CzechR and Estonia. These findings show that these series are stationary for only CzechR and Estonia.

5.3 Third group: non-linear unit root tests

Until the end of the 1970s, time series were modeled under the assumption of linearity. However, not all models are linear. Moreover, many real-world problems do not meet the assumptions of linearity. In addition, the reflection of social, political or economic changes is mostly reflected in non-linearity and smooth transition process, rather than revealing a sudden change. Non-linear unit root tests are successful in capturing non-linear patterns. In addition, non-linearity occurs in the form of structural changes in the deterministic components. That is, a broken time trend is a case of a non-linear time trend (Chen, 2014). In addition, failure to consider non-linearity will result in acceptance of the unit root null hypothesis. Non-linearity is included in the unit root process by Kapetanios *et al.* (2003). In

Table 3. Results of ADF, PP, KPSS and DF-GLS unit root tests

ADF model: $\Delta y_t = \mu + \beta T + \delta y_{t-1} + \Sigma_{i=1}^{k} \delta_i \Delta y_{t-i} + \varepsilon_t$

PP model: $\Delta y_t = \mu + \beta T + \delta y_{t-1} + \varepsilon_t$

KPSS model: $y_t = \delta T + r_t + \varepsilon_t$

$r_t = r_{t\text{-}1} + u_t$

DF-GLS model: $\Delta y_t^d = \delta y_{t-1}^d + \Sigma_{i=1}^{k} \delta_i \Delta y_{t-1}^d + \varepsilon_t$

Tests	ADF		PP		KPSS		DF-GLS	
Countries	Level	First difference	Level	First difference	Level	First difference	Level	First difference
Bulgaria	−0.005 [−1.367]	−0.304 [−6.312]***	−0.002 [−1.164]	−0.304 [−6.542]***	0.089 [0.275]	0.0006 [0.189]***	−0.005 [−1.424]	−0.007 [−0.397]
Croatia	−0.005 [−1.126]	−3.29 [−4.969]***	−0.001 [−1.108]	0.451 [−8.230]***	0.043 [0.308]	0.0002 [0.194]***	−0.005 [−1.177]	−0.040 [−1.006]
CzechR	−0.026 [−1.650]	−0.634 [−4.325]***	−0.022 [−1.288]	−1.293 [−18.50]***	0.032 [0.119]	0.002 [0.176]***	−0.027 [−1.918]	−0.483 [−3.763]***
Estonia	−0.016 [−1.579]	−0.700 [−10.31]***	−0.013 [−1.730]	−0.700 [−10.60]***	0.129 [0.151]***	0.002 [0.115]***	−0.013 [−1.381]	−0.412 [−4.420]***
Hungary	0.006 [1.422]	−0.400 [−5.749]***	0.015 [1.364]	−0.511 [−8.621]***	0.334 [0.064]	0.0003 [0.682]***	−0.0009 [−0.206]	−0.381 [−5.604]***
Kazakhstan	−0.029 [−1.265]	−1.235 [−9.739]***	−0.100 [−2.773]*	−1.423 [22.64]***	0.002 [0.291]	0.0004 [0.425]***	−0.013 [−1.006]	−0.136 [−1.286]
KyrgyzR	−0.030 [−1.806]	−1.034 [−15.02]***	−0.030 [−1.990]	−1.034 [−15.00]***	0.003 [0.192]***	0.0002 [0.081]***	−0.027 [−1.702]	−0.032 [−1.069]
Latvia	−0.010 [−2.072]	−0.245 [−4.124]***	−0.006 [−1.602]	−0.287 [−6.072]***	0.101 [0.155]***	0.001 [0.116]***	−0.009 [1.966]	−0.186 [−3.560]***
Lithuania	−0.011 [−2.235]	−0.255 [−3.558]***	−0.004 [−1.394]	−0.366 [−7.002]***	0.167 [0.197]***	0.001 [0.135]***	−0.010 [−2.113]	−0.244 [−3.523]***
Poland	−0.007 [−1.810]	−0.207 [−4.179]***	−0.006 [−1.648]	−0.219 [−4.964]***	0.044 [0.144]***	0.0003 [0.273]***	−0.005 [−1.527]	−0.036 [−1.490]
Romania	−0.020 [−0.739]	−1.322 [−19.95]***	−0.055 [−1.798]	−1.322 [−19.16]***	0.009 [0.133]***	0.001 [0.233]***	−0.024 [−0.987]	−1.318 [−19.90]***
SlovakR	−0.008 [−1.517]	−0.320 [−6.278]***	−0.001 [−1.432]	−0.320 [−6.260]***	0.024 [0.178]***	0.0003 [0.154]***	−0.009 [−1.601]	−0.152 [−4.074]***
Slovenia	−0.013 [−1.663]	−0.512 [−7.303]***	−0.007 [−1.372]	−0.432 [−7.192]***	0.035 [0.242]	0.0007 [0.157]***	−0.010 [−1.445]	−0.504 [−7.218]***

Notes: The null hypothesis of Dickey-Fuller (1979), PP (1988) and DF-GLS (1996) is established as $\delta = 0$; there is unit root. In the DF-GLS test, y_t^d the detrending series of y_t; The variance of the residual obtained from the $r_t = r_{t-1} + u_t$ equation is tested. The null hypothesis of KPSS (1992) is established as $\sigma_u^2 = 0$, there is no unit root; MacKinnon (1991) table critical values were used for the Dickey-Fuller (1979) and PP (1988) tests. In the ADF and PP tests, the table critical values for the level data are −3.99, −3.43 and −3.13, respectively, for 1%, 5% and 10% and −3.46, −2.88 and −2.57, respectively, for the difference series. The critical values for KPSS test statistics are taken from Kwiatkowski et al. (1992). In the KPSS test, the table critical values for level data are 0.21, 0.14 and 0.11, respectively, for 1%, 5% and 10% and 0.73, 0.46 and 0.34, respectively, for the difference series. The critical values for the test statistics of DF-GLS are taken from Elliott et al. (1996). In the DF-GLS test, the table critical values for level data are −3.46, −2.93 and −2.64, respectively, for 1%, 5% and 10% and −2.57, −1.94 and −1.61, respectively, for the difference series; *** and * imply rejection of the unit root at the 1%, and 10% levels, respectively, for ADF, PP and DF-GLS; *** and * imply rejection of the no unit root at the 1% and 10% levels, respectively, for the KPSS test

Table 4.
Results of ZA and FKPSS unit root tests

ZA models:

Model A: $y_t = \mu + \beta T + \delta y_{t-1} + \theta_1 DU(\lambda) + \Sigma_{i=1}^{k} \delta_i \Delta y_{t-i} + \varepsilon_t$

Model B: $y_t = \mu + \beta T + \delta y_{t-1} + \theta_2 DU(\lambda) + \Sigma_{i=1}^{k} \delta_i \Delta y_{t-i} + \varepsilon_t$

Model C: $y_t = \mu + \beta T + \delta y_{t-1} + \theta_1 DU(\lambda) + \theta_2 DU(\lambda) + \Sigma_{i=1}^{k} \delta_i \Delta y_{t-i} + \varepsilon_t$

Fourier KPSS Model 1: $y_t = \alpha_0 + \beta T + \alpha_1 \sin\left(\frac{2\pi k^* t}{T}\right) + \alpha_2 \cos\left(\frac{2\pi k^* t}{T}\right) + v_t$

Fourier KPSS Model 2: $y_t = \delta T + r_t + \varepsilon_t$

$r_t = r_{t-1} + u_t$

Tests	ZA					FKPSS		
Countries	k	T_B	δ	θ_1	θ_2	k^*	k	FKPSS
Bulgaria	14	2008:11	−0.020 [−4.602]	0.043 (5.708)	-	2	11	0.336***
Croatia	14	2011:11	−0.031 [−3.766]	0.016 (2.681)	-	1	11	0.117***
CzechR	7	2008:11	−0.070 [−3.987]	0.054 (3.773)		2	11	0.058
Estonia	8	2008:05	−0.092 [−7.081]***	0.139 (6.587)	-	2	11	0.074
Hungary	14	2012:03	−0.067 [−4.040]	-	−0.001 (−4.243)	1	11	0.141***
Kazakhstan	12	2010:01	−0.198 [−4.813]*	−0.023 (−4.032)	0.0005 (4.758)	1	11	0.204***
KyrgyzR	13	2005:09	−0.155 [−4.647]*	0.027 (4.039)		1	11	0.145***
Latvia	7	2008:06	−0.050 [−6.283]***	0.063 (5.533)	-	2	11	0.092***
Lithuania	6	2008:06	−0.046 [−5.882]***	0.083 (5.378)	-	2	11	0.212***
Poland	5	2009:10	−0.014 [−3.411]	0.010 (2.796)	-	1	11	0.156***
Romania	3	2014:10	−0.066 [−2.245]	-	−0.001 (−3.063)	2	10	0.102***
SlovakR	4	2008:12	−0.029 [−4.517]	0.030 (5.457)	-	2	11	0.196***
Slovenia	6	2008:12	−0.031 [−3.646]	0.038 (4.880)	-	1	11	0.103***

Notes: In the ZA tests, Model A allows for a structural break change in intercept, Model B allows for a structural break in the slope and Model C allows for a change in both the intercept and slope; DU and DT are dummy variables that control the changes in the level and trend, respectively; In the ZA tests, the null hypothesis is that the series has unit root without a structural break against the alternative hypothesis that they are stationary with break; All unit root tests include an intercept and trend; If null hypotheses are rejected in the FKPSS, there is unit root; k* indicates the optimal frequency, while k indicates the optimal number of lags. TB shows the estimated breakdown date. Values in parentheses show the *t* statistic and values in square brackets represent the test statistics value. δ shows the unit root test statistic values; The critical values for test statistics were taken from Zivot and Andrews (1992). In the ZA test, the table critical values for Model A are −5.34, −4.80, −4.58, for Model B are −4.93, −4.42, −4.1 and for Model C are −5.57, −5.08 and −4.82 for 1%, 5% and 10%, respectively; In the study, Lee and Strazicich (2003, 2004) unit root test allows endogenous one and/or two structural breaks. The results of this test are not included because the dummy variables are not significant. This situation is interpreted as the LM root unit root test could not catch smooth breaks because it captures sharp breaks better; Table critical values of the Fourier KPSS (FKPSS) unit root test are taken from Becker et al. (2006). The table critical values of the Fourier KPSS unit root test are 0.071, 0.054 and 0.047 for k* = 1, and 0.202, 0.133 and 0.103 for k* = 2 and for 1%, 5% and 10%, respectively; *** and *imply rejection of the unit root at the 1% and 10% levels, respectively, for ZA; *** and * imply rejection of the no unit root at the 1% and 10% levels, respectively, for FKPSS this test procedure, non-linearity is considered by using a smooth transition threshold autoregressive (STAR) model. This model type can be described as the exponential smooth transition threshold autoregressive (ESTAR) model. Sollis (2009) developed a unit root test based on the asymmetric exponential smooth transition threshold autoregressive model type, when Kruse (2011) developed a unit root test based on the ESTAR model type. The unit root test based on a logistic smooth transition threshold autoregressive model type was developed by Leybourne *et al.* (1998), Sollis (2004) and Pascalau (2007). Chong *et al.* (2008) and Cuestas and Garratt (2011) suggested non-linear unit root tests, which are specific tests, and can be used to test economic hypotheses. In addition, Enders and Granger (1998) and Caner and Hansen (2001) tests are sharp transition non-linear unit root tests that reveal the presence of the unit root. These tests can be defined as compliant with a self-exciting threshold autoregressive model.

In this study, non-linear unit root tests based on the STAR model type are used. Transitions in the economic structure are often soft. For this reason, KSS (2003), Sollis (2009), CG (2011) and Kruse (2011) tests were used because of their higher test power. The non-linear unit root test equations, and their results, are presented in Table 5.

According to the non-linear unit root test results, the unit root hypothesis is not rejected for all countries. In the case of SlovakR for the KSS test, Romania for the Sollis test and Latvia, Romania and SlovakR for the Kruse test, hysteresis effects have not been observed

KSS model: $\Delta y_t = \theta y_{t-1}^3 + \Sigma_{i=1}^k \delta_i \Delta y_{t-i} + \varepsilon_t$
Sollis model: $\Delta y_t = \theta_1 y_{t-1}^3 + \theta_2 y_{t-1}^4 + \Sigma_{i=1}^k \delta_i \Delta y_{t-i} + \varepsilon_t$
CG Model 1: $y_t = \alpha_0 + \alpha_1 T + \alpha_2 T^2 + \alpha_3 T^3 + \varepsilon_t$
CG Model 2: $\hat{\varepsilon}_t = \theta_1 \hat{\varepsilon}_{t-1}^3 + \theta_2 \hat{\varepsilon}_{t-1}^4 + \Sigma_{i=1}^k \delta_i \Delta \hat{\varepsilon}_{t-i} + \varepsilon_t$
Kruse model: $y_t = \theta_1 y_{t-1}^3 + \theta_2 y_{t-1}^2 + \Sigma_{i=1}^k \delta_i \Delta y_{t-i} + \varepsilon_t$

Countries	k	KSS	Sollis	CG	Kruse
Bulgaria	6	−2.294	2.704	3.586	7.047
Croatia	6	−2.064	2.617	1.468	7.112
CzechR	5	−2.085	2.807	3.529	6.963
Estonia	8	−2.643	3.634	4.577	7.184
Hungary	8	−1.033	0.628	6.914	2.639
Kazakhstan	8	−0.937	0.764	7.084	1.311
KyrgyzR	1	−0.637	0.359	0.419	0.717
Latvia	7	−3.159	5.197	6.949	11.16*
Lithuania	6	−2.280	3.100	3.667	8.022
Poland	5	−2.789	3.994	4.340	8.309
Romania	3	−0.966	7.161**	8.203	13.49**
SlovakR	8	−3.304*	5.490	6.742	15.56**
Slovenia	7	−1.903	2.012	3.284	6.578

Notes: For the KSS test, if null hypotheses are $\theta = 0$, there is unit root, while for Sollis, CG and for Kruse tests, if null hypotheses are $\theta_1 = \theta_2 = 0$, there is unit root; Model 2 is estimated, as in the Sollis (2009) test, using residual from Model 1 in the Cuestas and Garratt test; k indicates the optimal number of lags. All unit root tests include intercepts and trends; Table critical values of unit root tests are taken from KSS (2003), Sollis (2009), Cuestas and Garratt (2011) and Kruse (2011). The critical values of the KSS unit root test are −3.93, −3.40, −3.13 and 1%, 5% and 10%, respectively. Table critical values of the Sollis unit root test are 8.95, 6.59, 5.59; table critical values are 22.44, 17.27 and 14.97 for the CG unit root test, and 17.10, 12.82 and 11.10 for the Kruse unit root test for 1%, 5% and 10%, respectively; **and *imply rejection of the unit root at the 5% and 10% levels, respectively

Table 5.
Results of non-linear unit root tests

because there was no unit root. According to the CG test result, there is a unit root for all countries, and the null hypothesis is not rejected.

5.4 Fourth group: structural breaks and non-linear unit root tests

The use of dummies in structural break unit root tests indicates sharp and sudden changes to the slope or constant. However, these tests will not provide sensitive results if the breaks are smooth. Moreover, it was emphasized by Leybourne *et al.* (1998) that breaks should be considered as smooth and progressive processes. Thus, because the reflection of structural breaks takes a certain time, this makes the transition smooth. Becker *et al.* (2006) developed a unit root test with a Fourier function to catch smooth breaks. The behavior of a non-periodic and unknown function can be captured using the Fourier function. When we consider the tests that accommodate structural breaks and non-linearity, the Fourier KSS test developed by Christopoulos and Leon-Ledesma (2010) and Fourier Kruse unit root tests developed by Guris (2019) are the most effective. In this study, the hysteresis effect was investigated using the Fourier Kruse (Guris, 2019) test because it has higher test power. The Fourier Kruse unit root test equations, and their results, are listed in Table 6.

For all countries except Kazakhstan and SlovakR, the null hypothesis could not be rejected, and it was found that the series contained unit roots. In the case of the Kazakhstan and the SlovakR, the F test proposed by Becker *et al.* (2006) was applied, and it was concluded that the series was stationary around the broken deterministic function. According to these findings, the unemployment hysteresis hypothesis holds true in all cases except the Kazakhstan and the SlovakR.

Table 6.
Results of Fourier Kruse unit root test

Fourier Kruse Model 1: $y_t = \alpha_0 + \beta T + \alpha_1 \sin\left(\frac{2\pi k^* t}{T}\right) + \alpha_2 \cos\left(\frac{2\pi k^* t}{T}\right) + v_t$

Fourier Kruse Model 2: $\Delta v_t = \theta_1 y_{t-1}^3 + \theta_2 y_{t-1}^2 + \Sigma_{i=1}^{k} \delta_i \Delta v_{t-i} + \varepsilon_t$

Countries	k*	k	FKruse	F-stat.
Bulgaria	1	1	10.14	159.32
Croatia	1	2	1.730	182.80
CzechR	2	4	8.459	97.21
Estonia	2	4	6.191	167.19
Hungary	1	1	5.380	934.34
Kazakhstan	1	12	20.61**	107.71***
KyrgyzR	2	1	3.727	42.21
Latvia	2	4	11.11	191.90
Lithuania	2	5	10.15	171.17
Poland	2	5	9.041	413.55
Romania	2	1	2.250	85.70
SlovakR	2	8	14.750**	135.69***
Slovenia	1	3	6.615	96.73

Notes: All unit root tests include an intercept and trend; If null hypotheses are $\theta_1 = \theta_2 = 0$, there is unit root; Model 2 is estimated, as in Kruse (2011) test, using error terms from Model 1; k* indicates the optimal frequency, while k indicates the optimal number of lags; Table critical values of unit root tests are taken from Guris (2019). The table critical values of the FKruse unit root test are 23.56, 18.54, 15.74 for k* = 1 and 18.78, 14.2, 12.32 for k* = 2 and Becker et al. (2006) F table value is 6.87, 4.97 and 3.92 for 1%, 5% and 10%, respectively; In case, the unit root null hypothesis is rejected, Becker et al. (2006) used the F statistic to test the null hypothesis of the absence of the non-linear trend suggested in the study, and the rejection of the null hypothesis states that the series is stationary around the broken deterministic function; *** and ** imply rejection of the unit root at the 1% and 5% levels, respectively

5.5 Comparison of the unit root tests

The results regarding the existence of unit root tests are mixed for a few countries. It is very important to lay out the structure of the data and to perform the appropriate test accordingly. Thus, we compared the results of the unit root tests implemented in this study, and a comparison of these tests is displayed in Table 7.

According to ADF, PP and DF-GLS unit root tests, the unemployment hysteresis is valid for all selected countries. According to the KPSS test, the null hypothesis of unit root is not rejected for Bulgaria, Croatia, CzechR, Hungary, Kazakhstan and Slovenia. The ZA unit root test results show that the null hypotheses were rejected for Estonia, KyrgyzR, Latvia, Lithuania and the trend stationary with the structural break was found. According to the consequences of the FKPSS, the series is stationary for only CzechR and Estonia. When we look at the non-linear tests, it is seen that the results exhibit differences. Additionally, the unit root hypothesis could not be rejected for all countries. According to the KSS, the unemployment hysteresis is not valid for the SlovakR. There was no hysteresis effect for Romania using the Sollis test, nor Latvia, Romania and SlovakR, for the Kruse test. According to the CG test result, there is unit root for all countries and the null hypothesis could not be rejected. The FKruse test results revealed that the unemployment hysteresis is valid for all countries except Kazakhstan and SlovakR.

Generally, the findings of the study show that the unemployment hysteresis is valid in 11 out of the 13 transition economies. It is invalid for the Kazakhstan and SlovakR, attributable to the following factors: Kazakhstan is characterized by comparatively high labor market performance, as high labor force participation rates, low inactivity and low unemployment were observed even during the economic recession. Long-term unemployment remains very low (Strokova *et al.*, 2016). Another particularity of Kazakhstan's labor market is its widely used vocational guidance, vocational training and retraining programs (ILO, 2015).

In the SlovakR, the employers' right to fire workers was considerably more restricted (Domonkos, 2016), together with its measures focused on job creation and the retraining of jobseekers (Ham *et al.*, 1995). The share of spending on these programs exceeded 80% of the total spend on active labor market policies (Terrell *et al.*, 1996).

Our findings contradict those of León-Ledesma and Mcadam (2004). They rejected the unit root hypothesis after controlling for structural changes and business cycle effects in the case of CEE countries. Similar findings have been obtained by Bechný (2019) and Furuoka

Countries	ADF	PP	KPSS	DFGLS	ZA	FKPSS	KSS	Sollis	CG	Kruse	FKruse
Bulgaria	√	√	X	√	√	√	√	√	√	√	√
Croatia	√	√	X	√	√	√	√	√	√	√	√
CzechR	√	√	X	√	√	X	√	√	√	√	√
Estonia	√	√		√	X	X	√	√	√	√	√
Hungary	√	√	X	√	√	√	√	√	√	√	√
Kazakhstan	√	√	X	√	√	√	√	√	√	√	X
KyrgyzR	√	√	√	√	X	√	√	√	√	√	√
Latvia	√	√	√	√	X	√	√	√	√	X	√
Lithuania	√	√	√	√	X	√	√	√	√	√	√
Poland	√	√	√	√	√	√	√	√	√	√	√
Romania	√	√	√	√	√	√	√	X	√	X	√
SlovakR	√	√	√	√	√	√	X	√	√	X	X
Slovenia	√	√	X	√	√	√	√	√	√	√	√

Note: √ implies that there is unit root

Table 7. Comparison of unit root tests

(2014) for CzechR. In addition, our findings concur with Gozgor (2013) results in the case of 10 CEE countries.

6. Conclusion

In this study, alternative approaches to unemployment hysteresis have been tested for selected transition economies by using different unit root tests that focus on the different properties of the time series. It was revealed that the results were highly dependent on the power of the unit root tests applied. Moreover, if non-linearity and/or structural breaks are not taken into consideration, the series may present as if it is not stationary.

When unit root tests are applied to unemployment rates, we find mixed evidence for hysteresis for all countries. The results of the study show that the unemployment hysteresis is valid in 11 out of the 13 countries in transition (Bulgaria, Croatia, CzechR, Estonia, Hungary, KyrgyzR, Latvia, Lithuania, Poland, Romania and Slovenia), while the unemployment hysteresis is not valid for the Kazakhstan and SlovakR. According to our findings, the unemployment rate of most transition economies is permanently affected by shocks. The deviation that will occur in the average unemployment rate affects the macro economy. Therefore, a rather structural approach is needed to reduce the unemployment rate. As a result of crisis, breaks and shocks in the economy, the unemployment rate series will not return to its previous level and will tend to remain at the new balance level. Negative effects caused by these structural changes need to be reduced, thus structural reforms are needed to increase the efficiency of transition economies in the labor market.

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