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Investigating the stationarity hypothesis of Gross Domestic Product per capita in Central and Eastern Europe and Commonwealth of Independent State countries: Evidence using Fourier based panel KPSS test

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Using annual data from 1985 to 2016, the study conducts a robust panel stationarity analysis by accounting for cross-sectional dependency, sharp breaks and gradual structural shifts for per capita Gross Domestic Product (PCGDP) of Central and Eastern Europe (CEE) and Commonwealth of Independent State (CIS) countries. The empirical finding reveals that PCGDP at different Fourier frequency and model structure (trend or constant) for both CEE and CIS countries are unit root process. Moreover, the PCGDP of CEE and CIS countries are nonmean reverting in the presence of cross-sectional dependence and gradual structural shifts which previous studies using well-known panel stationarity estimators fail to find. Policy insights are highlighted in the conclusion section.

1 | BACKGROUND OF THE STUDY

This study investigates the stationarity and asymptotic properties of per capita Gross Domestic Product (PCGDP) for the case of Central and Eastern Europe (CEE) and Commonwealth of Independent State (CIS) countries. The CEE countries are capturing 4% growth rate of the world.[1] The CEE countries not only accelerate growth rate, but also focus on innovations through investment in research and development in solving structural problems particularly unemployment and poverty. On the other side, CIS countries are contributing 4.9% to the world Gross Domestic Product (GDP) in term of PPP.[2] The current study also seeks to conduct a more robust and powerful test of the null hypothesis of stationarity against an alternative of nonstationarity (unit root) for PCGDP in both CEE and CIS countries by the adoption of Fourier panel statistics[3] $Fp(k)$. Furthermore, we also conduct Im, Lee, and Tieslau (2005) and Hadri and Rao (2008) proposed panel LM unit root tests and in comparison, with the Fourier approximation test that account for cross-sectional dependence (CSD) and gradual structural shifts for CEE and CIS countries.

The choice of CIS and CEE countries is motivated by the dynamic characterization in the blocs.[4] The CIS countries are an offshoot of the breakup of the Soviet Union. Many of the countries in the panel of CIS countries are in their transition period towards the market-based economy. However, there is still a noticeable disparity in the individual countries in terms of economic and development dynamics. For instance, Russian federation economic performance overruns Tajikistan and Kazakhstan in same bloc. While on the other hand, for the CEE countries, there exist similarity in their economic nature as most member states have undergone significant political and economic stress in their transition to market-based economies in the early 1990's prior to the war years. Thus, this current study is worthy of investigation, and handy to the literature, as it arms econometricians and economists with adequate information for the modeling process. Therefore, we are motivated to examine whether CEE and CIS countries affiliate stationarity or not with the presence of shocks on per capita GDP. Furthermore, we re-analyze whether per capita GDP for both CEE and CIS countries are transitory or permanent over a balanced panel framework by employing the Fourier approximation.

Since Stock and Watson (1986), the modeling of PCGDP as either a difference stationary or a trend stationary process have acknowledged considerable attention in the recent trend. The characteristics of PCGDP have imperative inferences for macroeconomic strategy making, modeling, testing and forecasting. The question of whether PCGDP can be characterized by a unit root has been a subject of specific curiosity (Wasserfallen, 1986; Ben-David and Papell, 1995; Cheung and Westermann, 2002; Rapach, 2002). Stock and Watson (1986) explain that a unit root in PCGDP is inconsistent with the concept that business cycles are stationary fluctuations around a deterministic trend in the United States. In its place, it advocates that shocks to real output have perpetual effects on the system. The substance of the standing research works has concentrated on the application of unit root tests that allows structural breaks in the trend function under the trend stationary alternative but not under the unit root null. Therefore, we use Fourier approximation[5] and constant and/or trend model structure that can capture unknown type and functional forms of the structural breaks. Research studies on the aforementioned matter are of concern both to empirical researchers and policymakers. Hence, many theoretical and empirical studies in this area were devoted to test for unit root or stationarity hypothesis in panel data (as they improve the power of the tests[6]) with a large T (time dimension) and a large N (cross-section dimension). The power of the tests draws from the combination of both T (time series dimension) N (cross-sectional) (Baltagi & Kao, 2001).[7] Historically, in theoretical setting, the initial version of panel unit root tests was developed during the mid-1990s and the early 2000s by assuming independent cross-sectional or uncorrelated cross-sectional units. At the same vein, Banerjee (1999), Baltagi and Baltagi (2001) and Baltagi and Kao (2001) provide comprehensive surveys on the first-generation panel unit root tests.[8]

Nevertheless, in the case of empirical applications, this postulation is flawed. O'Connell (1998) for the first time verified that the panel tests are significantly controlled by violating the independent postulation via simulation. Therefore, Banerjee, Marcellino, & Osbat, 2004 viewed arguments in contradiction of the use of panel unit root tests. At the same line, the development of panel test that captures CSD became necessary and test based on CSD referred as second-generation panel unit root tests. Phillips and Sul (2003), Chang (2004), Bai and Ng (2004), Moon and Perron (2004), Choi and Chue (2007), and Pesaran (2007) purposes for panel unit root tests by focusing this into the account. For the implication of panel stationarity tests, both Bai and Ng (2004) and Harris, Leybourne, and McCabe (2005), correct the CSD by using the Bai and Ng (2004) principal component analysis.

This study relies on the novel simple panel stationarity test that is robust in the presence of CSD and gradual structural shift. It also distinguishes it from previously conducted studies in this regard. In addition to the previously mentioned novelty of the current study, this study distinct from the bulk of previous studies by capturing for unknown break dates(s), unlike previously known tests that do not or only attempts to account for the traditional dummy variable creation procedure. The dummy traditional dummy procedure is arguably to be flawed. Only recently did the novel panel stationarity test gain prominence as seen in the study (inter alia Nazlioglu & Karul, 2017), in investigating the stationarity properties of international commodity prices. This study at this point claims to offer more reliable results that are free from spurious analysis, given the estimators applied in the course of the study. Thus, our findings can be used for policy framework construction(s) for the blocs investigated.

Moreover, this study conducts CSD tests (Breusch & Pagan, 1980; Pesaran, 2004; Pesaran, Ullah, & Yamagata, 2008) and slope homogeneity test proposed by Pesaran and Yamagata (2008) that confirm the presence of slope heterogeneity in both the countries. On the other hand, it also reveals that the per capita GDP in CIS and CEE countries are nonmean reverting. This shows that shock on per capita GDP is persistent over time period. Furthermore, the Im et al. (2005) proposed panel LM test affiliate the existence of stationarity for both (level and trend) shift at difference breaks.

The layout of the paper is organized as follows, Section 2 outlines the review of the related studies, Section 3 describes the empirical modeling, test statistic and asymptotic distribution, and Section 4 shows the results discussion and implication. Finally, Section 5 provides the concluding remarks and policy recommendations.

2 | REVIEW OF RELATED STUDIES

Since 1990s, a couple of researchers have been focusing on panel data for unit root test but the most noticeable studies in this field of econometrics for panel data modeling are Levin and Lin (1993), Quah (1994), Breitung and Meyer (1994), and Maddala and Wu (1999).[9] Nevertheless, several the problem with unit root methods have been well documented in the research works such as the methods that test the null hypothesis of unit root do not reject the null hypothesis unless there is strong evidence against them and even weak alternative hypothesis.

In trying to decide whether a series is stationary or not, one could utilize either the tests that are based on the null hypothesis of non-stationary against an alternative of stationarity or both type of tests for the purpose of robustness. Kwiatkowski, Phillips, Schmidt, and Shin (1992), hereafter Kwiatkowski–Phillips–Schmidt–Shin (KPSS) develop test of the null hypothesis of stationarity against the alternative hypothesis of a unit root. Unit root tests are biased towards accepting the false unit root null hypothesis by using structural break on the KPSS test (Lee, Huang, & Shin, 1997). Moreover, the distributions of the stationarity tests are invariant asymptotically to break exclusion if the alternative hypothesis of a unit root tests are true. By using univariate KPSS test, Hadri (2000) outspreads the test of panel stationarity with *independent and identically distributed* (*i.i,d*[10]) disturbance term across "*i*" over "*t*." Furthermore, it is extended to heterogeneous CD that is built on common factor disturbance (Hadri & Kurozumi, 2011, 2012). Although, the structural breaks affect the individual distribution in null hypothesis, it needs to control the distribution to elaborate with the size distortion problem. Furthermore, a couple of researchers have been devoted to considering breaks in the sample for better policy insights.[11]

Balestra and Nerlove (1966), incorporate a panel dynamic model in empirical research by focusing on both homogeneous and heterogeneous panel dynamic. To incorporate the power of the tests, most of the researchers got interested on both time and cross-sectional dimension to develop a new mode in the research content. However, the first generation of unit root tests[12] are based on CSD in a panel data with independent vector but it is not practically holding. Furthermore, Breuer, McNown, and Wallace (2002) demonstrate second-generation unit root tests that account for CSD tests that increase the power of the test over the single equation tests. On the other hand, Smith, Leybourne, Kim, and Newbold (2004) use the bootstrap technique that allows CSD test with power. Pesaran (2007) also uses the second-generation unit root tests that allow lagged value with CSD tests. But both first generation and second generation have not initiated any breaks. Therefore, Im et al. (2005), postulate "*dummy variable approaches*" where structural shifts are implemented instantaneously. On the other hand, Carrion-i-Silvestre, Kim, and Perron (2009) and Westerlund (2012), have absorbed on endogenous multiple structural breaks that determine the maximum number of breaks and also address the issues of the location, over parameterization, and power loss (Enders & Lee, 2012; Rodrigues & Taylor, 2012). The study conducts a robust panel stationarity analysis by accounting for CSD, sharp breaks, and gradual structural shifts for per capita GDP of CEE and CIS countries. Fourier approximation postulated by Becker et al. (2006); Hadri and Kurozumi (2011, 2012) give the combination results of both cross-section and time series structural shifts stationarity tests.

The traditional unit root tests incorporate the structural breaks that are suffering from less powerful and greater size inaccurate in the system. This basically infers that one do not reject the false null hypothesis of unit root and hence committing type II error. In order to solve this issue, Kapetanios, Shin, and Snell (2003) developed a nonlinear unit root tests for a given sample that captures the possibility of smooth transaction nonstationary within a threshold level and prospect of a mean-reverting stationary process. Moreover, few studies are highlighted the nonlinear mean-reverting stationary hypothesis are Leybourne, Newbold, and Vougas (1998) for Chinese provinces, Christopoulos (2006) for OECD countries, Chang, Su, and Lee (2009) for EU, Murthy and Anoruo (2009) for African countries, Chang, Ho, and Caudill (2010) for 11 Middle Eastern countries and Cuestas and Garratt (2011) for developing countries. Cuestas and Garratt (2011) for developing countries. More recently, Tiwari and Suresh (2014) for 17 Asian countries and Solarin and Anoruo (2015) for 52 African countries.

On the other hand, Bahmani-Oskooee and Gelan (2018) use the nonlinear quantile unit root test for unemployment rate of 52 U.S. states and find that some states follow stationarity where as some are nonstationarity. Furthermore, Bahmani-Oskooee and Gelan (2018) use nonlinear quantile unit root test for exchange rate for African countries and find the nonlinear stationarity relationship in the African countries. Bahmani-Oskooee and Gelan (2018) by using the fourier quantile unit root test in the manufacturing goods, find the stationarity relationship in the manufacturing goods. Xie, Tiwari, and Chang (2018) examine the nonstationarity hypothesis for tourist arrives to India from different cities. The panel KPSS test is used in their analysis that support the nonstationarity impact on tourist arrives to India from different cities.

3 | EMPIRICAL MODELING, TEST STATISTIC AND ASYMPTOTIC DISTRIBUTION

This section focuses on the modeling construct as the study dwells on examining the stationarity and asymptotic properties of PCGDP for the case of CEE and CIS countries over annual period of 1985–2016.[13] This study uses data generating process (DGP) as follow.

$$y_{i,t} = \beta_i(t) + r_{i,t} + \phi_i F_i + \varepsilon_{i,t} \quad (1)$$

$$r_{i,t} = r_{i,t-1} + \mu_{i,t} \quad (2)$$

In this current study y_{it} is defined as per capita GDP.

Here, cross sectional dimension is presented by i = 1, 2, …, N while time dimension is denoted by subscripts, t = 1, 2, …, T represents time dimension. $r_{i,\,t}$ is a simple autoregressive process (random walk) with an asymptotic expectation of zero, that is, $r_{i0} = 0\forall_i$ to avoid loss of generality in the model setup, heterogeneous constant terms are included. $\varepsilon_{i,\,t}$ and $\mu_{i,\,t}$ are the stochastic error term which are mutually independent and identically distributed (*iid*) with expected value of zero and positive constant variance across both time and cross section. $\phi_i F_i$ represents the CD terms (unknown common factor and its loading weights), Also both ϕ_i and F_i have same properties. However, F_i is assumed to be known (Nazlioglu & Karul, 2017).

From Equation (1) $\beta_i(t)$ is the time-dependent deterministic term to capture structural unknown break(s). Becker et al. (2006) applied Fourier approximation to carbon copy various shifts irrespective of date, number and break(s) forms. Thus, the Fourier expansion of the deterministic term (intercept) with one frequency component is expressed as;

$$\beta_{i,t} = \lambda_i + \varphi_{1,i}\sin\left[\frac{2\pi kt}{T}\right] + \varphi_{2,i}\cos\left[\frac{2\pi kt}{T}\right] \quad (3)$$

where $\varphi_{1,\,i}$ and $\varphi_{2,\,i}$ denotes the amplitudes and displacement of shifts while K is the Fourier frequency as seen in Equation (3) above. Including trend, Equation (3) becomes:

$$\beta_{i,t} = \lambda_i + b_i t + \varphi_{1,i}\sin\left[\frac{2\pi kt}{T}\right] + \varphi_{2,i}\cos\left[\frac{2\pi kt}{T}\right] \quad (4)$$

The incorporation of the trend into Equation (4) allows the sinusoidal function to have different starting and ending values. Hence can be used to produce smoothly curving trend function (see Xu & Lee, 2015). Although the single frequency Fourier approximation does not accommodate sudden structural breaks, it captures breaks with unknown forms (Nazlioglu & Karul, 2017). Thus, using the Fourier panel statistics[14] the current study seeks to conduct a simple test on the null hypothesis of stationarity against an alternative of nonstationarity (unit root) for per capita GDP in both CEE and CIS countries by the adoption of Fourier panel statistics $Fp(k)$. The $Fp(k)$ statistics is developed from the average individual statistics of KPSS test which allows for Fourier frequency, which was advanced by Becker et al. (2006). The use of this test is informed by the fact that it is considerably easier to develop the augmented KPSS test statistic than the LM test statistic even though both tests have the similar asymptotic optimality. Also, the test is highly resilient with cross-sectional dependency (CD) and gradual structural shifts. Equally, the test has the empirical advantage over other tests in practical analysis. We also conduct Hadri and Rao (2008) and panel LM unit root tests in comparison with The Fourier approximation test that account for CD and gradual structural shifts.

The statistics of KPSS is defined as:

$$\eta(k) = \frac{1\sum_{t=1}^{T} \tilde{S}_{i,t}(k)^2}{T^2 \tilde{\sigma}_{\varepsilon,i}^{\ 2}} \tag{5}$$

Here, $\tilde{S}_{i,t}(k) = \sum_{j=1}^{t} \tilde{\varepsilon}_{i,j}$ is derived from ordinary least square residuals obtained from Equation (1) as being the partial sum process while $\tilde{\sigma}_{\varepsilon,i}^{\ 2}$ denotes estimate that captures for the long run variance of $\varepsilon_{i,t}$ that is given below as:

$$\sigma_{\varepsilon,i}^{\ 2} = \lim_{T \to \infty} T^{-1} E\left(S_{i,t}^2\right) \tag{6}$$

Thus, the Fourier approximation can be computed as:

$$Fp(k) = \frac{1}{n} \sum_{i=1}^{n} \varphi_i(k) \tag{7}$$

As T approach infinity the asymptotic distribution $\eta_i(k)$ follows that of Becker et al. (2006) as well as it depends on only n. The n here is invariant other parameters in the DGP.

Nazlioglu and Karul (2017), posits that when the common factor is incorporated as T and N approach infinity $Fp(k)$converges to standard normal distribution as provided below:

$$FZ(k) = \frac{\sqrt{N}(Fp(k) - \psi(k))}{\psi(k)} N(0,1) \tag{8}$$

The Fourier approximation panel statistics is then computed from Equation (8). We also conduct Lluís Carrion-i-Silvestre et al., (2005) alongside Hadri and Rao (2008) panel stationary tests in comparison with the Fourier approximation panel stationarity test that accommodates for gradual structural shifts and CD.

4 | RESULTS DISCUSSION AND IMPLICATIONS

In panel econometrics, it is pertinent to carry out preliminary analysis. Therefore, this study presents the basic summary statistics which indicate the Russian federation with the highest average while Tajikistan possess lowest average for the CIS countries over the sampled period. The three normality tests indicators namely skewedness, kurtosis and Jarque Bera test for CIS suggest all CIS countries per capita GDP are normally distributed. For the case of CEE countries Germany display highest per capita GDP followed by Czech Republic and the lowest recorded average experience by Albania over investigated period. All sampled countries shows huge departure from their mean as seen by standard deviation. However, for symmetry all countries in CEE bloc shows normality traits are reported by the Jarque Bera probability statistics.[15] Furthermore, the presents study conducts different CSD tests (Breusch & Pagan, 1980; Pesaran, 2004; Pesaran & Yamagata, 2008) and slope homogeneity test proposed by Pesaran and Yamagata (2008). The results are presented in Table 1. The results show the existence of CSD given the rejection of the null hypothesis of CSD at the 1% level of significance. This implies that, per capita GDP in both CEE and CIS countries investigated is driven by common factor(s). That is, the variation of GDP per capita in one country influences its variation in other countries. So, per capita GDP is determined by the same pool of factors among all the countries. In short, there is co-movement of per capita GDP among the countries driven by common factors. Meanwhile, the results of the slope homogeneity test reveal the presence of slope heterogeneity. This indicates there exist heterogeneity in the domestic policies of the countries considered.

Subsequently, we proceed to investigate the unit root properties of PCGDP for both CEE and CIS countries. Table 2 reports the Hadri

TABLE 1 Cross sectional dependence results and slope heterogeneity

CSD and slope heterogeneity results	CEE countries		CIS countries	
	Statistics	Prob.	Statistics	Prob.
CD tests				
LM (Breusch & Pagan, 1980)	80.789	0.000	86.539	0.000
CDlm (Pesaran, 2004)	5.278	0.000	5.956	0.000
CD (Pesaran, 2004)	−2.373	0.009	−3.184	0.001
LMadj (Pesaran & Yamagata, 2008)	11.314	0.000	4.004	0.000
Slope homogeneity test				
Delta_tilde:	8.792	0.000	6.978	0.000
Delta_tilde_adj:	9.326	0.000	7.401	0.000
b2_wfe (k2)	−0.00796		−0.05054	

Note: Delta_tilde statistic is defined by (27), and Delta tilde_adj statistic is defined by (29) in Pesaran and Yamagata (2008), (2) b_wfe(k2) are the values of the weighted Fixed Effects estimates of k2 slope coefficients under the tests.

TABLE 2 Results of Hadri and Rao (2008) panel unit root test with break: Commonwealth of Independent State (CIS) countries

Results of Hadri and Rao (2008) panel unit root test with break: CIS Countries								
	Break dates	**Individual LM**	**Optimum lag**	**90%**	**95%**	**97.50%**	**99%**	**Selected Model**
Azerbaijan	1995	0.084	3	0.095	0.116	0.135	0.158	2
Kazakhstan	1995	0.085	3	0.094	0.112	0.131	0.159	2
Belarus	1995	0.085	3	0.094	0.114	0.132	0.158	2
Kyrgyz Republic	1993	0.06	1	0.098	0.117	0.136	0.159	3
Russian Federation	1995	0.021	1	0.095	0.114	0.134	0.159	2
Tajikistan	1996	0.121	3	0.092	0.111	0.129	0.153	2
Uzbekistan	1997	0.184	3	0.084	0.102	0.119	0.139	2
Turkmenistan	1997	0.054	1	0.085	0.104	0.118	0.14	2
Ukraine	1996	0.053	2	0.089	0.107	0.124	0.143	2
		HR stat	***p*-value**	90%	95%	97.50%	99%	
		0.083	**.93**	0.449	0.554	0.662	0.792	

TABLE 3 LM panel based unit root test (with breaks) for Central and Eastern Europe (CEE) countries

Panel LM unit root test (with breaks)							
	Level shift: One break test			**Level shift: Two breaks test**			
	LM-stat	**Break**	**Lag**	**LM-stat**	**Breaks**		**Lag**
Azerbaijan	−4.709	13	1	−8.328	9	19	1
Kazakhstan	−2.318	20	1	−4.929	7	15	1
Belarus	−3.464	12	1	−6.642	9	19	1
Kyrgyz Republic	−5.335	8	1	−6.057	7	22	1
Russian Federation	−2.921	12	1	−8.792	9	19	1
Tajikistan	−3.199	12	1	−8.656	7	14	1
Uzbekistan	−2.865	13	1	−4.977	6	17	1
Turkmenistan	−5.028	13	3	−9.478	9	20	3
Ukraine	−2.823	11	1	−5.018	7	15	1
Panel LM	−7.721			−23.336			
***p*-value**	.000			.000			
	Trend shift: One break test			**Trend shift: Two breaks test**			
	LM-stat	**Break**	**Lag**	**LM-stat**	**Breaks**		**Lag**
Azerbaijan	−4.751	13	1	−8.259	10	19	1
Kazakhstan	−2.485	9	1	−4.848	7	14	1
Belarus	−4.113	10	1	−6.636	9	19	1
Kyrgyz Republic	−5.389	9	1	−5.941	7	22	1
Russian Federation	−2.91	12	1	−8.843	9	19	1
Tajikistan	−4.168	6	1	−8.082	7	14	1
Uzbekistan	−2.878	13	1	−4.746	6	13	1
Turkmenistan	−5.092	13	3	−9.496	9	21	3
Ukraine	−3.531	22	1	−4.925	16	22	2
Panel LM	−5.675			−18.36			
***p*-value**	.000			.000			

and Rao (2008) stationarity test results for CIS countries. The results advocate that PCGDP is not stationary. The result of stationarity is also affirmed by LM test statistics for both (level shift and trend) shift at different break levels respectively as reported in Table 3. Thus, we validate the claim that both test statistics are in harmony. The results therefore imply that per capita GDP is nonmean reverting. Thus, the effect of shock on per capita GDP is persistent in all the countries given the period considered.

The result reported in Tables 4 and 5 contains the results of Hadri and Rao (2008) and panel LM unit root tests for the CEE countries respectively. The results show that both tests conclude that per capita GDP is not stationarity at level. This means, the effect of policy on the per capita GDP lasts permanently. In other words, the shock on the per capita GDP persists over time.

TABLE 4 Hadri and Rao (2008) panel unit root test with break for Central and Eastern Europe (CEE) countries

Results of Hadri and Rao (2008) panel unit root test with break: CEE countries								
	Break dates	Individual LM	Optimum lag	90%	95%	97.50%	99%	Selected Model
Poland	1994	0.081	2	0.091	0.11	0.129	0.152	3
Germany	1989	0.094	2	0.121	0.147	0.173	0.208	−1
Czech Republic	2004	0.114	2	0.057	0.066	0.073	0.084	3
Slovak Republic	2005	0.038	1	0.06	0.069	0.078	0.087	3
Hungary	2000	0.036	1	0.106	0.129	0.153	0.183	1
Romania	2002	0.166	3	0.056	0.064	0.071	0.081	3
Bulgaria	2001	0.051	1	0.057	0.065	0.073	0.084	3
Albania	1991	0.061	3	0.118	0.144	0.171	0.203	2
Macedonia, FYR	1995	0.072	2	0.093	0.113	0.132	0.154	2
		HR stat	*p*-value	90%	95%	97.50%	99%	
		0.079	**1**	0.898	1.124	1.354	1.693	

TABLE 5 LM panel based unit root test (with breaks) for Commonwealth of Independent State (CIS) countries

Panel LM unit root test (with breaks)							
Level shift: One break test				Level shift: Two breaks test			
	LM-stat	Break	Lag	LM-stat	Breaks		Lag
Poland	−2.946	6	1	−4.227	14	20	1
Germany	−5.684	13	1	−6.119	9	15	1
Czech Republic	−2.443	9	1	−3.394	9	19	1
Slovak Republic	−5.565	20	1	−10.361	16	22	1
Hungary	−2.337	12	1	−4.092	10	19	1
Romania	−2.969	14	1	−5.557	8	19	1
Bulgaria	−2.61	10	1	−4.808	6	16	1
Albania	−4.44	8	1	−12.377	8	17	1
Macedonia, FYR	−3.2	12	1	−5.73	8	17	1
Panel LM	−7.446			−20.124			
***p*-value**	.000			.000			
	Trend shift: One break test			Trend shift: Two breaks test			
	LM-stat	Break	Lag	LM-stat	Breaks		Lag
Poland	−3.752	6	1	−4.275	13	16	1
Germany	−5.952	15	1	−9.032	18	22	1
Czech Republic	−3.04	6	1	−4.031	14	20	1
Slovak Republic	−4.783	20	1	−13.374	15	20	1
Hungary	−3.282	18	1	−4.557	6	19	3
Romania	−3.427	8	1	−5.692	8	19	1
Bulgaria	−2.389	8	1	−3.84	8	14	1
Albania	−5.023	8	1	−12.937	8	17	1
Macedonia, FYR	−3.305	12	1	−5.704	8	17	1
Panel LM	−5.471			−19.209			
***p*-value**	.000			.000			

However, Tables 6 and 7 report the results of stationarity tests that accounts for constant and trend with different K, where K is the Fourier frequency. Table 7 reports the case of CIS countries. It displays the result of unit root at different K levels. The results show the unit root process at 10% significance level quite weak for five of the countries at individual-country specific level, namely (Azerbaijan, Belarus, Uzbekistan, Turkmenistan, and Ukraine), while the remainder in the bloc displayed stationarity. This is also the case with the model constant and trend model for CIS countries as reported in Table 6. However, the entire statistics provide strong empirical evidence at 1% significance level of unit root process in the total bloc. This implies that, per capita GDP in CIS countries are nonmean reverting. That is, the effect of shock on the series is persistent. On the other hand, In Table 8 for the case of CEE countries with model with constant and trend as well as sharp shift and different Fourier frequencies, the null hypothesis of stationarity could not be rejected at any acceptable statistical threshold. Thus, suggests stationarity of PGDP for CEE bloc.

Table 9 reports a similar trend that PCGDP of CEE countries is nonstationary. This affirms that CEE countries per capita GDP is nonmean-reverting. The novelty and contribution of the aforementioned stationarity analysis lie in their resilience in the existence of CD and gradual structural shifts which previous well-known panel unit root tests (Hadri, 2000; Hadri & Rao, 2008) fail to address. In addition to the already aforementioned tests, we also conducted panel KPSS stationarity tests for country-by-country test for both level and trend shift reported in Tables 7 and 9 for CIS and CEE panels respectively. Interestingly, the results from the panel KPSS in different bootstrap simulation lend support to the claim that for the entire block's investigated, exhibits unit root process while accommodating for both cross-sectional dependency and heterogeneity. Thus, our study draws strength that the novel panel unit root test is robust and resilience in the presence of CD issues and gradual or sharp shift.

The empirical findings reveal interesting and insightful economic and political episodes in the investigated regions. For instance, case of Romanian in CEE region, the break years identified in this study corroborate with the post economic revolution period (December 1989), which was characterized by an economic downturn. A similar trend experienced by other neighboring countries like Bulgaria in the bloc of CEE countries, which are coincidentally, members of the European member (EU). Also captured by the current study was the end of the Soviet Union era. Also, the findings, majorly reflect the amalgam of the membership EU in the late 1990s and early 2000s, which is insightful and depicts the robustness of the estimators.

5 | CONCLUDING REMARKS AND POLICY DIRECTION

The primary purpose of this study is to disclose the stationarity traits and asymptotic characteristics of per capita GDP in CEE and CIS countries. Thus, a simple stationarity test is conduct on the null hypothesis of stationarity against an alternative of nonstationarity (unit root) for per capita GDP in both CEE and CIS countries by the adoption of Fourier panel statistics *Fp*(*k*). The statistics is developed from the average individual statistics of KPSS test proposed by Becker et al. (2006), the statistics accommodates for Fourier frequency. The Fourier frequency test statistics also have the merit of being considerably easier to develop the augmented KPSS test statistic relative to the LM test statistic. However, both tests have the similar asymptotic optimality. This study also conducts the Hadri and Rao (2008), and

TABLE 6 Constant and trend model for Commonwealth of Independent State (CIS) countries

	Constant model				Trend model			
CIS countries	**Sharp shifts**	***K* = 1**	***K* = 2**	***K* = 3**	**Sharp shifts**	***K* = 1**	***K* = 2**	***K* = 3**
Azerbaijan	**0.072**	0.12	0.195	0.236	**0.069**	0.053	0.129	0.101
Kazakhstan	0.111	0.332	0.283	0.273	0.733	0.053	0.14	0.116
Belarus	**0.063**	0.259	0.262	0.301	0.153	0.061	0.136	0.135
Kyrgyz Republic	0.344	0.33	0.357	0.311	**0.06**	0.051	0.05	0.083
Russian Federation	0.121	0.171	0.17	0.117	0.586	0.042	0.145	0.121
Tajikistan	0.305	0.269	0.282	0.316	0.419	0.05	0.134	0.115
Uzbekistan	**0.08**	0.279	0.255	0.205	0.3	0.051	0.135	0.121
Turkmenistan	**0.098**	0.264	0.136	0.114	0.209	0.043	0.133	0.121
Ukraine	**0.077**	0.251	0.363	0.275	0.121	0.054	0.13	0.11
FZ(k) test		10.413	2.594	1.766		4.889	5.679	3.914
***p*-value**	.000		.005	.039	.000		.000	.000

Note: Sharp shift: Panel stationarity test with sharp breaks (dummy variables) by Lluís Carrion-i-Silvestre et al. (2005). Gradual/smooth shift: Fourier panel stationarity test developed by Nazlioglu and Karul (2017). Bold numbers: The null hypothesis of stationarity cannot be rejected at least at the 10% level of significance. The statistics are constructed using the Bartlett kernel with the Kurozumi (2002) rule. The *p*-values are for a one-sided test based on the normal distribution. The constant model critical values for individual statistics are 0.1318 (10%), 0.1720 (5%), 0.2699 (1%) for $k = 1$; 0.3150 (10%), 0.4152 (5%), 0.6671 (1%) for $k = 2$; 0.3393 (10%), 0.4480 (5%), 0.7182 (1%) for $k = 3$. The constant and trend model critical values for individual statistics are 0.0471 (10%), 0.0546 (5%), 0.0716 (1%) for $k = 1$; 0.1034 (10%), 0.1321 (5%), 0.2022 (1%) for $k = 2$; 0.1141 (10%), 0.1423 (5%), 0.2103 (1%) for $k = 3$. (see, Becker et al. (2006, p.389)).

TABLE 7 Results of panel stationarity test with sharp breaks for Commonwealth of Independent State (CIS) countries

Trend shift model						Level shift model				
Panel A: Country-by-country KPSS test										
			Critical values					**Critical values**		
Countries	**KPSS test**	**Breaks**	**0.90**	**0.90**	**0.90**	**KPSS test**	**Breaks**	**0.90**	**0.95**	**0.99**
Azerbaijan	**0.069**	2	0.553	0.753	1.482	**0.072**	1	0.414	0.589	1.137
Kazakhstan	0.733	2	0.637	0.854	1.525	0.111	2	0.419	0.573	1.012
Belarus	0.153	2	0.403	0.58	1.089	**0.063**	2	0.435	0.596	1.032
Kyrgyz Republic	**0.06**	1	0.232	0.35	0.668	0.344	2	0.345	0.519	0.947
Russian Federation	0.586	2	0.638	0.851	1.441	0.121	2	0.338	0.493	0.916
Tajikistan	0.419	2	0.586	0.841	1.601	0.305	2	0.343	0.505	0.971
Uzbekistan	0.3	2	0.434	0.633	1.252	**0.08**	2	0.485	0.692	1.288
Turkmenistan	0.209	2	0.516	0.724	1.268	**0.098**	2	0.487	0.683	1.265
Ukraine	0.121	2	0.608	0.841	1.47	**0.077**	2	0.34	0.507	0.991
Panel B1: Panel KPSS test (assuming cross-sectional independence)										
		Test	***p*-value**					**Test**		***p*-value**
LM (λ) Homogeneity		**15.639**	.0000					**2.226**		.013
LM (λ) Heterogeneity		**54.694**	.0000					**4.787**		.0000
Panel B2: Bootstrap distribution (assuming cross-sectional dependence)										
		Critical values					**Critical values**			
		0.90	0.95	0.99			0.90	0.95	0.99	
LM (λ) Homogeneity		24.510	29.589	41.557			8.847	11.051	17.168	
LM (λ) Heterogeneity		66.447	79.827	108.922			15.728	19.634	30.195	

Note: the number of break points is denoted by m. Also, $T_{b,\ 1}$, $T_{b,\ 2}$, $T_{b,\ 3}$, $T_{b,\ 4}$, $T_{b,\ 5}$ stands for structural breaks dates. Monte-Carlo simulations are employed with bootstrap distribution via 20,000 repeated iteration for the finite sample critical values. Lagrange Multiplier **(λ)** and LM **(λ)** heterogeneity by KPSS test of Lluís Carrion-i-Silvestre et al. (2005) is used for estimation of the long-run variance. ***<0.01, **<0.05, and *<0, percent respectively.
Bold values signifies 10% statistical level.

TABLE 8 Constant and trend model for Central and Eastern Europe (CEE) countries

	Constant model				**Trend model**			
CEE countries	**Sharp shifts**	***K* = 1**	***K* = 2**	***K* = 3**	**Sharp shifts**	***K* = 1**	***K* = 2**	***K* = 3**
Poland	0.106	0.085	0.163	0.106	0.531	0.076	0.14	0.132
Germany	0.126	0.059	0.066	0.101	**0.094**	0.031	0.026	0.03
Czech Republic	0.189	0.066	0.136	0.121	0.147	0.058	0.136	0.15
Slovak Republic	0.146	0.076	0.152	0.121	0.538	0.065	0.133	0.11
Hungary	0.12	0.077	0.149	0.117	0.108	0.077	0.145	0.116
Romania	0.115	0.082	0.155	0.126	0.494	0.069	0.145	0.137
Bulgaria	0.166	0.059	0.143	0.115	0.435	0.053	0.14	0.137
Albania	1.027	0.047	0.162	0.139	0.916	0.047	0.158	0.138
Macedonia, FYR	**0.063**	0.104	0.149	0.152	**0.076**	0.096	0.146	0.151
FZ(k) test		0.392	0.017	−0.699		7.831	6.017	4.54
***p*-value**	.348		.439	.758	.000		.000	.000

Note: Sharp shift: Panel stationarity test with sharp breaks (dummy variables) by Lluís Carrion-i-Silvestre et al. (2005). Gradual/smooth shift: Fourier panel stationarity test developed by Nazlioglu and Karul (2017). Bold numbers: The null hypothesis of stationarity cannot be rejected at least at the 10% level of significance. The statistics are constructed using the Bartlett kernel with the Kurozumi (2002) rule. The *p*-values are for a one-sided test based on the normal distribution. The constant model critical values for individual statistics are 0.1318 (10%), 0.1720 (5%), 0.2699 (1%) for $k = 1$; 0.3150 (10%), 0.4152 (5%), 0.6671 (1%) for $k = 2$; 0.3393 (10%), 0.4480 (5%), 0.7182 (1%) for $k = 3$. The constant and trend model critical values for individual statistics are 0.0471 (10%), 0.0546 (5%), 0.0716 (1%) for $k = 1$; 0.1034 (10%), 0.1321 (5%), 0.2022 (1%) for $k = 2$; 0.1141 (10%), 0.1423 (5%), 0.2103 (1%) for $k = 3$. (see, Becker et al. (2006, p.389)).
Bold values signifies 10% statistical level.

TABLE 9 Results of Panel stationarity test with sharp breaks for Central and Eastern Europe (CEE) countries

Trend shift model						**Level shift model**				
Panel A: Country-by-country KPSS test										
			Critical values					**Critical values**		
Countries	**KPSS test**	**Breaks**	**0.90**	**0.90**	**0.90**	**KPSS test**	**Breaks**	**0.90**	**0.95**	**0.99**
Poland	0.531	0	0.247	0.377	0.716	0.106	2	0.461	0.659	1.203
Germany	**0.094**	0	0.32	0.449	0.807	0.126	2	0.444	0.648	1.135
Czech Republic	0.147	2	0.412	0.598	1.047	0.189	2	0.437	0.611	1.07
Slovak Republic	0.538	2	0.556	0.784	1.447	0.146	2	0.431	0.635	1.252
Hungary	0.108	2	0.541	0.761	1.408	0.12	2	0.423	0.601	1.165
Romania	0.494	2	0.679	0.906	1.586	0.115	2	0.434	0.605	1.025
Bulgaria	0.435	2	0.675	0.927	1.647	0.166	2	0.428	0.583	0.992
Albania	0.916	2	0.38	0.581	1.119	1.027	2	0.457	0.661	1.225
Macedonia, FYR	**0.076**	2	0.463	0.646	1.209	**0.063**	2	0.432	0.6	1.043
Panel B1: Panel KPSS test (assuming cross-sectional independence)										
		Test	***p*-value**					**Test**		***p*-value**
LM (λ) Homogeneity		**41.955**	.0000					**7.886**		.0000
LM (λ) Heterogeneity		**46.353**	.0000					**14.066**		.0000
Panel B2: Bootstrap distribution (assuming cross-sectional dependence)										
		Critical values					**Critical values**			
		0.90	**0.95**	**0.99**			**0.90**	**0.95**		**0.99**
LM (λ) Homogeneity		15.459	19.349	27.639			9.346	11.542		16.562
LM (λ) Heterogeneity		42.087	50.017	70.397			20.668	24.873		35.039

Note: the number of break points is denoted by m. Also, $T_{b,1}$, $T_{b,2}$, $T_{b,3}$, $T_{b,4}$, $T_{b,5}$ stands for structural breaks dates. Monte Carlo simulations are employed with bootstrap distribution via 20,000 repeated iteration for the finite sample critical values. Lagrange Multiplier (λ) and LM (λ) heterogeneity by KPSS test of Lluís Carrion-i-Silvestre (2005) is used for estimation of the salong-run variance. ***, ** and *denotes statistical rejection level of 0.01, 0.05, and 0.10% respectively. Bold values signifies 10% statistical level.

panel LM unit root tests in comparison with the Fourier panel stationarity test that account for CD and gradual structural shifts for robustness of estimation.

Furthermore, the current study proceeds to investigate the common effect shock via the CSD tests advanced by Breusch and Pagan (1980), Pesaran (2004) and Pesaran and Yamagata (2008). Subsequently, this study also shows the slope homogeneity tests proposed by Pesaran and Yamagata (2008). It confirms the presence of CSD and the slope heterogeneity in both the CIS and CEE countries. This depicts the effect of common labor and capital market among the countries. There is the perfect mobility of labor and capital between the countries. This serves as a common determinant of output and income of the groups of countries considered. On the other hand, it also reveals that the per capita GDP in CIS and CEE countries are non-mean reverting (nonstationary). This outcome is revealing, it implies that the effect of shock on PCGDP is persistent over sampled time period. Furthermore, the LM panel based unit root test conducted for level shift with one break test and trend shift as well as for level shift with two break test, both test also affirms the presence of stationarity. The novelty and contribution of the aforementioned stationarity test lie in their resilience in the existence of CD and gradual structural shifts which previous well-known panel unit root test (Hadri, 2000; Hadri & Rao, 2008) fails to address.

The empirical revelations from this study have inherent policy direction in CEE and CIS countries for government administrators and policymakers that design and formulate policy framework. This is crucial given the findings that per capita GDP for the entire blocs were nonstationary. This means the per capita GDP follows a long run path and any deviation from the path due to shock keeps it on the new trajectory permanently. Put differently, the effect of policy measure or shock on the per capita GDP of the CEE and CIS countries remains permanent. This reflects the effect of rapid growth and innovations on the per capita income of the countries. This development places the CEE and CIS countries on a pedestal of a level of income which will not return to previous average of income even when shock occurs. This is indicative to government and policy makers in the CEE and CIS countries that any shock(s) on economic output (GDP) does not die out quickly and measures should be put in place and frequently checked to avert negative shocks. This outcome is a call to timely action to insulate the investigated panel of countries against external shocks. As such adequate policy mix aimed at economic stability is encouraged in the panel of the countries under consideration over the investigated period. Furthermore, there is room to further query the theme under consideration and test long-run equilibrium (cointegration) relationship between per capita GDP and other macroeconomic variables that might be possible sources of external shocks. In addition, other scholars can investigate another panel of countries like (OECD, SSA, and MENA)[16] to refute or validate this study's position.

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ENDNOTES

[1] See for more details (http://www.nationmaster.com/country-info/groups/Eastern-Europe).

[2] Russia (51.4%), Ukraine (16.4%), Uzbekistan (10.5%), Kazakhstan (6%), Belarus (3.4%), and rest of the CIS countries (12.3%) respectively, See for more details (https://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:EU-Commonwealth_of_Independent_States_(CIS)_-_statistics_on_GDP)

[3] The *Fp*(*k*) statistics is developed from the average individual statistics of KPSS test, which allows Fourier frequency, which was advanced by Becker, Enders, and Lee (2006). Moreover, the construction of the Augmented KPSS statistic is considerably easier than that of the LM test statistic despite the fact that both tests achieve same asymptotic optimality.

[4] See Appendix section for details of each country that constitute both the CIS and CEE countries

[5] Becker et al., (2006), Enders and Lee (2009), and Pascalau (2010), documented that a Fourier approximation can frequently seizure the behavior of an unidentified function even though the function itself is not periodic. These authors further argue that utilizing the Fourier transformation while testing the unit root hypothesis requires only the specification of the proper frequency in the estimating equations not the functional form of the model. Further, by dropping the number of estimated parameters, these authors argue that one can safeguard the test with good size and power properties regardless of the time or shape of the break.

[6] The cross-sectional dimensions to the usual time dimension have the tendency of lower power in the small sample sizes to differentiate nonstationarity series from stationarity series that are persistence in nature. In order to solve this problem, panel data framework is used to increase the power of unit root tests.

[7] As noted by Baltagi and Kao (2001), the econometrics of nonstationary panel data aims at combining "*the best of both worlds: the method of dealing with nonstationary data from the time series and the increased data and power from the cross sectional.*"

[8] The first generation of panel unit root tests is based on the CSD hypothesis. Within this content, the correlation across units denotes the presence of nuisance parameters. Therefore, the cross-sectional independency proposition is relatively deterring and rather impracticable in the mainstream of macroeconomic applications of unit root tests (i.e., convergence). So that, we will go for second order panel unit root tests because of (a) it relies on the factor structure approach (b) it is also imposing of nonrestrictions on the residual covariance matrix.

[9] These panel unit root tests play an imperative role in empirical analysis of panel data framework. Moreover, there has been a greater development and panel unit root tests have been utilized in the field of economics and finance.

[10] Each random variable are equal probability distribution with others variables and it also mutually independent.

[11] See for details Lluís Carrion-i-Silvestre et al., (2005); Hadri and Rao (2008); Hadri, Larsson, and Rao (2012).

[12] See for more details Maddala and Wu (1999), Choi (2001**)**, Levin, Lin, and Chu (2002), and Im, Pesaran, and Shin (2003).

[13] Details on the countries that form both blocs are available in the appendix section of this paper.

[14] Detailed explanations are provided in the study of Becker et al. (2006) for interested reader.

[15] Details on summary statistics are available in appendix section

[16] For easy readership OECD-the organization for economic cooperation and development; SSA—Sub Saharan Africa; MENA—Middle East and North Africa region.

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APPENDIX A.1. DATA (1985–2016)

Central and Eastern Europe (CEE)	Commonwealth of Independent States (CIS)
Estonia, Latvia, Lithuania, Poland, Germany, Czech Republic, Slovak Republic, Slovenia, Hungary, Romania, Bulgaria, Croatia, Albania, Montenegro, Serbia, Macedonia, FYR, Bosnia and Herzegovina, Kosovo	Azerbaijan, Kazakhstan, Belarus, Kyrgyz Republic, Moldova, Russian Federation, Tajikistan, Uzbekistan, Turkmenistan, Ukraine

CIS countries

	AZERBAIJAN	BELARUS	KAZAKHSTAN	KYRGYZ_ REPUBLIC	RUSSIAN_ FEDERATION	TAJIKISTAN	TURKMENISTAN	UKRAINE	UZBEKISTAN
Mean	7.967642	8.241041	8.758433	6.660008	9.038675	6.446324	8.097992	7.856062	6.955584
Median	7.989372	8.122422	8.717307	6.636629	9.096937	6.494274	7.972508	7.947638	6.878986
Maximum	8.719804	8.804490	9.272888	6.999361	9.376169	7.152728	8.851786	8.285358	7.581456
Minimum	7.103386	7.613174	8.226432	6.282349	8.613526	5.901096	7.537093	7.430673	6.588354
Std. Dev.	0.608314	0.412586	0.376677	0.209995	0.266248	0.355787	0.402299	0.258416	0.315029
Skewness	−0.013694	0.086218	−0.000273	−0.127938	−0.218059	0.070681	0.495112	−0.417602	0.605101
Kurtosis	1.427042	1.495648	1.489264	1.830704	1.546395	2.096468	2.015913	1.881562	2.034286
Jarque-Bera	2.784314	2.579412	2.567615	1.611815	2.591061	0.940898	2.192592	2.192028	2.696845
Probability	0.248539	0.275352	0.276981	0.446682	0.273753	0.624722	0.334106	0.334201	0.259650
Sum	215.1263	222.5081	236.4777	179.8202	244.0442	174.0508	218.6458	212.1137	187.8008
Sum Sq. Dev.	9.621198	4.425917	3.689033	1.146544	1.843087	3.291197	4.207956	1.736246	2.580319
Observations	27	27	27	27	27	27	27	27	27

CEE countries

	ALBANIA	BULGARIA	CZECH_ REPUBLIC	GERMANY	HUNGARY	MACEDONIA__ FYR	POLAND	ROMANIA	SLOVAK_ REPUBLIC
Mean	7.900408	8.543372	9.708725	10.56601	9.337249	8.246714	9.133559	8.756889	9.404158
Median	7.947133	8.495925	9.689258	10.56043	9.385954	8.194620	9.119807	8.695300	9.372064
Maximum	8.452114	8.983152	9.993973	10.73303	9.615619	8.560794	9.620194	9.216868	9.866569
Minimum	7.161047	8.183916	9.418414	10.38397	9.053045	8.025191	8.614302	8.371720	8.945800
Std. Dev.	0.418304	0.287266	0.195739	0.105901	0.195818	0.175149	0.325285	0.284770	0.318056
Skewness	−0.271583	0.132279	−0.072046	0.035838	−0.215173	0.346083	−0.108477	0.166973	−0.046331
Kurtosis	1.704455	1.334529	1.483700	1.798908	1.441625	1.699490	1.720102	1.425889	1.557947
Jarque-Bera	2.220151	3.199259	2.609920	1.628730	2.940448	2.441722	1.895858	2.913014	2.349116
Probability	0.329534	0.201971	0.271183	0.442920	0.229874	0.294976	0.387543	0.233049	0.308956
Sum	213.3110	230.6711	262.1356	285.2823	252.1057	222.6613	246.6061	236.4360	253.9123
Sum Sq. Dev.	4.549428	2.145570	0.996156	0.291593	0.996960	0.797609	2.751077	2.108441	2.630148
Observations	27	27	27	27	27	27	27	27	27