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Stationarity Properties of Renewable Energy Consumption in the Commonwealth of Independent States

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ABSTRACT

This study investigates the stochastic properties of renewable energy consumption series across 11 Commonwealth of Independent States countries through the period of 1990-2015. For this purpose, along with traditional stationarity analysis recently improved unit root techniques which allows for nonlinear adjustments in the data generating process are used in this paper. Based on our findings we may conclude that, consideration of nonlinearity in regression process causes to more frequent non rejection of the null hypothesis of stationarity. It implies that ignoring possible nonlinearities in time series regression process may lead to some misleading results. Hereby, fluctuations in global energy supply and trade systems influence renewable energy consumption in nonlinear pattern and policy-makers should take it into consideration in terms of proper energy policy implication.

Keywords: Renewable energy consumption, Panel Unit Root, Nonlinearity, ESTAR Panel Unit Root
JEL Classifications: C22, Q20, P28

1. INTRODUCTION

Raising awareness on environmental degradation issues such as global warming or air pollution, which are mostly based on consumption expansion of fossil fuels as well as increase in demand and dependence of countries on traditional energy resources imports, accelerated the efforts of governments to develop new and alternative ways of energy supply process. Recent developments in global energy supply security and high volatility of fossil energy prices, also stimulate investments in alternative energy resources causing renewables to become one of the rapidly growing sources in the world energy system.

Even though there are several researches on relationship of economic growth and alternative energy consumption based on varied country groups, time spans and empirical techniques, there is no single empirical evidence achieved as a consequence of these studies. One of the earlier studies in this field is Chien and Hu (2007), which investigates technical efficiency of production process for the 45 economies employing data envelopment analysis and concludes that renewable energy usage promotes technical efficiency and output in observed economies. Similar results are obtained by Payne (2010), Fang (2011), Tiwari (2011), Bilgili and Özturk (2015), Ozturk and Bilgili (2015), Bhattacharya et al. (2016), Hassine and Harrathi (2017), Ozcan and Ozturk (2019). These studies provide verification of causality running from renewable energy consumption to real output. However, following Sari and Soytas (2008) that examines the causal relationship between disaggregate energy consumption and industrial production in USA, real output and employment stimulate renewable energy usage. Much the same findings are obtained by Sadorsky (2009) and Cho et al. (2015) arguing that expanding in real GDP will increase the renewable energy usage in emerging countries.

So, causality between renewable energy consumption and production is one of the well-studied subjects in the empirical literature. Nevertheless, outcomes from these investigations provide some controversial evidences. One of the possible reasons of this situation is non-stationarity in concerned series which is ignored in previous studies causing to statistically questionable results. If any time series have non-stationary pattern, then considered variables from this regression model may hold biased information leading to the inefficient energy policy implications. Moreover, if renewable energy usage series are non-stationary, then any conjectural shocks in energy supply or trade processes may cause to persistent effects on energy consumption series. However, if energy consumption series provide some evidence of non-stationarity, then any fluctuations in energy market process may have impermanent effects, and after a while energy consumption may come back to its initial equilibrium level, encouraging policy-makers take more liberal or non-interventionist measures in the energy supply process.

On the other side, it is well known from applied literature that, if time series follow some non-stationary process, then there is a possibility of transferring it to other related variables. As Hasanov and Telatar (2011) states, determination of the stochastic features of the energy consumption series will help us to analyse the relationship between these series and other macroeconomic as well as to choose the appropriate empirical regression model in terms of statistically acceptable results. Hereby, the main motivation of this study is investigating of the stochastic pattern of renewable energy consumption for a panel of Commonwealth of Independent States (CIS) over the period 1987–2017. For this purpose, along with traditional stationarity tests we also use recently improved unit root tests which consider nonlinearity in the time series regression process.

The CIS which is established in December 1991, and consisting of twelve former Soviet Union countries is generally known as country union with the transition economies. However, as Apergis and Payne (2009) indicates, these countries play a critical role in the world energy sectors in terms of production of crude oil and natural gas, as well as distribution of these energy resources to other demanded countries as energy transit centres. Moreover, since the fossil energy transportation pipelines in these former Soviet Union countries were based on principles of division of labour and dependency in USSR's planned economic system, there are some disagreement between the countries in the region in terms of transportation of fossil fuels especially to the European energy market.

From the table below it is obvious that when fossil energy reserves and production are considered, Russian Federation which the world's second biggest producer of crude oil and second-largest producer of natural gas is a leading producer and exporter of traditional energy resources in this group, that is followed by Kazakhstan, Turkmenistan, Ukraine and Uzbekistan. Russia Federation is also ahead of the other CIS countries in sense of energy consumption consisting with the BP statistics, which indicates that Russia Federation was fourth largest energy consumer in the world in 2017.

As it can be seen from the Table 1, energy intensity indicators of CIS countries are relatively high exceeding the GDP energy intensity value of the OECD countries which was observed as 3.81[1] in 2015. It seems to be the main motivation for governments'

1 As indicated by the Energy Information Administration 2015 statistics.

Table 1: Some statistics for CIS countries

	Total Primary Energy Production (Quard Btu)	Total Primary Energy Consumption (Quard Btu)	Petroleum Production (Quard Btu)	Petroleum Consumption (Quard Btu)	Natural Gas Production (Quard Btu)	Natural Gas Consumption (Quard Btu)	Coal Production (Quard Btu)	Coal Consumption (Quard Btu)	Energy Intensity (1000Btu/$2010 GDP PP)
Armenia	0.051	0.138	0	0.016	0	0.076	0	S	5,91
Azerbaijan	2.509	0.623	1,821	0.204	0.666	0.402	0	S	3.89
Belarus	0.06	1.002	0.056	0.341	0.001	0.635	0	0.014	6.27
Kazakhstan	6.46	2,507	3.548	0.513	0.855	0.503	1.826	1.404	6.2
Kyrgyz Rep.	0.129	0.22	0.02	0.067	0.001	0.007	0.023	0.042	11.59
Moldova	0.003	0.129	0	0.034	-	0.088	0	0.004	7.79
Russian Fed.	55.935	29.629	22.005	7.014	21.691	15.178	7,514	3.894	8.49
Tajikistan	0.173	0.208	S	0.042	S	S	0.016	0.014	9.87
Turkmenistan	3.665	1.901	0.522	0.307	3.095	1,605	0	0	23.25
Ukraine	2.33	3.438	0.077	0.444	0.64	1.167	0.62	0.866	1.097
Uzbekistan	2.318	2.011	0.129	0.123	2	1.729	0.054	0.054	11.51

Energy production and consumption data is measured in quadrillion Btu and obtained from Energy Information Administration, where "s" represent too small data. (Energy Information Administration, 2015 statistics) attention on the significance of adopting national energy polices which is based on reducing of GDP energy intensity, in terms of restricting consumption of imported energy resources and increasing the consumption of domestic conventional and renewable energy resources. On the other side, the possible reasons of limited production and consumption of renewables in these countries up to recent years, are relatively high costs, significantly lack of experience in production and consumption of renewable energy resources, the low level of motivation for using these types of energy as well as unimproved financing mechanisms and difficulties with the integration of renewable energy sources in the energy systems of CIS countries. However, nowadays this situation dramatically has changed and these countries has begun to be closely concern about employing of renewable energy sources such as atomic energy (Armenia, Belarus) and solar, wind, biomass and small rivers (Azerbaijan, Armenia, Kazakhstan, Turkmenistan, Uzbekistan), hydropower plants (Tajikistan).

2. ECONOMETRIC METHODOLOGY

To investigate the stochastic pattern of any time se4ries, the empirical literature suggests firstly to employ Augmented Dickey Fuller (Dickey and Fuller, 1979), which can be represented as below.

$$\Delta y_{i,t} = \Delta_i + \beta_i y_{i,t-1} \sum_{j=1}^{k} \gamma_i \Delta y_{t-j} + u_{it} \quad (1)$$

for $i = 1,\ldots N$ cross section units and $t = 1,\ldots T$ refers to the observation period. Here, $y_{i,t}$ denotes renewable energy consumption and Δ is difference operator. α_i, β_i and γ_i are parameters to be estimated, and the u_{it} is accepted to be white noise. The null hypothesis of non-stationarity is H_0: $\beta_i=0\ \forall\ i$, against the alternatives H_1:, $\beta_i = 0 \neq \forall\ i$, based on $t_{NL} = \dfrac{\hat{\beta}}{s.e.(\hat{\beta})}$, where $\hat{\beta}$ is the estimate of β and and s.e. ($\hat{\beta}$) is the coefficient standard error (Hasanov and Telatar, 2011).

To distinguish whether a data generation process stationary around a mean or linear trend, or containing a unit root, Kwiatkowski et al. (1992) introduces a new test procedure that is fundamentally similar with ADF test procedure. However, unlike the conventional ADF, in KPSS test process observed series are assumed to be stationary against the alternative hypothesis of non-stationarity; H_1: $\beta_i = 0\ \forall\ i$.

On the other side, it is well known from applied literature that nonlinearities in time series may lead to the statistically insignificant results. That is why we employ Kapetanios et al. (2003) technique which considers possible nonlinearities in the observed time series. This method is established on an exponential smooth transition (ESTAR) regression model, which allow us to identify whether data generating process is non-linear but globally stationary process against the presence of unit root.

Suppose that, y_t follows a simple exponential smooth transition autoregressive model of order 1:

$$y_t = \beta y_{t-1} + \gamma y_{t-1}\left[1-\exp\left(-\theta\, y_{t-d}^2\right)\right] + u_{it} \quad (2)$$

Subsequent to some adjustments this equation can be demonstrated as follow:

$$\Delta y_t = \varphi y_{t-1} + \gamma y_{t-1}\left[1-\exp\left(-\theta\, y_{t-d}^2\right)\right] + u_{it} \quad (3)$$

where $\varphi = \beta - 1$ and function $F(\theta, y_{t\text{-}d}) = \left[1-exp\left(-\theta y_{t-d}^2\right)\right]$

According to the KSS testing process the global stationarity of the process should be tested under the null hypothesis H_0: $\theta = 0$, whereas since γ is not defined under the null, testing of H_0: $\theta = 0$ without deviation is not possible. Kapetanios et al. (2003) suggests to implement the methodology which is recommended by Luukkonen et al. (1998) and based on substitution of the transition function $F(\theta, y_{t-d}) = \left[1-\exp\left(-\theta\, y_{t-d}^2\right)\right]$by its suitable (first order) Taylor approximation around $\theta = 0$, to obtain a t-type test value. In this case following regression

$$\Delta y_{i,t} = \delta y_{t-d}^3 + e_t \quad (4)$$

is a new equation obtained after employing Taylor approximation.

The null hypothesis of non-stationarity $\delta = 0$, against alternative hypothesis of nonlinear ESTAR stationarity $\delta < 0$ can beested by the following test statistic: $t_{NL} = \dfrac{\hat{\delta}}{s.e.(\hat{\delta})}$ Here, $\hat{\delta}$ is again the OLS estimate of δ and s.e.($\hat{\delta}$) is the standard error of $\hat{\delta}$. As a whole if errors are serially associated, the estimation augmented by the p^th^ order lag of dependent factor and the augmented model can be expressed as below:

$$\Delta y_{i,t} = \sum_{j=1}^{p} \rho \Delta y_{t-j} + \delta y_{t-d}^3 + e_t \quad (5)$$

3. ESTIMATION RESULTS

This paper investigates the stochastic features of renewable energy consumption for 11 CIS countries spanning the period 1990-2015. We used the annual data which was procured from the World Bank's World Development Indicators.

We first test the stationarity of the renewable energy consumption ignoring possible non-linarites in the observed series. With this intention, we employ the ADF stationarity analysis for raw data with intercept, raw data with intercept and trend, de-meaned data with no intercept and no trend and finally de-trended data with no intercept and no trend.

According to the ADF test results which are presented in Table 2, the null hypothesis of non-stationarity can be rejected only in 7 countries for raw data with intercept, in 5 countries for raw data with intercept and trend, in 8 countries for de-meaned data with no intercept and no trend and finally in all countries for de-trended data with no intercept and no trend. Even if these findings obtained from the ADF unit root tests, do not provide a single result

Table 2: ADF linear unit root tests

	Raw data with intercept	Raw data with intercept and trend	De-meaned data with no intercept and no trend	De-trended data with no intercept and no trend
Armenia	−2.764216*	−2.711145	−2.872870***	−2.987468***
Azerbaijan	−2.157566**	−1.852784	−2.182260**	−3.352359***
Belarus	−4.041800***	1.045654	−1.435570	−5.130749***
Georgia	−2.115372**	−1.732020	−2.129571**	−2.133280**
Kazakhstan	−1.753602**	−1.773837	−1.789455*	−2.187727**
Kyrgyz Rep.	−2.755869**	−4.766014***	−2.765249***	−2.265040**
Moldova	1.032060	−5.863963***	0.642665	−1.916760*
Russian Fed.	−2.420698	−4.548709***	−2.489094**	−5.323152***
Tajikistan	−2.620718	−1.584694	−2.613931**	−2.506828**
Turkmenistan	−5.131030***	−5.621987**	−3.823160***	−5.502129***
Ukraine	1.049741	−0.968283	0.703466	−3.040922***
Uzbekistan	0.112836	−2.340661**	−0.724298	−4.216885***

*,**, and *** denote rejection of the null hypothesis at 10%, 5%, and 1% significance levels respectively

Table 3: KPSS linear unit root tests

	Raw data with intercept	Raw data with intercept and trend	De-meaned data with intercept	De-trended data with intercept
Armenia	0.081176	0.088706	0.081176	0.087291
Azerbaijan	0.553243**	0.153810**	0.553243	0.095891
Belarus	0.699385	0.193069**	0.699385**	0.046266
Georgia	0.196916	0.182807**	0.196916	0.101899
Kazakhstan	0.169242	0.161029**	0.169242	0.087071
Kyrgyz Rep.	0.201937	0.163415***	0.201937	0.104879
Moldova	0.626453**	0.126454	0.626453**	0.093083
Russian Fed.	0.615484**	0.099940	0.615484**	0.063596
Tajikistan	0.266147	0.181964**	0.266147	0.088738
Turkmenistan	0.148808	0.090861	0.148808	0.082545
Ukraine	0.680812**	0.162033**	0.680812**	0.055692
Uzbekistan	0.623740**	0.178595**	0.623740**	0.070176

*,**, and *** denote rejection of the null hypothesis at 10%, 5%, and 1% significance levels respectively

about stationarity behaviour of the series, we may conclude that renewable energy consumption series present a stationary pattern for most of the countries at the observed time period.

Besides the ADF, we employ the KPSS test procedure which in difference to conventional ADF considers that the observed series do not contain a unit root under the null hypothesis. Table 3 presents the findings from the KPSS unit root test.

The KPSS test results implies that the null hypothesis of stationarity can be rejected for only in 5 countries for raw data with intercept, in 8 countries for raw data with intercept and trend, in 5 countries for de-meaned data with no intercept and no trend and finally the null hypothesis of stationarity cannot be rejected in all countries for de-trended data with no intercept and no trend. So, we can conclude that the results obtained from both linear unit root tests are relatively consistent.

Next we employ the KSS stationarity test procedure which suggest more statistically acceptable results if there are some nonlinearities in data generating process.

As it can be seen from Table 4, applying the KSS nonlinear stationarity analysis leads to the rejection of the null hypothesis of non-stationarity in 5 countries for raw data and only in one country for de-meaned data and de-trended data.

Table 4: KSS nonlinear unit root tests

	Raw data	De-meaned data	De-trended data
Armenia	−3.164692***	−1.188541	−1.078778
Azerbaijan	−2.660227**	−1.197401	0.024518
Belarus	−4.925964***	−0.351454	−0.111389
Georgia	−1.497538	0.149014	−0.126225
Kazakhstan	−1.726644	−0.471935	−0.245586
Kyrgyz Rep.	−3.122817***	1.314084	−0.651503
Moldova	−0.420427	0.914088	−2.464667
Russian Fed.	−2.222347**	0.655135	0.185543
Tajikistan	−3.003050***	0.833457	0.866780
Turkmenistan	−3.449387***	−3.336155**	−4.589578***
Ukraine	4.161178	1.320626	0.762421
Uzbekistan	−0.738551	0.522501	−2.759963
Asymptotic critical values of t_{NL} statistic:			
1%	−2.82	−3.48	−3.93
5%	−2.22	−2.93	−3.40
10%	−1.92	−2.66	−3.13

Critical values of t_{NL} statistic are obtained from Table 1, Kapetanios et al. (2003, p. 364). *,**, and ***denote rejection of the null hypothesis at 10%, 5%, and 1% significance levels respectively

4. CONCLUSION

This article investigates the stationarity feature of renewable energy consumption among 11 CIS countries. The major contribution of this study is employing recently improved stationarity test procedures that consider nonlinear adjustment in the data generating process. According to our findings, if we allow for nonlinearities in estimating process it will cause to more frequent non rejection of the null hypothesis of non-stationarity nearly in each country. It implies that in time series estimation process if data generating process is nonlinear then the traditional unit root tests may lead to some misleading results. On the other hand, following Telatar and Hasanov (2009), this finding suggests that fluctuations in global energy trade system influence renewable energy consumption in nonlinear pattern. This result is also corresponded with the findings of Telatar and Hasanov (2009) and Rahman and Serletis (2010) that argue that energy usage shocks affect economic growth process nonlinearly.

On the other side, the possible reason of nonlinear and non-stationary renewable energy usage in most of CIS countries, is the abundance of fossil energy resources enables these countries to maintain stability in fossil energy consumption. Furthermore, these countries with transition economies are in the initial level of economic development, which cause to employing more conventional technological methods in production process that makes renewable energy usage volatile.

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