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Article

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Renewable Energy Consumption Convergence in G-7 Countries

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ABSTRACT

This study examines the convergence of renewable energy consumption in G-7 countries. We employ LM unit root and RALS version of LM unit root tests with endogenously determined with structural one or two breaks. Despite the increase in renewable energy consumption in G-7 countries, it is important to identify whether renewable energy consumption converges across these countries to formulate appropriate policies to support sustainable energy consumption and reduce CO2 emissions. Our analysis indicated that Germany, Italy, and Canada exhibit evidence of convergence. However, after employing both the LM and RALS versions of the LM unit root tests, which consider level shifts with one or two breaks or trend shifts with one or two breaks, we found that there is no evidence of convergence for France, Japan, and the United Kingdom. Overall, our results highlight the importance of formulating country-specific policies to support renewable energy consumption and reduce CO2 emissions. Policymakers need to identify the drivers of renewable energy consumption and adopt appropriate measures to ensure that the countries can meet their climate goals while also ensuring energy security.

Keywords: Renewable Energy, G-7 Countries, Convergence
JEL Classifications: Q42; C32

1. INTRODUCTION

According to the IEA (2019), renewable energies rose by 4% in 2018, accounting for 45% of global electricity growth covering 25% of global power generation. As indicated BP (2019) the share of renewable energy consumption has significantly raised in G-7 countries between 2007 and 2017 as follows: Canada, 13.4%, France 17.4%, Germany 11.3%, Italy 16.3%, Japan 13.5%, United Kingdom 20.4%, and United States 14.3%. While all G7 countries increased the consumption of renewable energy during the period, United Kingdom and France are the leading countries. As indicated in the report of REN21 (2018:17) renewable energy accounts for approximately 18.2% of world total energy consumption in 2016. It was 18.1% in 2017 (REN21, 2019:17). China installed about 30% of the global renewable power capacity alone leaving behind the United States and Germany in 2017. Besides, United States, Germany, Japan and the United Kingdom are among the top-6 countries in the world which install non-hydropower capacity, namely such as ocean and geothermal power, bio-power, solar, and wind power (REN21, 2018:42). In 2000, the Germany launched a feed in electricity tariff program aiming at the promoting to invest in renewable energy technologies. This program is designed to supports investor to purchase electricity from renewable energy sources at predetermined rates. In 2010, feed in electricity tariff came into force in UK. In 2017, the level of renewable energy consumption in UK grew eight times compare to 2000 (BEIS, 2018:31). The similar program came into force in 2009 and 2012 in Canada and Japan. Thus energy from renewable energy generation increased by 14.5% in 2015 in Japan (JFS, 2017).

In 2017, energy from hydropower generation was 67.1% of Canada's total renewable energy consumption. Besides, as indicated by Natural Resources Canada 17.3% of Canada's energy generates from renewable energies (NRC, 2019). G-7 countries' electricity generation from renewable energies in 2017 is reported in Table 1. As can be seen from the Table 1, United States has the greatest investment in all types of renewable energy sources, with wind, solar, geothermal, biomass and other sources. Canada accounts for the lowest electricity generation from solar energy among G7 countries. IEA (2018) indicates that while an upward trend in CO2 emissions was witnessed in most major countries, a decline was reported in many countries (United Kingdom, US, Japan) in 2017. The highest drop occurred in the US by 0.5% due to its shifting away from coal consumption to natural gas consumption leading a reduction in CO2 emissions. Similar trend is observed for the United Kingdom. CO2 emissions fell by 3.8% as a results of switching coal consumption toward natural gas and renewable energies. In case of Japan, CO2 emissions declined by 0.5% given that the share of renewables and nuclear generation in electricity increased.

Several researchers utilized LM and RALS version of LM tests to scrutinize convergence of energy consumption, renewable energy consumption, electricity consumption, and CO2 emissions (among others, Meng et al., 2013; Payne et al., 2017b; Mishra and Smyth, 2017; Pan et al.,2019; Churchill et al., 2020). Though, there is an increase in renewable energy consumption in G-7 countries, to formulate appropriate policies to support renewable energy sources, sustainable energy consumption and reduce CO2 emissions, it is vital to identify whether renewable energy consumption converges across G7 countries. To our best knowledge, this study is the first attempt to examine the renewable energy convergence of G-7 countries employing LM test unit root test and a new test is called RALS version of LM unit root test with endogenously determined with structural one or two breaks.

The remainder of the study is organized as follows. Section 2 includes the literature review. Section 3 presents the data and methodology. Section 4 provides the empirical results. Section 5 concludes.

2. LITERATURE REVIEW

Many scholars have paid attention to the investigation of convergence in different contexts, including total energy consumption, renewable energy consumption, energy intensity (2006; Huang et al., 2019), CO2 emissions. There appears to be basically two research strands in literature studying convergence. The first strand is composed of the studies, investigating a large panel group of countries, for total energy consumption (e.g., Mohammadi and Ram, 2012; Meng et al., 2013; Mishra and Smyth, 2014; Fallahi and Voia. 2015; Fallahi, 2017; Solarin and Lean, 2018; Solarin, 2019; Pan and Maslyuk-Escobedo, 2019), for renewable energy consumption (Maza et al., 2010; Berk et al., 2018; Solarin et al. 2018; Kasman and Kasman, 2019). For instance, to test the convergence in per capita energy consumption Mohammadi and Ram (2012) utilize regression analysis. They cannot find enough evidence in favor of convergence in per capita energy consumption. Meng et al. (2013) find convergence in energy use in most OECD countries employing LM and RALS version of LM unit root tests. Employ panel tests with structural shifts, Mishra and Smyth (2014) find that validity convergence of energy consumption per capita of ASEAN countries. Fallahi and Voia (2015) find evidence of convergence per capita energy use in half of OECD countries constructing confidence intervals in AR models.

Constructing confidence interval, Fallahi (2017) investigates convergence for energy use of 109 countries. Applying non-linear unit root tests Solarin and Lean (2018) find support of convergence of energy consumption in OPEC members including 11 countries. In addition, Solarin (2019) don't find any evidence convergence in energy consumption of 79 countries applying the residual augmented least squares regression. Employing LM and RALS-LM unit root tests, Pan and Maslyuk-Escobedo (2019) find evidence of stochastic conditional convergence in per capita energy consumption in most African countries. Maza et al. (2010) find convergence for 27 European Union for the share of renewable energy in total electricity consumption. Applying System-GMM approach, Berk et al. (2018) fail to find evidence the convergence of the share of renewable energies in primary energy consumption for 14 EU countries. Similar results were obtained by Kasman and Kasman (2019) for 15 EU member countries. Solarin et al. (2018) find that renewable energy consumption do not converge for most OECD countries applying fractional integration tests.

Moreover, Balcılar et al. (2018) cannot expose in favor of convergence in the energy intensity for EU-28 countries using the Phillips and Sul club convergence approach. Utilizing panel quantile regression Qi et al. (2019) provide evidence of convergence in total-factor energy efficiency for 60 of the Belt and Road Initiative countries. Maza and Villaverde (2008) find sigma convergence of per capita electricity consumption for 98 countries utilizing the generalized least squares. Employing panel unit root tests, Hassan and Isiaka (2019) find that per capita electricity consumption does not convergence among some West African countries. Kim (2015) provide evidence of convergence of electricity intensity 109 countries applying clustering algorithm. There are many studies examining the convergence of CO2 emissions among countries (e.g., Ulucak and Apergis, 2018; Bilgili and Ulucak, 2018; Cai et al., 2018; Bilgili et al., 2019; Erdogan and Acaravci, 2019; Emir et al., 2019; Solarin et el., 2019; Ozcan et al., 2019; Haider and Akram, 2019a; Haider and Akram, 2019b). For example, applying different unit root tests, according to Cai et al. (2018) there is evidence that CO2 emissions per capita converge in 21 OECD countries. Bilgili and Ulucak (2018) find evidence in favor of convergence in per capita ecological footprint in the G20 countries by utilizing a bootstrap-based panel KPSS test with structural breaks and club convergence test. Using club clustering approach, Ulucak and Apergis (2018) has mixed results on convergence ecological footprint. Erdogan and Acaravci (2019) provide evidence in favor of carbon emissions convergence in OECD countries applying Fourier panel KPSS test. Also, Emir et al. (2019) don't find the convergence CO2 intensity in EU-28 countries. Solarin et el. (2019) obtain 10 convergence clubs for ecological footprint of 92 countries.

Ozcan et al. (2019) conclude that while ecological footprints are stationary in a panel of low and high income countries, it is nonstationary in a lower-middle income country. Haider and Akram (2019a) find that per capita carbon dioxide emission, coal, oil, and gas do not convergence for 53 countries. Haider and Akram (2019b) provide no evidence of carbon footprint and ecological footprint convergences across 77 countries. The second strand includes studies both at sectoral and state levels of individual countries also examined in different frameworks, including for energy consumption (Ozturk and Aslan, 2011; Hao et al., 2015; Herrerias et al., 2017; Payne et al., 2017b; Mishra and Smyth, 2017; Hao and Peng, 2017; Mohammadi and Ram, 2017; Li et al., 2022), for renewable energy consumption, including electricity consumption and natural gas consumption (Payne et al., 2017a). Ozturk and Aslan (2011) provide evidence of the existence of stationarity of energy consumption for seven energy sector in Turkey. Hao et al. (2015) find that there is an energy consumption convergence for China's 29 provinces using a system generalized methods of moments. Herrerias et al. (2017) find four club convergence for coal, two for electricity and liquid clusters at regional level in China. Payne et al. (2017b) find convergence of fossil fuel consumption in most USA states utilizing LM and RALS-LM unit root tests. Following the same methodology, Mishra and Smyth (2017) find support for stochastic convergence in energy consumption per capita at all sector levels, expect for transportation in Australia. Hao and Peng (2017) provide an evidence of spatial energy consumption convergence for China at provincial level. Mohammadi and Ram (2017) find no support for convergence in energy consumption for USA.

3. DATA AND MODEL

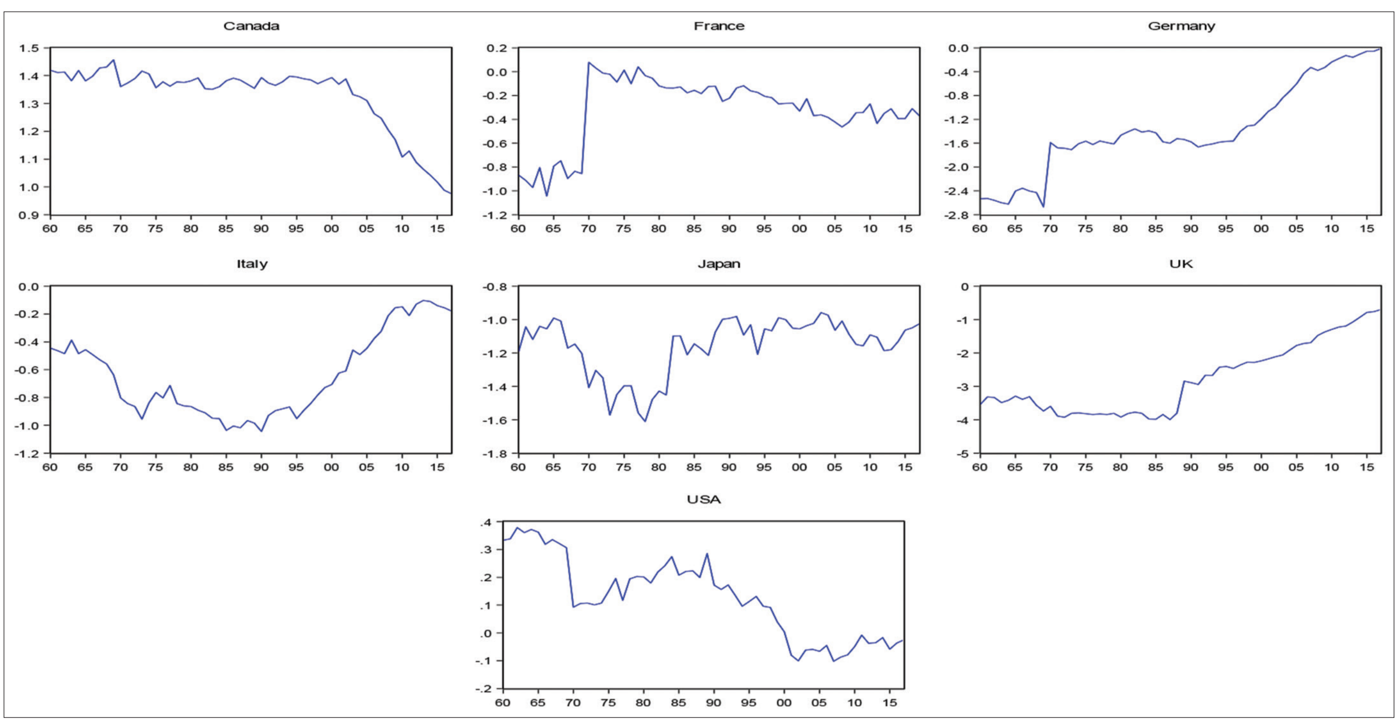
Per capita relative renewable energy consumption data across G-7 countries were collected from the EIA database. Figure 1 illustrates the per capita relative renewable energy consumption among G7 countries in the period between 1960 and 2017. As it can be seen from Figure 1, while there is no trend till 2005, after that, a sharp downward trend is observed for Canada. Regarding France, until 1970, France has low average, but after 1970, it appears to have a level shift with a decreasing trend. Similar result is observed for Germany. After 1970, there has been a sharp increase in the level of relative renewable energy consumption. After 1995s, it has an increasing trend in Germany. On the other hand, relative renewable energy consumption for Italy has downward trend until 1990 and after that period, it has become an increasing trend. Japan has the most volatile relative renewable energy consumption across G-7 countries.

Relative renewable energy consumption has decreasing trend until 1980s, but in the following period, it has an upward level shift with no trend. Until late 1985s, relative renewable energy consumption has no trend, but in the next period, the increasing trend attracts attention for UK. USA has declining trend overall period except for in the period between 1970 and 1985. As it can be seen from Figure 1 has three sharp decline is observed, which the first one is in the year of 1970, and the others are in 2002 and 2007, respectively. In order to investigate the conditional convergence for renewable energy per capita in G-7 countries, following Solarin et. al., (2018) and Solarin and Lean (2018), we use the model as follows:

$$\text{Relative renewable energy consumption per capita}_{it} = \ln\left(\frac{REC_{it}}{AEC_t}\right)$$

Where REC_{it} and AEC_t denote the renewable energy consumption per capita for each country i and average renewable energy consumption per capita at the time t, respectively.

Figure 1: Per capita relative renewable energy consumption for G-7 Countries



4. METHODOLOGY

Conventional unit root tests assume that error terms should be distributed normal. However, like AREC, many series in the economy is not always meeting the normality condition as in Table 1, which illustrates the Jarque-Berra statistics for ADF test. RALS version of LM test procedure stretches the condition that the error term is distributed normal in the unit root tests. Therefore, in this paper, so as to search the presence of the convergence of renewable energy consumption among the G7 countries we took advantage of RALS-LM unit root procedure. To implement the RALS version of LM test strategy, we prosecuted five steps, following Meng (2013); Im et al. (2014); Meng et al. (2013) and Meng et al. (2014). In the first step, LM test strategy is computed, and in the second step using the final equation in step 1 the w_t term is calculated. Regressing RALS model with w_t term is the third step of the RALS-LM test. In step four, using the estimation of the error variance of the last equation in step three, ρ which helps to obtain t statistics in step five, is calculated. Finally, in the fifth step, t statistics are obtained. The details of these 5 steps to compute RALS-LM test strategy are as follows:

In the first step, LM test strategy should be computed. RALS- LM test depends on LM test strategy, which is suggested by Schmidt and Phillips (1992). Null hypothesis intimates $\beta = 1$, against $\beta < 1$,

$$y_t = \psi + \xi t + x_t \tag{1}$$

$$x_t = \beta x_{t-1} + e_t \tag{2}$$

Where Ψ and ξ denote level and deterministic trend respectively.

LM and the DF test strategies differs from each other in the de-trending. For the LM version tests, the regression in differences of Δy_t on Δz_t with $z_t = [1,2]'$ is used for determining the coefficients of the deterministic trend components. Expressing the Maximum Likelihood Estimates (MLEs) from the LM procedure as $\tilde{\psi}$ and $\tilde{\xi}$, de-trending form of y_t is:

$$\tilde{y}_t = y_t - \tilde{\psi} + \tilde{\xi} t \tag{3}$$

If there is no-break, z_t can be represented as $z_t = [1,t]'$. On the other hand, if the model involves level shift where a break occurs at $t = T_B$, defining the D is the dummy variable which described as $D_t = 1$ if $t \geq T_B + 1$ and $D_t = 0$ if $t \leq T_B$, we can rewrite equation (1) and (2) as follows:

$$y_t = \psi + \xi t + dD_t + x_t \tag{4}$$

$$x_t = \beta x_{t-1} + e_t \tag{5}$$

Therefore, z_t can be described as $z_t = [1,t,D_t]'$. Besides, in process of multiple structural shifts, the similar critical values of the LM test (with no-break) are employed.

Eventually, the LM unit root test statistics are acquired from the following regression:

$$\Delta y_t = \delta' z_t + \varphi \tilde{y}_{t-1} + e_t \tag{6}$$

Where $\tilde{\psi}$ represents the restricted MLE and $\tilde{y}_t = y_t - \tilde{\psi} - z_t \tilde{\delta}$; $\tilde{\delta}$ is the vector of coefficients in the regression of Δy_t on ΔZ_t for t=2,3,…,T.

Finally, new model taking into account the autocorrelation problem:

$$\Delta y_t = \delta' z_t + \varphi \tilde{y}_{t-1} + \sum_{j=1}^{p} c_j \Delta \tilde{y}_{t-1} + e_t \tag{7}$$

In the second step using the final equation in step 1 the w_t term is calculated using the equation (7). To obtain w_t, we need to get m_j ($m_j = \frac{1}{T}\sum_{t=1}^{T} \hat{e}_t^{\,j}$ for $j = 2,3,\ldots,\rho$) which should be calculated for RALS(2&3). After that, the w_t term can be calculated as follows:

$$\hat{u}\ddot{y}\ddot{u}\ddot{i}_t = \left[\,\hat{}^{2}_{t} - {}_{2},\ \hat{}^{3}_{t} - {}_{3} - 3\ {}_{2t}\,\hat{}^{2}_{t}\right]' \tag{8}$$

After obtaining w_t, third step is regressing RALS model with w_t term.

$$\Delta\ddot{u}\ddot{y}\ddot{u}\ddot{i}\ \delta'\Delta \quad + \varphi\,\tilde{}_{-1} + \sum_{j=1}^{p} \quad \Delta\tilde{}_{-1} + \hat{}\,'\gamma + \tag{9}$$

To adjust LM procedure against to non-normal error, Meng (2013) used the method of Im et al. (2012). $\hat{\sigma}_A^2$ and $\hat{\sigma}^2$ are denotes the estimation of the error variance in the regression (7) and RALS-LM regression in (9), respectively. In step four, using the estimation of the erros variance of equation (9) in step three ρ should be calculated.

Table 1: G-7 countries' electricity generation from renewable energies in 2017

Countries	Wind (TWh)	Solar (TWh)	Geothermal, biomass and other sources of renewable energy (TWh)	Total (TWh)
Canada	29.07	3.29	9.72	42.08
United States	256.87	78.06	82.83	417.76
France	24.32	9.16	7.99	41.47
Germany	105.69	39.40	51.09	196.19
Italy	17.74	24.38	25.58	67.70
United Kingdom	50.00	11.52	31.87	93.40
Japan	6.11	61.83	30.87	98.81

Source: BP (2019)

Table 2: No-break LM unit root and RALS-LM unit root tests

Countries Name	LM Test	RALS-LM Test	P^2	Lag	Critical Value (%5)	Jarque Bera Test Statistics	Jarque Bera Probability
Canada	−0.21	−1.76	0.69	0	−2.93	33.28	0
France	1.87	−1.82	0.34	0	−2.57	10.07	0.06
Germany	1.33	−1.51	0.28	0	−2.57	1.45	0.48
Italy	−0.31	−0.83	1.02	0	−3.08	5.05	0.07
Japan	−0.77	−2.66	0.81	0	−2.99	12.86	0
UK	0.03	0.01	0.51	0	−2.78	5.48	0.06
USA	−1.85	−2.15	0.71	0	−2.92	3.17	0.2

Table 3: LM Unit Root and RALS-LM Unit Root Test Results with Level Shift (One Break)

Countries Name	LM Test	RALS-LM Test	P^2	Break date	Lag	Critical value (%5)
Canada	−2.53	−2.07	0.91	1977	18	−3.04
France	−1.27	−1.18	1.06	2010	51	−3.09
Germany	−2.53	−1.51	0.26	1985	26	−2.57
Italy	−2.45	−2.17	0.88	1974	15	−3.04
Japan	−2.39	−2.35	0.61	1981	22	−2.86
UK	−2.03	0.36	0.43	1983	24	−2.86
USA	−3.87	−3.23	0.97	1984	25	−3.09

Table 4: LM Unit Root and RALS-LM Unit Root Test with Level Shift (Two Break)

Countries Name	LM Test	RALS-LM Test	P^2	Break date	Break date	Lag	Critical value (%5)
Canada	−2.71	−2.55	0.97	1977	1982	10	−3.04
France	−1.64	−1.46	1.06	1990	2010	11	−3.1
Germany	−5.4	−6.16	0.77	1981	2004	12	−2.99
Italy	−2.76	−2.37	0.85	1974	1985	10	2.99
Japan	−3.95	−2.15	0.81	1996	2011	12	−2.99
UK	−2.38	−0.08	0.43	1983	1991	3	−2.68
USA	−4.32	−3.85	0.99	1984	2000	11	−3.1

Table 5: LM Unit Root and RALS-LM Unit Root Test with Trend Shift (One Break)

Countries Name	LM Test	RALS-LM Test	P^2	Break date	Lag	Critical value (%5)
Canada	−5.21	−2.18	0.76	2001	5	−3.61
France	−9.07	−3.21	0.47	1971	0	−3.27
Germany	−5.31	−5.05	0.88	2004	10	−3.69
Italy	−3.48	−3.54	0.99	1989	3	−3.79
Japan	−3.28	−3.01	0.9	1978	0	−3.69
UK	−3.56	−1.87	1.04	1988	3	−3.79
USA	−2.98	−1.53	0.79	1970	0	−3.61

Table 6: LM Unit Root and RALS-LM Unit Root Test with Trend Shift (Two Break)

Country	LM	RALS-LM	P^2	Break date	Break date	Lag	Critical value (%5)
Canada	−4.75	−5.27	0.71	2002	2010	12	−3.99
France	−2.45	−2.07	0.87	1974	1976	11	−4.25
Germany	−6.05	−6.68	0.79	2004	2009	12	−4.13
Italy	−3.51	−2.17	0.99	2000	2010	0	−4.37
Japan	−4.01	−1.74	0.85	1992	2011	12	−4.13
UK	−2.4	0.81	0.47	1983	1986	0	−3.68
USA	−4.3	−2.89	1.06	1984	1995	12	−4.37

$$\hat{\rho} = \frac{\hat{\sigma}_A^2}{\hat{\sigma}^2} \quad (10)$$

Finally, in the fifth step, using ρ, we can obtain t statistics as follows:

$$\tau_{RLM} \Rightarrow \rho\tau_{RLM} + \sqrt{1-\rho^2}\,N(0,1) \quad (11)$$

Where τ_{RIM} is the limiting distribution of the t-statistic and ρ represents the correlation between e_t and $\Psi(e_t)$.

5. EMPIRICAL RESULTS

We utilized LM unit root and RALS version of LM unit root tests with no break, level shift one and two-break, and finally with trend shift with one and two-break. The null hypothesis of a presence of unit root suggest that per capita relative energy consumption of time series do not converge across G-7 countries. The rejection of the null hypothesis that revealed that per capita relative renewable energy consumption is stationary.

The results of the no-break LM unit root and RALS version of LM unit root tests are shown in Table 2. The results show that the null hypothesis of a unit root is rejected at the 5% significance level suggesting there is no evidence that relative energy consumption is converging among G-7 countries.

Table 3 shows the results of the one-break LM unit root and RALS version of LM unit root tests with level shift. The null hypothesis cannot be rejected at the 5% significance level. Hence, the unit root test results with one-break provide support for convergence in relative energy consumption for USA at the 5% significance level.

To scrutinize the impacts of allowing for two-break instead of one-break in level shift model, we employ LM and RALS version LM unit root test with level shift (two break). The unit root test results are reported in Table 4. The unit root test results provide evidence of convergence in renewable energy consumption for Germany.

Table 5 displays the results LM unit root and RALS version of LM unit root tests with trend shift model (one-break). According to the results, the null hypothesis of a presence of unit root cannot rejected for Canada, France, Japan, UK and USA, while the null hypothesis can be rejected for Germany and Italy at the 5% level.

The results of two-break LM unit root and RALS version of LM unit root tests with trend shift are reported in Table 6. The null hypothesis is rejected for Canada and Germany indicating that there is convergence in relative renewable energy consumption for Canada and Germany. The null hypothesis of a presence of a unit root cannot be rejected for France, Japan, and UK when utilizing LM unit root and RALS version of LM unit root tests with level shift with one or two-break or trend shift with one or two-break.

The endogenously determined break dates provide important information and implications for the countries under investigation. Those break dates may be attributed the economic policies, crises, and regime shifts. For instance, the break dates in renewable energy consumption in France, Italy and Canada occurred in 1974, 1974 and 1977 were associated with the energy crisis in 1973. Then, many countries seek energy alternatives, including renewable energy sources. The second break date in relative renewable energy consumption in Italy detected in 1982 when government implemented an important act in terms of renewable energy sources (Farinelli, 2004). For Germany, 2004 seems to be most frequent break date corresponded to the feed in electricity tariff program launched in 2000. The similar program came into force in 2012 corresponded to the break date detected in 2011 in Japan. The break date in relative renewable energy consumption in Canada occurred in 2010 is coincided with the implementing Green Energy and Green Economy Act in 2009 in Canada (Hoberg and Rowlands, 2012). Regarding UK and USA, the most frequent break dates are 1983 and 1984 which may be associated with the increases in oil prices after the 1979. The most likely reason behind the second break in relative renewable energy consumption in UK occurred in 1991 is the UK's Non Fossil Fuel Obligation program in 1990 for supporting the nuclear and renewable energy sources (EIA, 2018).

6. CONCLUSION

This paper investigates convergence in renewable energy consumption across G-7 countries the data from 1960–2017 employing LM unit root and RALS version of LM unit root tests with no break, level shift with one and two-break or trend shift with one or two-break. Overall, the empirical evidence of no-break LM and RALS-LM unit root tests cannot provide a clear support for convergence in renewable energy consumption across G7 countries. On the other hand, the null hypothesis of a unit root can be rejected while considering the structural breaks. Considering the endogenously determined breaks, the results of the LM unit root test and RALS version of LM unit root test with level shift one-break) provide evidence in favor of convergence in renewable energy consumption in the United States. Besides, we found evidence for Germany, Italy and Canada in favor of convergence. However, utilizing the LM and RALS version of LM unit root tests with level shift (one or two-break or trend shift with one or two-break) findings revealed that there is no convergence for France, Japan, and UK.

REFERENCES

Balcilar, M., Emir, F., Shahbaz, M, (2018), The Dynamics of Energy Intensity Convergence in the EU-28 Countries. Working Papers 15-37. Famagusta: Eastern Mediterranean University, Department of Economics.

BEIS. (2018), UK Energy in Brief. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/728374/UK_energy_in_brief_2018.pdf [Last accessed on 2020 Jan 02].

Berk, I., Kasman, A., Kilinç, D. (2018), Towards a common renewable future: The System-GMM approach to assess the convergence in renewable energy consumption of EU countries. Energy Economics, 87, 103922.

Bilgili, F., Ulucak, R. (2018), Is there deterministic, stochastic, and/or club convergence in ecological footprint indicator among G20 countries? Environmental Science and Pollution Research, 25(35), 35404-35419.

Bilgili, F., Ulucak, R., Koçak, E. (2019), Implications of environmental convergence: continental evidence based on ecological footprint. In: Energy and Environmental Strategies in the Era of Globalization. Cham: Springer. pp133-165.

BP. (2019), Statistical Review of World Energy. 68th ed. Available from: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-renewable-energy.pdf [Last accessed on 2020 Jan 02].

Cai, Y., Chang, T., Inglesi-Lotz, R. (2018), Asymmetric persistence in convergence for carbon dioxide emissions based on quantile unit root test with fourier function. Energy, 161, 470-481.

Churchill, S.A., Inekwe, J., Ivanovski, K. (2020), Stochastic convergence in per capita CO_2 emissions: Evidence from emerging economies, 1921-2014. Energy Economics, 86, 104659.

EIA. (2018), Available from: https://www.eia.gov/international/analysis/

country/gbr [Last accessed on 2020 Jan 15].

Emir, F., Balcilar, M., Shahbaz, M. (2019), Inequality in carbon intensity in EU-28: Analysis based on club convergence. Environmental Science and Pollution Research, 26(4), 3308-3319.

Fallahi, F, (2017), Stochastic convergence in per capita energy use in world. Energy Economics, 65, 228-239.

Fallahi, F., Voia, M.C. (2015), Convergence and persistence in per capita energy use among OECD countries: Revisited using confidence intervals. Energy Economics, 52, 246-253.

Farinelli, U. (2004), Renewable energy policies in Italy. Energy for Sustainable Development, 8(1), 58-66.

Haider, S., Akram V. (2019a), Club convergence of per capita carbon emission: Global insight from disaggregated level data. Environmental Science and Pollution Research, 26(11), 11074-11086.

Haider, S., Akram, V. (2019b), Club convergence analysis of ecological and carbon footprint: Evidence from a cross-country analysis. Carbon Management, 10, 1-13.

Hao, Y., Peng, H. (2017), On the convergence in China's provincial per capita energy consumption: New evidence from a spatial econometric analysis. Energy Economics, 68, 31-43.

Hao, Y., Wang, S., Zhang, Z.Y. (2015), Examine the convergence in per capita energy consumption in China with breakpoints. Energy Procedia, 75, 2617-2625.

Hassan, Y.A., Isiaka, M.A. (2019), Convergence in electricity consumption among selected West African countries. Colombo Business Journal, 10(1), 1-18.

Herrerias, M.J., Aller, C., Ordóñez, J. (2017), Residential energy consumption: A convergence analysis across Chinese regions. Energy Economics, 62, 371-381.

Hoberg, G., Rowlands, I. (2012), Green Energy Politics in Canada: Comparing Electricity Policies in BC and Ontario. In: APSA 2012 Annual Meeting Paper. Available from: https://ssrn.com/abstract=2108967

Huang, J., Zheng, X., Wang, A., Cai, X. (2019), Convergence analysis of China's energy intensity at the industrial sector level. Environmental Science and Pollution Research, 26(8), 7730-7742.

IEA. (2018), Global Energy and CO_2 Status Report 2017. International Energy Agency. Available from: https://www.iea.org/reports/global-energy-co2-status-report- [Last accessed on 2020 Feb 26].

IEA. (2019), Global Energy and CO_2 Status Report 2018. International Energy Agency. Available from: https://iea.blob.core.windows.net/assets/23f9eb39-7493-4722-aced-61433cbffe10/Global_Energy_and_CO2_Status_Report_2018.pdf [Last accessed on 2020 Feb 26].

Im, K.S., Lee, J., Tieslau, M.A. (2014), More powerful unit root tests with non-normal errors. In: Festschrift in Honor of Peter Schmidt. New York: Springer. p315-342.

JFS. (2017), Japan for Sustainability, No 176, Available from: https://www.japanfs.org/en/news/archives/news_id035824.html [Last accessed on 12 2020 Feb 12].

Kasman, A., Kasman, S, (2019), Convergence of renewable energy consumption in the EU-15: Evidence from stochastic and club convergence tests. Environmental Science and Pollution Research, 27, 1-11.

Kim, Y.S. (2015), Electricity consumption and economic development: Are countries converging to a common trend? Energy Economics, 49, 192-202.

Li, X., Ozturk, I., Raza Syed, Q., Hafeez, M., Sohail, S. (2022), Does green environmental policy promote renewable energy consumption in BRICST? Fresh insights from panel quantile regression. Economic Research-Ekonomska Istraživanja, 35(1), 5807-5823.

Maza, A., Hierro, M., Villaverde, J. (2010), Renewable electricity consumption in the EU-27: Are cross-country differences diminishing? Renewable Energy, 35(9), 2094-2101.

Maza, A., Villaverde, J. (2008), The world per capita electricity consumption distribution: Signs of convergence? Energy Policy, 36(11), 4255-4261.

Meng, M. (2013), Three Essays on More Powerful Unit Root Tests with Non-normal Errors (Doctoral Dissertation, University of Alabama Libraries).

Meng, M., Im, K.S., Lee, J., Tieslau, M.A. (2014), More powerful LM unit root tests with non-normal errors. In: Festschrift in Honor of Peter Schmidt. New York: Springer. p343-357.

Meng, M., Payne, J.E., Lee, J. (2013), Convergence in per capita energy use among OECD countries. Energy Economics, 36, 536-545.

Mishra, V., Smyth, R, (2017), Conditional convergence in Australia's energy consumption at the sector level. Energy Economics, 62, 396-403.

Mishra, V., Smyth, R. (2014), Convergence in energy consumption per capita among ASEAN countries. Energy Policy, 73, 180-185.

Mohammadi, H., Ram, R. (2012). Cross-country convergence in energy and electricity consumption, 1971-2007. Energy Economics, 34(6), 1882-1887.

Mohammadi, H., Ram, R. (2017). Convergence in energy consumption per capita across the US states, 1970-2013: An exploration through selected parametric and non-parametric methods. Energy Economics, 62, 404-410.

NRC. (2019), Natural Resources Canada. Available from: https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/renewable-energy-facts/20069#L3 [Last accessed on 2020 Feb 12].

Ozcan, B., Ulucak, R., Dogan, E. (2019), Analyzing long lasting effects of environmental policies: Evidence from low, middle and high income economies. Sustainable Cities and Society, 44, 130-143.

Ozturk, I., Aslan, A. (2011), Are fluctuations in energy consumption per capita transitory? Evidence from Turkey. Energy Exploration and Exploitation, 29(2), 161-167.

Pan, L., Maslyuk-Escobedo, S. (2019), Stochastic convergence in per capita energy consumption and its catch-up rate: Evidence from 26 African countries. Applied Economics, 51(24), 2566-2590.

Payne, J.E., Vizek, M., Lee, J. (2017a), Is there convergence in per capita renewable energy consumption across U.S States? Evidence from LM and RALS-LM unit root tests with breaks. Renewable and Sustainable Energy Reviews, 70, 715-728.

Payne, J.E., Vizek, M., Lee, J. (2017b), Stochastic convergence in per capita fossil fuel consumption in U.S. states. Energy Econ, 62, 382-395.

Qi, S., Peng, H., Zhang, X., Tan, X. (2019), Is energy efficiency of belt and road initiative countries catching up or falling behind? Evidence from a panel quantile regression approach. Applied Energy, 253, 113581.

REN21. (2018), Renewable Energy Policy Network for the 21st Century. Available from: https://www.ren21.net/wp-content/uploads/2019/08/Full-Report-2018.pdf [Last accessed on 2020 Feb 10].

REN21. (2019), Renewable Energy Policy Network for the 21st Century. Available from: https://www.ren21.net/wp-content/uploads/2019/05/gsr_2019_full_report_en.pdf [Last accessed on 2020 Feb 25].

Schmidt, P., Phillips, P. (1992), LM tests for a unit root in the presence of deterministic trends. Oxford Bulletin of Economics and Statistics, 54(3), 257-287.

Solarin, S.A. (2019), Parametric and non-parametric convergence analysis of electricity intensity in developed and developing countries. Environmental Science and Pollution Research, 26(9), 8552-8574.

Solarin, S.A., Gil-Alana, L.A., Al-Mulali, U. (2018), Stochastic convergence of renewable energy consumption in OECD countries:

A fractional integration approach. Environmental Science and Pollution Research, 25(18), 17289-17299.
Solarin, S.A., Lean, H.H. (2018), Conditional convergence in energy consumption per capita of OPEC member countries: Evidence from non-linearity tests. OPEC Energy Review, 42(3), 199-211.
Solarin, S.A., Tiwari, A.K., Bello, M.O. (2019), A multi-country convergence analysis of ecological footprint and its components. Sustainable Cities and Society, 46, 101422.
Ulucak, R., Apergis, N. (2018), Does convergence really matter for the environment? An application based on club convergence and on the ecological footprint concept for the EU countries. Environmental Science and Policy, 80, 21-27.