Threshold Effects of Renewable Energy Consumption Among the G20 Countries: Asymptotic and Bootstrap Test for Linearity and Non-linearity in a TAR Approach

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Abstract

The relationship between renewable energy and economic growth is one of the most attractive subjects in economic literature. The purpose of this study is to investigate ten different panel data sets for G20 countries in the 1970- 2013 period using TAR models with two regimes used for panel-data in a non-linear framework. In the literature, there is a limited number of studies using non-parametric techniques. The estimates indicate that the results may change according to the linear and nonlinear analysis. The linear model indicates that these countries have been converging during the last fourthly decades. The result of the non-linear model is absolute convergence under both regimes.

Keywords: *economic growth, energy consumption, renewable energy, panel TAR, G-20 countries*

G20 Ülkeleri Arasında Yenilenebilir Enerji Tüketiminin Threshold Etkileri: TAR Yaklaşımında Doğrusal ve Doğrusal Olmayan Asimtotik ve Bootstrap Testi

Öz

Yenilenebilir enerji ve ekonomik büyüme arasındaki ilişki iktisat yazınında en cazip konulardan biridir. Bu çalışmanın amacı, doğrusal olmayan panel veri çatısında iki rejimli TAR modelini kullanarak 1970-2013 döneminde G20 ülkelerinde 10 farklı panel grubunu araştırmaktır. Literatürde, sınırlı sayıda parametrik olmayan teknik kullanılarak yapılan çalışma bulunmaktadır. Tahminler doğrusal ve doğrusal olmayan analize göre sonuçların değişebileceğini göstermektedir. Doğrusal model son kırk yılda bu ülkelerde yakınsamayı yansıtmaktadır. Doğrusal olmayan sonuçlar her iki rejimde de mutlak yakınsamayı göstermektedir.

Anahtar Kelimeler: *Ekonomik Büyüme, Enerji tüketimi, yenilenebilir Enerji, Panel TAR, G20 Ülkeleri*

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1. Inroduction

Energy plays vital role in economic development. Both developed and developing countries need more energy to ensure economic growth. However, energy demand derived from fossil fuels contribute to greenhouse emissions all over the world.

The question of whether or not energy conservation policies affect economic activity is of great interest in the international debate on global warming and the reduction of greenhouse gas emissions. Although the causal relationship between energy consumption and economic growth has been widely studied, no consensus regarding this so-called energy consumption-growth nexus has yet been reached. The direction of causality is highly relevant for policy makers. For instance, if causality runs from energy consumption to economic growth, energy conservation policies aiming at reducing energy consumption may have a negative impact on economic growth.

The literature insists on four main hypotheses regarding the possible outcomes of causality (Apergis and Payne, 2009). The growth hypothesis suggests that energy consumption is the most important component in growth, directly or indirectly as a complement to capital and labour as a factor of production. For this reason, a decrease in energy consumption causes a decrease in real GDP. This hypothesis was demonstrated by Damette & Seghir (2013), Acaravci & Ozturk (2013), Shahiduzzaman & Alam (2012), Mazbahul & Nazrul (2011), Chang (2010), Yoo & Lee (2010). By contrast, the conservation hypothesis argues that policies directed towards lower energy consumption may have little or no adverse impact on real GDP. This hypothesis is based on a uni-directional causal relationship running from real GDP to energy consumption. The running causality from GDP to energy consumption was recently demonstrated by Baranzini et al. (2013), Azlina & Mustapha (2012), Adom (2011), Jamil & Ahmad (2010). Bi-directional causality corresponds to the feedback hypothesis, which suggests that energy consumption and real GDP affect each other simultaneously. Therefore, policy makers should take into account the feedback effect of real GDP on energy consumption by implementing regulations to reduce energy use. Furthermore, economic growth should be decoupled from energy consumption to avoid a negative impact on economic development resulting from a reduction of energy use. This hypothesis was demonstrated by Hu & Lin (2013), Tang & Tan (2013), Kouakou (2011), Ouédraogo (2010) and many others. Finally, the neutrality hypothesis indicates that reducing energy consumption does not affect economic growth or vice versa. This hypothesis assumes no causality between energy consumption and economic growth. Hence, energy conservation policies would not have any impact on real GDP. The neutrality hypothesis is supported by many recent studies including Stern & Enflo (2013), Ozturk & Acaravci (2011) and Ozturk & Acaravci (2010).

The concept of renewable energy and economic growth has received attention by both policymakers and the general public in the recent years due to alarming factors in environment quality. Using renewable resources can reduce carbon dioxide emissions furthermore it may mitigate natural resource depletion. Renewable energy is expected to provide a good solution for climate change, global warming and energy security. Renewable energy deployment brings economic growth and sustainable development. Promoting renewables means providing secure and clean energy supply while supporting GDP growth, improving trade balances, creating local value and jobs.

Economic literature has focused on investigating the relationship between energy and economic growth by using linear models. If series follow a nonlinear process, the results may be unbiased. Therefore, non-parametric approaches are more appropriate to test the relationship between these variables. There is a limited number of study conducted using non-parametric techniques in the literature. This paper aims to fulfill this gap and contribute to the empirical literature. The causal relationship between renewable energy consumption and economic growth is vital for the policy implications. The purpose of this study is to examine ten different panel data sets for G20 countries over the 1970-2013 period using TAR models with two regimes which is a non-linear panel-data framework. The study is organized as follows: Section 1 introduces the problem and the review of the literature is given in Section 2, in Section 3 data and methodology are presented and results are presented in Section 4. Final section concludes.

2. Literature Review

Numerous studies have analyzed the relationship between economic growth and energy consumption by focusing on different countries, time periods, using different techniques and parameters Kraft & Kraft, 1978; Yu & Hwang, 1984; Yu & Jin, 1992; Masih & Masih, 1996; Asufu-Adjaye, 2000; Stern, 2000; Soytaş et. al., 2001; Hondroyiannis et al., 2002; Wolde-Rufael, 2004; Sarı & Soytaş, 2004; Yoo, 2006; Jobert & Karanfil, 2007; Lise & Montfort, 2007; Erdal et al., 2008; Mandal & Madheswaran, 2010; Wang et al., 2011 However, empirical research has not yielded a consensus on the causal relationship between energy consumption and economic growth and the results of these studies are mixed. The literature review of the subject is widely placed in some (see for example Payne, 2010; Ozturk, 2010; Omri et al., 2015) studies. Recently, non-parametric models have been used to examine the relationship between energy consumption and economic growth (Huang et al., 2008; Chiou-Wei et al., 2008; Park & Hong, 2013; Ajmi et al., 2013; Dergiades et al., 2013; Mensah, 2014).

There are number of studies attemped to investigate the relationship between economic growth and renewable energy by using multi-country sample and time series. For instance Chien and Hu (2008) analyze the relationship between GDP, capital formation, trade balance, energy imports, renewables, consumption for 116 countries by applying Structural Equation Modelling (SEM). The result shows that there is a positive relationship between renewable energy and GDP through the path of increasing capital formation. Moreover, it is found that the use of renewable energy increases GDP. Silva et al. (2011) use structural vector autogressive approach (SVAR) to find the relationship between renewable energy sources share in electricity (RES), gross domestic product (GDP), carbon dioxide (CO_2) emissions for US, Denmark, Portugal, Spain over the period of 1960-2004. The analysis indicates that a significant part of forecast error variance of GDP was explained by the share of RES. However, a smaller part of the forecast error variance of CO_2 per capita is explained by tha share of RES. Salim and Rafiq (2012) examine the relationship among real GDP, carbon emission, oil price, renewable energy consumptions for Brazil, China, India, Indonesia, Phillippines and Turkey for the period of 1980-2006. They find that renewable energy consumption was significantly determined by income and pollutant emission in Brazil, China, India and Indonesa in the long run. Carbon emission has positive, significant elasticity for most of the countries except for Philippines and Turkey. Hence, it can be inferred through both panel and individual country analyses that for all the countries except Philippines and Turkey carbon emission has been a significant determinant of renewable energy consumption in the long run. However, for Philippines and Turkey income has been the only long-run determinant of renewable energy consumption. Causalities between income and renewable energy are found to be bi-directional both in Philippines and Turkey. However, there is no causal link between pollutant emission and renewable energy in these countries. This result can be interpreted as the outcome of oil price not significantly contributing to renewable energy adoption and pollutant emission per se.

In addition to the multi-country time series analyses, there is another group of studies (Fang, 2011; Tiwari, 2011; Pao & Fu, 2013; Ocal & Aslan, 2013) dealing with single country time series. For the US, Sarı et al. (2008) use distributed lag (ARDL) approach to indicate cointegration between industrial production, employment, coal, fossils fuels, conventional hydroelectric-power, solar energy, wind energy, natural gas, wood and waste consumption over 2001:1-2005:6 period. The results show that in the long run output and labor are the key determinants of fossil fuel, conventional hydroelectric power, solar, waste and wind energy consumption. Fang (2011) analyzes the period of 1978-2008 employing multivariate OLS and find that 1% increase in renewable energy consumption increases real GDP by 0.120%, GDP per capita by 0.162% in China. Tiwari (2011), on the other hand, investigates Indian's renewable energy consumption, economic growth, CO_2 emission variables. Johansen-Juselius test indicates that there is no evidence of cointegration among the variables. However, structural vector autogressive approach (SVAR) result shows that consumption of renewable energy sources increases GDP and decreases CO_2 emissions. Futhermore, a positive shock on GDP has very high positive impact on the CO_2 emissions.

On the other hand, in numerous other studies (Chang et al., 2009; Sadorsky, 2009a; Sadorsky, 2009b; Apergis & Payne, 2010a; Apergis & Payne, 2014; Zeb et al., 2014; Omri et al., 2015) panel cointegration technique is employed to examine relationship between variables. Sadorsky (2009a) analyzes the relationship between the renewable energy per capita, real GDP percapita, CO_2 emission per capita, real oil price in case of G7 countries over the period of 1980-2005. Results from panel cointegration model show that in the long run increase in real GDP and CO_2 per capita are major drivers behind per capita renewable energy consumption. Similarly, Sadorsky (2009b) observes the relationship for 18 emerging countries for the 1994-2003 period. The result reveals that increase in real per capita income has a positive and statistically significant impact on per capita renewable energy consumption. Zeb et al. (2014) employ Panel Fully Modified OLS approach to investigate the relationship between electricity production from renewable energy (ERS), carbon dioxide emissions (CO_2), natural resource depletion (NRD), gross domestic product (GDP), poverty (POV). The results of this study analyzing SAARCH countries for the 1975-2010 period indicate that an increase in energy production to a decrease in carbon emissions and an increase in GDP. Besides, they find that GDP and POV has positive impact on energy production, while CO_2 has negative impact on energy production.

Recently, various studies have analyzed the relationship between economic growth and renewable energy by using non-parametric approach. Chang et al. (2009) which has analyzed 30 OECD countries using a panel threshold regression technique find a relationship between contibution of renewables to energy supply, gross domestic product and CPI of energy. The results show that countries with high economic growth are able to respond to high energy prices by increasing renewable energy use, however countries with low-economic growth do not. For some EU countries over the 1971-2009 period, Bilgili (2012) employs linear models and nonlinear threshold autoregressison models to test biomass energy supply. The results indicate that panel of Austria, Denmark, Finland, France and Portugal follows a nonlinear process and there is partial convergence while the panel of Belgium, Greece, Norway, Poland and Sweden indicates linearity and divergence. Apergis and Payne (2014) examine seven countries in Central America for the period of 1980-2010 by using linear and nonlinear methods. Nonlinear panel cointegration results indicate that, the effects of renewable energy consumption per capita strengthened for the post 2002 period compared to the pre-2002 period. The general conclusion of studies using causality test is reported in Table 1.

Table 1. Summary of empirical studies on renewable energy and economic growth

Authors	Period and Country	Methodolgy	Conclusion(s)
Payne (2009)	1949-2006 US	Toda-Yamamoto Causality	RE<≠> GDP, NONRE <≠> GDP
Sadorsky (2009b)	1994-2003, 18 emerging countries	Panel causality test	Granger causality; GDP≠> RE ELP≠> RE ECM for full model; RE<≠>GDP
Bowden and Payne (2009)	1949-2006, US	Toda-Yamamoto causality	TEC <≠>GDP TTEC <≠>GDP GDP↔CTEC GDP↔RTEC ITEC →GDP
Apergis et al. (2010)	1984-2007, 19 developed and developing countries	Panel causality	NE→ CO_2 RE ≠> CO_2 RE↔GDP GDP↔CO_2
Apergis and Payne (2010a)	1985-2005, Twenty OECD countries	Error correction model	GDP↔RE

Menyah and Wolde-Rufael (2010)	1960-2007, US	Modified Granger causality	NE→ CO_2, RE<≠> CO_2 GDP↔CO_2, NE<≠> GDP GDP→ RE
Apergis and Payne (2010b)	1992-2007, 13 countries within Eurasia	Heterogeneous panel cointegration, Error correction model	GDP↔RE
Menegaki (2011)	1997-2007, 27 Europen countries	Random effect model, Causality test	RE<≠>GDP
Tugcu et al. (2012)	1980-2009, G7 Countries	Distributed Lag (ARDL) approach, Hatemi-J causality test	Augmented production function; RE<≠> GDP (in France, Italy, Canada, USA) GDP↔RE (in England, Japan), GDP→RE (in Germany) Classical production function; GDP↔RE (in all countries)
Yildirim et al. (2012)	1949-2010; 1960-2010; 1970-2010, US	Toda-Yamamoto procedure, Bootstrap-corrected causality	BRE →GDP, RE<≠> GDP, GRE<≠> GDP, HRE<≠> GDP,
Salim and Rafiq (2012)	1980-2006, Brazil, China, India, Indonesia, Philippines, Turkey	Granger causality	In the short run; GDP↔RE CO_2 ↔RE
Pao and Fu (2013)	1980-2010, Brazil	Johansen cointegration, VECM model	NHREC→GDP GDP ↔ TREC GDP→NREC GDP→TEC
Zeb et al. (2014)	1975-2010 SAARC countries	Granger Causality	CO_2 ↔NRD (in Nepal), ERE↔POV (in Pakistan), ERE→POV (in Bangladesh and India), POV→ERE (in Sri Lanka),
Omri et al. (2015)	1990-2011, 17 developed and developing countries	Dynamic simultaneous-equation panel data model	NE→GDP (in Belgium, Spain), GDP→NE (in Bulgaria, Canada, Netherlands, Sweden), GDP↔ NE (in Argentina, Brazil, France, Pakistan, USA), GDP<≠>NE (in Finland, Hungary, India, Japan, Switzerland, U.K.), RE→GDP (in Hungary, India, Japan, Netherlands, Sweden), GDP→RE (Argentina, Spain, Switzerland), GDP↔RE (in Belgium, Bulgaria, Canada, France, Pakistan, USA), GDP<≠>RE (in Brazil, Finland, Switzerland), For global panel; GDP↔ NE, GDP→RE

The empirical results may indicate conflict outcomes because of using different data, methodology and investigating different countries. Therefore, in some studies unidirectional causality running from renewable energy to economic growth is found while in some others, unidirectional causality running from economic growth to renewable energy. On the other hand, there are studies finding no causality and/or bidirectional causality between renewable energy and economic growth.

3. Methodology

The convergence hypothesis has a long tradition in economic growth theory . The basis of convergence hypothesis is Barro and Sala Martin (1991). This study states that the rate of convergence tends to be higher if we allow for the flow of technological advances from developed to developing economies. Technology convergence is a widely debated phenomenon by policy makers as well as experts and researchers. According to Barro and Salai Martin (1995), in the long run all economies grow at the rate finding in the leading places. Thus, the rate of discovery takes a more important place in this model than the exogenous rate of technical change plays in the neoclassical model. The comparison of growth rates across countries reflects the conditional convergence behavior related to the cost of copying inventions.

Several studies have employed panel data and time series techniques, i.e., unit root or cointegration tests, to investigate the hypothesis of convergence in per capita output (Bernard and Durlauf, 1996; Carlino and Mills, 1993; Oxley and Greasley, 1995; Maddala and Wu, 1999; Pesaran, 2003; Levin and Lin, 1992; Funk and Strauss, 2003; Carrion-i-Silvestre et al., 2005; Beyaert and Camacho, 2008; Bilgili, 2012; Kalita and Tiwari, 2012; Yavuz and Yilanci, 2013). Panel convergence is based on Evans and Karras (1996) that provides strong evidence for 54 countries in the period 1950-1990.

The innovative contribution of our paper is to employ a new approach introduced by Beyaert and Camacho (2008). They used the threshold model, the panel data unit root tests, and the computation of critical values by bootstrap simulation. Following Beyaert and Camacho (2008) and Evans and Karras (1996), we use a new panel data methodology to test real convergence in a linear and non-linear framework.

The method used to test the real convergence with panel data of Evans and Karras (1996) yields linear and non-linear framework as follows:

$$\Delta g_{n,t} = \delta_n + \rho_n g_{n,t-1} + \sum_{i=1}^{p} \varphi_{n,i} \Delta g_{n,t-i} + \varepsilon_{n,t} \quad (1)$$

$$\Delta g_{n,t} = \left[\delta_n^I + \rho_n^I g_{n,t-1} + \sum_{i=1}^{p} \varphi_{n,i}^I \Delta g_{n,t-i}\right] I_{\{z_{t-d}<\lambda\}} + \left[\delta_n^{II} + \rho_n^{II} g_{n,t-1} + \sum_{i=1}^{p} \varphi_{n,i}^{II} \Delta g_{n,t-i}\right] I_{\{z_{t-d}\geq\lambda\}} + \varepsilon_{n.t} \quad (2)$$

where $n = 1,2, \dots N$ and $t = 1,2, \dots T$ and where δ, ρ and φ are parameters of country to be estimated and Δ, d, λ and $\varepsilon_{n,t}$ denote respectively difference operator, delay parameter, threshold parameter and residual term of country i.

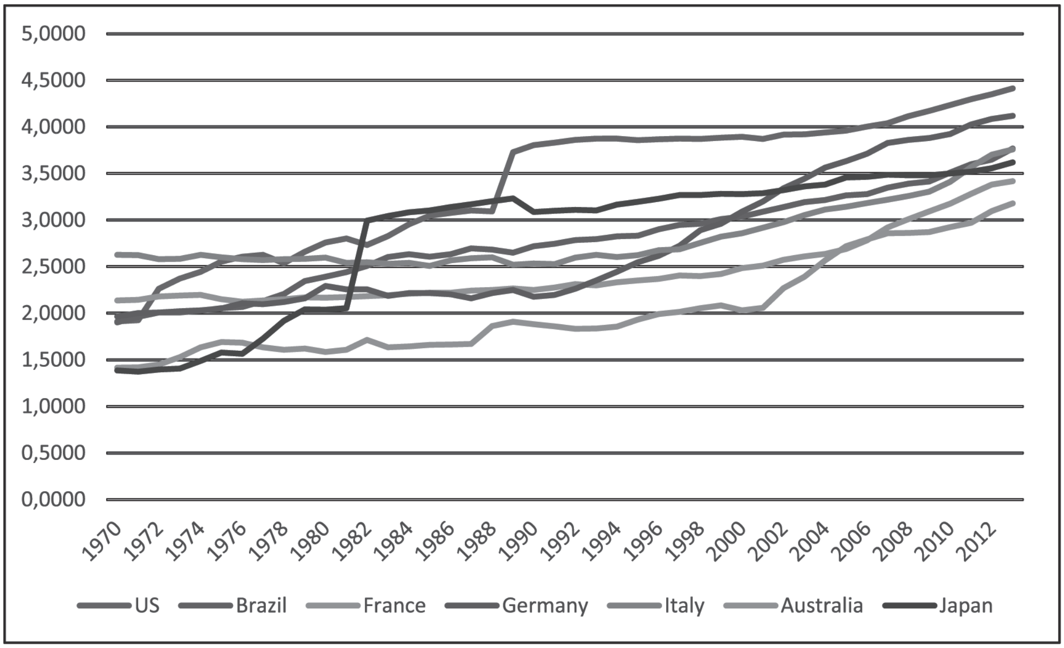
4. Data and Empirical Results

Renewable energy use made up more than 18% of total global final energy consumption in 2012. G20 countries account for the bulk of this, and host 80% of existing renewable power capacity around the world (World Bank, 2015). The G20 countries will therefore have a key role to play. Today, G20 has a leading role in technology development and innovation that can help to accelerate renewable energy deployment. Because of this, countries in the analysis are chosen to be as G20 countries.

The data for total renewable consumption (Renewables - Other renewables consumption -Twh) of G20 countries comes from Statistical Review of World Energy 2014 (http://www.bp.com). Panel 1970-2013 annual data set of renewable energy consumption covers United States, Brazil, France, Germany, Italy, Australia and Japan.

As Figure 1 demonstrates, except for US the series tend to converge on a common mean value indicating a converging pattern among the renewable energy consumption levels. To make a comparison we have used the TAR model put forward by Beyaerth and Camacho (2008). In the paper basically two main problems have been investigated. Firstly, is renewable energy consumption in developed countries showing a difference? And secondly, how does this situation varies in the period of economic expansion and contraction?

Figure. 1. Plot of renewable energy consumption for US, Brazil, France, Germany, Italy, Australia and Japan



The statistical results are showed in Table 2 for the linear model (equation 1), and in Table 3 for the TAR model (equation 2). In the study ten different panels were employed. As expected, the linear model reflects that these countries have been converging during the 1970-2013 for all Panel-1/9. For example, p value for the null of divergence for panel 1 is equal to 0,0000. We also conclude that there is absolute convergence in all panel countries because the p value for the absolute convergence is above the standard critical value.

Table 2. Linearity tests for United States, Brazil, France, Germany, Italy, Australia and Japan.

	Results of Evans–Karras Linear Model	
	Divergence & convergence	Absolute & conditional convergence
Panel-1	0,0000 (Convergence)	0,7860 (0,0000)
Panel-2	0,0000 (Convergence)	0,9100 (0,0007)
Panel-3	0,0000 (Convergence)	0,6170 (0,0000)
Panel-4	0,0000 (Convergence)	0,9070 (0,0005)
Panel-5	0,0000 (Convergence)	0,6430 (0,0000)
Panel-6	0,0000 (Convergence)	0,7680 (0,0000)
Panel-7	0,0000 (Convergence)	0,8480 (0,0001)
Panel-8	0,0001 (Convergence)	0,2260 (0,0000)
Panel-9	0,0227 (Convergence)	0,3310 (0,0000)
Panel-10	0,0547 (Divergence)	0,4650 (0,0031)

Panel-1: United States, Brazil, France, Germany, Italy, Australia and Japan.
Panel-2: Brazil, France, Germany, Italy, Australia and Japan
Panel-3: United States, France, Germany, Italy, Australia and Japan

Table 3 and Table 4 show the statistical results for the TAR model. In the analysis according to Table 3 we didn't reject the null hypothesis of linearity because both unrestricted and restricted bootstrap-p values were below the critical value for panel 1-7. But in panel 8 and 9, we have rejected the null hypothesis of linearity with %5 and in panel 10 we have rejected the null hypothesis of linearity with %10 confidence. We can conclude that both panel 8 and 9 favor non-linearity and convergence for the panel countries. We estimated the threshold value as -5,8354 and 4,9659 for panel 8 and 9 and we determined the exogenous variables transition. Threshold value of 4,9659 implies that growth rate of Germany renewable energy consumption is above the mean of panel 9 renewable energy consumption by 4,9659 unit in regime I. Regime I corresponds respectively to 17,0732 and 70,7317% of the total observation. On the contrary, Regime II corresponds to 82,92 and 29,27% of observation of the whole sample. Regime II realizes when the relative growth of Germany renewable energy consumption is above this level. Threshold value of -5,8354 implies that growth rate of Brazil renewable energy consumption is under the mean of panel 8 renewable energy consumption by 4,9659 unit in regime I.

Table 3. Linear and TAR panel models for renewable energy consumption in G20 countries.

Panel	*Lag*	*Linearity Test Bootstrap-p*		*Transition Country*	λ	*% Observation in Regime I*
		Unrestricted	Restricted			
Panel-1	1	1,0000	1,0000	US	-3,0850	53,6585
Panel-2	1	1,0000	1,0000	Brazil	-7,9033	14,6341
Panel-3	1	1,0000	1,0000	US	-8,6628	21,9512
Panel-4	1	1,0000	1,0000	US	-2,8089	56,0976
Panel-5	1	1,0000	1,0000	US	-1,1472	53,6585
Panel-6	1	1,0000	1,0000	US	-3,4493	46,3415
Panel-7	1	1,0000	1,0000	US	5,5074	75,6098
Panel-8	1	0,0080	0,0120	Brazil	-5,8354	17,0732
Panel-9	1	0,0340	0,0370	Germany	4,9659	70,7317
Panel-10	1	0,0560	0,0580	France	3,9822	65,8537

Table 4 indicates the results of both linear model and TAR. Turning to the TAR model, there are some important results. Firstly, according to the results of linearity, panels 1, 4, 5, 6 and 7 reach full convergence in both regimes. Secondly, one can say that panels 2 and 3 converge partially in regime II. Figures 2 and 3 can be examined respectively through value of the transition variable for Brazil and Germany. The Figure 2 shows that regime II completely dominates decades from 1970 to 2013 for Brazil, whereas Figure 3 reveals that regime I is the dominant for Germany during the same period. As for panels 8, 9, and 10, we can suggest that regime II displays stronger signs of absolute convergence (p value 0,8190, 0,4590 and 0,7070) than regime I (p value 0,2220, 0,4220 and 0,3480). The whole sample conclusion is absolute convergence under both regimes. This may mean that during this period, renewable energy policy is similar in those countries.

Table 4. Convergence test of linear and TAR panel models for renewable energy consumption in G20 countries.

Panel	*Divergence versus Convergence*			*Absolute versus Conditional Test*			
	Regime I	Regime II	Result	Regime I	Regime II	Both	Result
Panel-1	0,0003	0,0003	Full convergence	0,4290	0,6980	0,6560	Absolute
Panel-2	0,4779	0,0000	Partial convergence Regime II	0,9160	0,6890	0,8640	Absolute
Panel-3	0,0927	0,002	Partial convergence Regime II	0,1040	0,7890	0,3220	Absolute
Panel-4	0,0004	0,017	Full convergence	0,5110	0,6270	0,6940	Absolute
Panel-5	0,0000	0,0073	Full convergence	0,2510	0,8150	0,5860	Absolute
Panel-6	0,0030	0,0000	Full convergence	0,5200	0,3890	0,5200	Absolute
Panel-7	0,0005	0,0135	Full convergence	0,5310	0,5230	0,6580	Absolute
Panel-8	0,0482	0,1051	Partial convergence Regime I	0,2220	0,8190	0,6760	Absolute
Panel-9	0,0183	0,6849	Partial convergence Regime I	0,4220	0,4590	0,4720	Absolute
Panel-10	0,0038	0,5743	Partial convergence Regime I	0,3480	0,7070	0,5210	Absolute

Figure 2: Threshold value refer to Brazil for Panel 8

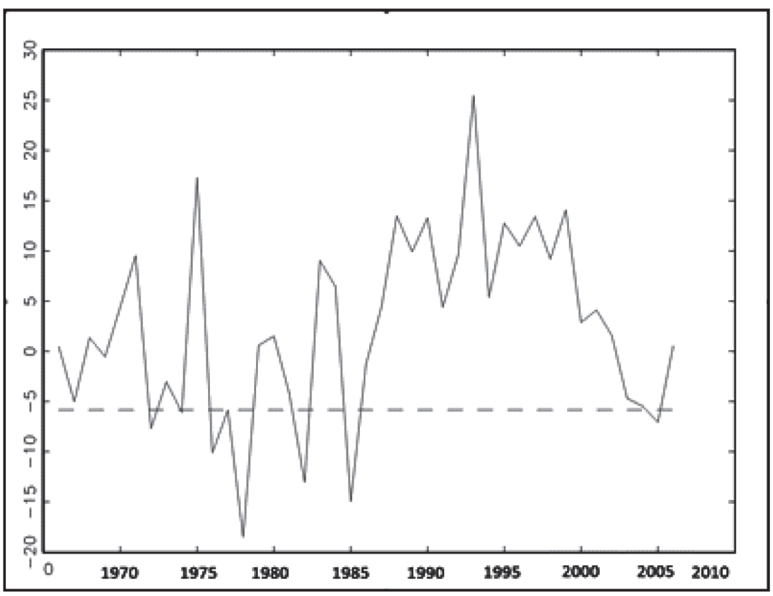
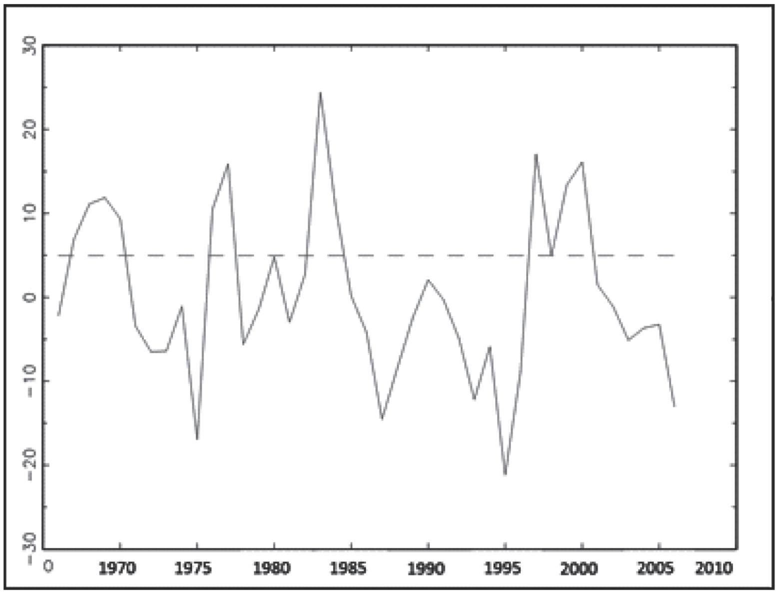


Figure 3. Threshold value refer to Germany for Panel 9



Conclusion

Renewable energy is a very important topic all over the world. Countries have encountered environmental degradation because of the use of more energy to meet economic growth. Energy in all forms (e.g. power generation, industry use, transportation, residential use) is a major driver behind economic growth and prosperity. Using renewable resources is a way to avoid environmental depletion and renewable energy has a vital role in mitigating climate change and greenhouse emissions. Process of shifting resources from non-renewable to renewable helps reducing environmental problems. Furthermore, the use of renewable energy plays an important role to eliminate dependence on imported energy.

The importance of renewable energy has been discussed in many studies. Previous studies have employed linear univariate or panel data methods to analyze the unit root properties of renewable energy consumption. This stufy, on the other hand, has applied a recently introduced nonlinear panel unit root test that allows two regimes depending on the threshold variable and we use panel TAR convergence proposed by Beyaert and Camacho (2008). We have employed annual 1970-2013 periods with 10 different panel data sets of G20 countries. TAR models with two regimes propose a panel-data non-linear framework. One of the major advantages of the model is that it allows for the presence of a unit root. In our work, basically two main questions have been investigated. Firstly, does renewable energy consumption in developed countries follow different convergence path and secondly, how does this situation vary in the period of economic expansion and contraction?

We have found the following results. Firstly, according to the results of linearity, full convergence appears for panel 1, 4, 5, 6 and 7 in both of two regimes. Secondly, one can say that there exists partial convergence for panel 2 and panel 3 in regime II and that panels 8, 9 and 10 reach partial convergence in regime I. The other conclusion is that absolute convergence changes according to expansion and contraction of economy. Fourthly, in this case renewable energy policy of the country should be specified according to regime. Especially in regime II, we may conclude that these countries have shared a common steady state path over 1970-2013. Finally, the results may vary according to the linear and nonlinear analyses. The linear model reflects that these countries' renewable energy consumption have been converging during the last fourthy decades. The non-linear model shows absolute convergence under both regimes.

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