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GREEN ECONOMIC GROWTH AND RENEWABLE ENERGY CONSUMPTION: EMPIRICAL EVIDENCE FROM EMERGING COUNTRIES*

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ABSTRACT

This paper examines the relationship between energy consumption and green economic growth for 21 emerging countries over the period 1993-2015 by controlling the impact of trade openness, technological development, and urbanization. The empirical evidence is based on the cointegration tests and mean group estimators, which address the issue of heterogeneity and cross-sectional dependence. The results suggest that green economic growth and its determinants are cointegrated in the long run and the impact of renewable energy consumption on green economic growth is statistically significant and negative in emerging countries. It means that the use of renewable energy is far from stimulating sustainable economic growth in these countries. While the effect of urbanization on green economic growth is found to be positive, the estimated parameters of trade openness and technological development are statistically significant and negative. The findings reveal important policy implications for achieving green economic growth in emerging economies.

Keywords: *Green Economic Growth, Renewable Energy, Panel Data, Emerging Countries.*

YEŞİL EKONOMİK BÜYÜME VE YENİLENEBİLİR ENERJİ TÜKETİMİ: YÜKSELEN EKONOMİLER İÇİN AMPİRİK KANITLAR

ÖZET

Bu çalışma yenilenebilir enerji tüketimi ile yeşil ekonomik büyüme arasındaki ilişkiyi 1993-2015 dönemi ve 21 yükselen ülke için ticari açıklığın, teknolojik gelişmenin ve kentleşmenin etkisini kontrol ederek incelemektedir. Ampirik inceleme heterojenlik ve yatay-kesit bağımlılığına karşı sağlam sonuçlar üreten eşbütünleşme testlerine ve ortalama grup tahmincilerine dayanmaktadır. Elde edilen sonuçlar, yeşil ekonomik büyüme ile belirleyicilerinin uzun dönemde eşbütünleşme ilişkisine sahip olduğunu ve yenilenebilir enerji tüketiminin yeşil ekonomik büyüme üzerindeki etkisinin yükselen ekonomiler için istatistiki olarak anlamlı ve negatif olduğunu göstermektedir. Bu bağlamda, yenilenebilir enerji tüketiminin bu ülkelerde sürdürülebilir ekonomik büyüme teşvik etmekten uzaktır. Kentleşmenin yeşil ekonomik büyüme üzerindeki etkisi pozitif bulunurken, ticari açıklık ve teknolojik gelişme için tahmin edilen parametreler istatistiksel olarak anlamlı ve negatiftir. Çalışmadan elde edilen bulgular, yükselen ekonomilerde yeşil ekonomik büyümeye ulaşmak için önemli politika önerileri ortaya koymaktadır.

Anahtar Kelimeler: *Yeşil Ekonomik Büyüme, Yenilenebilir Enerji, Panel Veri, Yükselen Ekonomiler.*

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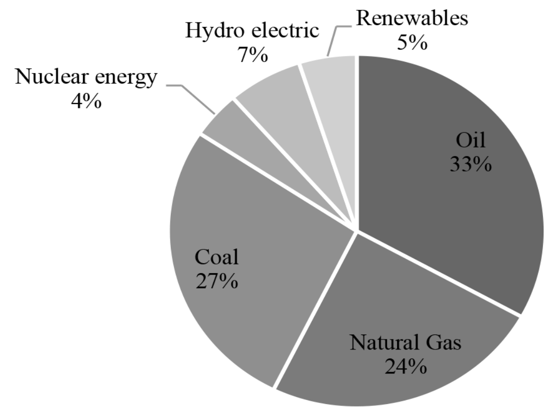
1. Introduction

There is no doubt that energy consumption is an important driver of economic growth and significantly contributes to economic activity. On the other hand, it is also well-known that the continuous depletion of energy sources deteriorates the quality of the environment and harms human health as it increases greenhouse gas (GHG) emissions and results in climate change. Considering this trade-off, countries are always being faced with the big challenge of promoting economic growth without degrading the environment. This makes the investigation of the growth-energy nexus highly important in the academic literature as the accurate information between these variables has important policy implications for fighting against climate change. Therefore, the relationship between economic growth and energy consumption is one of the most studied topics in the existing literature and has generated an extensive body of applied energy economics research over the past decades (Adedoyin et al., 2020; Bourcet, 2020; Dogan et al., 2020; Munir et al., 2020).

The empirical literature mainly proposes four hypotheses to explain the economic growth-energy consumption nexus: growth hypothesis, conservation hypothesis, feedback hypothesis, and neutrality hypothesis (Ozturk, 2010; Shahbaz et al., 2015; Wesseh & Zoumara, 2012; Yildirim & Aslan, 2012). According to the growth hypothesis, there exists a unidirectional causality from energy consumption and economic growth. Therefore, it is suggested that energy consumption has a positive impact on growth and any shocks to the energy supply negatively affect economic growth rates. In this scenario, policies implemented to reduce energy consumption are expected to have negative effects on economic growth. The conservation hypothesis also suggests one-way causality. However, unlike the growth hypothesis, the causality relationship runs from economic growth to energy consumption, meaning that energy supply shocks do not negatively affect growth rates. The feedback hypothesis suggests that there exists bidirectional causality between growth and energy consumption, implying a mutual relationship. If this hypothesis is verified, energy policies should be designed carefully. It is because in this scenario heavily relying on a nondiversified energy policy has an important potential to harm economic growth and the environment. Unlike the feedback hypothesis, the neutrality hypothesis suggests that there is no causality between these variables. Therefore, the validation of this hypothesis suggests that economic growth and energy consumption do not have a significant effect on each other (Koçak & Şarkgüneşi, 2017; Ozturk, 2010; Taşkın et al., 2020; Yildirim & Aslan, 2012).

Given these hypotheses and empirical results obtained so far, two issues become highly important for correctly analyzing the economic growth-energy consumption nexus and manifesting the main purpose of this paper. The first one is related to the type of energy consumption. In other words, the interpretation of results significantly varies depending on whether the indicator of energy consumption is renewable or non-renewable. The second issue is about how to measure the economic well-being of the countries.

Figure 1: The Share of Renewable Energy in Comparison with Other Fuel Types



Source: British Petroleum. (2020). Statistical review of world energy, 2020 | 69th Edition. In Bp (Vol. 69). Retrieved from https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf

Regarding the first issue, the transition from non-renewable to renewable sources might be an important way to reach sustainable economic growth rates and address environmental concerns. More importantly, some factors, such as the implicit cost of non-renewable energy, energy security issues for energy importing economies, high price volatility and the extinction risk of the traditional energy sources, and government's commitments to reducing carbon emissions make this transition inevitable for most countries (Koçak & Şarkgüneşi, 2017; Taşkın et al., 2020). However, renewable energy consumption share in the total mix has not reached the desired level so far (Ozcan & Ozturk, 2019). Figure 1 depicts renewable energy share in comparison with other fuel types in 2019. According to Figure 1, the share of renewable in the energy mix (oil, natural gas, coal, nuclear energy, and hydroelectricity) has risen to 5% in 2019. It is equally important to note that this share is substantially lower than the share of oil (33%), coal (27%), and natural gas (24%).

As to the second issue, gross domestic product (GDP) is regarded as a key indicator of measuring the economic well-being of countries. However, it does not perfectly reflect all components of life quality. These concerns have motivated international organizations to develop a new term, which is known as green economic growth (GEG) (OECD, 2009, 2011; UNEP, 2011). The concept of GEG refers to the output without degrading the environment and harming environmental quality. Therefore, it highlights the importance of economic growth ensuring natural resource sustainability (Asongu & Odhiambo, 2020; Danish & Ulucak, 2020; Sohag et al., 2019; Taşkın et al., 2020; Zaman et al., 2016).

In the light of these above-mentioned issues, in this paper, we aim to investigate the effect of renewable energy consumption (REN) on GEG for 21 emerging countries over the period 1993-2015 by controlling the impact of trade openness, technological development, and urbanization. The effect of REN on GEG occurs in several ways. First, the use of renewable energy in the production process is more environmentally desirable than nonrenewable energy use, as it results in less externalities to the environment. Therefore, substituting renewable energy for non-renewables makes green growth possible and achievable. Second, especially for energy importing countries, energy security is a highly important issue due to high price volatility and the extinction risk of the traditional energy sources. For this reason, the use of renewable sources might promote green growth by not only minimizing the negative shocks of price volatility but also reducing the pressure on the balance of payments (Sohag et al., 2019). Third, technological development and participation in the global economy by integrating into the global economy might play important role in explaining the nexus between GEG and REN (Alataş, 2021; Tang et al., 2020). To this end, we control these variables in our estimations to better explain the changes in GEG.

The empirical evidence of the paper is based on the cointegration tests and mean group estimators. Methodologically, *(i)* we employ the Pesaran (2004) CD test to test the existence of the cross-sectional dependence between countries; *(ii)* we test unit root properties of the variables by employing the Pesaran (2007) cross-sectionally augmented Dickey-Fuller (CADF) unit root test; *(iii)* we examine the existence of cointegration by using two different tests: Westerlund & Edgerton (2007) and Westerlund (2007); *(iv)* we estimate the long-run parameters using the Pesaran & Smith (1995) mean group (MG), the Eberhardt & Teal (2010) augmented mean group (AMG), and Pesaran (2006) common correlated effects mean groups (CCEMG) estimators.

This paper contributes to the existing energy-growth nexus literature in three aspects. First, contrary to the extensive literature on the (non)renewable energy-growth nexus (Alper & Oguz, 2016; Apergis & Payne, 2010, 2012; Bhattacharya et al., 2016; Koçak & Şarkgüneşi, 2017; Shahbaz et al., 2015), we pay special attention to the GEG concept and analyze the relationship between REN and GEG by controlling for the effect of trade openness, technological development, and urbanization. Second, although some studies exist in the literature for a wide range of country groups, we investigate this link for emerging countries due to their higher energy demand and rapid population growth rates. Third, methodologically, we employ recently developed techniques, which address the issue of heterogeneity and cross-sectional dependence, to obtain more reliable estimates.

The remainder of this study is structured as follows. This introduction is followed by a literature review section. Section 3 introduces data, model, and methodology. While Section 4 presents empirical results, the last section concludes.

2. Literature Review

The energy-growth nexus is one of the most commonly studied topics in the energy economics literature over the past decades (Apergis & Tang, 2013; Aslan et al., 2021; Aydin, 2019; Inglesi-Lotz, 2016; Menegaki, 2011; Ocal & Aslan, 2013; Ozcan & Ozturk, 2019; Ozturk & Acaravci, 2010; Payne, 2009; Sadorsky, 2009; Yildirim et al., 2012). However, a clear consensus regarding this relationship has not been reached. While some studies suggest that energy consumption stimulates economic growth, confirming the growth hypothesis, some others support the conservation, feedback, or neutrality hypotheses, and find a statistically insignificant or negative relationship.[1] The inconsistency of the findings is more likely due

1 For further information, please see (Bourcet, 2020; Taşkın et al., 2020)

to the differences in the dataset, sample, period, or estimator used in these empirical studies (Bourcet, 2020; Dogan et al., 2020). For example, Inglesi-Lotz (2016) confirms the growth hypothesis for all OECD countries over the period between 1990 and 2010. The results highlight the importance of renewable energy consumption and its share in the total energy mix for economic growth. Chontanawat et al. (2008) analyze the relationship between energy consumption and economic growth for over 100 countries. The results validate the growth hypothesis for the developed OECD countries, but not for the developing non-OECD countries. Yildirim & Aslan (2012) test the economic growth-energy consumption nexus for 17 developed OECD countries. While the results confirm the existence of the growth hypothesis for Japan, the neutrality hypothesis is verified for the vast majority of countries in the sample. Pao & Tsai (2010) examine the same nexus for a panel of BRIC countries over the period between 1971 and 2005. The empirical findings show that there is bidirectional causality between energy consumption and output. Menyah & Wolde-Rufael (2010) find a unidirectional causality running from energy consumption to economic growth in South Africa.

A vast part of this extensive literature on the energy-growth nexus focus on the relationship between (non)renewable energy and economic growth (Alper & Oguz, 2016; Apergis & Payne, 2010, 2012; Bhattacharya et al., 2016; Koçak & Şarkgüneşi, 2017; Shahbaz et al., 2015). Koçak & Şarkgüneşi (2017) examine the renewable energy-growth nexus for the period between 1990 and 2012 in 9 Black Sea and Balkan countries. The long-run parameter estimates reveal that REN has a positive impact on economic growth. Using the autoregressive distributed lag (ARDL) approach, Alper & Oguz (2016) support that REN has a positive impact on economic growth in Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Poland, Romania, and Slovenia for the period of 1990-2009. Apergis & Payne (2010) support the growth hypothesis in South America. Apergis & Payne (2012) analyze the linkage between (non)renewable energy and growth for 80 countries and support the growth hypothesis in both the short and long run. Bhattacharya et al. (2016) investigate the impact of energy consumption on economic growth in 38 top renewable energy-consuming countries over the period 1991 and 2012. The findings suggest that the effect of REN on output is statistically significant and positive for the vast majority of countries in the sample. Using the ARDL and rolling window (RWA) approaches, Shahbaz et al. (2015) confirm the feedback hypothesis in Pakistan.

So far, there have been only sparse studies on the concept of GEG. Zaman et al. (2016) show the importance of GEG in the context of BRICS countries by examining the impact of energy consumption on economic growth. Panel DOLS and FMOLS estimation results confirm the link between environment, economy, and energy. Dai et al. (2016) use a computable general equilibrium model to assess the effect of REN on the macroeconomy. The findings show that large-scale developments in renewable energy have a significant effect on other sectors and the macroeconomy. Pahle et al. (2016) suggest that renewable deployment might lead to short-term socio-economic benefits, but they might not sustain. Wang & Shao (2019) examine the nonlinear link between GEG and environmental regulations for G20 countries. Panel threshold results reveal that formal regulations have a significant effect on GEG. However, this effect varies at different phases.

Sohag et al. (2019) employ the Autoregressive Distributed Lags technique to empirically test the linkage between clean energy and GEG for Turkey spanning the period 1980-2017. In order to measure GEG, they add merit goods (education expenditures) to the gross domestic product and subtract negative externalities (monetary value of CO2 damage, particulate emission damage, natural resources depletion). The findings reveal that both the production and use of cleaner energy significantly stimulate GEG in Turkey. Taşkın et al. (2020) estimate the long elasticity of GEG with respect to REN and trade openness for OECD countries by using annual data spanning the period 1990 to 2015. Panel OLS, DOLS, and FMOLS estimation results indicate that both REN and trade openness have a positive and statistically significant impact on GEG. Besides, there exists bidirectional causality between GEG and REN. Danish & Ulucak (2020) investigate the linkage between technological development and GEG by controlling the effect of renewable and nonrenewable energy consumption on GEG. To measure GEG, they follow a similar data construction process employed in Sohag et al. (2019) and Taşkın et al. (2020). Panel data estimation findings confirm the significant role of REN to promote GEG in BRICS countries. A recent paper by Asongu & Odhiambo (2020) focuses on the green economy in sub-Saharan countries over the period between 2004 and 2014. The results show the importance of REN thresholds in the green economy-income inequality nexus.

3. Data Description, Model Specification and Methodology

We use annual data spanning the period 1993 to 2015 for 21 emerging countries. Table 1 shows the variable description and data sources. As shown in Table 1, we mainly use five different variables: renewable energy consumption (REN), green economic growth (GEG), individuals using the internet (ICT), trade openness (TRA), and urbanization (URB).[2] All of these variables are compiled from the World Bank (2020) database.

Table 1: Data Description and Sources

Variable	Definition	Source
GEG	Green economic growth	WDI
REN	The share of renewable energy in total final energy consumption	WDI
TRA	The sum of exports and imports of goods and services (% of GDP)	WDI
ICT	Individuals using the internet (% of population)	WDI
URB	Urban population (% of total population)	WDI

Note: WDI denotes the World Bank's World Development Indicators.

The countries included in the empirical analysis are as follows: Argentina, Brazil, Chile, Colombia, Mexico, Peru, Czechia, Egypt, Greece, Russia, Saudi Arabia, South Africa, China, Korea, Malaysia, Pakistan, Phillippines, India, Indonesia, Turkey, and Thailand. The emerging countries have been selected based on the Morgan Stanley Capital International (MSCI) country classification (MSCI, 2020). United Arab Emirates, Hungary, Poland, Qatar, and Taiwan have been excluded due to data unavailability.

2 Following Sohag et al. (2019) and Taşkın et al. (2020), GEG is calculated by deducting negative externalities (CO2 damage, particulate emission damage, net forest depletion, natural resources depletion) from the growth process.

Table 2 reports the summary statistics (upper panel) and the pairwise correlation matrix (lower panel). The number of observations for each variable is 483, as our sample consists of 23 years and 21 countries. The average value of REN is 2.37 with a standard deviation of 1.86 (the highest volatility observed among variables), meaning that there is a wide dispersion from the average for REN. This highest volatility is followed by ICT and GEG, respectively. While the correlation between GEG and REN is negative, it is positive for TRA, ICT, and URB. Notably, the highest coefficient correlation is obtained for URB and REN, which suggests that URB and REN have a considerable impact on GEG in emerging countries.

Table 2: Summary Statistics and Pairwise Correlation Matrix

Variable	GEG	REN	TRA	ICT	URB
Observation	483	483	483	483	483
Mean	8.607	2.379	3.992	2.230	4.097
Std. Dev.	0.949	1.865	0.514	1.472	0.346
Min	6.343	-5.120	2.750	0	3.265
Max	10.301	4.043	5.396	4.510	4.516
GEG	1.000	-	-	-	-
REN	-0.507	1.000	-	-	-
TRA	0.272	-0.303	1.000	-	-
ICT	0.471	-0.161	0.321	1.000	-
URB	0.857	-0.379	0.033	0.393	1.000

Note: All series are in natural logarithm.

Our log-linear model can be defined as follows

$$GEG_{it} = \beta_0 + \beta_1 REN_{it} + \beta_2 TRA_{it} + \beta_3 ICT_{it} + \beta_4 URB_{it} + \varepsilon_{it} \quad (1)$$

where ***i*** and ***t*** stand for country and time period. The idiosyncratic error term (ε_{it}) consists of two parts: country-specific fixed effect and time-variant effect. All variables used are in natural logarithms. Therefore, the coefficient estimates represent the elasticity between GEG and REN, TRA, ICT, and URB.

The starting point of the empirical investigation is the cross-sectional dependence between countries for each variable. For that purpose, we employ the Pesaran (2004) CD test. This test is computed as follows (Pesaran, 2021).

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=1}^{N-1} \hat{\rho}_{ij}\right) \quad (2)$$

where $\hat{\rho}_{ij}$ denote the pairwise correlation of the residuals. Rejection of the null hypothesis implies that the residuals are cross-sectionally dependent. It means that a shock affecting a country might have a considerable impact on other countries in the sample.

We secondly test the existence of unit root in the study variables and employ the Pesaran (2007) cross-sectionally augmented Dickey-Fuller (CADF) unit root test. CADF is one of the most commonly used panel unit root tests in the empirical literature as it is capable of controlling the cross-sectional dependence. In order to deal with the cross-sectional dependence issue, this test mainly augments the standard ADF test by adding the cross-section averages of lagged levels and first-differences of the individual series to the estimated regression. Under the null hypothesis of non-stationarity, the CADF test statistic is the t-statistics of the OLS estimate of the one-lagged value of the dependent variable (Pesaran, 2007).

In order to analyze the relationship between variables, we thirdly test the existence of cointegration by using two different tests: Westerlund & Edgerton (2007) and Westerlund (2007). These tests also take the cross-sectional dependence issue into account. Under the null hypothesis of cointegration in panel data, the panel cointegration test suggested by Westerlund & Edgerton (2007) builds on the well-known LM test proposed McCoskey & Kao (1998) and employs bootstrap techniques to deal with cross-sectional dependence. On the other hand, the Westerlund (2007) error correction-based cointegration test can be regarded as a panel extension of Bannerjee et al. (1998). Under the null hypothesis of no cointegration, this test computes four different (two mean group statistics, two panel statistics) test statistics.

We lastly estimate the long-run parameters in Eq. (1) using three different estimators: the Pesaran & Smith (1995) MG, the Eberhardt & Teal (2010) AMG, the Pesaran (2006) CCEMG. All these mean group estimators allow for heterogeneous slope coefficients across cross-sectional units and follow the same empirical strategy: cross-section specific OLS estimates and calculating the mean of these estimates (Eberhardt, 2012).

4. Empirical Results

Table 3 presents the cross-sectional dependence and panel unit root test results. The Pesaran (2004) CD test strongly rejects the null hypothesis of no cross-sectional dependence, meaning that cross-correlation exists between countries. It means that a shock in a country might spill over other countries in the sample. Besides, the Pesaran (2007) CADF unit root test results suggest that series are integrated at first order. In other words, all variables are stationary at first difference.

Table 3: Cross-Sectional Dependence and Panel Unit Root Test

Variable	GEG	REN	TRA	ICT	URB
Pesaran (2004) CD test	56.400*** [0.000]	18.360*** [0.000]	17.950*** [0.000]	66.180*** [0.000]	40.730*** [0.000]
Pesaran (2007) CADF test (at level)	-1.848	-2.355	-2.294	-2.415	-2.056
Pesaran (2007) CADF test (first difference)	-2.629*	-3.383***	-2.869***	-3.196***	-3.227***

Note: The figures in the parentheses [ ] denote p-values. *, ** and *** denotes significance at 10%, 5% and 1%, respectively. The critical values for the Pesaran (2007) CADF unit root test are -2.58, -2.66 and -2.81 at the 10%, 5% and 1%, respectively.

Table 4: Cointegration Test

Westerlund & Edgerton (2007)		Westerlund (2007)							
Intercept	Intercept and trend	Intercept				Intercept and trend			
LM	LM	G_τ	G_α	P_τ	P_α	G_τ	G_α	P_τ	P_α
6.791 [1.000]	16.436 [0.999]	-3.360 (-4.39) [0.000]	-0.300 (7.750) [1.000]	-4.972 (4.499) [1.000]	-3.372 (3.587) [1.000]	-3.210 (-1.75) [0.040]	-1.727 (8.289) [1.000]	-9.500 (2.543) [0.995]	-2.898 (5.850) [1.000]

Note: The figures in the parentheses [ ] denote p-values.

Table 4 reports the cointegration test results from Westerlund & Edgerton (2007) and Westerlund (2007). The results reveal the presence of cointegration between GEG and its determinants. Therefore, we estimate the long-run parameters and analyze the elasticity between study variables.

Table 5: Long-Run Parameter Estimates

Estimator	MG (a)		AMG (b)		CCEMG (c)	
Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
REN	-0.264*** (0.094)	-0.150*** (0.048)	-0.139*** (0.050)	-0.103*** (0.040)	-0.045 (0.061)	-0.092 (0.063)
TRA	-0.086* (0.046)	-0.025 (0.035)	-0.133*** (0.029)	-0.091*** (0.028)	-0.125*** (0.026)	-0.071** (0.029)
ICT	-0.011 (0.025)	-0.052*** (0.017)	-0.006 (0.017)	-0.025* (0.014)	-0.021 (0.022)	-0.041** (0.016)
URB	3.713*** (1.317)	2.262 (2.054)	1.615*** (0.542)	1.208 (1.702)	-0.510 (2.564)	0.587 (2.358)
Trend	-	0.022 (0.018)	-	0.014 (0.019)	-	0.023 (0.032)
Constant	-4.198 (5.575)	-0.467 (8.138)	2.247 (2.219)	3.724 (6.815)	-8.117 (10.444)	17.428 (23.138)
Obs.	483	483	483	483	483	483
RMSE	0.042	0.027	0.029	0.022	0.019	0.016

Note: The figures in the parentheses ( ) denote standard errors. *, ** and *** denotes significance at 10%, 5% and 1%, respectively.

The long-run parameter estimates are illustrated in Table 5. While panel (a) shows the MG estimates, panels (b) and (c) report the results for the AMG and CCEMG estimators, respectively. The findings shown in panels (a) and (b) reveal that renewable energy consumption has a statistically significant and negative effect on green economic growth in emerging countries. As all variables are represented in the natural logarithm, we can interpret these parameter estimates as elasticity. For example, considering the size of the coefficients, a %1 percentage change in renewable energy would decrease green growth by more than 0.10%. Although the CCEMG estimates find a negative link between green growth and renewable energy, these estimates are not statistically significant at conventional significance levels. While these results are consistent with the findings of Ocal & Aslan (2013), Ozcan & Ozturk (2019), and Danish & Ulucak (2020), they are not in line with Sohag et al. (2019) and Taşkın et al. (2020).

Regarding the control variables, urbanization exerts a larger impact on green growth than renewable energy consumption. As expected, the sign of urbanization is positive. However, they are found to be statistically significant only in the MG and AMG estimates including the trend variable. On the other hand, the estimated parameters of trade and technological development are statistically significant and negative for almost all cases, indicating that these variables are negatively associated with green growth.

The existence of a negative and statistically significant relationship between GEG and REN implies that the use of renewable energy is far from stimulating sustainable economic growth in emerging countries. Therefore, renewable energy consumption can not be regarded as a possible solution in fighting against climate change and environmental degradation. The more likely reason for such an empirical result might be due to the low share of renewable energy consumption in total energy mix. In other words, as the share of renewable energy is lower in these countries, the effect of REN on GEG remains inadequate (Ozcan & Ozturk, 2019; Taşkın et al., 2020). Recent data also support this argument. According to the British Petroleum (2020) report, the share of renewable in the energy mix is lower than the world average of 5% in 14 out of 21 emerging countries (Mexico, Argentina, Colombia, Peru, Russia, Saudi Arabia, Egypt, South Africa, China, India, Indonesia, Malaysia, Pakistan, Korea).

Table 6: Pesaran (2007) Panel Unit Root Test Results

Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	-3.038***	-3.073***	-3.356***	-3.531***	-3.769***	-3.713***
Intercept and trend	-2.994***	-3.001***	-3.242***	-3.457***	-3.648***	-3.575***

Note: *, ** and *** denotes significance at 10%, 5% and 1%, respectively. While the critical values for the Pesaran (2007) CADF unit root test are -2.07, -2.15 and -2.30 for intercept model, they are -2.58, -2.66 and -2.81 for intercept and trend model at the 10%, 5% and 1%, respectively.

In order to check the fitness of our models, we apply the Pesaran (2007) CADF unit root test to the residuals. The results are shown in Table 6. As clearly seen, the findings strongly reject the null hypothesis of non-stationary for all residuals, which is consistent with the lower RMSE values reported in Table 5.

5. Conclusion and Policy Implications

The relationship between energy consumption and economic growth is one of the highly studied topics in the empirical energy economics literature. It is because reliable information regarding this link is considered to be highly crucial for reducing GHG emissions and fighting against climate change while ensuring high growth rates. However, scholars have not reached a clear consensus regarding this nexus. While some papers confirm the positive relationship, some others find a statistically insignificant and negative linkage between them.

In this paper, we focus on estimating the effect of renewable energy consumption on green growth. To this end, we cover 21 emerging countries for the period of 1993-2015 and control for the effect of trade openness, technological development, and urbanization. Methodologically, *(i)* we employ the Pesaran (2004) CD test to test the existence of the cross-sectional dependence between countries; *(ii)* we test unit root properties of the variables by employing the Pesaran (2007) CADF unit root test; *(iii)* we examine the existence of cointegration by using two different tests: Westerlund & Edgerton (2007) and Westerlund (2007); *(iv)* we estimate the long-run parameters using the Pesaran & Smith (1995) MG, the Eberhardt & Teal (2010) AMG, and Pesaran (2006) CCEMG estimators. This paper contributes to the existing energy-growth nexus literature in three aspects. First, we pay special attention to the GEG concept and analyze the relationship between REN and GEG. Second, we investigate this link for emerging countries due to their higher energy demand and rapid population growth rates. Third, we methodologically employ panel data techniques, which consider the cross-sectional dependence and heterogeneity in slope parameters, to obtain more reliable estimates.

The obtained results reveal that renewable energy consumption has a statistically significant and negative effect on green economic growth in emerging countries. Considering the size of the coefficients, a %1 percentage change in renewable energy would decrease green growth by more than 0.10%. It means that the use of renewable energy is far from stimulating sustainable economic growth in these countries. However, we approach this outcome cautiously. It is because this finding does not necessarily imply that renewable energy is not one of the most important driving forces of economic growth. It rather implies that the share of renewable is not high enough to boost the economic growth rates of emerging economies without degrading the environment. Recent data also support this finding. The share of renewable in the energy mix is higher than the world average of 5% in only 7 out of 21 emerging countries covered in this study (British Petroleum, 2020). Besides, we find that urbanization exerts a larger impact on green growth than renewable energy consumption, and its effect on growth is positive. On the other hand, the estimated parameters of trade and technological development are statistically significant and negative for almost all cases, indicating that these variables are negatively associated with green growth.

The findings of this study have some important policy implications. As the more likely reason for a negative linkage between renewable energy and green economic growth is due to the low share of renewable energy consumption in the total energy mix, policymakers in emerging countries should focus on reducing the dependence rates on nonrenewable energy by increasing the share of renewable energy to produce more output. For that purpose, the governments of emerging economies should devise energy policies for the transition to renewable energy without harming their economic growth path and invest more in the renewable energy sector. From this point o view, removing the impediments to renewable energy, incentives for renewable energy technologies, increasing public expenditures on research and development in renewable energy are expected to establish a green growth path and reduce environmental pollution.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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