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Salehin, Meshkatus; Kiss, Judit T.

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Kontakt/Contact

ZBW – Leibniz-Informationszentrum Wirtschaft/Leibniz Information Centre for Economics
Düsternbrooker Weg 120
24105 Kiel (Germany)
E-Mail: [rights\[at\]zbw.eu](mailto:rights[at]zbw.eu)
<https://www.zbw.eu/econis-archiv/>

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Testing the Causal Relationship between Economic Growth and Renewable Energy Consumption: Evidence from a Panel of EAGLE Countries

Meshkatus Salehin, Judit T. Kiss*

Department of Engineering Management and Enterprise, Faculty of Engineering, University of Debrecen, Hungary.

*E-mail: tkiss@eng.unideb.hu

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ABSTRACT

Economic growth and energy consumption are two main factors that play a vital role in any country's overall development. The researchers built and described different econometric models to evaluate the relationship between the two variables. In this research, we chose 15 emerging economy countries to examine the relationship between renewable energy consumption and economic growth. We applied the panel ARDL approach with PMG estimator which one of the best approaches to model long-term and short-term dynamics. Gross domestic product per capita and renewable energy consumption as a percent of total final energy consumption has a positive and significant coefficient when used as an independent variable in the long run. We also checked causality between the variables to test how the causal relationship occurs. We also found a causal relation from economic growth to renewable energy consumption, thus proving the conservation hypothesis. However, our outcome showed that the relationship is not statistically significant between renewable energy and economic growth in the short run. Finally, we pointed out few policy recommendations and future work directions based on our works at the end of this article.

Keywords: Renewable Energy, Economic Growth, Emerging Economy, Sustainable Energy Policy, Panel ARDL, Granger Causality

JEL Classifications: C23, Q20, Q42, Q43

1. INTRODUCTION

The source of energy is multidimensional, mainly depends on the geological location of that specific country, though, in the case of most countries, the primary source of energy is hydrocarbon-based fossil fuels. It is well known that using these fossil fuel energy sources like oil and natural gas has some externalities. First, this energy is non-renewable, as this fuel is extracted from the earth, so it is evident that the amount of this resource is decreasing day by day. Besides, the burning of fossil fuels causes the emission of Carbon Dioxide (CO₂), which is a vital part of emitted Greenhouse Gas (GHG). GHG is very harmful to nature which causes global warming, and may cause great havoc for the countries near the oceans. Therefore, the impact of renewable energy comes into

consideration, especially in this scenario. Despite still having low efficiency and energy conversion rate, it can take fossil fuel-based energy sources through proper research and development initiatives. In addition, renewable energy sources can meet all future energy demands, and renewable energy's CO₂ emission is nearly zero or very low compared to traditional energy sources. Economic development depends on energy availability, so researchers are of great interest to find the relationship between economic growth and energy consumption. Whether or not the implementation of renewable energy-friendly policy becomes crucial for a country's overall development depends on many conditions, including the country's political and geographical situation, people's mentality towards innovation and climate preservation, ease of access to raw materials, among others.

We selected a set of countries named EAGLE (Emerging and Growth Leading Economies - Bangladesh, Brazil, China, Egypt, India, Indonesia, Iran, Malaysia, Mexico, Nigeria, Pakistan, Philippines, Russia, Turkey, and Vietnam) that may play a vital role in the future world economy. These countries are chosen to examine as new heavy manufacturing industries are likely to be introduced in most of the mentioned countries in upcoming years. So, proper and sustainable energy policy of these countries will be resulted in a more significant reduction of greenhouse gas and hence, will ensure to minimise global warming. In this research, we included CO₂ emission and energy consumption as independent variables during modelling.

2. LITERATURE REVIEW

The search for inter-relation between economic growth and renewable energy with other relative economic and/or financial factors has a great interest for researchers over the last couple of decades (Sadorsky, 2009, Bowden and Payne, 2010; Apergis and Payne, 2010a; Apergis and Payne, 2010b; Apergis and Payne, 2010c, Hassine and Harrathi, 2017; Mahjabeen et al., 2020; Salam et al., 2020). Different studies exhibit different kinds of results that based as various kinds of econometric approaches such as bivariate approach, multivariate approach, time series regression, panel cointegration, ECM are used in these studies (Apergis and Payne, 2011; Omri, 2014; Magazzino, 2017; Darvishi and Varedi, 2018; Bulut and Muratoglu, 2018). One of the researches (Apergis and Payne, 2010a) implied that the geological location impacted the relationship between economic growth and renewable energy when conducted research within Eurasian countries. It was shown that the long-run relationship between these two variables acted differently while he included Russia and excluded it from the model. Several other variables involved in the models, like human behaviour and market accessibility, may also result in different outcomes.

However, all the studies found in the literature can be divided into four distinct types related to the relationships of energy and economic growth such as neutrality, bidirectional, growth and conservation hypothesis. Similarly, the mentioned four hypothesis could be revealed for the relationship between renewable energy and economic growth, as mentioned in Table 1.

The neutrality hypothesis is proved when there is no causal relation between renewable energy consumption and economic growth. It means there is no effect of renewable energy-friendly policy on economic growth. The growth hypothesis indicates there is a direct relation from renewable energy consumption to economic growth, and renewable energy policy may result in economic growth. The presence of a causal relationship from economic growth to renewable energy consumption proves the conservation hypothesis. In this case, a renewable energy-friendly policy may have a meagre impact on economic development depending on the other conditions. Finally, the feedback hypothesis represents a bi-directional causal relationship between renewable energy consumption and economic growth, so these two affect each other in the study area.

Our literature collection shows a satisfactory outcome where 41.2% of the studies detected the presence of growth hypothesis and the other 32.4% study proved the presence of feedback hypothesis, which is a direct indication that it is indeed essential for the economy of a country to take renewable energy-friendly policy (Figure 1).

3. DATA AND METHODOLOGY

Annual data of GDP per capita (constant 2010 US\$) and renewable energy consumption (% of total final energy consumption) for 15 countries from 2000 to 2014 are collected from the World Bank databank. In addition, we also collected the data of CO₂ emissions (kg per 2010 US\$ of GDP), energy use (kg of oil equivalent per capita) for the same period from the same source, which will be used as independent variables.

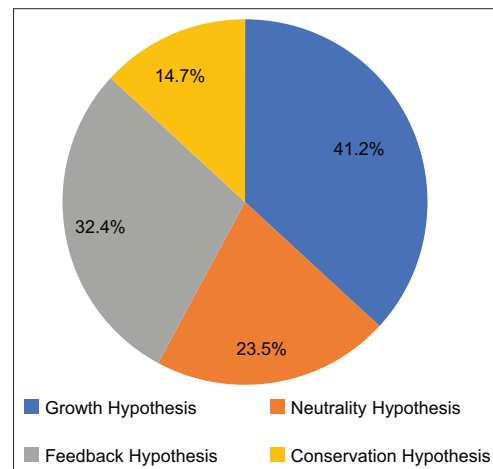
All these four variables are converted to per capita form to ensure data homogeneity. For example, if we compare the percent change of renewable energy consumption and the percent change of renewable energy consumption per capita over the period, we can see a huge difference in the outcome which is represented in Table 2. All the variables are then converted to the natural logarithmic form.

We have used the Panel ARDL method (Pesaran, 1997), (Pesaran et al., 1999), which is useful for determining short-run and long-run coefficients. We specifically chose this model as we assumed our data is dynamic and non-stationary in the level. The PMG estimation technique, which is the base of Panel ARDL, is used based on the concept of averaging the coefficients over the cross-section with the help of the following equation:

$$y_{i,t} = \sum_{j=1}^p \lambda_j^i y_{i,t-j} + \sum_{j=0}^q \delta_j^i \cdot X_{i,t-j} + \varepsilon_{i,t} \quad (1)$$

where the number of individuals $i = 1, 2, 3, \dots, N$ and time intervals, $t = 1, 2, 3, \dots, T$. X is a controlled vector of $K \times 1$ parameter, λ is

Figure 1: The four types of Hypothesis



Source: Authors' own illustration

Table 1: Renewable energy – economic growth nexus in the literature

Author	Country	Method	Time period	Proven hypothesis
(Sadorsky, 2009)	Emerging Economy Countries	Panel Cointegration Test	1994-2003	Conservation
(Apergis and Payne, 2010a)	Eurasian Countries	Panel Error Correction Model	1992-2007	Feedback
(Apergis and Payne, 2010b)	OECD Countries	Panel Cointegration and Panel Error Correction Model	1985-2005	Feedback
(Bowden and Payne, 2010)	USA	Toda Yamamoto Long Run Causality Test	1949-2006	Growth
(Apergis and Payne, 2011)	Central American Countries	Panel Cointegration and Panel Error Correction Model	1980-2006	Feedback
(Menegaki, 2011)	European Countries	Multivariate Panel Test	1997-2007	Neutrality
(Tiwari and Tiwari, 2011)	India	Structural VAR approach	1960-2009	Growth
(Yildirim et al., 2012)	USA	Toda–Yamamoto procedure and bootstrap-corrected causality test	1949-2010	Mostly neutrality, also growth
(Ocal and Aslan, 2013)	Turkey	Asymmetric Causality Test and ARDL Model	1990-2010	Growth and Conservation
(Lin and Moubarak, 2014)	China	ARDL and Granger Causality Test	1977-2011	Feedback
(Ohler and Fetters, 2014)	OECD Countries	Panel Error Correction Model	1990-2008	Feedback
(Chang et al., 2015)	G-7 Countries	Panel Heterogenous Causality Test	1990-2011	Feedback
(Alper and Oguz, 2016)	New EU countries	Asymmetric Causality Test and ARDL Test	1990-2009	Growth, Conservation and Neutrality
(Destek, 2016)	Newly Industrialised countries	Asymmetric Causality Test	1971-2011	Neutrality and Growth
(Alabi et al., 2017)	African OPEC Countries	Heterogenous Cointegrated Panel	1971-2011	Feedback
(Cherni and Essaber Jouini, 2017)	Tunisia	ARDL and Granger Causality Test	1990-2015	Feedback
(Destek and Aslan, 2017)	Emerging Economy countries	Bootstrap Panel Causality Test	1980-2012	Mostly Neutrality, also Growth, Conservation and Feedback
(Fotourehchi, 2017)	Developing Countries	Canning and Pedroni Long Run Causality Test	1990-2012	Growth
(Kahia et al., 2017)	Mena Net Oil Producing Countries	Panel Error Correction Model and Granger Causality Test	1980-2012	Feedback
(Koçak and Şarkgüneşi, 2017)	Black Sea and Balcan Countries	Panel Cointegration and Heterogenous Panel Causality Estimation Test	1990-2012	Feedback
(Magazzino, 2017)	Italy	Toda Yamamoto Long Run Causality Test	1970-2007	Growth
(Narayan and Doytch, 2017)	89 countries	GMM Model	1971-2011	Mostly neutrality, also growth
(Bulut and Muratoglu, 2018)	Turkey	Panel Cointegration Test	1990-2015	Neutrality
(Bayar and Gavriletea, 2019)	Emerging Economy Countries	Panel Cointegration Test and Granger Causality Test	1992-2014	Growth
(Maji et al., 2019)	West African Countries	Panel DOLS	1995-2014	Growth
(Ozcan and Ozturk, 2019)	Emerging Economy Countries	Bootstrap Panel Causality Test	1990-2016	Mostly neutrality, also Conservation.
(Asiedu et al., 2020)	European Countries	Panel Cointegration and Granger Causality Test	1990-2018	Feedback
(Bouyghrissi et al., 2020)	Morocco	ARDL and Granger Causality Test	1990-2014	Growth
(Chen et al., 2020)	103 Countries	Threshold Model	1995-2015	Growth
(Kasperowicz et al., 2020)	European Countries	FMOLS and DOLS	1995-2016	Growth
(Mahjabeen et al., 2020)	D-8 Countries	Panel ARDL, Panel FMOLS, Panel DOLS	1990-2016	Growth
(Rahman and Velayutham, 2020)	South Asian Countries	Panel FMOLS and Panel DOLS	1990-2014	Conservation
(Sulub et al., 2020)	Malaysia	ARDL and VECM	1978-2017	Conservation
(Radmehr et al., 2021)	EU Countries	Panel Spatial Simultaneous Model with GS2SLS	1995-2014	Growth

Source: Authors' own collection

a scaler parameter, and δ is a disturbance which relies upon time interval. Assuming the variables are cointegrated in $I(1)$, the δ will be constant for i in the $I(0)$ process.

We developed two ARDL models, assuming economic growth as a dependent variable and later renewable energy consumption as a dependent variable. The equations are given below:

$$\begin{aligned}
 \Delta LGDP_{i,t} &= \alpha_{1,i} + \lambda_{1,i} LGDP_{i,t-1} + \lambda_{2,i} LREC_{i,t-1} \\
 &+ \lambda_{3,i} LENC_{i,t-1} + \lambda_{4,i} LCO2_{i,t-1} + \sum_{j=1}^p \delta_{1,i} \Delta LGDP_{i,t-j} \\
 &+ \sum_{i=0}^q \delta_{2,i} \Delta LREC_{i,t-j} + \sum_{i=0}^q \delta_{3,i} \Delta LENC_{i,t-j} \\
 &+ \sum_{i=0}^q \delta_{4,i} \Delta LCO2_{i,t-j} + \varepsilon_{i,t}
 \end{aligned} \tag{2}$$

$$\begin{aligned} \Delta LREC_{i,t} &= \alpha_{1,i} + \lambda_{1,i}LREC_{i,t-1} + \lambda_{2,i}LGDPc_{i,t-1} + \\ &\lambda_{3,i}LENc_{i,t-1} + \lambda_{4,i}LCO_2c_{i,t-1} + \sum_{j=1}^p \delta_{1,i} \Delta LREC_{i,t-j} \\ &+ \sum_{i=0}^q \delta_{2,i} \Delta LGDPc_{i,t-j} + \sum_{i=0}^q \delta_{3,i} \Delta LENc_{i,t-j} \\ &+ \sum_{i=0}^q \delta_{4,i} \Delta LCO_2c_{i,t-j} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

where α is the intercept term λ , and δ is subsequent long-term and short-term coefficient with ε being the error term, LGDPc is the log-transformed GDP (constant 2010 US\$) per capita, LREc is the log-transformed renewable energy consumption (% of total final energy consumption) per capita, LENc is the log-transformed energy use (kg of oil equivalent) per capita, and LCO₂c is the log-transformed CO₂ emissions (kg per 2010 US\$ of GDP) per capita. Finally, we detected the causal relation using the Granger Causality test (Granger, 1981) and established an appropriate hypothesis for our data.

3. RESULTS AND DISCUSSIONS

Correlation analysis was performed to investigate the strength of the relationship between variables and the direction (negative or positive) in which it occurs (Table 3). Carrying out the correlation test is also very important for detecting any kind of multicollinearity within the variables of our model.

The absolute values of all correlation values keep an acceptable distance from unity to confirm no multicollinearity within the variables. If we further notice the data, we can see that the strongest positive relationship is present between LGDPc and LENc, as expected, and the lowest but a little surprisingly positive relationship is found between LREc and LCO₂c.

We carried out unit root tests for individual series. The main purpose of carrying out the unit root test is to examine the presence of the unit root that can prove that the series is non-stationary. The test starts with checking for unit root tests at the level. If the unit root is found in the level, we will take the 1st difference of the data and check again. For our data analysis and model specification, we need all our data to be stationary at I(0) (level) or I(1) (1st difference) or a mixture of both.

There are wide ranges of testing methods for unit root test of the individual series, including the Dickey-Fuller (DF) test, Augmented Dickey-Fuller (ADF) test, Im – Pesaran test. We chose the ADF test for the unit root testing as it provides the best result for dynamic Panel data.

All of the variables are found non – stationary in level, but they become stationary in the 1st difference. This means we could successfully reject the null hypothesis of unit root when the variables are in 1st difference (Table 4).

As we can see from Table 4, the null hypothesis, which states the presence of unit root, is rejected as the probability value is less than 0.05 in every case.

We run the lag order selection criterion three times to find out the optimum lag length for our model and each time with different maximum lag levels to find the most consistent criterion and hence accept the result suggested by the criterion. Table 5 includes the summary of our lag selection result. We chose 1 based on SC result.

The next step is carried out to determine whether the fixed effects or random effects estimator is best suited for our data. As we will use

Table 2: Original and per capita change rate of Renewable Energy share

Countries	Original value	Per capita value
Bangladesh	-36%	-47%
India	-29%	-16%
Pakistan	-9%	-62%
China	-59%	-32%
Indonesia	-18%	66%
Mexico	-20%	-34%
Nigeria	1%	-30%
Philippines	-18%	-36%
Iran	114%	-42%
Russia	-2%	0%
Turkey	-33%	-45%
Egypt	-28%	-45%
Brazil	-2%	-33%
Malaysia	-29%	-45%
Vietnam	-36%	-44%

Source: Author’s own calculation

Table 3: Correlation analysis report

	LGDPc	LCO ₂ c	LREc	LENc
LGDPc	1	0.1473	-0.3494	0.8701
LCO ₂ c	0.1473	1	0.0599	0.2924
LREc	-0.3494	0.0599	1	-0.5847
LENc	0.8701	0.2924	-0.5847	1

Source: Authors’ own calculation

Table 4: ADF Test result Summary

Series	Method			
	ADF - Fisher		ADF - Choi Z-stat	
	Chi-square			
	Statistic	Prob.**	Statistic	Prob.**
D(LCO ₂ c)	65.0549546	0.0002158	-4.074907	2.30E-05
D(LENc)	55.950796	0.0027661	-3.29396	0.0004939
D(LGDPc)	64.2161515	0.0002761	-4.050516	2.56E-05
D(LREc)	56.5662877	0.0023492	-3.348187	0.0004067

Null hypothesis: Unit root

**Probabilities for Fisher tests are computed an asymptotic Chi - square distribution. All other tests assume asymptotic normality.

Source: Authors’ own calculation by using EViews 10

Table 5: Lag length selection test result Summary

Max Lag Included	VAR Lag Order Selection Criteria				
	Lag Order Selected By -				
	LR	FPE	AIC	SC	HQ
3	3	2	2	1	2
8	8	8	8	1	1
5	5	2	2	1	1

Source: Authors’ own calculation by using EViews 10, LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

the PMG estimator to proceed with our Panel ARDL modelling, we need to confirm the effects. The presence of fixed effects is the best condition to apply the PMG estimator. The Hausman test helps to determine which effects are more dominant in the variables under study. The Null Hypothesis for the Hausman test is Random effects are more dominant (Tables 6 and 7).

Table 6 represents the summary result of the Hausman test, where LGDPc is our dependent variable. As we can see from the test result, the Hausman test probability value is nearly 0, which satisfies our condition to reject the null hypothesis. It proves the presence of a fixed-effects estimator when LGDPc is our dependent variable.

The same situation happened in Table 7, where LREc is the dependent variable. The null condition is also rejected, and the

Table 6: Hausman test result Summary 1

Correlated Random Effects - Hausman Test				
Dependent Variable: LGDPc				
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.	
Cross-section random	25.27511	3	1.35E-05	
Cross-section random effects test comparisons				
Variable	Fixed	Random	Var (Diff.)	Prob.
LENc	0.890647	0.91961	5.58E-05	0.000105
LCO ₂ c	-0.53073	-0.50993	5.27E-05	0.00416
LREc	-0.12846	-0.11021	4.21E-05	0.004886

Source: Authors' own calculation by using EViews 10

Table 7: Hausman test result Summary 2

Correlated Random Effects - Hausman Test				
Dependent Variable: LREc				
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.	
Cross-section random	11.00544	3	0.011696	
Cross-section random effects test comparisons				
Variable	Fixed	Random	Var (Diff.)	Prob.
LENc	-0.14388	-0.31085	0.002968	0.002178
LGDPc	-0.72832	-0.56013	0.003421	0.004031
LCO ₂ c	-0.08657	0.022823	0.002174	0.018971

Source: Authors' own calculation by using EViews 10

Table 8: Panel ARDL estimation output taking LGDPc as a dependent variable

Variable	Coefficient	Std. Error	t-statistic	Prob.*
Long Run Equation				
LREc	0.249162	0.080531	3.093974	0.002365
LCO ₂ c	-0.09465	0.075829	-1.24817	0.213954
LENc	1.11626	0.085149	13.10948	1.71E-26
Short Run Equation				
COINTEQ01	-0.07309	0.04247	-1.72103	0.087349
D (LREc)	0.018933	0.059591	0.317711	0.751155
D (LCO ₂ c)	-0.3428	0.098938	-3.46482	0.000696
D (LENc)	0.372333	0.116374	3.199467	0.001687
C	0.226866	0.126729	1.790174	0.075484
Mean dependent var	0.035639	S.D. dependent var		0.031662
S.E. of regression	0.012757	Akaike info criterion		-5.49482
Sum squared resid	0.023924	Schwarz criterion		-4.31058
Log likelihood	696.1678	Hannan-Quinn criter.		-5.01686

*P-values and any subsequent tests do not account for model selection. Source: Authors' own calculation by using EViews 10

alternative hypothesis is accepted as the P-value for Cross-section random effects is lower than 0.05. The Hausman tests confirmed the presence of fixed effects in the estimator. Finally, we will fit our data in the Panel ARDL modelling approach and evaluate how the variables affect each other in both the short and long run.

In Table 8, we used the PMG estimator to fit our data in the ARDL model. We have got both short and long-run values of our equation by taking a fixed lag value of 1 and considering LGDPc as our dependent variable. As we can see from the Table, the coefficients for both energy use per capita (LENc) and renewable energy percent in total energy consumption per capita (LREc) are statistically significant. Still, the CO₂ emission per capita coefficient (LCO₂c) is not statistically significant in the long run. Another important thing is the coefficient of LREc is positive, which proves in the long run, an increase in renewable energy share in a country's energy use results in an increase in the country's GDP. But LREc coefficient value in the short-run model is not as statistically significant as we found it in the long run. However, both LENc and LCO₂c have a significant impact on LGDPc, and in the case of LCO₂c it is negative. To get more insights, we checked the short-run estimation output for individual cross-sections.

It is worth mentioning that most of the countries exhibit a significant short-run relationship between LGDPc and LREc. The long-run estimation output where LREc is a dependent variable showed a more consistent outcome since all the independent variables estimations are statistically significant (Table 9). As we see in the earlier case, we can also notice a positive relationship between LGDPc and LREc.

However, in the short – run, none of the variables exhibits a significant relation with LREc. So, we assumed collectively there are no relations among these variables. To check more into the issue, we checked the short-run model for each country.

We checked the stability of the coefficient by carrying out the Wald test. Our main concern is to check the significance of the coefficient of the LREc when the dependent variable is LGDPc, and the significance of the coefficient of the LGDPc when the dependent variable is LREc.

The Wald test is a way to check if there is any possibility for the unrestricted estimates to somehow satisfy the restricted estimation under the null hypothesis. That means if we cannot reject the null hypothesis for any given condition, the unrestricted condition should be satisfying the imposed restriction.

In this study, we checked if there is any possibility of the coefficient of LREc in our 1st model and the coefficient of LGDPc in the 2nd model becoming 0. We carry out the Wald test two times for two models (Table 10).

As we can see from Table 10, all the probability values reject our null hypothesis in both cases. So, we can say that the coefficients are stable and always be significant with the model.

Finally, we will proceed with causality testing. There are two types of causality tests for the panel data based on whether the

coefficients maintain homogeneity across the cross-section or not. In our case, we will use the Granger causality test as we are using the PMG estimator, which assumes that coefficients are the same for each country in the long run. So, we assumed that for the short–run, it would be the same as well. Table 11 includes details of the Granger causality test of our panel data.

It is evident from the test report that economic growth (LGDPc) and renewable energy consumption (LREc) has a unidirectional relationship. LGDPc Granger cause LREc, but LREc does not. The same result is found between LGDPc and LENc. Thus, we can only see a unidirectional relationship from LGDPc to LENc.

According to the results of (Table 11), we accept the null hypothesis for the Granger cause between LCO₂ and LGDPc; as well as LREc and LCO₂c, LCO₂ and LENc, we conclude that

Table 9: Panel ARDL estimation output taking LREc as a dependent variable

Variable	Coefficient	Std. Error	t-statistic	Prob.*
Long Run Equation				
LCO ₂ c	0.720609	0.176393	4.085239	7.21E-05
LENc	-1.52134	0.157564	-9.65543	2.19E-17
LGDPc	0.477731	0.173479	2.75382	0.006634
Short Run Equation				
COINTEQ01	-0.20242	0.059085	-3.42594	0.000795
D(LCO ₂ c)	-0.75475	0.385144	-1.95966	0.051927
D(LENc)	0.251694	0.353585	0.711836	0.477694
D(LGDPc)	-0.52601	0.342585	-1.53542	0.126831
C	0.798724	0.252359	3.16503	0.001885
Mean dependent var	-0.02956	S.D. dependent var		0.082962
S.E. of regression	0.071184	Akaike info criterion		-3.86493
Sum squared resid	0.744871	Schwarz criterion		-2.68068
Log likelihood	512.8047	Hannan-Quinn criter.		-3.38696

P-values and any subsequent tests do not account for model selection. Source: Authors' own calculation by using EViews 10

Table 10: Summary of Wald Test

Null Hypothesis	Wald Test					
	t-statistic		F-statistic		Chi-square	
	Value	Probability	Value	Probability	Value	Probability
C(3) = 0	2.75382	0.006634	7.583525	0.006634	7.583525	0.00589
C(1) = 0	3.093974	0.002365	9.572675	0.002365	9.572675	0.001975
C(3) is the coefficient of LREc while LGDPc is the dependent variable						
C(1) is the coefficient of LGDPc while LREc is the dependent variable						

Source: Authors' own calculation by using EViews 10

Table 11: Granger causality test

Null Hypothesis	Obs	F-statistic	Prob.
D(LENc) does not Granger Cause D(LGDPc)	195	1.336225069	0.249137
D(LGDPc) does not Granger Cause D(LENc)		5.938926841	0.015722
D(LCO ₂ c) does not Granger Cause D(LGDPc)	195	0.042979105	0.835984
D(LGDPc) does not Granger Cause D(LCO ₂ c)		0.027913617	0.867488
D(LREc) does not Granger Cause D(LGDPc)	195	0.513343336	0.474566
D(LGDPc) does not Granger Cause D(LREc)		5.425100644	0.020889
D(LCO ₂ c) does not Granger Cause D(LENc)	195	0.071068021	0.790074
D(LENc) does not Granger Cause D(LCO ₂ c)		0.124413443	0.724683
D(LREc) does not Granger Cause D(LENc)	195	0.36990264	0.543776
D(LENc) does not Granger Cause D(LREc)		0.058185145	0.809645
D(LREc) does not Granger Cause D(LCO ₂ c)	195	0.709856562	0.40054
D(LCO ₂ c) does not Granger Cause D(LREc)		0.734471754	0.392506

Source: Authors' own calculation by using EViews 10

there are not Granger Causality between the mentioned variables. Hence, the Granger Causality is non-directional between the series.

5. CONCLUSION

The main goal of this study was to find the relationship (if any) between two important economic factors: economic growth and renewable energy consumption. As we discussed, a lot of research was carried out where researchers tried to find the relation between these two variables. Our study takes a new set of countries that are not considered together as of today. Therefore, we urged to test the dynamic relationship between these two variables for these 15 countries as they are listed as emerging economic countries by the economic research institution BBVA.

The main benefit of using the panel ARDL approach is it allows the estimation of both long-run and short-run coefficients. With the help of the PMG estimator, we estimated the coefficients as mentioned in the last chapter. The empirical study shows that Gross Domestic Product per capita and renewable energy consumption as a percent of total final energy consumption has a positive and significant coefficient when used as an independent variable in the long run.

In the 1st case, we used the LGDPc as a dependent variable, and we saw that almost 0.25 units of LGDPc would increase an increase of 1 unit of LREc. This means when a country implements a renewable energy policy and increases the share of renewable energy in the total consumed energy, the country is expected to experience economic growth in the long run. However, in the short run, our outcome showed that the coefficient is not statistically significant. So, we conclude that an increase in renewable energy share does not contribute to the country's development in the short run. Understandably, most of these countries are in the initial phase of integrating renewable energy, and it does not immediately affect a country's economic development. For the other two variables, LCO₂c has no significant effect on LGDPc in the long run, but it affects negatively in the short run. That means, to ensure economic development, we must reduce the emission of CO₂.

However, LENc has a significant impact on LGDPc in both the short-run and long run. It proves that energy contributes directly to the country's economic development in a positive way.

If LREc is the dependent variable, an increase of 1 unit of LGDPc will increase 0.48 units of LREc in the long run, which is very significant both statistically and economically. Though the effect of LGDPc is positive in the long run, in the short run, it does not have any effect on the country's share of Renewable Energy. We assume it is happening because to increase the GDP in the short run, the countries rely on a readily available energy source, the conventional fossil-fuel-based energy source. So, the integration of renewable energy cannot create any impact in a short period.

Additionally, there is also a long-run relationship between LENc and LCO₂c, but no significant relationship was found in the short run.

More insightful results are found in our Granger causality test. The test report shows that the relationship between LREc and LGDPc is unidirectional, and it runs from LGDPc to LREc. This means, in the short-run economic growth can Granger cause Renewable Energy share, i.e. increase in economic growth can boost the implementation of Renewable Energy policy, but it does not happen the way around if there is no presence of other variables. The Granger causality test proves the presence of the Conservation Hypothesis. We assume that certain policy implementation is required to ensure the betterment of the overall energy scenario.

As this group of countries consists of diverging countries such as countries with an already strong economy like Russia, China with countries who have just started climbing on the development ladders like Bangladesh, Pakistan, it isn't easy to make some common policy recommendations to increase the share of renewable energy. However, it is important to ensure the increased amount of renewable energy usage, when companies from the developed countries make any investment in any of these countries' industries, they can make a clause to ensure all the energy the new industry will use will come from clean energy sources. Moreover, a long-term subsidy plan for green-tech companies can be introduced so that more companies in this field will be founded and work to make clean energy and/or technology more accessible and efficient. Finally, a network and/or alliance within these countries can ensure that they can share the technology and can help to develop each-others energy technology.

Due to the limitation of data, we could not check the performance of the countries based on their present economic stability. However, classifying these countries into two/three groups and carrying out the test again after a couple of years with a longer period of data will be interesting as we believe it should demonstrate more insights on this group of countries' performance after the economic boom.

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