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Article

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The Impact of Renewable Energy Consumption and Economic Growth on CO_2 Emissions: New Evidence using Panel ARDL Study of Selected Countries

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ABSTRACT

Most countries consume more non-renewable energy to generate economic activities. Hence, economic growth plays a vital role in contributing to higher CO_2 emissions. Therefore, this type of energy has reduced and replaced by renewable energy. Renewable energy is said not to be detrimental to the environment. Consequently, it is imperative to examine the effects of renewable energy consumption and economic growth on CO_2 emissions in selected countries by per capita income. Using a sample of high-income, upper-middle-income, and lower middle -income, and low-income countries for the period of 1990-2017, and the estimation method of the panel ARDL, the main results show that in the long run, overall renewable energy consumption can reduce CO_2 emissions. However, economic growth and population growth can result in higher CO_2 emissions in the long term. In the short run, the results show that higher overall economic growth can contribute to higher CO_2 emissions. Contrarily, higher population growth, and renewable energy consumption can help reduce CO_2 emissions in the short run.

Keywords: Panel ARDL, CO_2 Emissions, Economic Growth, Renewable Energy

JEL Classifications: Q3, Q4, Q5

1. INTRODUCTION

Energy consumption has increased to boost economic growth. Bildieci (2014), in his study, found that economic growth has intimately connected with energy consumption. This finding suggests that depletion in energy sources can serve a stumbling block for economic development. The importance of energy in generating economic activities is on par with the stress of labor and capital. Hence, the demand for all energy sources such as coal, gas, and oil in all economics sectors exhibits a steady rise every year. According to the International Energy Agency (2018), the transportation and industrial sectors in Malaysia consume the largest share of total energy. Silva (2018) stated that higher economic activities require more energy. In the absence of energy, economic development has disrupted, and high unemployment ensues.

Despite the importance of energy in economic growth, it can trigger harmful effects on the environment. Dogan and Seker (2016) gave credence to the fact that non-renewable energy, such as oil and coal can increase CO_2 emissions. Environmental degradation stems from CO_2 emission released in the aftermath of inexorable energy consumption. Harmful gas emissions are released as a result of combustion. The release of CO_2 emissions is inevitable in power generation. As a result, humans have to suffer several environmental problems such as haze, acid rain, and higher global temperature.

This will be complex when a country consumes non-renewable energy in every sector. This suggests that greater economic activities can culminate in environmental degradation. Hence, Saidi and Mbarek (2016) found that an increase in economic growth can lead to higher CO_2 emissions. The economic sectors, such as industries and transportation that are dependent on energy, can harm the environment. The transportation and industrial sectors contribute most to CO_2 emissions as these sectors consume the largest share of total energy in Malaysia. Therefore, non-renewable energy must be replaced by renewable energy to mitigate environmental effects. For example, biofuel is one of the alternative energy sources which are not detrimental to the environment. Chen (2018) supported that the use of renewable energy can reduce carbon emissions. Renewable energy is the largest contributor to the reduction of CO_2 emissions (Dong et al., 2018). A vast array of literature proposed that renewable energy as the best alternative energy to ensure that economic growth can be boosted and the environment can be preserved. This is because their findings showed that renewable energy consumption could reduce CO_2 emissions. For example, Bhattacharya et al. (2017) and Dong et al. (2018) stated that renewable energy should be used to promote economic growth and reduce CO_2 emissions.

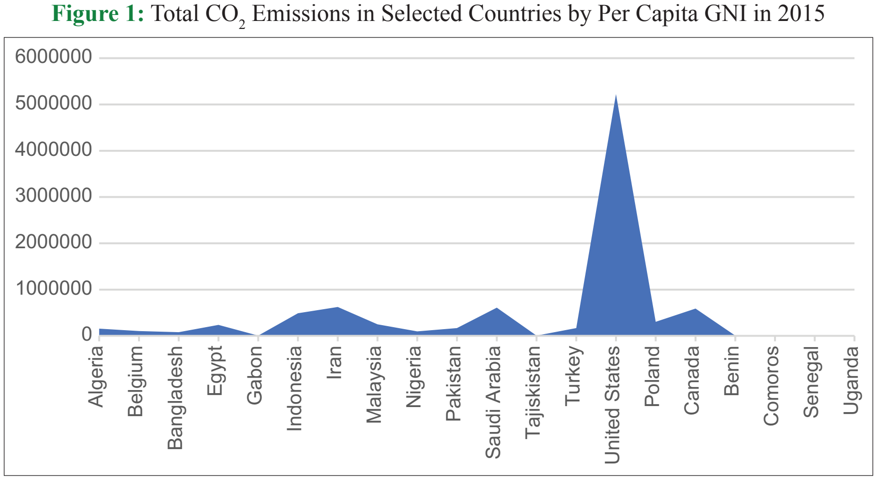
This paper contributes to policymakers and the existing literature in the following ways. First, this study employs the panel ARDL method to examine the impacts of renewable energy consumption and economic growth on CO_2 emissions in various countries. This method has not been used by previous studies on renewable energy consumption. Furthermore, none of the previous studies delved into the effects of renewable energy consumption and economic growth on CO_2 emissions in comparison among different income groups. Hence, this current study splits into four groups according to per capita GNI: high-income, upper-middle-income, lower-middle-income, and low-income groups. This study can determine whether economic growth in countries with high income contributes more CO_2 emissions and whether the use of renewable energy in those countries can reduce CO_2 emissions. We can also compare these findings with the findings in upper-middle-income, lower-middle-income, and low-income countries. The amount of CO_2 emissions in high-income countries is larger than that in low-income countries. Figure 1 shows the total CO_2 emitted by selected countries by per capita GNI in 2015. The United States was the largest emitter of CO_2 with a total of 5,225,394 kilotons, followed by Iran (623,255 kilotons), Saudi Arabia (608,804 kilotons), and Canada (589,780 kilotons). Comoros was the smallest producer of CO_2 with a total of 189 kilotons, followed by Uganda (4,693 kilotons), and Tajikistan (5,383). The marked difference between CO_2 in the high-income country (the United States) and low-income country (Comoros) stood at 5,225,205 kilotons. Based on the figure, it shows that high-income countries produced more CO_2 than low-income countries created. These findings suggest that as income increases, pollution goes up simultaneously and vice versa.

Given this backdrop, this article attempts to examine the impact of renewable energy consumption and economic growth on CO_2 emissions in selected countries by per capita GNI. The writing of this article has segregated into five sections. The second section reviews past studies, followed by methodology and model specification in the third section. The fourth section deals with study results; and finally, the conclusion in the fifth section.

2. LITERATURE REVIEW

Numerous studies investigated the effects of energy consumption and economic growth on CO_2 emissions without specifying whether non-renewable or renewable energy such as Alam et al. (2015), Aiyetan and Olomola (2017) as well as Stamatiou and Dritsakis (2019). However, their findings are mixed. For example, Islam and Ghani et al. (2017) tested their hypotheses by using panel co-integration and panel granger causality, and the results showed that there are positive relationships among energy consumption, economic growth, and CO_2 emissions. Aiyetan and Olomola (2017), on the other hand, found that economic growth plays an essential role in determining CO_2 emissions in the long run but not in the short run. Apart from that, energy consumption is a positive determinant of CO_2 emissions in the long run and short run in Nigeria. In Italy, the findings are slightly different, as Stamatiou and Dritsakis (2019) discovered that economic growth could increase CO_2 emissions. Other than that, a decrease in energy consumption does reduce not only CO_2 emissions but also economic growth.

Figure 1: Total CO_2 Emissions in Selected Countries by Per Capita GNI in 2015



Source: www.countryeconomy.com

Several previous studies are focusing on the effect of renewable energy and economic growth on CO_2 emissions in various countries (Jebli and Youssef 2017; Dogan and Seker 2016; Bhattacharya et al. 2017; Sinha and Shahbaz 2018; Dong et al. 2018; Cherni and Jouini, 2017; Paramati et al. 2017; Bekhet et al. 2018; Chen and Geng 2017; Dong et al. 2017; Waheed et al. 2018; Zaidi 2017; Chen et al. 2018; Ozcan and Ozturk, 2019). However, their results are also not consistent with each other.

According to Jebli and Youssef (2017), in the long run, an increase in renewable energy consumption and economic growth can result in higher CO_2 emissions. The study employed a panel data analysis, namely FMOLS, DOLS, and OLS, focusing on the North African country to examine the effects of renewable energy consumption and economic growth on CO_2 emissions from 1980 to 2011. The FMOLS approach has employed by Paramati et al. (2017), and another method, Pairwise Dumitrescu-Hurlin panel causality, was included in the study. The results were consistent in all countries (Argentina, Australia, Brazil, Canada, China, France, German, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the UK, and the US. A period ranging from 1991 to 2012 has analyzed in all of the countries. Zoundi (2016) examined the effects of renewable energy consumption and economic growth on CO_2 emissions in 25 selected Africa countries for the period 1980-2012. The findings revealed that economic growth does not affect CO_2 emissions. As for renewable energy consumption, it can reduce CO_2 emissions

Cherni and Jouini (2017), Chen et al. (2018), and Sinha and Shahbaz (2018) employed the ARDL approach to examine the effects of renewable energy consumption and economic growth on CO_2 emissions, but their findings were not consistent. Cherni and Jouini (2017) discovered that economic growth contributes to CO_2 emissions, but renewable energy consumption does not contribute to CO_2 emissions in Tunisia and Turkey, respectively. Contrarily, Sinha and Shahbaz (2018) found that renewable energy consumption can reduce CO_2 emissions in India from 1971 to 2015. The results also showed that economic growth increases CO_2 emissions in the early stages, and then it can reduce CO_2 emissions in the final stages. Thus, the findings supported the Environmental Kuznets Curve (EKC). Dong et al. (2018) also provided consistent results that the ECK exists, and renewable energy consumption plays a vital role in reducing CO_2 emissions. The study also employed the same method but was conducted in China to analyze data from 1965 to 2016. Chen et al. (2018) supported that renewable energy consumption can influence CO_2 emissions negatively from 1980 to 2014 in China.

However, Dogan and Seker (2016) argued that renewable energy consumption did not reduce CO_2 emissions in the European Union using the OLS approach. The findings gave credence to the results found by Paramati et al. (2017) that renewable energy consumption could reduce CO_2 emissions in Turkey. Besides, FDI and stock market growth play an essential role in reducing CO_2 emissions.

Most previous studies focused on renewable energy consumption on CO_2 emissions in a single country by using time series data analysis. Their findings are still mixed and still baffling why renewable energy consumption can lead or not lead to CO_2 emissions. A limited number of previous studies such as Zoundi (2016) investigated using a panel data analysis. However, the research just focused on developing countries in Africa. The study did not compare among high-income, upper-middle-income, lower-middle-income, and low-income countries. Therefore, this study provides a better understanding by comparing the effects of renewable energy consumption and economic growth in different countries by per capita GNI.

3. METHODOLOGY

This study employs the panel ARDL approach to investigate the effects of renewable energy consumption and economic growth on CO_2 emissions in selected countries by per capita GNI. The selected countries have divided into high-income countries (Canada, the United States, Poland, Belgium and Saudi Arabia), upper-middle-income countries (Algeria, Gabon, Iran, Malaysia and Turkey), lower-middle-income countries (Bangladesh, Egypt, Indonesia, Nigeria and Pakistan), and low-income countries (Benin, Comoros, Senegal, Tajikistan and Uganda). Data on CO_2 emissions, real GDP, population, and renewable energy consumption have used. All the data in this study have obtained from the World Bank and countryeconomy.com. There are several tests conducted in this study, namely panel unit root tests and panel estimation tests. The panel estimation tests consist of three estimators: Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed-Effect (DFE). The formation of the basic model is as follows:

$$lnCO2_{it} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnPOP_{it} + \beta_3 lnRE_{it} + v_{it} \quad (1)$$

Where CO_2 represents CO_2 emissions (kilotons), GDP represents a real gross domestic product (GDP) (LCU), POP is population, and RE is renewable energy consumption (% of total energy consumption). All of the variables have transformed into their logarithms.

3.1. Panel Unit Root Test

Panel data analysis needs to test for stationarity issues, and hence unit root tests are conducted. The tests are essential to examine the presence of stationarity for panel data, as suggested by Levin-Lin-Chu (2002) (LLC) and Im-Pesaran-Shin (2003) (IPS). All the data set are tested to determine the integration order of I (0) or I (1). The tests have conducted to check whether our variables are not stationary at level, but they must be stationary at first difference. Furthermore, Levin et al. (2002) found that the use of panel unit root tests is more efficient than time series unit root. There are two-panel unit root test methods used in this study, namely Levin et al. (2002), Breitung (2000), and Im et al. (1997). However, the IPS unit root test is more critical than the LLC unit root test due to its appropriateness for regression of heterogeneity unit root.

3.2. Panel Estimation

Pooled Mean Group (PMG) estimation or panel ARDL model has the advantage of determining dynamic long-run and short-run relationships. The PMG estimator can estimate relationships in the short run, including the coefficients and the adjustment for long-run equilibrium (speed of adjustment) and error variance to be heterogeneous. The long-run coefficients are restricted to be homogenous across countries. The use of this method is appropriate as it is more efficient and consistent with the existence of long-run relationships. The second method of estimation is Mean Group (MG). According to Pesaran and Smith (1995), it has less restrictive procedures that can estimate the diversity of parameters. It can also estimate different coefficients for each country. Both of the MG and PMG estimators require the selection of appropriate lag lengths using the Schwarz Bayesian Criterion (SBC) or Akaike Information Criterion (AIC). The MG estimator provides consistent long-run mean estimation, although it is inefficient with homogeneity. In the presence of long-run homogeneity, pooled estimators are consistent and efficient. The third estimator is the Dynamic Fixed Effect (DFE). This estimator is the same as the PMG estimator. It can limit the co-integration vector coefficient to have consistency for all long-run panels. Apart from that, it also limits the time adjustment coefficient and produces consistent short-run estimation. DFE limits the coefficients of integration vectors for all panels. All the estimators (PMG, MG and DFE) can show the long-run and short-run effects of each variable. According to Pesaran and Shin (1999), these approaches are more consistent in generating long-run coefficients regardless of whether the order of integration is I (0) or I (1). This method uses the combination of time series and cross-section data with T larger than N. According to Pesaran and Shin (1999, 2001), the most appropriate number of N is about 20-30 countries. Next, the Hausman tests have used to determine which one is better in this study: PMG, MG or DFE.

The MG model for testing a long-run relationship between variables is as follows:

$$lnCO2_{it} = \theta_i + \beta_{0i}lnCO2_{i,t-1} + \beta_{1i}lnGDP_{i,t-1} + \beta_{2i}lnPOP_{i,t-1} + \beta_{3i}RE_{i,t-1} + \varepsilon_{it} \quad (2)$$

Equation 2 shows that the MG estimator with a high order of lag that can estimate long-run average parameters consistently. The MG estimator introduced by Pesaran and Shin (1999) has standard features between the MG estimator and the DFE estimator. The MG estimator can estimate long-run and short-run coefficients for each country while the DFE estimator can only estimate overall short-run and long-run coefficients. Besides, the PMG estimator cannot estimate long-run coefficients for each country.

The long-run relationship model using the PMG and DFE estimators are as follows:

$$ln\,CO2_{it} = \alpha_i + \sum_{j=1}^{p}\lambda_{ij}\, ln\,CO2_{i,t-j} + \sum_{j=0}^{q}\delta_{1ij}\, ln\,GDP_{i,t-j} + \sum_{j=0}^{r}\delta_{2ij}\, ln\,POP_{i,t-j} + \sum_{j=0}^{s}\delta_{3ij}\, ln\,RE_{i,t-j} + \varepsilon_{it} \quad (3)$$

Where, i represents the number of countries (1, 2, 3...,20), t is the number of years (1990-2017), (p,q,r,s) is the optimum time lag, α_i is the countries specific effect, and ε_{it} refer to the remainder error terms. The short-run relationship with an error correction model is as follows:

$$\Delta\, ln\,CO2_{it} = \alpha_i + \varphi_i(ln\,CO2_{i,t-1} - \lambda_1\, ln\,GDP_{i,t-1} - \lambda_2\, ln\,POP_{i,t-1} - \lambda_3\, ln\,RE_{i,t-1}) + \sum_{j=1}^{p}\lambda_{ij}\Delta\, ln\,CO2_{i,t-j} + \sum_{j=0}^{q}\delta_{1ij}\,\Delta\, ln\,GDP_{i,t-j} + \sum_{j=0}^{r}\delta_{2ij}\,\Delta\, ln\,POP_{i,t-j} + \sum_{j=0}^{s}\delta_{3ij}\,\Delta\, ln\,RE_{i,t-j} + \varepsilon_{it} \quad (4)$$

Where λ_i are long-run parameters, and ϕ_i is the parameter for the error-correction term that measures the speed of adjustment to the long-term equilibrium of $lnCO_2$ due to changes in lnGDP, lnPOP, and lnRE. ϕ_i indicates the existence of a long-run relationship. Thus, a negative and significant value of ϕ_i shows the existence of a co-integrating relationship among lnCO2, lnGDP, lnPOP, and lnRE. All ECM dynamics and terms can freely change. Besides, the parameter estimation for this model is consistent and asymptotically normal to estimate long-run coefficients for both stationary and non-stationary regressors I (1). The MG and PMG estimators are appropriate for panel data analyses with large cross-section time series. However, if there is an existence of homogeneity, then the MG estimator is inefficient. Instead, the PMG estimator based on the maximum likelihood is efficient. To determine which estimator is appropriate: PMG, MG or DFE, the Hausman test must be performed.

3.3. Hausman Test

Hausman test has used to choose the preferred estimator between the PMG or MG estimator and either the PMG or DFE estimator. According to Pirotte (1999), the MG estimator allows parameters to be independent across groups and do not take into account the heterogeneity between groups. However, Pesaran and Shin (1999) argued that the PMG is better because it gives coefficients of different short-run variance by country. In contrast, for long-term coefficients, it is assumed that all countries are homogeneous (similar). In contrast, for the MG estimator, it allows only short- and long-term coefficients heterogeneous (different) length of time between countries. The choice between PMG or MG estimators depends on the null hypothesis testing. If the null hypothesis is accepted, then the PMG estimator is selected because it is more efficient than the MG estimator. If the null hypothesis has rejected, then the MG estimator is chosen over the PMG estimator. Next, to choose either the PMG or DFE estimators, if the null hypothesis is accepted, the PMG estimator is better than the DFE estimator.

4. EMPIRICAL RESULTS

This study employs the panel ARDL technique to examine the effects of renewable energy consumption and economic growth on CO_2 emissions in selected countries by per capita GNI. The countries have divided into four groups: high-income, upper-middle-income, lower-middle-income, and low-income groups. The LLC and IPS unit root tests have conducted, and the results are summarized in

Table 1. The LLC results show that all the variables (lnGDP, lnPOP & lnRE) except for $lnCO_2$ are not significant at level, suggesting that they are not stationary. Therefore, the null hypothesis is accepted. However, all the variables, including lnCO2 are significant at first difference. This findings mplies that they are all stationary, and thus the alternative hypothesis is accepted. In addition to the LLC tests, the IPS tests are also performed, and the results reveal that all the variables (lnGDP, lnPOP, lnCO2 and lnRE) are not significant at level but significant at first difference. This indicates that the variables are not stationary at level but stationary at first difference. Next, the panel ARDL technique is employed.

Table 2 shows the results of long-run estimation using PMG, MG and DFE estimators. The results of the Hausman test to choose either PMG or MG show that it is not significant, and thus PMG is better than MG. The results of the Hausman test for PMG and DFE show that PMG is still preferable as the p-value is higher than the significance level. The results of the three estimators (PMG, MG and DFE) show that renewable energy consumption can influence CO_2 emissions in the long run. The coefficient value is negative, and thus it suggests that higher renewable energy consumption can reduce CO_2 emissions. The results of PMG and DFE show that population growth can increase CO_2 emissions in the long run. However, these findings are not consistent with the results of the MG estimator. The results of PMG show that economic growth can cause CO_2 emissions to increase. The results of MG and DFE, on the other hand, show that economic growth does not contribute to CO_2 emissions.

Table 3 shows the results of short-run estimation using PMG, MG and DFE. The values of error correct term (ECT) are negative and significant for all of the three estimators, and thus they confirm the existence of long-run relationships. The results of PMG and DFE indicate that economic growth and renewable energy consumption can influence CO_2 emissions in the short run. Higher economic growth can increase CO_2 emissions but higher renewable energy consumption can reduce CO_2 emissions. These findings are not consistent with the findings obtained from the MG estimator. The results of the MG estimator reveal that all the variables do not have any effect on CO_2 emissions in the short run. Only the results of PMG show that population growth can lead to lower CO_2 emissions in the short run. The results of the Hausman tests suggest that PM is better than MG and DFE.

Table 4 shows the results of short-run estimation in specific countries. The results are divided into four categories: high-income, upper-middle-income, lower-middle-income, and low-income countries. In the high-income countries (Canada, the United States, Poland, Belgium and Saudi Arabia), renewable energy consumption does not affect CO_2 emissions in the short run. Population growth does not also contribute to CO_2 emissions in the high-income countries except for Saudi Arabia. In Canada and the United States, economic growth can increase CO_2 emissions in the short run. However, in Poland, Belgium, and Saudi Arabia, economic growth does not affect CO_2 emissions.

In the upper-middle-income countries (Algeria, Gabon, Iran, Malaysia and Turkey), renewable energy consumption does not

Table 1: Unit root results

	Levin, Lin, and Chu (LLC)		IM, Pesaran, and Shin (IPS)	
	Level	First Difference	Level	First difference
lnGDP	0.3412	−4.3899***	5.8681	7.0214***
lnPOP	13.6161	−12.4932***	16.6788	−8.4027***
lnCO2	−3.0310***	−5.7018***	0.5687	−8.5010***
lnRE	−1.2735	−9.6191***	0.8189	−11.0950***

*** and ** indicate the significance levels of 1% and 5%, respectively

Table 2: Long-run estimation results

Variable	PMG Coefficient	Prob.	MG Coefficient	Prob.	DFE Coefficient	Prob.
lnGDP	0.1223**	0.034	0.5859	0.109	0.2123	0.406
lnPOP	0.7456***	0.000	−0.6509	0.586	1.3104**	0.013
lnRE	−0.5504***	0.000	−0.8660***	0.000	−0.3015**	0.021
Hausman	1.27	0.736			0.04	0.998

***, ** and * indicate the significance levels of 1%, 5% and 10%, respectively.

Table 3: Short-run estimation results

Variable	PMG Coefficient	Prob.	MG Coefficient	Prob.	DFE Coefficient	Prob.
ECT	−0.1649***	0.000	−0.6768***	0.000	−0.0976***	0.000
lnGDP	0.3231**	0.019	−0.0189	0.909	0.4451***	0.000
lnPOP	−10.5526*	0.068	−1.3943	0.902	−1.1956	0.395
lnRE	−0.5592**	0.036	−0.1310	0.588	−0.0604**	0.048
C	−0.31476**	0.014	−3.0264	0.606	−1.6297***	0.005
Hausman	1.27	0.736			0.04	0.998

*** and **indicate the significance levels of 1% and 5%, respectively.

Table 4: Short-run estimation in specific countries

High-income countries				
	lnGDP	lnPOP	lnRE	C
Canada	0.9557***	-0.1598	-0.07866	-0.4849
United States	0.9620***	-1.2890	-0.0401	-0.2061
Poland	0.2457	0.3448	-0.0100	-0.0926
Belgium	0.3258	-4.7461	-0.0221	0.0183
Saudi Arabia	-0.0321	2.5394*	0.0090	-0.2991
Upper-middle income countries				
	lnGDP	lnPOP	lnRE	C
Algeria	1.0267**	5.1459	0.0048	-0.2574
Gabon	0.1941	-22.5346***	0.21992	-1.7079*
Iran	0.2237	1.4874	-0.0130	-0.1159
Malaysia	0.6610***	-0.2871	0.07981	-0.6843
Turkey	0.0321	-9.1142*	0.0212	-1.3475*
Lower-middle income countries				
	lnGDP	lnPOP	lnRE	C
Bangladesh	1.5664*	-0.1214	-1.5815***	-0.4478
Egypt	-0.1896	-5.0434	-0.3448***	-0.1780
Indonesia	0.0385	-24.155	-0.4600*	-1.0280
Nigeria	-0.6359**	-9.5785	-4.4107***	-0.14909
Pakistan	0.2261	0.8347	-1.4866***	-0.2132
Low-income countries				
	lnGDP	lnPOP	lnRE	C
Benin	-0.5399	-113.1698***	-2.3022***	1.0586
Comoros	-0.4761	-27.5954*	0.3947	-0.0983
Senegal	0.1992	-6.2636	-0.3008**	0.03325
Tajikistan	0.2268	1.1933	-1.6136***	0.0383
Uganda	1.4516	1.4595	0.7500	-0.1336

***, ** and *indicate the significance levels of 1%, 5% and 10%, respectively.

affect CO_2 emissions. Besides, the results show that economic growth can increase CO_2 emissions only in Algeria and Malaysia, but it cannot increase CO_2 emissions in other upper-middle-income countries. Population growth reduces CO_2 emissions in Gabon and Turkey, but it does not reduce in Algeria, Iran, and Malaysia.

In all of the lower-middle-income countries (Bangladesh, Egypt, Indonesia, Nigeria & Pakistan), renewable energy consumption can have a desirable effect on CO_2 emissions. As the countries consume more renewable energy, CO_2 emissions decline. Population growth does not cause any changes in CO_2 emissions in lower-middle-income countries. Economic growth affects CO_2 emissions in Bangladesh and Nigeria but does not affect Egypt, Indonesia, and Pakistan. The coefficient value in Bangladesh is positive; this suggests that higher economic growth can result in higher CO_2 emissions. Contrarily, higher economic growth can reduce CO_2 emissions in Nigeria as the coefficient value is negative.

In low-income countries (Benin, Comoros, Senegal, Tajikistan and Uganda), economic growth does not influence CO_2 emissions. Renewable energy consumption can cause CO_2 emissions to fall only in Benin, Senegal, and Tajikistan as the coefficient values are negative and significant in those countries. Population growth is found to reduce CO_2 emissions in Benin and Comoros only as negative and significant coefficient values are detected. In other countries (Senegal, Tajikistan and Uganda), economic growth does not affect CO_2 emissions.

5. SUMMARY AND CONCLUSIONS

This study aims to examine the effects of renewable energy consumption and economic growth on CO_2 emissions in selected countries (Canada, the United States, Poland, Belgium, Saudi Arabia, Algeria, Gabon, Iran, Malaysia, Turkey, Bangladesh, Egypt, Indonesia, Nigeria, Pakistan, Benin, Comoros, Senegal, Tajikistan & Uganda) by per capita GNI. The countries have divided into four categories: high-income, upper-middle-income, lower-middle-income, and low-income countries. The panel ARDL method was employed, and the results show that in the long run, overall renewable energy consumption can reduce CO_2 emissions. However, economic growth and population growth can result in higher CO_2 emissions in the long term. In the short run, the results show that higher economic growth can contribute to higher CO_2 emissions. Contrarily, higher population growth, and renewable energy consumption can help reduce CO_2 emissions in the short run.

In all of the high-income and upper-income countries, renewable energy consumption does not play any role in reducing CO_2 emissions. This is because renewable energy in those countries accounts for a tiny percentage of total energy consumption. This means that the countries are highly dependent on non-renewable energy instead of renewable energy. However, in all of the lower-middle-income countries and most of the low-income countries, renewable energy consumption can reduce CO_2 emissions. This is because those countries are highly dependent on renewable energy instead of non-renewable energy. For example, renewable energy contributed to 73% of total energy consumption in Bangladesh in 1991, and that was the highest percentage over the period 1990-2017 (World Bank, 2019).

Economic growth in the low-income countries does not affect environment degradation. In some high-income, upper-middle-income, and lower-middle-income countries, economic growth can contribute to environmental degradation. Population growth does not result in higher CO_2 emissions in most countries.

These findings are essential for policymakers to formulate the right policies. A shift from non-renewable energy such as oil and coal to renewable energy such as solar and biofuel is a good move to mitigate environmental degradation. Other than that, the governments can give fiscal incentives such as tax reductions to firms that use clean energy in their production. This incentive is essential to reduce CO_2 emissions.

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