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Linking Non-renewable and Renewable Electricity and Government Expenditures to Environmental Degradation: Evidence of 10 Newly Industrialized Countries

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ABSTRACT

This research aims to identify the relationship between non-renewable electricity (NRE), renewable electricity (RE) and government expenditures (EXPD) on environmental degradation using the ARDL model for 10 Newly Industrialized Countries (NIC) during the period 1990-2021. Our empirical findings show that the NRE increases the CO_2 emissions, however the RE decrease the CO_2 emissions in the long and short run. For the effect of governement expenditure on the environment, it may be classified as direct and indirect. In fact, EXPD affect positively the CO_2 emissions. In contrast, The indirect effect operates through the interaction between EXPD and NRE and RE. Our results demonstrate that the interaction between EXPD and NRE affects negatively the CO_2 emissions. Nevertheless, the impact of the interaction between EXPD and RE on the CO_2 emissions is more important. The results show also there is a bidirectional causality between each variable and CO_2 emissions. With the empirical findings as a basis, we suggest that the NI countries should reduce NRE consumption and enhance the environmental expenditures so that they may produce more RE to combat environmental issues.

Keywords: Non-renewable electricity, Renewable electricity, Government expenditures environmental degradation, ARDL

JEL Classifications: Q2, Q3

1. INTRODUCTION

In recent decades, a massive and unprecedented explosion in energy consumption has taken place. Abundance of energy is the engine of the world economy. Pollution generated by energy production and consumption, including the burning of biomass, is changing the ecology of the entire planet. Climate change is the largest and most serious of these impacts, caused mainly by the combustion of fossil fuels, as well as by significant emissions of greenhouse gases. So, in order to mitigate climate change, the challenge and the opportunity are to maximize the use of renewable energy (Ahmad and Majeed, 2019).

The increasing share of renewable energy (RE) in the global energy can be explained by several reasons and motivations: Concerns about greenhouse gas emissions from fossil fuels, scarcity of oil resources and reserves, gas and coal, energy security, etc.

So, increasing use of renewable energy from 1 year to another has many potential benefits such as: Renewable energies are an inexhaustible source of energy. Available at will, these sources are diverse and varied, ranging from solar to wind through geothermal energy. Thanks to these low-polluting energies, we can envisage a prolific energy production system that is more respectful of nature.

Many researchers have attempted to examine the relationship between energy comsumption and CO_2 emissions (Shafiei and Salim, 2014; Shahbaz et al., 2017; Bhat, 2018), however, few of studies examined the effect of electricity on CO_2 emissions. In light of this, we first contribute to the existing literature by testing the impact of electricity on CO_2 emissions, especially, we examine this impact for both renewable electricity and non-renewable electricity for 10 Newly Industrialized Countries (NIC). This study also contributes to this by examining the short and long run causality among non renewable energy, renewable energy and carbon emissions using the ARDL technique. To our knowledge, no previous study has explored the role of government expenditures in explaining the relationship between renewable electricity and non-renewable electricity and environmental degradation. So, the third contribution is to examine direct and indirect effect of government expenditures on CO_2 emissions.

The rest of our paper is structure as follows: The literature review is presented in Section 2. Section 3 presents the data and model. Results and discussion are presented in Section 4. Lastly, in Section 5, we focus the conclusion and policy recommendations.

2. LITERATURE REVIEW

This study examines on the first hand a brief review of the literature on the relation between non renewable and renewable energy and environmental degradation. On the second hand, we examine the effect of government expenditures on environmental degradation.

2.1. The Impact of Non Renewable and Renewable Energy on Environmental Degradation

The relationship between non renewable and renewable energy and environmental degradation has been investigated extensively in last decades, However, the empirical results have been mixed. Some researchers in the literature argue that renewable and non renewable energy is harmful for environmental quality while some have found that non renewable and renewable energy is good for the quality of environment and some others have stated no association between the two variables. For example, Farhani and Shahbaz (2014) showed that renewable and non renewable energy increase the carbon emissions over the period 1990-2009 for MENA countries. Similarly, Bhat (2018) analyzed the effect of energy consumption on carbon dioxide using the panel ARDL model. The results showed that non-renewable energy consumption increases the carbon emissions. Using the ARDL approach, Sulaiman and Abdul-Rahim (2017) investigated the relationship between carbon emissions, energy consumption and economic growth in Malaysia. Their results showed that economic growth is not impacted by energy consumption and CO_2 emission, while energy consumption and economic growth positively influence the carbon emissions.

Shafiei and Salim (2014) examined the association between non-renewable and renewable energy consumption and CO_2 emissions for OECD countries using Regression on Population, Affluence, and Technology model (STIRPAT model) during the period 1980-2011. Their findings indicated that renewable energy consumption decreases CO_2 emissions, however, non-renewable energy consumption increases CO_2 emissions. Furthermore, the results showed the existence of an Environmental Kuznets Curve between carbon emissions and urbanization.

Using Johansen cointegration test, Saboori et al. (2017) analyzed the relationship between oil consumption, economic growth and environmental degradations in three Asian countries. Their results indicated that uni-directional causality running from oil consumption to economic growth in China and Japan, while oil consumption to CO_2 emissions in South Korea. Using causality and cointegration approches, Chontanawat (2020) examined the nexus between energy consumption, CO_2 emissions, and economic production in ASEAN. The results revealed a long-term link and causality between these variables, this confirms that energy consumption and output are related to CO_2 emissions.

Charfeddine and Kahia (2019) studied the effects of renewable energy consumption and financial development on CO_2 emissions and economic growth for 24 MENA countries during the period 1980-2015. Their finding showed that renewable energy consumption and financial development slightly explain both measures of CO_2 emissions and economic growth. This findings showed that the financial and renewable energy sectors need improvements to increase the quality of the environment and to grow the economies of MENA countries.

Nathaniel and Khan (2020) analyzed the effects of renewable and non-renewable energy consumption on the environmental degradation in MENA countries. Their results showed that renewable energy has an insignificant correlation with the quality of environment. Bélaïd and Youssef (2017) concluded that non renewable energy increases carbon dioxide emissions, however, renewable energy mitigates carbon dioxide emissions.

However, Bhattacharya et al. (2017) found that renewable energy mitigates CO_2 emissions for a panel of 85 developed and developing countries. Anwar et al. (2021) indicated the positive effect of clean energy sources on the atmosphere using the FGLS technique for G7 nations. Also, other study such as Jin and Kim (2018) found the two-way causality between the energy sources and the environment, however a negative effects was found between these variables for 30 states and Sub-Saharan African countries, respectively. Furthermore, Nathaniel and Iheonu (2019) showed that the renewable energy sector enhances environmental sustainability for developed and emerging countries. Similarly, Zhang et al. (2017) concluded that renewable energy reduces the carbon dioxide emissions in Pakistan.

Recently, Ansari et al. (2021) showed that renewable energy consumption affects negatively the ecological footprint. Moreover, Caglar et al. (2021) concluded that renewable energy consumption reduces environmental degradation for top pollutant footprint countries. This meaning that renewable energy consumption is important for environmental sustainability.

Thus, we formulate the following two hypotheses:

- H1. The non renewable energy consumption increases the CO_2 emissions;
- H2. The renewable energy consumption decreases the CO_2 emissions.

2.2. The Effect of Government Expenditures on Environmental Degradation

Several studies have examined the effect of government expenditures on environmental degradation. For example, Halkos and Paizanos (2013) studied the direct and indirect effects of government expenditures on CO_2 emissions. The results showed that the direct effect of government expenditures on carbon emissions is not significant; however there is a negative relationship for the indirect effect.

Furthermore, Halkos and Paizanos (2016) found that expansionary fiscal spending would lead to a reduction in carbon emissions, while contractionary fiscal spending, resulting from increased consumption, would lead to an increase in CO_2 emissions. Adewuyi (2016) found a significant positive effect of government expenditures on CO_2 emissions in the long term, but a negative effect in the short term.

Using the dynamic panel approach, Oh (2023) examined the direct and indirect effects of government expenditure on CO_2 emissions. The results show that government expenditure has a positive effect on air quality. For the average direct and indirect effects of local government expenditure on CO_2 emissions, they showed that government expenditure directly reduces CO_2 emissions, while it indirectly increases CO_2 emissions through regional economic growth.

Despite a few studies examined the effect of renewable and non renewable energy and environmental degradation, the majority of studies do not take into account the role of government expenditure in the relationship between renewable and non renewable energy and environmental degradation in the long run.

Thus, our main hypothesis is:

H3. The government expenditure mitigates the effect of renewable and non renewable energy on environmental degradation.

3. DATA DESCRIPTION AND MODEL

We use panel of 10 Newly Indusrialized Countries over the period 1990-2021. Our study includes the following countries: Turkiye, Indonesia, India, Thailand, Philippines, Malaysia, China, Brazil, Mexico, and South Africa.

We control for a number of variables in order to reduce the omitted variable. We include GDP per capita that is measured in constant 2010 US$. We include trade as % of GDP in order to take into consideration the effect of trade liberalization on CO_2 emissions. Also, we include government expenditures, represented by General government final consumption expenditure (% of GDP). We use renewable electricity measured by Electricity production from renewable sources (% of total). Finally, we also include non renewable electricity measured by Electricity production from oil, gas and coal sources (% of total).

Following related research (Azam et al., 2020; Awodumi and Adewuyi, 2020; Maji et al., 2019), we rely on conventional empirical model which specifies CO_2 emissions as a function of renawable electricity, non renewable electricity, government expenditures, GDP per capita, and trade openness:

The first estimated model is specified as follows:

$$CO_{2it} = \alpha_i + \beta_1 RE_{it} + \beta_2 NRE_{it} + \beta_3 EXPD_{it} + \beta_4 GDP_{it} + \beta_4 TRADE_{it} + \varepsilon_{it} \quad (1)$$

Then, we introduce in the model below the interaction between government expenditures and renewable electricity; and the interaction between government expenditures and non renewable electricity. So, the second estimated model is specified as follows:

$$CO_{2it} = \alpha_i + \beta_1 RE_{it} + \beta_2 NRE_{it} + \beta_3 EXPD_{it} + \beta_4 GDP_{it} + \beta_4 TRADE_{it} + \beta_5 (RE_{it} * EXPD_{it}) + \beta_6 (NRE_{it} * EXP_{it}) + \varepsilon it \quad (2)$$

Data for all variables is taken from World Bank Data (2022).

4. RESULTS AND DISCUSSION

4.1. Impact of NRE, RE and Government Expenditures on CO_2 Emissions

The first step of empirical analysis is to check the stationarity properties of our series. To do this, it is necessary to identify the number of lags employing the Akaike (AIC) and Scwartz (SC) criteria. According to Table 1, the optimal number of lags for our model is 3.

Therefore, in order to test the stationarity of our time series, we apply Levin, Lin and Chu and Im, Pesaran and Shin tests, which are presented in Table 2 The unit root test results indicate that the null hypothesis of the unit root is not rejected for the variables (CO_2, GDP, EXP, RE and Trade) at the level, so these variables are stationary at first difference. However, the tests confirm that the null hypothesis of the unit root is rejected for the variable NRE at the level. So this variable is stationnary at level.

Table 1: Determination of lag number

Lag	AIC	SC
0	27.92085	28.02728
1	3.955817	4.700840*
2	3.641275	5.024890
3	3.609682*	5.631888
4	3.817508	6.478305
5	3.872289	7.171678
6	4.001585	7.939565
7	3.984401	8.560973
8	4.034280	9.249443

Table 2: Unit root test results

Variable	Levin, Lin and Chu t*	Im, Pesaran and Shin W-stat
CO_2		
Level	0.5202	0.9836
First Difference	0.0000	0.0000
EXPD		
Level	0.2410	0.2519
First Difference	0.0000	0.0000
GDP		
Level	0.3574	0.2748
First Difference	0.0000	0.0000
NRE		
Level	0.0216	0.0788
First Difference	0.0000	0.0000
RE		
Level	1.0000	1.0000
First Difference	0.0145	0.0051
TRADE		
Level	0.2688	0.7612
First Difference	0.0000	0.0000

In this case, we will examine the possibility of cointegration test in order to examine the long-run relationship between these studied variables.

Therefore, we test the existing of cointegration relationship between all series using the Kao test of cointegration. Results reported in Table 3 suggests that there is at least one cointegrating relationship between RE, NRE, CO_2, DEP and GDP. As is presented in Table 3, the Kao test statistics reject the null hypothesis of no cointegration in favor of the alternative, for the two model. These results confirm the presence of the long-run cointegration relationships among the selected series across Newly Industrialized countries from 1990 to 2022.

Consequently, the ARDL method examines the short and long run relationships between the variables and obtain coefficients. Table 4 reports the coefficients of the long-term relationship, however, Table 5 represents the coefficients of the short-term relationship.

Results presented in Table 4 show that NRE variable in first Model has a positive and statistically significant effect on CO_2 emissions in long run at the 5% level of significance. This means that an increase in NRE increases the CO_2 emissions, So, the climate change has been deteriored by the NRE in long run in 10 Industrialized Countries. However, the RE has negative and statistically significant impact on CO_2 emissions. This means that RE ameliorates in long run the climate change in 10 Industrialized Countries. So, we can conclude that the 10 NIC are shifting from using less non renewable electricity to more renewable electricity.

It is noted that renewable electricity mitigates the carbon rejection model in the 10 NICs. So, the consumption of renewable electricity in these countries enriches the ecological eminence. Hence, these countries must take measures to increase the consumption of renewable electricity.The results of our study underline the importance of regulating electricity production through renewable electricity sources. Shifting the electricity mix from more polluting electricity sources to less polluting enlectricity sources would be very necessary in order to achieve the Sustainable Development Goals.

For the EXPD variable, its coefficient is positive and significant in the long run. This implies that EXPD increases CO_2 emissions in the long term. The positive relationship can be explained by the fact when government expenditures increases, the energy consumption, especially the pollued energy, increases, that deteriorates the climate change by increasing the CO_2 emissions.

For the GDP variable, the environmental degradation increases with the increase in GDP per capita. The findings of this study are similar with previous literature (Ahmed et al., 2017; Zafar et al.,

Table 3: Kao test results

Model	M (1)	M (2)
t-Statistic	−1.812527	−1.724043
Prob.	0.0350	0.0424

Table 4: Long run relationship results

Selected model	ARDL (3, 1, 1, 1, 1, 1)			
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
NRE	3.809303	1.786235	2.132587	0.0344**
RE	−0.143934	0.073748	−1.951687	0.0527***
EXPD	0.039790	0.020759	1.916754	0.0586***
GDP	2.876802	0.343648	8.371361	0.0000*
TRADE	−0.007870	0.006647	−1.184022	0.2381

Values in parenthesis correspond to P-value; *, ** and *** indicate the significance level at 1%, 5% and 10%, respectively

Table 5: Short run relationship results

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
ECT(-1)	−0.106753	0.040836	−2.614177	0.0098*
D (CO_2(-1))	0.022771	0.103505	0.219998	0.8261
D (CO_2(-2))	0.028218	0.102561	0.275138	0.7836
D (NRE)	0.654236	0.369849	1.768927	0.0788**
D (RE)	−1.974482	0.514291	−3.839232	0.0002*
D (EXPD)	3.765975	1.463656	2.572993	0.0110**
D (GDP)	0.042942	0.116083	0.369922	0.0119**
D (TRADE)	−0.002696	0.002314	−1.165196	0.2456
C	0.001090	0.025531	0.042687	0.9660
Akaike info criterion			−1.679674	
Schwarz criterion			−0.378656	
Hannan-Quinn criterion			−1.156648	

Values in parenthesis correspond to p-value; *, ** and *** indicate the significance level at 1%, 5% and 10%, respectively

Table 6: Long run relationship results in the presence of the interaction between RE and government expenditures

Selected model	ARDL (4, 1, 1, 1, 1, 1, 1, 1)			
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
NRE	8.589201	3.788944	2.266912	0.0250**
RE	0.50407702	0.211448	−2.383929	0.0687***
EXPDNRE	−0.026554	0.015871	−1.673101	0.0967***
EXPDRE	−18.71873	8.112653	−2.307351	0.0226**
EXPD	1.631476	0.694255	2.349967	0.0202**
GDP	−3.011062	1.394157	−2.159773	0.0326**
TRADE	0.140713	0.045394	3.099833	0.0024*

Values in parenthesis correspond to P-value; *, ** and *** indicate the significance level at 1%, 5% and 10%, respectively

Table 7: Short run relationship results in the presence of the interaction between RE and Government expenditures

Variable	Coefficient	Standard Error	t-Statistic	Prob.*
ECT(-1)	−0.239279	0.122671	−1.950570	0.0544
D (CO_2(-1))	−0.077004	0.142602	−0.539994	0.5901
D (CO_2(-2))	0.038600	0.112597	0.342820	0.7323
D (CO_2(-3))	0.091078	0.080129	1.136642	0.2577
D (NRE)	0.688548	1.092760	0.630100	0.5297
D (RE)	−2.403953	2.529084	−0.950523	0.3436
D (EXPDNRE)	−0.124019	0.130667	−0.949125	0.0443
D (EXPDRE)	−11.13113	7.543490	−1.475594	0.0424
D (EXPD)	−0.648950	0.489827	−1.324854	0.1875
D (GDP)	2.636786	0.785347	3.357478	0.0010
D (TRADE)	7.39E-05	0.002426	0.030474	0.9757
C	1.141696	1.477661	0.772638	0.4411
Akaike info criterion	−1.749929			
Schwarz criterion	−0.010673			
Hannan-Quinn criterion	−1.050725			

Values in parenthesis correspond to P-value; *, ** and *** indicate the significance level at 1%, 5% and 10%, respectively

Table 8: Pairwise dumitrescu hurlin panel causality test results

Null Hypothesis	W-Stat.	Zbar-Stat.	Prob.	Causality direction
EXPD does not homogeneously cause CO_2	2.31842	2.29305	0.0218	Bidirectionnal causality
CO_2 does not homogeneously cause EXPD	3.20851	4.11489	4.E-05	
GDP does not homogeneously cause CO_2	3.97013	5.58960	2.E-08	Bidirectionnal causality
CO_2 does not homogeneously cause GDP	2.47346	2.69166	0.0071	
NRE does not homogeneously cause CO_2	2.20015	2.07048	0.0384	Bidirectionnal causality
CO_2 does not homogeneously cause NRE	3.75035	4.98794	6.E-07	
TRADE does not homogeneously cause CO_2	4.99155	7.56734	4.E-14	Bidirectionnal causality
CO_2 does not homogeneously cause TRADE	3.27010	4.23415	2.E-05	
RE does not homogeneously cause CO_2	4.10175	5.64929	2.E-08	Bidirectionnal causality
CO_2 does not homogeneously cause RE	2.71850	3.04601	0.0023	

2019b). The positive relationship can be explained by the fact that when the economy is ameliorated, it moves from industries, especially the primary industries to detriment of secondary and tertiary industries. The industrie sector use more energy intensive and more pollution concentrated than agriculture and services sector.These results coincide with the previous literature (Ali et al., 2017; Tajudeen et al., 2018).

Results reporting in Table 5 is the results of the short run relationship between RE, NRE, trade and GDP on CO_2 emissions. We obtain the same effects of RE, NRE, GDP and EXPD on CO_2 emissions in the short-term perspective, except for the variable trade that has non significant effect on CO_2 emissions in short and long term in 10 Newly Industrialized Countries.

So, the empirical findings of our study suggest that Non Renewable Electricity, government spending, and GDP per capita deterirate the environmental quality by increasing the CO_2 emissions in the long and the short run. However, Renewable Electricity ameliorate the environmental quality by decreasing the CO_2 emissions. So, the study suggests that policy makers take steps to meet energy demands through renewable electricity sources.

4.2. Impact of the Interaction between REN and Government Expenditures and the Interaction between RE and Government Expenditures on CO_2 Emissions

In this stade, we examine the effect of the interaction between governmant expenditures and electricity (renewable and non renewable) on CO_2 emissions in 10 Newly Industrialized Countries over the periode 1991-2020. Our findings reported in Table 6 demonstrate that the coefficient of the variable EXPDNRE is positive and significant at 10% level, that means that, in the long term, when government expenditures are oriented vers non renewable electricity, the impact of the NRE in CO_2 decreases. In fact in the first model (results of Table 4), a 1% increase in NRE leads to a 3.809 increase in CO_2. However, when the government expenditures are oriented to the NRE, a 1% increase in EXPDNRE leads to a 0.026 decrease in CO_2.

Fuethermore, the climate change has been ameliorated by the increase of government expenditures in RE. In fact, our findings reported on Table 6 show that the coefficient of the variable EXPDRE is negative and significant. It means that when government expenditures are oriented to RE, the climate change is mitigated.Moreover, we can see that the impact of RE on climate change is more important in the second model (in the presence of the interaction between government expenditures and RE (−18.781) then in model 1 (−0.143934).

The same results can be showed in the short run (Table 7). Indeed, the coefficients of the variables EXPDNRE and EXPDRE are negative and significant. So, the increase in government expenditures in NRE and RE ameliorates the climate change. In addition, we show that impact of NRE and RE on CO_2 is less important in the model 2 than in model 1. It means that the interaction between NRE and EXPD and the interaction between RE and EXPD mitigate the impact of NRE and RE on CO_2 emissions in the short run.

The panel causality test reported in Table 8 revealed that there is a bidirectional causality between non renewable and renewable energy and carbon emissions. Also, there is a causality between government expenditure and carbon emissions.

5. CONCLUSION AND POLICY IMPLICATIONS

The main objective of this study is to examine the long term and the short term impact of non-renewable electricity, renewable electricity and government expenditures on environmental degradation using the ARDL model for 10 Newly Industrialized Countries (NIC) during the period 1991-2020. To achieve this goal, we adopted the ARDL model. To the best of our knowledge, none of empirical studies focused in three- way linkages between these variables in long and short run.

This empirical study examined the long-run effect of NRE, RE and government expenditures on CO_2 emissions. A particular attention was given to the causal relationship between the considered variables. Based on ARDL model, on first hand, our results show that NRE increases CO_2 emissions in the 10 Newly Industrialised Countries, however, the renewable energy decreases the CO_2 emissions. Also, the positive impact of the interaction between government expenditures and RE is enormous for NIC compared to the interaction between government expenditures and NRE. The results showed also there is a bidirectional causality between each variable and CO_2 emissions.

With the empirical findings as a basis, we suggest that it is important to increase the share of public expenditure in renewable electricity to the detriment of the share of public expenditure in non-renewable electricity. In other words, we suggest that the

Newly Industrialized Countries should reduce NRE consumption and enhance the environmental expenditures so they may produce more RE to combat environmental issues.

Several significant limitations were faced in this study and need attention for future studies. Especially, we have considered mainly 10 Newly Industrialized Countries. Meanwhile, many industrialized countries were not included in the study.

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