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Remittance Inflows, Economic Output, Electricity Use and CO_2 Emissions in the D-8 Countries: A Panel ARDL Analysis

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ABSTRACT

The effects of remittance inflows, economic output, and electricity use on CO_2 emissions in the Developing-8 countries are examined in this study from 1989 to 2019, employing the Autoregressive Distributed Lag (ARDL) approach. The findings indicate that remittance inflows can mitigate CO_2 emissions in the long run. However, economic output and electricity use can increase environmental degradation in the region in the long run. Besides, CO_2 emissions can intensify in the long run if population growth and exports rise, while imports do not have impact on environmental degradation in the long run. The short-run results show that all the variables do not significantly impact the environment, except for exports and imports. Therefore, in order to lower CO_2 emissions, the D-8 countries must embrace the use of more renewable energy. Although remittance inflows can mitigate environmental degradation in the D-8 countries, a brain drain that affects economic output may occur. Hence, we recommend that governments focus on improving their economies while reducing environmental degradation by using more green technology and renewable energy.

1. INTRODUCTION

Remittance inflows are personal transfers and compensations of employees made by resident households to non-resident households. These non-resident workers include border, seasonal, and other transient workers who work in other countries [1]. Remittance inflows are an important aspect of income, especially in developing nations. Remittances received over the previous ten years have outpaced FDI inflows and exports of goods and services [1]. Developing nations now see remittances as a stable and important source of funds, impacting individuals and economies more than public and private investments [2]. Remittances help to reduce poverty and working capital constraints and facilitate household use while increasing household expenditure, which can lead to economic development [3].

Remittances are accountable for either improving or harming the environment [4]-[6]. The environment may improve if remittance inflows are channelled into using more renewable energy and low-carbon technologies [7]. On the other hand, remittances may adversely affect the environment if they increase the demand for goods and services, thus boosting economic activity that subsequently increases CO_2 emissions.

The issue that arises when CO_2 emissions increase is global warming which the World Health Organization reported that it has resulted in at least 150,000 deaths each year, and the figure is likely to double by 2030 if countries across the globe take no action. Besides, climate change is also responsible for many infectious diseases like malaria (common in Africa), bacterial lung infection (that plagued the United Kingdom in 2006), heat waves, droughts that can worsen the living conditions of people, asthma and other respiratory diseases. In addition, climate change can affect farm yields as it can cause a reduction in nutrients needed by crops, such as iron, zinc, and protein [8]. Also, there is a significant connection between economic activity and environmental quality [5].

The D-8 nations, particularly Bangladesh, Nigeria, Indonesia, Malaysia, Iran, Pakistan, Egypt, and Turkey, have recorded rising CO_2 emissions, which sets alarm bells ringing and calls for concern. Analysing its trend based on data from Countryeconomy [9], it is clear that some of these countries have failed to reduce their total CO_2 emissions, although some have experienced a decline in CO_2 emissions. None of them has been able to avoid environmental degradation over the past years. Hence, based on the trend of CO_2 emissions in the region (see Figure 1), environmental degradation must merit serious attention and a meticulous investigation into the determinants.

Researchers are working continuously to identify the causes of CO_2 emissions that can have detrimental impacts on people and economic development. The causes consist of energy use [10], economic output [11], financial development [12]-[15], FDI [13]-[17], population growth [13],[18], trade openness [19]-[20],

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and so forth. The IPAT model is frequently used to examine how technology, affluence, and population growth affect the environment (I).

It can also be used to explain how population growth contributes to environmental degradation. For example, China, the nation with the largest population, is responsible for the largest proportion of the world's CO_2 emissions. As the global population increases, environmental degradation increases simultaneously, suggesting that economic activity can harm the environment. In the D-8 countries, Nigeria and Egypt rank the first and third most populous countries in Africa, respectively [21], while Indonesia and Pakistan also rank among the first five most populous nations in Asia. Therefore, it is important to explore how regional population growth can affect CO_2 emissions.

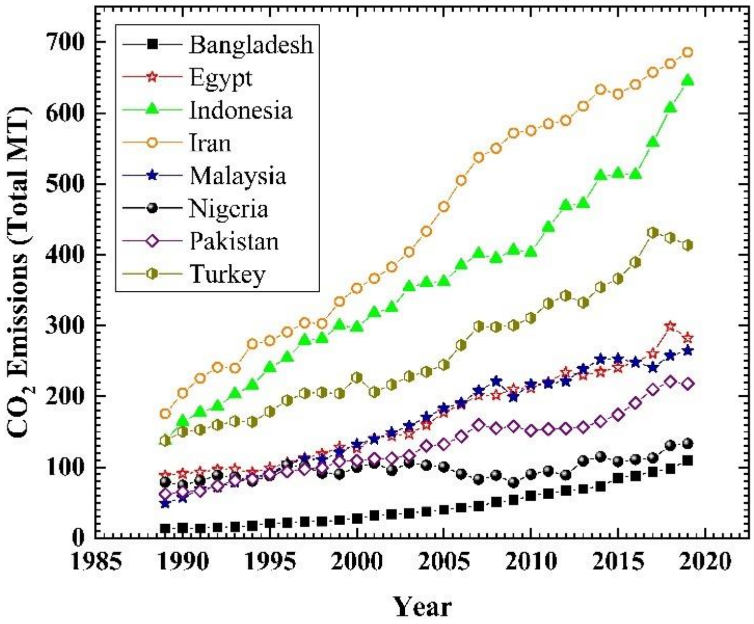

Fig. 1. CO_2 emissions in the D-8 countries (1989 and 2019).
Source: Countryeconomy, 2022

Increasing the use of non-renewable energy sources like fossil fuels, which might result in higher CO_2 emissions, is necessary for economic development [22], [23]. This is due to the fact that green energy sources, like hydro, biomass, and many others, are scarce and expensive [24]. A decrease in the utilization of non-renewable energy may have a negative impact on the economy as the D-8 nations produce insufficient renewable energy [25]. Therefore, examining whether energy use affects the economy of the D-8 countries is important. The results of this study may be used to guide policymakers to formulate policies that can boost sustainable development. This study will focus on electricity use instead of energy use in the D-8 countries, as electricity is an important energy source in the region. Most of the D-8 countries still generate electricity from non-renewable energy sources. For example, Nigeria's primary source of electricity generation is fossil fuels, which are responsible for 86% of the total electricity generation, while hydropower sources account for the rest [26].

Based on Haiges *et al.* [27], hydropower only captures 11.4% of electricity generation in Malaysia, while renewable energy use in Malaysia contributes only 6% [28]. Therefore, it is no wonder that the country continues to use more non-green energy, especially oil, gas and coal, to generate electricity, which can result in environmental degradation. With data from Countryeconomy [9], Figure 2 depicts the three-decade trend of electricity use in the D8 countries.

The IPAT model also demonstrates how a country's wealth might influence environmental degradation. Energy use inevitably increases as economic income and production increase. Besides, it is interesting to note that remittance inflows can contribute to environmental degradation. Based on data retrieved from World Bank [1], Figure 3 compares remittance inflows and outflows in the D-8 countries. The figure shows that in most of these countries, remittances received from abroad exceeded those paid abroad. This clearly indicates the importance of remittance inflows in boosting the economy. Therefore, remittance inflows as a potential determinant of environmental degradation should not be ruled out. Among the D-8 countries, Nigeria has the lowest ratio of remittances paid abroad to those received from abroad (0.38%), while Egypt has a ratio of 1.76%. In Malaysia and Turkey, the percentage of remittances paid abroad is greater than those received from abroad. This could be because Malaysia is one of the upper middle-income countries with stable financial institutions, a strong currency value and political stability, which is attractive to foreign investors and workers [29]. Turkey's economy is flourishing; hence, its citizens do not migrate like other D-8 countries. This may be because the country is one of the wealthiest in Asia, despite being a middle-income nation.

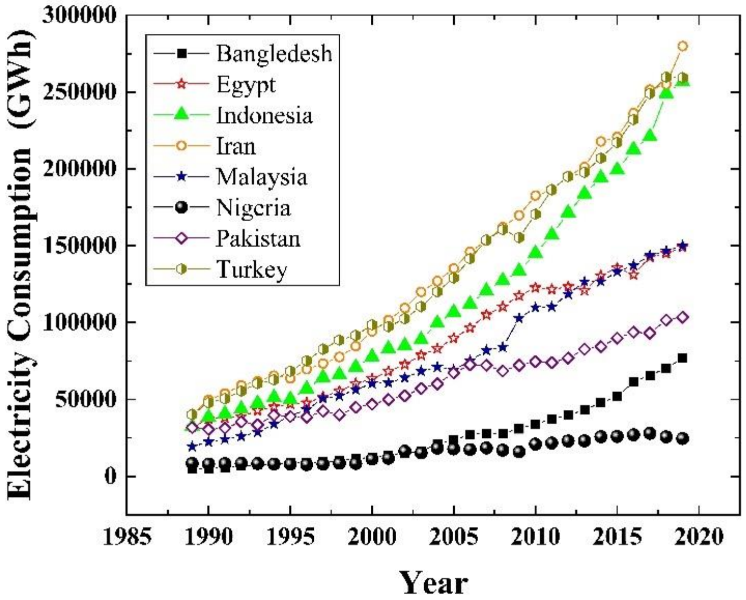

Fig. 2. Electricity use in D-8 countries.
Source: Countryeconomy, 2022

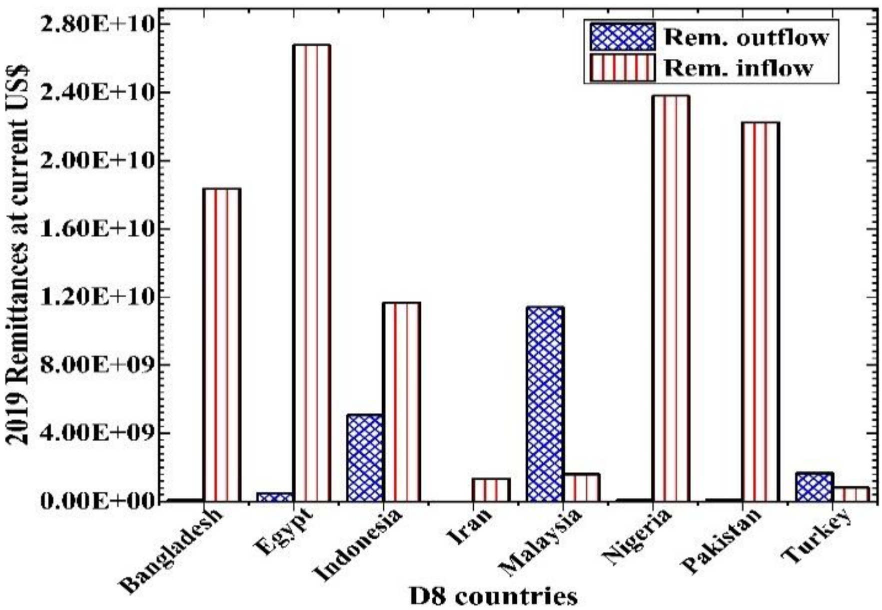

Fig. 3. Remittance inflows and outflows in D-8 countries in 2019.
Source: Worldbank, 2022.

Other variables considered in this study are exports and imports. Developing countries, like the D-8 countries, engage in external trade to boost economic output and development. Their imports of high-tech and capital goods and export of domestic inputs have helped improve their economy [30]. However, the production of domestic inputs can increase CO_2 emissions. Hence, the significant effect of external trade on CO_2 emissions should not be ignored. Most literature did not split trade openness into exports and imports such as study by Musah *et al.* [31] and some treat only exports as a proxy for trade openness [20]. A few studies considered exports and imports separately but did not explore their effects on CO_2 emissions in the D-8 countries [32]. Therefore, there is a need to disaggregate trade openness and explore its effects on CO_2 emissions in the D-8 countries as imports are expected to negatively affect CO_2 emissions, suggesting that there is no production in the domestic market that can lead to environmental degradation. However, exports can aggravate CO_2 emissions as there is a need for more production that entails using more energy that can result in greater CO_2 emissions.

This study is different from the previous ones due to its investigation into the nexus between remittances and CO_2 emissions, focusing on the D-8 countries. Past studies that considered remittance inflows as a determinant of environmental degradation have not concentrated on developing nations, especially in the D-8 countries. Although studies such as Li *et al.* [33], focused on Ghana, one of the developing nations, there is still a need to explore the issue in more developing nations. As far as we are aware, this is the first study to use panel data analysis to investigate how remittance inflows affect CO_2 emissions within the D-8 countries. Yang *et al.* [7] and Jamil *et al.* [5] are two studies that employed panel data but focused on industrialised nations, particularly the BRICS and G-20 countries. The majority of earlier studies on panel analysis of remittances, including Yang *et al.* [4], Jamil *et al.* [5], and Yang *et al.* [7], used the FMOLS (fully modified ordinary least squares), DOLS (dynamic ordinary least squares), and GMM (generalised method of moments) methods; however, the panel ARDL approach is used in the current study.

2. LITERATURE REVIEW

Numerous studies on the factors that influence CO_2 emissions in the D-8 countries have been undertaken, and various econometric techniques have been used to acquire the results. The connection between economic output, trade, and CO_2 emission in the D-8 countries from 1970 to 2011 was studied using panel co-integration and panel error correction models [34]. The findings suggested that rising emissions are a result of economic development. Similar to this, a positive link between trade openness and emissions suggests that emissions rise as trade openness rises. In the D-8 countries, there is also a unidirectional causal association that runs from economic output and trade openness to environmental degradation. In addition, no causal association was found between trade openness and GDP.

Avci [25] examined how the D-8 countries' economic output is impacted by the use of renewable energy and found that while GDP has a short-term positive correlation with renewable energy use, there is no long-term causal connection. The D-8 nations produce insufficient renewable energy, which might not have an impact on economic expansion. In developing countries, non-renewable energy, labour, and capital formation all have a substantial impact on economic production. The findings revealed that GDP has a favourable effect on non-renewable energy.

Between 1995 and 2017, 39 developing nations, including the D-8 nations with the exception of Iran, were examined by Haldar and Sethi [35] to determine the factors that contribute to CO_2 emissions. The outcomes verified the EKC's existence. According to the FMOLS findings, there is a long-term, significant negative association between renewable energy use and CO_2 emissions in developing countries. Panel regressions also showed how crucial good governance and institutions are for minimising the influence of energy use on CO_2 emissions.

Energy use influences CO_2 emissions in the D-8 and G-8 nations, according to Shoaib *et al.* [12]. However, the G-8 countries are more affected than the D-8 countries. Higher energy use and economic output in the G-8 countries are linked to higher CO_2 emissions, according to research by Li *et al.* [33]. But according to Shoaib *et al.* [12], economic output and CO_2 emissions are inversely correlated in the G-8 countries, implying that industrialised nations have higher economic output and less environmental deterioration. The amount of energy consumed depends on a nation's economic output, according to Islam *et al.* [36]. Therefore, raising the region's standard of living may harm the environment.

In the same vein, using the DCCEMG, AMG, and CCEMG estimators, Haldar and Sethi [35] examined the correlation between trade and CO_2 emissions in the D-8 countries. They discovered that FDI lowers CO_2 emissions whereas energy use, GDP, and financial development can aggravate environmental degradation in the countries. Previous research on the connection between CO_2 emissions and population growth have produced mixed results. According to Islam *et al.* [36], Malaysia's population growth eventually leads to an increase in energy consumption and economic output.

Bakhsh *et al.* [37] used the 3SLS in Pakistan, one of the D-8 countries, and discovered that environmental deterioration increases as population increases. Miloud *et al.* [18] used the ARDL approach to examine the validity of the EKC in Algeria between 1971 and 2009. Their findings indicated that GDP and population expansion could have a long-term impact on CO_2 emissions due to higher liquid fuel. Furthermore, population growth in Azerbaijan might have a substantial impact on CO_2 emissions [38]. This also confirms Shaari *et al.*'s [39] conclusions that Algeria's population expansion has no impact on the nation's CO_2 emissions.

Data from 1990 to 2017 were used in a study by Olaniyan *et al.* [22] to look at how CO_2 emissions in a few countries fluctuate in response to renewable energy use and economic production. In the long run, population growth and GDP have a considerable relationship, which can ultimately increase CO_2 emissions, according to the panel ARDL approach. In contrast, population growth has a negative impact on CO_2 emissions in high-income countries—with the exception of Saudi Arabia. Furthermore, they discovered that whereas population growth has a positive impact on CO_2 emissions in Iran, Malaysia, and Algeria, it has a negative impact in Gabon and Turkey. It is interesting to note that in certain European nations, population growth has little impact on CO_2 emissions [14]. These outcomes correspond those of Begum *et al.* [40] who conducted research in Malaysia.

The association between fossil fuels, economic output, FDI, and CO_2 emissions between 1990 and 2013 in Asian emerging nations was examined by Imran *et al.* [17] using the ARDL technique. Between population growth and CO_2 emissions, they found a weak but positive link. Alam *et al.* [41] also looked into the implications of energy use, population growth, and economic expansion for the environment using the ARDL approach. They found a high and positive association between population growth and CO_2 emissions in Brazil and India, but not in Indonesia and China.

From 1990 to 2017 across nations with various income levels, Shaari [24] examined the link between CO_2 emissions, the use of renewable energy, and economic output. The author used the panel ARDL technique and found that using more renewable energy would result in a long-term reduction in CO_2 emissions. Environmental deterioration will, however, increase as economic productivity increases. Nigeria, Bangladesh, Egypt, Pakistan, and Indonesia in particular were found to have favourable environmental impacts from their use of renewable energy. In addition, economic output and CO_2 are positively correlated in Bangladesh while they are negatively correlated in Nigeria. This means that as economic activity rises, CO_2 emissions will rise in Bangladesh but fall in Nigeria. In low-income nations like Senegal, Benin, Uganda, and Tajikistan, there was no correlation between the two factors. However, it was discovered that using renewable energy lessens environmental deterioration in Benin, Senegal, and Tajikistan. In developed nations, including Saudi Arabia, Poland, the US, Canada, and Belgium, the use of clean energy has no immediate negative effects on the environment. In upper-middle-income countries, the use of clean energy has little impact on the environment.

Salahuddin *et al.*'s [42] research on Kuwait's environment looked into the effects of economic output and electricity consumption. It was discovered that CO_2 emissions, economic output, and power use are all positively correlated. According to the findings, Kuwait's increasing consumption of power will exacerbate CO_2 emissions.

A number of studies have focused on remittances [4]-[7], [43]. From 1981 to 2019, Jafri *et al.* [43] assessed the asymmetric impact of remittances on China's environment. They discovered that remittances and GDP per capita have no influence on CO_2 emissions using the non-linear ARDL method. These findings conflict with research by Yang *et al.* [7] that was found in India, Britain, South Africa, and China, as well as research by Brown *et al.* [6] that has been discovered in Jamaica. Their results demonstrate that in the long run, a connection exist between remittances and CO_2 emissions. They validated the direct correlation in Jamaica, which exhibits an inverted U-shaped EKC, between CO_2 emissions and remittances. Although Rahman *et al.* [29] discovered a U-shaped curve in Malaysia. The use of coal, oil, and electricity were shown to have a positive impact on CO_2 emissions in Malaysia, whereas the arrival of tourists, natural gas consumption, and foreign labour were found to have no effect.

Similarly, Jafri *et al.* [43] found energy use as a significant factor that affects CO_2 emissions positively in China. In order to investigate the association between CO_2 emissions and other variables, such as remittances in a few chosen G-20 countries, Jamil *et al.* [5] used the FMOLS and DOLS techniques. Financial development, economic output, remittances, and CO_2 emissions are all correlated. While trade has no influence on CO_2 emissions, the study also found that there is a substantial inverse association between the use of renewable energy and emissions. In contrast to remittances and energy usage, which both raise emissions in both developing and developed nations, trade openness reduces emissions [4].

3. RESEARCH METHODOLOGY

3.1 Introduction

A good number of previous studies have employed the IPAT model to analyse how economic output influences CO_2 emissions [24]. This study also uses this model based on its simplicity and reliability to investigate the role of economic output, remittance inflows, and energy use in affecting CO_2 emissions. The IPAT model is written as follows:

$$I = f(P, A, T) \tag{1}$$

Where; (I) represents environmental degradation, (P) represents population growth, (A) represents affluence and (T) represents technology.

In this present study, CO_2 emissions are treated as a proxy for environmental degradation, population (POP) measures population growth, electricity use (ELECT) is a proxy for technology, and affluence is proxied by GDP per capita (GDP). The study extended the IPAT model by including personal remittance inflows (REM), exports (EXP) and imports (IMP). Data on CO_2 emissions, electricity consumption, population, GDP per capita, exports and imports are extracted from countryeconomy.com, while the World Bank provides data on personal remittance inflows. This study applies a panel data analysis as well as dynamic heterogeneous panel estimations. The estimators used are PMG (pooled mean group), MG (mean group) and DFE (dynamic fixed effect).

The model is therefore specified as:

$$\begin{aligned}\ln CO_{2_{it}} = \ & \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln REM_{it} \\ & + \beta_3 \ln POP_{it} \\ & + \beta_4 \ln ELECT_{it} \\ & + \beta_5 \ln EXP_{it} + \beta_6 \ln IMP_{it} \\ & + v_{it}\end{aligned} \tag{2}$$

3.2 Panel Unit Root Tests

This study conducts panel unit-root tests to ensure that the regression would not produce spurious results when using panel data. Therefore, the study performs LLC (Liven, Lin, and Chu) and the IPS (Im, Pesaran, Shin) unit-root tests to examine the stationarity of each variable used in this study. These tests are mostly used and are relevant because of their significantly greater power when compared with the power of the time-series unit-root tests [24].

3.3 Panel Co-integration Test

A panel co-integration test is performed on the condition that every variable is integrated of order I(1), 1(0) or mixed order. The test reveals the existence of a long-run correlation between variables [44]. Pedroni [45] proposed a co-integration test that can allow homogenous and heterogeneous panels, especially when dealing with a single regressor. In general, the regression residuals from the hypothesised co-integration regression take the form:

$$y_{i,t} = \propto_i + \delta_i t + \beta_{1i} x_{1i,t} + \beta_{2i} x_{2i,t} + \cdots + \beta_{Mi} x_{Mi,t} + e_{i,t} for\ t = 1, \ldots, T; i = 1, \ldots, N; m = 1, \ldots, M \quad (3)$$

Seven different tests given in two categories were proposed by Pedroni [45] to examine co-integration relationships between more than two variables and consider the heterogeneity of the parameters. The first category consists of four tests (within the dimension) while the other category comprises three tests (between the dimension).

The null hypothesis of the seven tests suggests the absence of co-integration:

H_0:f_i=0; ∀ i(no co-integration)

3.4 Panel Estimation

The PMG estimator helps to obtain the long-run and short-run coefficients. It can only be applied when data is integrated at level I(0) or at first difference order I(1). It does not apply to variables that are integrated of order I(2) [16]. The method is only used when estimating panel data using the ARDL approach that requires T to be larger than N.

The intercept, the error variance and the speed of adjustment can change in the short run. The short-run estimation restricts the long-run coefficients to be homogeneous. In other words, the PMG estimator can be used even if there is homogeneity. However, the MG estimator can be employed in the absence of homogeneity. Hausman test is carried out to choose between the two estimators. This MG estimator was introduced by Pesaran and Smith. This estimator permits distinct regressions with coefficients for each country. Unlike the PMG estimator, it allows for heterogeneous co-efficients for every cross-section in the long run and short run. DFE (Dynamic Fixed Effect) estimator is however not different from the PMG estimator. It provides (i) a homogenous vector co-integration coefficient, (ii) limited speed of adjustment allowing for a homogenous short-run coefficient and (iii) a specific panel coefficient.

The MG long-run model is therefore given as follows:

$$\ln CO_{2_{it}} = \theta_i + \delta_{oi} \ln CO_{2_{t-i}} + \delta_{1i} \ln GDP_{it} + \delta_{2i} \ln POP_{it} + \delta_{3i} \ln ELECT_{it} + \delta_{4i} \ln REM_{it} + \delta_{5i} \ln EXP_{it} + \delta_{6i} \ln IMP_{it} + \varepsilon_{ii} \quad (4)$$

The long run relationship for the PMG and the DFE models is given below:

$$\ln CO_{2_{it}} = \mu_i + \sum_{j=1}^{p} \lambda_{ij} \ln CO_{2_{I,t-j}} + \sum_{j=1}^{q} \delta_{ij} \ln GDP_{2_{I,t-j}} + \sum_{j=1}^{q} \delta_{ij} \ln POP_{2_{I,t-j}} + \sum_{j=1}^{q} \delta_{ij} \ln ELECT_{2_{I,t-j}} + \sum_{j=1}^{q} \delta_{ij} \ln REM_{2_{I,t-j}} + \sum_{j=1}^{q} \delta_{ij} \ln EXP_{2_{I,t-j}} + \sum_{j=1}^{q} \delta_{ij} \ln IMP_{2_{I,t-j}} + \varepsilon_{it} \quad (5)$$

Where: i is the countries (1,2…8), t is the optimal time lag, and μ represents the fixed effect. The model below represents the short-run relationship between electricity consumption, economic output, remittance inflows, exports, imports and CO_2 emissions:

$$\Delta lnCO_{2_{it}} = \mu_i + \varphi_i (lnCO_{2_{it-1}} - \lambda_1 lnGDP_{i,t} - \lambda_2 lnPOP_{i,t} - \lambda_3 lnELECT_{i,t} - \lambda_4 lnREM_{i,t} - \lambda_5 lnEXP_{i,t} - \lambda_6\, lnIMP_{i,t}) + \sum_{j=1}^{q} \delta_{i,j}\, lnGDP_{i,t-j} + \sum_{j=1}^{q} \delta_{ij} lnPOP_{i,t-j} + \sum_{j=1}^{q} \delta_{i,j} lnELECT_{i,t-j} + \sum_{j=1}^{q} \delta_{i,j} lnREM_{i,t-j} + \sum_{j=1}^{q} \delta_{i,j}\, lnEXP_{i,t-j} + \sum_{j=1}^{q} \delta_{i,j} lnIMP_{i,t-j} \quad (6)$$

3.5 Hausman Test

Selecting between PMG and MG estimators and between PMG and DFE estimators, is determined by the result of the Hausman test. Hausman test considers PMG a more efficient estimator than MG only if the alternative hypothesis is not accepted. Supposing the alternative hypothesis is not rejected, then MG is regarded as more efficient than PMG. If the null hypothesis is accepted between the PMG and DFE, then

PMG is favoured and considered more reliable than DFE. However, should the alternative hypothesis be accepted, DFE is chosen over PMG because it is considered more efficient.

4. INTERPRETATION AND DISCUSSION

This study adopts the panel ARDL approach and thus performs unit-root tests to check for stationarity for every variable of interest. The results presented in Table 1 show that $\ln CO_2$, lnELECT, InEXP and InIMP are integrated of order I(0), while other variables, lnPOP and lnGDP are integrated of order I(1). The IPS unit-root test result reveal that every variable is stationary at the first difference, although only lnREM and lnIMP are found to be stationary at the level. This study's adoption of the panel ARDL approach is therefore supported by the findings.

A co-integration test is performed following the unit root test. The results given in Table 2 reveal the rejection of the null hypothesis, implying that there is a co-integrating relationship. The results of six statistics indicate the acceptance of the alternative hypothesis at the 1% significance level, with the exemption of panel v-statistic, panel rho-statistic (together with the weighted statistics) and the group rho-statistic. The existence of co-integration for all the variables (CO_2, GDP, POP, ELECT, REM. EXP and IMP) establishes a long-run linkage among the variables for all the D-8 countries.

In estimating the influences of remittance inflows, economic output and energy use on CO_2 emissions, this present study adopts PMG, the MG as well as the DFE estimators. A Hausman test was conducted, and the results show that the result of PMG estimator is preferred to the MG estimator as the alternative hypothesis is accepted. The alternative hypothesis between the PMG and DFE estimators is also accepted, indicating that the DFE estimator is not as efficient as the PMG estimator. Results of the long-run impacts of remittances, economic output and electricity use on CO_2 emissions are presented in Table 3. Results of the PMG estimator disclose that, in the long run, CO_2 emissions is significantly influenced by economic output. The results contradict those of the MG and the DFE estimators.

Table 1. Unit root test.

Variable	Levin, Lin, and Chu (LLC)		Im, Pesaran, and Shin (IPS)	
	Level	First difference	Level	First difference
$\ln CO_2$	-2.9188***	-6.9088***	0.5345	-8.2165***
	(0.0018)	(0.0000)	(0.7035)	(0.000)
lnGDP	1.4592	-6.7471***	1.5544	-7.0325***
	(0.9277)	(0.000)	(0.9400)	(0.0000)
lnPOP	0.0311	-4.9626***	0.8062	-4.7631***
	(0.5124)	(0.000)	(0.7900)	(0.0000)
lnELECT	-3.1814***	-4.5766***	0.9252	-7.3441***
	(0.0007)	(0.000)	(0.8226)	(0.0000)
lnREM			-1.4493*	-6.5659***
			(0.0736)	(0.0000)
lnEXP	-1.7470**	-7.3424***	-0.9130	-8.2625***
	(0.0403)	(0.000)	(0.1806)	(0.000)
lnIMP	-1.8162**	-8.7377***	-1.8524**	-9.3611***
	(0.0347)	(0.000)	(0.0320)	(0.000)

Note: *** indicates a 1% level of significance.

Table 2. Pedroni co-integration test results.

Within Dimension	Statistic	Prob
Panel v-statistic	-0.506170	0.6936
Panel rho-statistic	1.520211	0.9358
Panel PP-statistic	-1.535253*	0.0624
Panel ADF-statistic	-1.779414**	0.0376
Panel v-statistic (Weighted-Statistic)	-0.933672	0.8248
Panel rho-statistic (Weighted-Statistic)	1.387301	0.9173
Panel PP-statistic (Weighted-Statistic)	-3.607897***	0.0002
Panel ADF-statistic (Weighted-Statistic)	-3.867356***	0.0001
Between Dimension		
Group rho-statistic	2.402122	0.9918
Group PP-statistic	-4.959144***	0.0000
Group ADF-statistic	-4.702380***	0.0000

Note: ***, **, and * imply 1%, 5%, and 10% significance levels, respectively.

The PMG estimator's outcomes disclose that CO_2 emissions can increase by 0.516% due to a 1% increase in economic output. These findings agree with those of Rahman [29], who also found that GDP can lead to greater environmental degradation. Higher GDP suggests that productivity increases, and thus more energy is consumed. Besides, a 1% increase in population growth can also lead to a rise of 0.59% in environmental degradation. Bakhsh *et al.* [37] also obtained the same findings that population growth increases CO_2 emissions. China that is the most populous country is also the biggest emitter of CO_2 emissions globally. There is also a positive and significant correlation between energy use and CO_2 emissions in the long run, which is in agreement with the outcomes of the MG and DFE estimators. Energy use increases by 1%, resulting in a 0.38% rise in CO_2 emissions. In contrast, remittance inflows have a negative relationship with CO_2 emissions, contradicting the results of the MG and the DFE estimators. A 1% increase in remittance inflows into the D-8 countries can decrease CO_2 emissions by 5.15%. This is in agreement with the findings of Jamil *et al.* [5] who also found that remittances can mitigate environmental degradation in selected countries. This suggests that remittance inflows can boost economic output without affecting environmental degradation as income earned from abroad without involving any domestic production that can harm the environment. In the long run, exports have a positive effect on CO_2 emissions, while imports have no significant influence on the environment.

Table 4 presents the results of the FMOLS and DOLS estimators for a robustness check. The table shows that economic output, population growth and electricity use can trigger environmental degradation. The results of the FMOLS estimator suggest that remittance inflows can negatively affect CO_2 emissions, but exports and imports do not significantly impact the environment. The results of the DOLS estimator show that exports can influence CO_2 emissions, but imports and remittance inflows do not leave any impact on environmental degradation.

Table 5 shows the short-run estimations results using PMG, MG and DFE estimators. ECT (error correction term) shows the existence of a long-run relationship for all three estimators. The PMG estimator result show that none of the variables has any significant relationship with environmental degradation in the D-8 countries, except for exports and imports that can negatively and positively affect CO_2 emissions, respectively. The DFE estimator results disclose a short-term positive impact of economic output on CO_2 emissions. In contrast, MG estimator result reveals the effects of all the variables are insignificant.

Table 3. Results of the long-run estimation.

Variable	PMG		MG		DFE	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
lnGDP	.0516574**	0.015	.0758703	0.245	-.0178483	0.874
lnPOP	.5918715**	0.018	1.624838*	0.080	.36135	0.425
lnELECT	.3777596***	0.000	.3074274*	0.083	.49057***	0.003
lnREM	-.051463***	0.000	.0017363	0.963	-.0550117	0.117
lnEXP	.1914182***	0.000	-.1143268	0.184	-.0747221	0.712
lnIMP	.032559	0.525	.2365238**	0.023	.313199	0.164
Hausman	9.84	0.1314			0.00	1.0000

Note: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively

Table 4. Results of FMOLS and DOLS (Robustness check).

Variable	FMOLS		DOLS	
	Coefficient	Prob.	Coefficient	Prob.
lnGDP	0.103847**	0.0101	0.144736***	0.0029
lnPOP	1.853307***	0.0000	0.943756***	0.0001
lnELECT	0.228887***	0.0000	0.265652***	0.0022
lnREM	-0.095331**	0.0376	-0.003655	0.7536
lnEXP	0.071318	0.1894	0.262185***	0.0022
lnIMP	0.088398	0.1482	-0.127370	0.2145

Note: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.

Table 5. Short-run estimation results.

Variable	PMG		MG		DFE	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
ECT	-.3011123 ***	0.000	-.6685565***	0.000	-.1314877***	0.000
lnGDP	.0268216	0.467	-.0248536	0.166	.0525958**	0.010
lnPOP	-31.22883	0.293	-41.70101	0.348	-.983765	0.134
lnelect	.0458879	0.744	.0098256	0.937	.0385417	0.143
lnREM	.0119914	0.324	-.006513	0.709	.001646	0.862
lnEXP	-.1199635***	0.001	-.0247263	0.255	.0385417	0.143
lnIMP	.0803813**	0.012	-.0424903	0.282	.0299561	0.295
C	-2.481146***	0.000	-17.28988**	0.039	-.9412283	0.316
Hausman	9.84	0.1314			0.00	1.0000

Note: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.

Table 6. Short-run results on the D-8 countries (country-specific).

Countries	lnGDP	lnPOP	lnELECT	lnREM	lnEXP	lnIMP	C
Bangladesh	.1604258	-5.567636	.0275527	.0042741	-.1392628	.1723704	-2.248478
Egypt	.0576451	-1.036275	-2.0665222	.0820178**	-.0132517	.0961816	-1.627789
Indonesia	-.0505713	-.9771532	.0457994	-.0185818	-.1452459	.0680119	-2.13405**
Iran	-.0023011	1.059428	.038795	-.0077983	.0203599	-.0922618***	-3.884295**
Malaysia	.1742003***	-.9063654	-.3374059***	.0271543	-.2711693*	.2043596	-2.832702**
Nigeria	-.0166136	-238.8964***	-.2016047*	.0278511*	-.0417051	.0267271	-3.034416
Pakistan	.0291571	-2.307095*	.0411867	-.0264016	-.2142856***	.076945	-1.533081
Turkey	-.1373692**	-1.199175**	.9593022***	.0074154	-.1551475**	.0907171*	-2.554359**

Note: ***, ** and * indicate 1%, 5% and 10% significance levels, respectively.

The results of the Hausman test suggest that the PMG estimator should be selected over other estimators. The impacts of each variable on each country's environmental quality in the short run can be captured by the PMG estimator. Table 6 shows the results revealing the effects of the explanatory variables on CO_2 emissions in the short run for each D-8 country. GDP has been found to have a short-run positive relationship with CO_2 emissions in Malaysia and a short-run negative relationship with CO_2 emissions in Turkey. GDP has no significant influence on environmental degradation in the other D-8 countries (Nigeria, Bangladesh, Iran, Indonesia, Egypt and Pakistan). Population growth can affect CO_2 emissions negatively in Nigeria, Pakistan and Turkey. However, there is no significant relationship between the variables in Bangladesh, Egypt, Indonesia, Iran and Malaysia.

Similarly, energy use and CO2 emissions exhibit a negative correlation in Malaysia and Nigeria and a positive correlation in Turkey in the short run. However, there is no significant association in the other D-8 countries (Pakistan, Egypt, Bangladesh, Iran, and Indonesia). In addition, remittance inflows have a short-run association with environmental degradation in Egypt and Nigeria. In Bangladesh, Pakistan, Indonesia, Iran, Malaysia and Turkey, remittance inflows are found to have no significant association with CO_2 emissions. Exports significantly decrease CO_2 emissions in Malaysia, Pakistan, and Turkey, while imports can increase CO_2 emissions in Turkey and decrease CO_2 emissions in Iran. Exports and imports do not affect CO_2 emissions in other countries (Bangladesh, Egypt, Indonesia, and Nigeria).

The VIF (variance inflation factor) test is conducted to confirm the presence or correlation among the explanatory variables. This helps to avoid producing biased results and spurious regression. Before the test is carried out, a linear regression analysis needs to be performed. The results are shown in Table 7 revealing the absence of multicollinearity. Based on the rule of thumb for VIF, there is no multicollinearity as the values of VIF for all variables are less than 10.

Table 7. Regression analysis.

	Coefficient	Prob.	VIF
lnGDP	.1080543***	0.001	3.73
lnPOP	-1911863***	0.000	2.66
lnELECT	.7002947***	0.000	2.88
lnREM	-.068509***	0.000	1.72
InEXP	.7002947	0.000	5.81
InIMP	-.8440114	0.000	5.60
C	-6.567861***	0.000	

5. SUMMARY AND CONCLUSION

This study uses the IPAT model while examining the response of CO_2 emissions to GDP, remittance inflows and energy use in the D-8 countries from 1989 to 2019. The results of unit-roots tests have confirmed that all the variables are either integrated of order I(1) or I(0), not I(2). Then, the existence of a long-run relationship among the variables in all the D-8 countries is confirmed by the results of the co-integration test. According to the result of the panel ARDL approach, in the long run, a rise in remittance inflows in the D-8 countries can lessen CO_2 emissions. However, economic output and electricity use can increase CO_2 emissions.

The findings are similar to those of Karsalari *et al.* [34], where economic output can cause an increase in CO_2 emission in the D-8 countries but contradict the findings of Rahman *et al.* [29]. Jamil *et al.* [5] support the findings of this study where remittances can affect CO_2 emissions negatively. Exports, energy use and population growth increases CO_2 emissions, while in the long run, imports insignificantly increase CO_2 emissions. Interestingly, no variable has a short-run influence on CO_2 emissions, except for exports and imports, which can negatively and positively influence CO_2 emissions, respectively. Jafri *et al.* [43] also obtained consistent findings that, in the short run, there is an insignificant effect of remittance inflows and GDP on CO_2 emissions in China.

In specific countries, remittance inflows will aggravate CO_2 emissions in Nigeria and Egypt. These two countries had the highest inflow of remittances among the D-8 countries in 2019. About 50% of young people were reported to leave Nigeria in 2021 based on David [46], while 70% of emigrants from Egypt were youths aged 20-39 years [47]. As remittance inflows increase, the demand for goods and services will rise. Thus, this will cause production to escalate, which can release more CO_2 emissions. GDP will mitigate environmental degradation in Turkey by 0.137% but will drive up Malaysia's emissions by 0.174%. These results are consistent with the findings of Rahman *et al.* [29] that GDP will increase CO_2 emissions in Malaysia in the final stage of development. When countries like Turkey increase their economies coupled with technological improvements, environmental degradation will be reduced simultaneously. Population growth will reduce CO_2 emissions in Nigeria, Pakistan, and Turkey by 238.896%, 2.307% and 1.199%, respectively. These findings agree with the findings of Olaniyan *et al.* [22] but different from the findings of Bakhsh *et al.* [37] that population growth can increase environmental degradation. Therefore, this suggests that green human capital exists in the regions as they have greater awareness, green skills and so forth to ensure that environmental degradation can be reduced. Electricity use has been found to reduce environmental degradation in Malaysia and Nigeria, but it can be detrimental to the environment in Turkey. This study agrees with the findings of Shaari *et al.* [39] that energy use can reduce CO_2 emissions in Nigeria, although Shaari [24] found that it can increase CO_2 emissions in Malaysia. Similar results are also provided by Salahuddin *et al.* [42] in Kuwait that exports can reduce environmental pollution in Malaysia, Pakistan and Turkey. CO_2 emissions will drop in Iran but increase in Turkey if there is an increase in imports.

Therefore, the findings of this study are important for policy implications in the D-8 countries. Economic output and electricity use can harm the environment, but remittance inflows help improve environmental quality. As remittance inflows can reduce CO_2 emissions, it is not favourable to encourage more people to work abroad to increase remittance inflows. The governments and policymakers of the D-8 countries may formulate policies to encourage firms to use eco-friendly energy (renewable energy), such as hydro, biomass, and so forth, to boost economic activity. Besides, strict rules and regulations should be imposed to ensure that green technology can be used in support of the government's plan to reduce environmental degradation. In addition, incentives, such as tax exemption or subsidies, can be given to firms that adhere to environmental regulations.

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