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Environmental Emissions and Economic Growth: Evidence from Highly Polluting Countries

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Abstract

The studies in the field of energy and environmental economics focus on examining the determinants of environmental emissions namely CO_2 NO_2, CH_4, or ecological footprint while analyzing the environmental emissions economic growth relationship. This study examines the impact of green growth and other determinants on four types of environmental emissions. The study is carried out for a sample of highly polluted countries over the period 1990 to 2018. The second-generation panel data methods such as Pesaran (2007) test for cross-section dependence, Pesaran and Yamagata (2008) test for slopes homogeneity/heterogeneity, Bai and Carrion (2009) unit root test, Westerlund & Edgerton's (2008) co-integration-test, and cross-sectional augmented Auto-regressive distributive lag model are used for dynamic analysis. Results reveal that there is a stable long-run relationship between variables of interest. The financial development is found to increase $C0_2$ emissions. Moreover, higher per capita GDP growth deteriorates the environment. The results model also suggests that an increase in environment-related taxes, non-renewable energy, and per capita GDP increases CH_4 emissions. Similarly, results indicate that per capita consumption of ecological footprint increases with the increase of green growth and non-renewable energy.

Keywords: Green economic growth, environmental emissions, environment-related taxes, panel data.

JEL Classification: 0, H23, E01, C23

I. Introduction

Air pollution disrupts the well-being of animals, plants, human health, ecosystems, and human-made structures like crops and buildings. Air pollutants can originate from either human activities (anthropogenic) or natural sources, or sometimes a combination of both (Mensah et al., 2019). Two notable examples of natural pollution sources are volcanic eruptions, and wind erosion, while emissions from internal combustion engines serve as a prominent example of anthropogenic pollution. Similarly, forest fires are one of the potential sources of pollution that has both natural and human causes. Keeping in view the consequences of air pollution and global warming, countries across the globe and international organizations have taken multiple measures to mitigate the impact of air pollutants and reduce greenhouse gas emissions. In this connection, environmental protection authorities have established criteria and guidelines for maintaining ambient air quality, aiming to achieve specific air quality objectives. In this connection, the Environmental Protection Agency (EPA) approved the regulations called the National Ambient Air Quality Standards (NAAQS). (The NAAQS encompasses both primary and secondary standards, addressing the protection of human health and public welfare. Primary standards are designed to safeguard vulnerable individuals from the adverse health effects of specific air pollutants, while secondary standards are intended to protect the general population from any known or anticipated negative consequences associated with the presence of pollutants in the surrounding air.

It is the continued interest of academicians and policy-oriented researchers to address environmental issues such as pollution, global warming, overexploitation of natural resources, and deforestation. The ever-increasing $\mathrm{C0_2}$ emissions appeal for the adoption of a two-tiered approach comprises of environmental and economic approach to keep the level of emissions that compatible with the economic growth. In the perspective of economic approach, increasing and unregulated industrial and economic activities result in increasing in $\mathrm{C0_2}$ emissions. On the other hand, sustainable development in the environmental approach cannot be based on polluting industries until the social welfare is greater than the realized economic growth. Supporting the economic approach, Nordhaus & Boyer (2000) provide evidence to argue for a positive relationship between economic growth and CO_2 emissions. They also came with the findings that in Africa and Asia, warming of 2 C^0 could lead to a five-percent decrease in the average annual per-capita consumption.

Several studies, including Atems & Hotaling (2018), Kumari & Sharma (2018), Bayat et al., (2017), and Lechthaler (2017), support the growth hypothesis, recognizing the signified role of energy consumption in the production processes. According to these studies, increased energy consumption contributes to the production of goods for both exportation and local consumption, thereby promoting growth. These studies, however, did not extensively explore the possibility of reverse causality. On the other hand, studies like Rahman & Velayutham (2020), Chen & Fang (2018), Nyasha et al., (2018), and Kirikkaleli et al., (2018), argue that economic growth can lead to increase environmental emissions, supporting the conservation hypothesis.

Countries around the world are concerned about environmental degradation in the form of an increase in level of CO_2, $NO_2$and CH_4 along with environmental degradation associated with the demand for ecological footprint. Hence, environmental policies in most of the countries are mainly focuses on the determinants of various kinds of emissions and its implications for the sustainability of economic growth.[1]

This study aims to estimate sustainable level of environmental emissions and its impact on economic growth. More specifically, the analysis carried in three steps. Firstly, both short and long-term determinants of different environmental emissions have been identified.[2] Secondly, the equilibrium (sustainable) levels of these environmental emissions have been estimated. Finally, the relationship between equilibrium level of environmental emissions and economic growth has been explored. The analysis covered sample of 40 economies around the global[3] that grouped into developed and developing

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[1] According to the world in data website, most of the emissions comes from energy (73.2%) i.e., electricity, heat, and transport, followed by direct industrial process (5.2%), waste (3.2%) and agriculture, forestry and land use (18.4%).

[2] CO_2, $NO_2$and CH_4 along with Ecological Footprint

[3] Selection of countries is based on the availability of data.

countries, highly polluted countries and less polluted countries. The study attempts to answer to the question "Does green growth affect different kind of emissions i.e. CO_2, NO_2, CH_4 and ecological footprint?"

Most recently, Hao et al., (2021) investigate the factors that affect CO_2 emissions, including green growth. However, the study has some potential gaps. In this study, we try to fill these gaps and capture the issue at its full length. Our study is different from Hao et al., (2021) in three different ways. First, Hao et al., (2021) examine the impact of green growth, environment-related tax and human capital along with other variables only on CO_2 emissions. To explore the issue with its full length, instead of single emission CO_2, we consider different kinds of emissions (i.e.,CO_2, NO_2, CH_4 and ecological footprint) to explore the role of green growth. Second, Hao et al., (2021) analysis is for G7 countries while we extend our analysis to 40 countries. Moreover, the sample countries are grouped into highly polluted countries and less polluted countries. A country is considered highly polluted if its emissions value is greater than the average emission value of all countries and vice versa.

2. Literature Review

Due to the extreme weather conditions a significant share of planet the habitat has been lost in the past few decades, and it has gained considerable attention. The Paris Agreement, established under the United Nations Framework Convention on Climate Change, represents a significant advancement within the framework. Its primary objective is to decrease global greenhouse gas emissions, thereby ensuring that the annual global temperature rise remains below 2°C (United Nations, 2015).

The global greenhouse is mainly affected by the excessive increase in CO_2 emissions. The excessive emissions of CO_2 is creating a global warming because of radiation in the atmosphere caused by CO_2. The dramatic increase in CO_2 is also due to the Industrial Revolution. Even though the UN is trying to implement policy changes which in turn can slow down global warming. However, the Paris agreement is not viable for some countries due to political and economic reasons.

There has been a lot of discussion on how green growth would affect environmental quality, jobs, climate change, and sustainable development. However, there is conflicting evidence to support these claims (Wang et al., 2021a; Apergis & Payne, 2010; Sandberg, et al., 2019; Shahbaz et al., 2018; Hussain, et al., 2021). Additionally, varieties of important elements that affect green development are considered in the literature (Inglesi-Lotz & Dogan, 2018; Mensah, et al., 2018). The following factors are essential contributors to green growth including but not limited to GDP, environmental taxes, energy use, and green patents.

Sohag et al., (2021) examine the relationships between green growth, energy, and technical innovation in OECD nations. Using the CS-ARDL approach, the study finds a long-run relationship between technical innovation and green growth. Results also reveal that military activities are detrimental to green economic development. Ulucak (2020) conducted research using hypothetical emerging economies and initiate a significant positive relationship between green technology and green growth. These findings highlight how new technologies can mitigate negative environmental consequences and promote sustainable development by reducing reliance on natural resources.

Several studies have investigated the relationship between energy consumption and green growth. It has been observed that the use of fossil fuels for energy has a detrimental effect on green growth and contributes to the depletion of natural resources. Kirikkaleli and Adebayo (2021) emphasize the positive influence of renewable energy sources on green growth, as they help reduce atmospheric emissions. Similarly, Khan et al., (2021) find significant evidence linking energy consumption to environmental quality. Furthermore, the use of nonrenewable energy degrades environmental quality since natural resources steadily diminish because of an increase in environmental strain. Baniya et al., (2021) and Ulucak (2020) for high-income nations have established some outcomes about the relationship between energy use and greenhouse gas emissions. Studies, such as those by Farhani and Shahbaz (2014) and Bulut (2017) reveal a beneficial influence of energy consumption on green growth despite the negative impact of renewable energy consumption on green growth. Lu et al., (2017) agree that renewable energy contributes to green growth.

Numerous academics, environmentalists, and economists have debate whether resource-constrained nations can increase their economies while also reducing environmental damage through "green growth." The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) is the pioneer to propose the idea of "green growth" in an effort to find a sustainable low-carbon development model (ESCAP, 2005). Globally, academicians have expressed a great deal of interest in this sustainable method of development, Additionally, the (OECD, 2011) describes "green growth" as a mode of development that integrates economic expansion with environmental concerns in order to achieve sustainable economic growth. For sustainable development, the idea of "green growth" is widely acknowledged (Zhao et al., 2022b).

The relationship between economic growth and CO_2 emissions has sparked a debate, leading to research on green growth and carbon emissions. Researchers such as Acheampong (2018), Chen (2016), Mikayilov (2018), Ozturk & Salah Uddin (2012), Shahbaz (2018), and Wang (2018) contend that rapid economic growth has a significant impact on CO_2 emissions. Gorus and Aydin (2019) and Salahuddin et al. (2016), on the other hand, present contrary evidence.

Khan et al., (2018) investigate the impact of environmental laws on carbon emissions between 1991 and 2015 in China. The author discovers a negative correlation between financial development and carbon emissions, but the effect is statistically insignificant. Additionally, discharge fees and research & development are useful for reducing carbon emissions. On the other side, carbon emissions rise because of both urbanization and energy use. Shahbaz et al., (2013) discovered that financial development in Indonesia lowers carbon emissions. In contrast, Ahmad et al., (2018) between China, Jamel and Maktouf (2017) for European nations, Gokmenoglu et al., (2015) for Turkey, Al-Mulali et al., (2015) for 23European nations, Boutabba (2014) for India, Solarin et al., (2017), and Charfeddine and Khediri (2016) for examining United Arab Emirates (UAE), explore that increased financial development has a detrimental effect on carbon emissions.

There is a plethora of literature on determinants of ecological footprint. To gauge how a nation's consumption is sustainable, Wackernagel and Rees, (1998) developed the ecological footprint (EF). Additionally, ecological footprint considers how to handle trash during the production process. Fiala (2008) asserts that the EF identifies the resources needed to generate the things that people want, including several components like soil, forestry, mining, and oil reserves (Yilanci, et al. 2019; Ulucak, & Lin, 2017). In addition, the ecological footprint illustrates the amount of land required to produce greenhouse gases considering current technologies and resource management techniques.

The authors employed econometric methods to discover that the US's ecological footprint is positively impacted by economic complexity and the use of fossil fuels. By illustrating the causal relationships between complexity, energy consumption, and environmental harm, the authors also made a contribution. The environmental Kuznets curve (EKC) theory is examined by Pata (2018) for US CO_2 emissions as well as ecological footprint. The study confirmed that using renewable energy sources, as a tool for policy could be crucial for reducing environmental harm in the US.

The above-cited studies indicate that a variety of factors like socioeconomic, political, and geographic influence environmental emissions. The results of these studies show varying amounts and types of interaction between carbon emissions, environmental sustainability, and different socio-economic factors. However, there is a scarcity of academic research highlighting the significance of institutional quality, human capital, the financial development, and environment-related taxes with CO_2 and other emissions.

3. Methodology and data

3.1. Theoretical Framework

To investigate the relationship between sustainable level of environmental emission and economic growth We follow the model developed by Hao et al., (2021). The model proposes theoretical framework that channelizes the effect of sustainable level of environmental emissions on economic growth. Starting with the standard production function with Hicks neutral as:

$$Y_t = A_t[K_t, L_t] \qquad (1)$$

Where Y_t is the total output, A_t indicate productivity shift, K_t is capital and L_t is labor/human capital - covering all of the productive services provided by the workers. Following Eriksson (2013), a general equation for emission is given below as:

$$E_{i,t} = QE_{i,t}Y_{i,t} \qquad (2)$$

Here, $E_{i,t}$ are total emissions from different sectors of the economy, $QE_{i,t}$ is the quantity of emissions caused by industry i and $Y_{i,t}$ is output from ith industry. The emissions level depends on $QE_{i,t}, Y_{i,t}$; If $QE_{i,t}$ is negatively linked with $E_{i,t}$, then it is considered as environmentally friendly technological innovation and with increasing output, emissions shall decline.

Moreover, the total emissions level in a particular country is denoted by:

$$E_t = Y_t \sum_{i=1}^{n} \varphi_{i,t} \, QE_{i,t} \qquad (3)$$

Where Y_t is the total output from all industries, $\varphi_{i,t}$ share of each industry in total output[4], i.e., $\varphi_{i,t} = \frac{Y_{i,t}}{Y_t}$., Taking time derivative of equation (3), we obtained.

$$g^E = g^Y + \sum_{i=1}^{n} \tau_i \, g^{QE_i} + \sum_{i=1}^{n} \tau_i \, g^{\varphi_i} \qquad (4)$$

The rate of change of emissions can be decomposed into three components according to Kuznet, (1955) i) Scale effect (g^Y), ii) Technology effect (g^{QE}), and iii) Composition effect (g^{φ_i}). Further, $\tau_i = \frac{E^{i,t}}{E^t}$ shows share of industry i in total pollution. In equation (4) if we assume composition effect to be zero and g^E decreases with rise in total output, then it could be considered that g^{QE_i} is environment-friendly technological innovation and with rising output, emissions level may not increase. This condition is true if the following holds;

$$g^E \leq 0 \text{ and } g^Y \leq -g^{QE} \qquad (5)$$

Equation (5) suggests that a rise in total output is less than the rate of decline of emissions. This relation can be written as:

$$g^Y = -g^{QE} + g^E \qquad (6)$$

In our model, the increase in output is associated with the utilization of energy sources that generate emissions, such as fossil fuels. On the other hand, employing environmentally friendly technologies reduces output.

Suppose the government introduces taxes on pollution denoted by T_E, then the firm will maximize following profit function as suggested by , Fodha et al., (2018); Fan et al., (2019).

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[4] Total sum of each industry share is equal to “1”.

$$\pi = K^{\alpha}E^{\gamma}(AL)^{1-\alpha-\gamma} - rK - wL - T_E E \qquad (7)$$

where $K^{\alpha}E^{\gamma}(AL)^{1-\alpha-\gamma} = Y$ is production function, r is cost of capital , w is cost of labor and T_E tax.

Differentiating equation (7) with respect to E, we obtain the following equation:

$$\gamma \frac{Y}{E} = T_E \qquad (8)$$

Here, T_E is the marginal product of tax. Further, differentiating Eq. (8) with respect to time get:

$$g^E = g^Y - g^{T_E} \qquad (9)$$

From equation (9), we can see that emissions are negative only if tax exceeds the rate of output. Here, we obtained environmental tax shall have a negative effect on total emission level.

Following Hallegatte et al., (2012), Capasso et al., (2019), Hao et al., (2021) and Tzouvelekas et al., (2006), we take emissions function as:

$$E = Y^{a}QE^{-b} \qquad (10)$$

Y is the green growth, if it is environment friendly and QE is defined in equation (2). Taking the first and second-order derivative for E with respect to QE is obtained as:

$$\frac{\partial E}{\partial QE} = -bY^{a}QE^{-b-1} < 0 \qquad (11)$$

$$\frac{\partial^2 E}{\partial QE^2} = b(b+1)Y^{a}QE^{-b-2} > 0 \qquad (12)$$

The first-order condition suggests that an increase in environmentally friendly technology will result in a decrease in emissions. Additionally, the second-order derivative indicates that a further increase in environmentally friendly technology may lead to a diminishing marginal effect on emissions.

For green growth, the first and second-order derivatives are presented as follows:

$$\frac{\partial E}{\partial Y} = (-)aY^{a-1}QE^{-b} \underset{>}{\overset{<}{}} 0 \qquad (13)$$

$$\frac{\partial^2 E}{\partial Y^2} = a(a+1)GY^{-a-2}QE^{-b} \underset{>}{\overset{<}{}} 0 \qquad (14)$$

Equation 13 will be negative, if the growth rate is green and will be positive otherwise.

Here, the green growth that we assumed emerged because of expansion of environmentally friendly production processes; therefore, the first and second order derivative is negative and positive respectively. The second order derivative is positive since marginal effect of green growth after a satiety point may have less effect on emissions reduction.

Moreover, taking log of equation (10) we get:

$$lnE(t) = alnY - blnQE \tag{15}$$

Sustainable development is achieved only if the following condition holds:

$$g^E \leq 0 \text{ if and only if } a(g^A + n) \leq bg^{QE} \tag{16}$$

This suggests that the technology is greener in the case when the value of b is larger. Similarly, output will cause more emissions if a is high without green growth, however, the effect of green growth should also be negative on the pollution level. Putting $g^A = \theta^A S^A L$ and $g^{QE} = \theta^{QE} S^{QE} L$ in equation (16), and assuming $n = 0$ we obtain:

$$g^E \leq 0 \text{ if and only if } S^{QE} \geq \frac{a}{b} . \frac{\theta^A}{\theta^{QE}} . S^A \tag{17}$$

According to Equation (17), sustainable development can be attained by allocating additional resources to research endeavors. The higher value of a/b, which represents the relative position of gross emissions to green technology on net emissions, indicates the need for greater emphasis on promoting green technology.

3.2. Empirical Models

In order to achieve the objectives of the study and to test the proposed hypotheses, the following empirical models are estimated.

$$CO2_{,it} = \beta_0 + \beta_1 HC_{it} + \beta_2 ERT_{it} + \beta_3 NREC_{it} + \beta_4 FDI_{it} + \beta_5 GG_{it} + \varepsilon_{it} \tag{18}$$
$$NO2_{it} = \gamma_0 + \gamma_1 HC_{it} + \gamma_2 ERT_{it} + \gamma_3 NREC_{it} + \gamma_4 FDI_{it} + \gamma_5 GG_{it} + \varepsilon_{it} \tag{19}$$
$$CH4_{it} = \theta_0 + \theta_1 HC_{it} + \theta_2 ERT_{it} + \theta_3 NREC_{it} + \theta_4 FDI_{it} + \theta_5 GG_{it} + \varepsilon_{it} \tag{20}$$

$$EF_{it} = \alpha_0 + \alpha_1 HC_{it} + \alpha_2 ERT_{it} + \alpha_3 NREC_{it} + \alpha_4 FDI_{it} + \alpha_5 GG_{it} + \varepsilon_{it} \tag{21}$$

where CO_2 emissions, NO_2 emissions, CH_4 emissions and ecological footprint are dependent variables. HC, ERT, $NREC$, FDI, *and* GG are our independent variables that are common in all four models.

3.2. Data and Data Sources

The study uses panel data of high-polluted countries[5]. The analysis is carried out by using data from 1990 to 2018 in order to identify the determinants of environmental emissions at one hand and the role of sustainable level of environmental emissions on economic growth on the other hand. The data on variables under consideration such as Carbon dioxide emissions, Green Growth, Environment-related Tax, Human Capital Index, Financial Development Index, Non-renewable energy consumption, Ecological footprint, Nitrogen emissions, methane emissions and GDP growth per capita are taken from different sources such as World Bank, OECD website, Pen World Table 9.1, IMF, Fraser Institute Index, and global footprint network.

3.3. Estimation Methods

Our panel data analysis begins with a test for cross-sectional dependence (CD) among the units. The choice of unit root test, whether to apply a first-generation, second-generation, or third-generation test, depends on the results of the cross-sectional dependence test. Cross-sectional dependence can arise among residuals due to various factors, including international financial and economic market integration, unforeseen shocks such as oil price shocks, global financial crises, and other observed or unobserved common factors. Ignoring cross-sectional dependency in the analysis can lead to issues such as distorted results, spurious findings, and biased stationarity results (Salim et al., 2017; Westerlund, 2007).

In our study, we employ the Pesaran (2004) test to examine the presence of cross-sectional dependency.

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \widehat{\rho_{ij}} \sim Normal(0,1) \qquad (23)$$

Where T represents the time span and N denotes the number of observations in the data used..

Slope heterogeneity, which can make panel estimators inconsistent, since traditional estimators assume homogenous slopes, is another potential problem in panel data analysis. Therefore, before carrying out the final model estimation, it is necessary to investigate slope heterogeneity. The current study uses the

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[5] See appendix A for the list of the sample countries.

Hashem Pesaran & Yamagata (2008) test to examine slope heterogeneity. The test introduces two statistics, namely delta tilde ($\tilde{\Delta}HS$) and adjusted delta tilde ($\tilde{\Delta}AHS$) as follows:

$$\hat{\Delta}_{HT}= (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S}-k\right) \tag{24}$$

$$\hat{\Delta}_{AHS}= (N)^{\frac{1}{2}}\left(\frac{2k-T-k-1}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S}-2k\right) \tag{25}$$

The next step after checking the cross-sectional dependency is to test for stationarity property of the panel data. There are three strands of literature so far developed on the issue of non-stationarity i.e., first generation unit root test, second generation unit root test and third generation unit root test. Each strand of literature deals with different issue. For example, Levin et al., (2002), Choi (2001), and Maddala & W (1999) tests are best fitted for homogenous panel while Im, Pesaran & Shin (2003) is best fitted for heterogeneous panel. Though, Carrion-i-Silvestre et al., (2005) is suitable in case the data have multiple structural breaks; but it does not have the characteristic to overcome the problem of cross-sectional dependence. Therefore, in this study we will use second generation panel data unit root test developed by Pesaran (2007) as it tackles not only the issue of heterogeneity but also overcomes the problem of cross-section dependence between units.

The augmented version of the standard Augmented Dickey-Fuller (ADF) regressions incorporates cross-section averages of lagged levels and first differences, as shown below:

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + \sum_{j=0}^{p} d_{ij}\Delta\bar{y}_{t-j} + \sum_{j=1}^{p} \delta_{ij}\Delta\bar{y}_{i,t-j} + u_{it} \tag{26}$$

and

$$\Delta y_{it} = a_{0i} + a_{1i}t + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + \sum_{j=0}^{p} d_{ij}\Delta\bar{y}_{t-j} + \sum_{j=1}^{p} \delta_{ij}\Delta\bar{y}_{i,t-j} + u_{it} \tag{27}$$

Equation (26) presents the cross-sectional augmented version of the Dickey-Fuller regression (CADF) with a fixed effect, while equation (27) represents the CADF with both a fixed effect and an individual time trend.

4. Results of Second-Generation Panel Unit Root Test

First-generation unit root tests should not be used when there is cross-sectional dependence and varying coefficients. The second-generation panel unit root test, notably the CIPS unit root test, is the preferable substitute in such circumstances. (Hurlin, 2010; Hurlin & Mignon, 2007; Westerlund et al., 2016).

The results of the second-generation panel unit root test are provided in Table.1. These results indicate that some of the variables under consideration are integrated of order zero - I(0), while others are integrated of order one - I(1). This confirmation of different integration orders supports the use of the CS-ARDL (Cross-Sectional Augmented Autoregressive Distributed Lag) approach in our investigation.

Table.1: Test of the Panel Unit Root that Takes into Account Cross-Section Dependence (High Polluted)

Variables	Level, I (0)			First Difference, I (1)		
	Case I	Case II	Case III	Case I	Case II	Case III
CH_4	-2.147***	-0.980	-1.845	-2.568***	-2.794***	-3.128***
ERT	-1.473	-1.415	-1.881	-3.653***	-3.848***	-3.898***
GG	-3.489***	-3.711***	-4.474***	-5.499***	-5.812***	-5.821***
CO_2	-0.757	-1.232	-2.651	-4.005***	-4.391***	-4.435***
EFPCCON	-1.717*	-2.650***	-2.464	-4.446***	-4.546***	-5.173***
FDI	-2.073***	-1.715	-2.258	-4.196***	-4.741***	-4.798***
HC	2.404***	-1.034	-2.039	-3.263***	-3.363***	-5.181***
NO_2	-1.620*	-1.980	-2.206	-4.257***	-4.495***	-4.514***
NRE	-0.757	-1.232	-2.651	-4.005***	-4.391***	-4.435***
PCGDPG	-2.533***	-2.730***	-3.495***	-5.388***	-5.178***	-5.513***

Note: *** denote significance at 1 percent. ** Significance at 5 percent, and * significance at 10 percent. Case I mean model without an intercept or trend, Case II means models with an individual- specific intercept, and Case III models with an incidental linear trend.

4.1. Evidence from Simple Panel ARDL

In this section, we provide evidence on the determinants of environmental emissions based on linear ARDL. The results of high polluted sample are given in Tables (2–5). Each table provides results for the determinants of different environmental emissions. Table.2, Table. 3, Table.4 and Table.5 provide results of the determinants of CH_4 , CO_2, $NO_2$and EFPCCON, respectively.

Generally, the impact of variables determines environmental emissions are not statistically significant in the short run, while in the long run the impacts of the same variables are significant. This is true for all the models. In a sample with CH_4 as dependent variable, the impact of all independent variables is highly significant. For instance, environmental related taxes (ERT), non-renewable energy consumption (NRE) and per capita GDP positively affect CH_4 emissions while the remaining two determinants i.e., GG and FDI are negatively influence CH_4 emissions.

Table. 2: Linear ARDL, LCH_4 as Dependent Variable (High Polluted Sample)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
		Long Run Equation		
LERT	0.181	0.026	6.820	0.000
NRE	0.251	0.013	18.717	0.000
GG	-0.026	0.006	-4.325	0.000
PCGDPG	0.027	0.004	6.057	0.000
FDI	-2.315	0.276	-8.383	0.000
		Short Run Equation		
COINTEQ01	-0.097	0.059	-1.635	0.105
D(LERT)	-0.201	0.098	-2.042	0.043
D (LERT (−1))	0.015	0.119	0.133	0.894
D(NRE)	-0.005	0.012	-0.486	0.627
D (NRE (−1))	-0.047	0.025	-1.867	0.064
D(GG)	0.004	0.004	1.069	0.287
D (GG (−1))	0.006	0.005	1.136	0.258
D(PCGDPG)	-0.002	0.001	-1.664	0.098
D (PCGDPG (−1))	-0.000	0.001	-0.304	0.761
D(FDI)	0.284	0.123	2.296	0.023
D (FDI (−1))	0.325	0.175	1.853	0.066
C	1.003	0.618	1.621	0.107

Theoretically, an increase in environmental related taxes (ERT) should decrease the CH_4 emissions but we got the opposite results in our case. The answer could be found from the nature of the sample, the results coming from the high polluted sample, indicating that environment related taxes is not in coherence with the number of emissions in high polluted sample which needs attention and re-examination of the environment related taxes in these countries. The sign of GG is compatible with the theory, which emphasizes that green growth is important for reduction in environmental emissions including the methane emissions. The sign of the non-renewable energy consumption is also according to the theory. The results push us to use renewable energy more than non-renewable energy to limit the amount of emissions into the environment.

In Table.3 CO_2 emissions is taken as dependent variable. Estimated results indicate that ERT and FDI are not determining factors of CO_2 emissions in high-polluted sample, because these two variables are statistically insignificant. These are very unusual results and needs to be explored further. However, NRE, GG and per capita GDP significantly affect CO_2 emissions. The association of per capita GDP with CO_2 emission is negative while that of NRE and GG is positive.

Table.3: Linear ARDL, LCO_2 as Dependent Variable (High Polluted Sample)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
		Long Run Equation		
ERT	0.021	0.027	0.790	0.431
NRE	0.107	0.016	6.438	0.000
GG	0.107	0.023	4.600	0.000
PCGDPG	-0.027	0.007	-3.696	0.000
LFDI	-0.037	0.066	-0.569	0.570
		Short Run Equation		
COINTEQ01	-0.022	0.008	-2.601	0.010
$D(LCO_2\ (-1))$	-0.028	0.122	-0.230	0.817
D(ERT)	0.005	0.004	1.361	0.176
D (ERT (−1))	-0.009	0.010	-0.913	0.363
D(NRE)	0.145	0.041	3.536	0.000
D (NRE (−1))	-0.007	0.014	-0.545	0.586
D(GG)	-0.001	0.000	-1.944	0.054
D (GG (−1))	-0.000	0.000	-0.709	0.479
D(PCGDPG)	0.000	0.000	1.024	0.308
D(PCGDPG(−1))	6.42E-	0.000	0.195	0.845
D(LFDI)	-0.002	0.002	-0.843	0.400
D (LFDI (−1))	-0.007	0.006	-1.176	0.242
C	0.017	0.007	2.249	0.026

In Table.4, NO_2 emissions is taken as dependent variable. Only GG is not statistically significant in case of high-polluted sample. The impact of green growth on NO_2 emissions may not be statistically significant for a number of reasons. Firstly, the concept of green growth refers to economic growth that is environmentally sustainable. While green growth policies and practices can lead to reduce environmental impacts, including NO_2 emissions, the impact may not be immediately apparent or may be difficult to measure accurately. Secondly, the relationship between green growth and NO_2 emissions may be complex and influenced by a variety of factors. For example, while green growth policies may promote the adoption of cleaner technologies and practices, they may also stimulate economic activity and increase energy consumption, which can lead to increased NO_2 emissions. Thirdly, the statistical analysis used to look into the connection between green growth and NO_2emissions may be subject to methodological limitations, such as inadequate control for confounding variables or limited data availability. These limitations can make it difficult to accurately estimate the relationship between the variables. Finally, it is possible that the impact of green growth on NO_2 emissions is simply not statistically significant. This means that any relationship that exists between the variables is not strong enough to be detected using the available data and statistical methods.

Overall, the lack of statistical significance in green growth and the relationship between NO_2 emissions highlights the need for continued research and policy development in this area. It is important to carefully evaluate the effectiveness of green growth policies in reducing NO_2emissions and to consider the complex interactions between economic growth, environmental sustainability, and public health. The association of per capita GDP with CO_2 emission is negative again while that of ERT NRE and FDI is positive.

Environment-related taxes are taxes levied on products, services or activities that have negative environmental impacts. These taxes are intended to provide an economic incentive to reduce environmental pollution by discouraging the consumption or production of goods and services that generate pollution. It is unlikely that environment-related taxes would increase NO_2 emissions. In fact, such taxes are often implemented specifically to reduce pollution, including NO_2 emissions. However, there are some possible scenarios where environment-related taxes may not be effective in reducing NO_2 emissions and may even increase them. One possible scenario is that the tax rate is set too low, such that it does not provide a strong enough incentive to reduce NO_2 emissions.

Table.4: Linear ARDL, LNO_2 as Dependent Variable (High Polluted Sample)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
		Long Run Equation		
ERT	0.549	0.065	8.355	0.000

NRE	0.132	0.031	4.210	0.000
GG	-0.014	0.016	-0.837	0.404
PCGDPG	-0.028	0.010	-2.627	0.009
FDI	1.193	0.552	2.160	0.032
Short Run Equation				
COINTEQ01	-0.178	0.082	-2.165	0.032
D(ERT)	-0.131	0.063	-2.051	0.042
D (ERT (−1))	-0.083	0.089	-0.932	0.353
D(NRE)	0.009	0.023	0.399	0.690
D (NRE (−1))	-0.071	0.035	-2.026	0.045
D(GG)	0.008	0.010	0.879	0.381
D (GG (−1))	0.015	0.018	0.818	0.414
D(PCGDPG)	0.001	0.003	0.338	0.735
D(PCGDPG(−1))	0.007	0.006	1.221	0.224
D(FDI)	-0.193	0.330	-0.586	0.558
D (FDI (−1))	-0.197	0.411	-0.480	0.631
C	1.493	0.670	2.225	0.028

In this case, businesses and individuals may not change their behavior, and may continue to generate NO_2 emissions at the same rate, or even increase their emissions in response to the lower tax burden. Another possible scenario is that the tax is poorly designed, such that it creates unintended consequences that increase NO_2 emissions. For example, if the tax is applied only to certain types of vehicles or fuels, it may incentivize the use of alternative.

Table.5: Linear ARDL, LEFPCCON as Dependent Variable (High Polluted Sample)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Long Run Equation				
ERT	0.009	0.021	0.435	0.664
NRE	0.153	0.009	16.234	0.000
GG	-0.058	0.014	-4.053	0.000
PCGDPG	0.004	0.006	0.698	0.486
FDI	-1.141	0.268	-4.250	0.000
Short Run Equation				
COINTEQ01	-0.219	0.094	-2.307	0.022
D(ERT)	-0.058	0.027	-2.140	0.034
D (ERT (−1))	0.034	0.096	0.362	0.717
D(NRE)	0.072	0.029	2.482	0.014

D (NRE (−1))	-0.027	0.015	-1.750	0.082
D(GG)	0.011	0.005	2.147	0.033
D (GG (−1))	0.010	0.003	3.234	0.001
D(PCGDPG)	0.002	0.002	1.092	0.276
D(PCGDPG(−1))	0.000	0.003	0.198	0.842
D(FDI)	-0.034	0.259	-0.133	0.894
D (FDI (−1))	0.259	0.164	1.575	0.117
C	0.065	0.050	1.291	0.199

The observed effect on ecological footprint (EFP) is positive but not statistically significant in relation to GDP per capita and ERT. While foreign direct investment (FDI) exhibits a negative and substantial impact on EFPCCON, green growth (GG) and non-renewable energy consumption (NRE) have a positive and significant impact, as seen in Table.6.

5. Conclusion

The aim of this study was two-fold. First the study tended to examine the determinants of environmental emissions indicators such as environmental levies, green growth, and other relevant factors on ecological footprint, CH_4, CO_2 and NO_2 emissions which were previously not considered in a single study. The results of the panel unit root test, which accounts for cross-section dependence, indicate that some variables are integrated of order zero while others are integrated of order 1, confirming the suitability of the ARDL (either CS-ARDL or simple linear panel ARDL) model in this study. Additionally, the results indicate that the one-period lag effect of both CO_2 and NO_2 is statistically significant. Furthermore, ERT has a negative and significant impact on CO_2 emissions in the less polluted sample. It is noteworthy that the effects of ERT on CO_2 and NO_2 remain consistent in both the short run and the long run, indicating that the time dimension does not play any role.

the impact of all independent variables is highly significant. ERT, FDI NRE and per capita GDP positively affect NO_2 emissions while GG negatively influence NO_2 emissions. In model with CH_4 as dependent variable, the impact of all determinants in this model on CH_4 is significant. However, in this model only per capita GDP growth is positively associated with CH_4 emissions while the rest of the independent variables are negatively associated with CH_4 emissions. In the last model, in which per capita consumption of ecological footprint is dependent variable, once again, every independent variable significantly affects EFPCCON. Similarly, we estimate the linear ARDL for whole sample by keeping CH_4 and $EFPCCON$ as dependent variables. The interaction term of the log of average of all emissions with financial development index has significant and having positive effect on EFPCCON.

5.1. Policy Suggestions/Implications

Based on study results several implications can be presumed. We use cross-sectional augmented ARDL model compatible to handle cross sections dependency, and slope heterogeneity. If cross sections are dependents, it means that changes in the amount of one policy variable in one cross section can bring changes in the amount of the same and other policy variables in other cross sections. Therefore, Cross-sectional variations in the policy variables are interdependent. Since the amount of CO_2 emissions is linked with trade, cultural, and social preferences therefore the policy makers can determine the amount of CO_2 emissions by keeping in view the approaches and priorities to the abovementioned factors.

More specifically based on the available research and evidence, here are some policy recommendations and suggestions for achieving sustainable levels of environmental emission and economic growth:

1. Implement carbon pricing: A carbon tax or cap-and-trade system can help to internalize the costs of carbon emissions, which can motivate production units to adopt environmental friendly practices.
2. Development of renewable energy: The one feasible way to reduce emission of greenhouse gases is the promotion of renewable energies. Governments should promote the production of renewable energy and should replace non-renewable with renewable.
3. Promote energy efficiency: Energy efficiency measures can help reduce energy consumption, lower greenhouse gas emissions, and save money for households and businesses. This can be achieved through building codes, appliance standards, and public awareness campaigns.

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