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The nexus between poverty, inequality and environmental pollution: Evidence across different income groups of countries

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ABSTRACT

Even though the literature has extensively focused on a number of determinants of environmental pollution, it lacks to incorporate the importance of poverty and inequality on the environment. The nexus of poverty-inequality-environment is indeed in line with the agenda of the United Nations' Sustainable Development Goals. Furthermore, the existing studies usually rely on carbon dioxide (CO2) emissions as the proxy for the pollution in their analysis. This study fills the mentioned gaps by investigating the impacts of income inequality and poverty on environmental pollution using ecological footprint (a comprehensive measure of the pollution) in addition to CO2 emissions for 70 countries categorized by income groups. This research employs the dynamic panel system Generalized Method of Moments (GMM) and the Dumitrescu-Hurlin Granger causality techniques which are strong to several econometric issues that may frequently arise in the estimation procedures. The empirical outcomes show that income inequality and poverty increase carbon emissions and ecological footprint in the entire panel. However, when the panel is split into groups, the results indicate that income inequality mitigates carbon emissions and ecological footprint in high-income group but aggravates them in middle-income group. Though poverty has no significant impact on carbon emissions in high-income group, it raises the levels of carbon emissions and ecological footprint in middle-income group. This study overall implies that income inequality and poverty are significant determinants of environmental pollution. Hence, efforts to abate environmental degradation should give adequate attention to poverty and inequality in order to attain environmental sustainability.

1. Introduction

Poverty eradication and sustainable development have emerged as key global concerns in the present world, especially following the "United Nations (UN) World Summit on Sustainable Development" in 1992 and the "UN Conference on Environment and Development" in 2002. Besides, poverty reduction in conjunction with environmental preservation is the focus of UN "Sustainable Development Goals" (SDGs). In the last few decades, some progress has been shown in alleviating poverty across countries, however, poverty rates are still high particularly in underdeveloped countries. Searching the ways to reduce poverty coupled with environmental protection has increasingly become a complex and challenging issue for the developed and developing economies, especially following SDGs endorsed in 2015. New findings reveal that ecological disruption will create more than 68 million poor into the poverty trap up to 2030. Particularly, people residing in Africa and Asia are more exposed to hardships of the global warming because the poor of the contemporary world are concentrated in these regions (World Bank, 2020).

Addressing the twin issues of poverty eradication and environmental conservation will help to achieve sustainable development goals; however, growth-oriented policies put pressure on ecological systems, making the links between the poor and the environmental changes more complicated. In developing countries, economic growth is prioritized compromising environmental preservation (Baloch et al., 2020b). Managing the poor requires encouraging growth-oriented policies because growth has been shown favorable for the poor (Dollar, 2002: Majeed, 2015). Furthermore, economic growth and related economic

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activities increase the demand for natural resource extraction and use mainly through agriculture, deforestation, mining, and industrialization which are associated with environmental unsustainability (Langnel et al., 2021). In contrast, some studies also suggest that growth alleviates pressure on the ecological footprint (York et al., 2003; Moran et al., 2008; Majeed et al., 2021b). These studies suggest that an increase in economic growth escalates the real income of economic agents and their affordability and willingness to pay for environmental amenities. Besides, the growth supported by innovations and environmentally friendly technologies alleviates ecological pressure. Thus, it is generally believed that the connection between the poor and the environmental changes is rather complex. In this milieu, untangling the poverty-environment nexus remains a key concern among development practitioners and environmental economists to ensure a sustainable outlook.

The extant literature on poverty and the environment nexus offers two competing approaches. First, the trade-off approach suggests poverty reduction and environmental degradation go together (Shuai et al., 2019; Finco, 2009). The key argument is that the poor use natural resources for their survival and livelihood. The unsustainable use of natural resources degrades the environment and breeds the poverty exploit. Second, the win-win approach suggests that poverty reduction and environmental conservation can be managed simultaneously. In this respect, Masron and Subramaniam (2019) suggested that poverty reduction and ecological sustainability are akin to "killing two birds with one stone". The available empirical literature on the poverty and environment nexus provides conflicting results. On the one hand, a dominant group of studies has exhibited environmental deteriorating effects of poverty. For instance, Baloch, et al. (2020b) for 40 Sub-Saharan African (SSA) economies over the period 2010–2016, Koçak et al. (2019) for 48 SSA economies over the period 2010–2016, Masron and Subramaniam (2019) for 50 developing countries over the period 2001–2014, Khan (2019) for Association of Southeast Asian Nations (ASEAN) over the period 2007–2017 support the trade-off approach. Contrary to this, a few studies have also shown that poverty supports environmental conservation (Nabi et al., 2020; Islam et al., 2017). Meanwhile, few studies have produced mixed effects of poverty on environmental quality (Rizk and Slimane, 2018; Swinton and Quiroz, 2003). Some studies have shown a bilateral association between poverty and the environment (Bikorimana and Sun, 2020; Rizk and Slimane, 2018; Saliu et al., 2007; Onwuka, 2005). Though the literature suggests endogeneity between poverty and the environment, its treatment is overlooked in empirical studies.

The empirical studies mainly focus on different groups of countries and do not provide global evidence in a comparative setting. Besides, the studies did not address the issue of endogeneity between poverty and the environment. Another major issue with the existing literature is that the studies measure the environment employing the indicator of CO2 emissions (Baloch et al., 2020b). The use of emissions, however, just represents an individual aspect of environmental degradation. The environmental loss is attributed to other parts as well such as the loss of soil stock, forest cover, mineral stock, and oil sock. Besides, the poverty-environment nexus might not be truly captured by CO2 emissions because increasing emissions cannot be solely attributed to the poor segment of society. Thus, findings can mislead policymaker when the result mainly rely on CO2 emissions. Contrary to this ecological footprint (EFP) constructed by Wachernagel and Rees (1996) is a comprehensive and suitable measure of the environment. This measure also comprises CO2 emissions within the carbon footprint. Besides, it helps to understand the need for the regeneration of biological capacity in response to anthropogenic pressures on the ecosystems (Kitzes and Wackernagel, 2009). In sum, it can be referred to as the pressure of anthropogenic activities on the natural environment.

Given the above premises, we expand the literature on poverty, inequality and the environment nexus by addressing the following three research questions: (1) What are the impacts of income distribution and poverty on environmental pollution in panels of global, middle-income and high-income countries over the period 2000–2018; (2) Do these impacts vary across global (whole) sample, high-income countries and middle-income countries?; (3) Does the use of CO2 emissions and ecological footprint (EFP) as proxies for environmental pollution reveal different outcomes? In this respect, this research contributes to literature by covering the following literature limitations. First, the existing studies do not deliver a clear connection and consensus between the poverty-inequality-environment nexus. Second, the majority of existing studies use CO2 emission as a proxy for environmental pollution, which just measures one dimension of environmental degradation and provides an incomplete picture of the poverty-environment nexus. This study employs EFP to better represent the environmental changes as this measure is a more inclusive and strong reflection of environmental pressures. Third, unlike prior studies which ignore econometrics issues such as potential endogeneity, unobserved individual country-oriented effects, and error correlations, we use the system GMM estimator to tackle these issues. Fourth, we provide global evidence as well as evidence in a comparative setting of the high-income and middle-income countries in contrast to single-country case studies. Fifth, to unveil the causal associations between the series, this study utilizes the Dumitrescu and Hurlin (2012) approach to examine the causal relationship. This framework can control for the heterogeneous and cross-sectionally dependent nature of the variables. The estimated results of the present study are helpful for development practitioners, environmental economists, energy experts, political scientists, and international organizations.

The remaining sections are organized as follows: Section 2 delivers a literature review on poverty and environment nexus. Section 3 gives information about the model and data, while section 4 represents methods and empirical findings. Section 5 offers the conclusion along with some suitable policy suggestions.

2. Literature review

A growing stream of research has focused on GDP, and energy consumption to explain environmental issues. The mainstream economists largely focused on development strategies that help to escalate the growth rate of the global economy. Meanwhile, environmental concerns of growth are overlooked as the dominant view in the developing world had been prevailed "grow first, clean up later" (Rock and Angel, 2007). Resultantly, environmental loss and global warming have become the key concerns of the contemporary global economy. Now, the growth-environment nexus is increasingly receiving attention from all over the world.

The relationship of growth with environmental issues is explored in two manners. First, an extensive number of studies postulated a nonlinear link between economic prosperity and the environmental changes referred to as the "Environmental Kuznets Curve" following the pioneering research by Grossman and Krueger (1995). The studies have produced mixed evidence and to date, the validity of EKC remains a heated topic of discussion and analysis (Dogan et al., 2020; Majeed & Mazhar, 2019, 2020; Destek et al., 2018; Apergis and Ozturk, 2015). Second, many studies have analyzed the role of growth in a linear framework focusing on "Population, Affluence, and Technology (STIRPAT)" as the main control variables where economic growth is considered a proxy of affluence (Fan et al., 2006; Majeed and Tauqir, 2020). However, the results of affluence also remain inconclusive. Many studies documented environmental enhancing effects of economic growth while many have shown environmental deteriorating effects of economic growth (Khan, 2019; Masron and Subramaniam, 2019).

This led to a plethora of research studies that explored other avenues of the environmental and growth nexus such as sources of energy, degree of urbanization, and status of FDI inflows. A consensus is gradually emerging among researchers that conventional inputs of energy such as coal, gas, and oil harm the environment whereas clean inputs of energy

like renewable energy improve the environment (Majeed and Tauqir, 2020; Majeed and Luni, 2019; Inglesi-Lotz and Dogan, 2018). Thus, an ample body of literature has focused on GDP and energy to explain environmental issues. However, there is a growing concern that environmental issues cannot be fully resolved through GDP and energy only as long as the bottom billion poor are not considered in the solution.

2.1. Poverty and the environment nexus

In the literature two schools of thought have become apparent regarding poverty-environment connectedness. The first school of thought proposes a trade-off approach where economies can compromise the environmental quality or the poor (Collins and Zheng, 2015), whereas the second school of through suggests a win-win association between poverty and the environment (Jin et al., 2020). That is, poverty eradication and environmental preservation can be managed simultaneously. The win-win approach suggests that if factors mitigating environmental loss also support in poverty alleviation, economic prosperity will be boosted, and economies are likely to manage the clean environment (Baloch et al., 2020b). According to the trade-off approach, the elements which help to control ecological loss also breed poverty creating a trade-off scenario between social and ecological aspirations. The roots of such an issue can be traced from the tirade complex relationships between energy, ecosystem, and growth. The growth is vital to help the poor (Dollar and Kraay, 2002; Majeed, 2015) while rapid and long-term growth is essentially dependent on energy inputs. In the case of developing countries where poverty incidents are high, demand for energy is largely met by nonrenewable energy sources which pollute the environment (Majeed and Luni, 2019; Inglesi-Lotz and Dogan, 2018). Over the last few decades, many economies have demonstrated high growth rates uplifting the poor from the poverty traps. However, at the same time, environmental quality is compromised. For example, China has managed to lower poverty and high growth but also it is categorized as the high polluting economy in the global environmental rankings. Besides, greenhouse gas (GHG) mitigation strategies may shift industrial structure creating employment and livelihood challenges (Jin et al., 2020).

Besides, the "vicious circle model" suggests that a limited number of people can benefit from the natural resources and beyond that environmental degradation go on (Lawson et al., 2012). Recently, Shuai et al. (2019) developed a "coupling coordination model" to explore the environment-poverty nexus for rural China. They showed that poverty and environmental degradation couple each other and follow a vicious circle. That is, the poor overexploit the natural resources and the shortage of resources breeds poverty and so on. Usually, property rights are not efficient in the case of natural resource use and management. Natural resources are treated as a public good as they can be easily accessed. The undernourished people use natural resources in such a manner that sustainability is compromised, and the environment tends to deteriorate. Finco (2009) claimed that the people treat the natural resources as public goods because their property rights are not well defined, and their access is common. Consequently, the impoverished people tend to overexploit the resources without taking care of their sustainability. Hence, the depletion of natural resources augments environmental problems.

Another theoretical perspective, supporting trade-off view, is described through the "energy ladder" model which postulates that people belonging to high-income groups substitute primary energy inputs like animal dung and woodfire towards refined but costly energy inputs like kerosene and gas (Arnold et al., 2003). Contrary to this, the people associated with the low-income group rely generally on environmentally uncaring energy inputs such as their dependency on the firewood and disproportionally wood-burning pollutes the atmosphere. Further, illiteracy and unawareness related to the need for, and importance of a clean environment is leading to environmental degradation on the part of the poor. One strand of the literature, supporting trade-off view, links poverty and environment nexus through agricultural activities in developing countries. For instance, it is argued that poverty contributed to methane (CH_4) discharge. Since the poor of the developing countries mainly belong to the agriculture sector, their contribution to global CH_4 is the highest. Anthropogenic actives contribute two-third of methane emissions and key activities that discharge methane are biomass burning, ruminant animals and rice farming (Umweltver änd erungen 2011). More recently, Subramaniam and Masron (2020) explored the methane emission and poverty relationship for 22 developing economies over the period 1990–2016 employing the autoregressive distributed lag (ARDL) method. They provided evidence that poverty is the source of emissions discharge.

Contrary to this, the second school of thought underscores the importance of win-win choice by resolving both issues through improving environmental and developmental conditions and lowering poverty incidence (Masron and Subramaniam, 2019). The supporters of this approach view that focusing on the factors which enhance poverty eradication and empower environmental quality, simultaneously, can support both the environment and the poor. For example, Swinton and Quiroz (2003) claimed that farming practices by the poor farmers can compensate the natural resource loss. Besides, Gentle and Maraseni (2012) argued that climate-related effects create more problems when the livelihood of the inhabitants of a location largely depends on rain-fed farming land. Similarly, Jin et al. (2020) argued that a decoupling alliance persists between poverty alleviation and environmental degradation.

Among the studies that support a trade-off between poverty and CO2 emission, Swinton and Quiroz (2003) assert that poverty is a potential determinant of environmental loss. They employ four indicators of environmental loss namely "*soil erosion, soil fertility decline, overgrazing, and deforestation*" based on a survey data of 265 farms during 1999 for Peru. They use Probit model for empirical analysis. Their findings reveal a clear association between poverty and deforestation. The poor households in Peru overexploit natural forests for heating and cooking, thereby degrading natural resource preservation. However, they also showed that such losses are compensated by farming practices by the poor farmers. Swinton and Quiroz (2003) mainly focused on Peru and their findings may not represent other economies.

Koçak et al. (2019) explored an association between poor and the environment for 48 Sub-Saharan African economies over the period 2010–2016 by employing CO2 emissions as a proxy of the environment. Their empirical findings suggest a trade-off between poverty and CO2 emissions. In a successive study, Baloch, et al. (2020b) also confirm a choice between poverty and environmental pollution for 40 Sub-Saharan African economies over the span of 2010–2016. Masron and Subramaniam (2019) also proved poverty as the key factor of environmental loss in fifty developing countries from 2001 to 2014. Khan (2019) determined the role of poverty for environmental quality under the circumstance of logistical operations using panel data of the ASEAN over the period 2007–2017. The findings confirm that both poverty and logistical operations significantly increase environmental loss. Since the poor posses' low skills and largely depend on natural resource consumption, the overuse of natural resources deteriorates ecological quality. Dhrifi et al. (2020) for developing economies also confirmed a positive association between poverty and CO2 emissions. These studies measure the environment with CO2 emissions which a narrow measure of environmental quality. Though Baloch et al. (2020b) measured the environment with ecological footprint but their findings mainly represent SSA countries.

Among the studies that support a win-win approach for poverty eradication and CO2 emissions mitigation, Islam et al. (2017) confirmed a negative influence of poverty on carbon emission in the case of Malaysia, Indonesia, and Thailand. Meanwhile, Rizk and Slimane (2018) suggested a nonmonotonic association between poverty and environmental pollution. One group of empirical research papers has demonstrated a bilateral causality between the poor and the

environment (Bikorimana and Sun, 2020; Rizk and Slimane, 2018; Saliu et al., 2007; Onwuka, 2005). Bikorimana and Sun (2020) explored the association between poverty and deforestation in Rwanda from 1980 to 2016. They used cointegration and Granger causality tests. Their findings confirm the bilateral relationship between poverty and deforestation. Rizk and Slimane (2018) assert a two-way association between the poor and the environment because the poor act as both as an agent and victim. The empirical studies mainly use CO2 emissions as the proxy of the environment, focus on country-specific evidence or a group of countries and ignore the issue of endogeneity. Besides, conflicting evidence on poverty and the environment nexus and the needs for global evidence in a comparative setting motivates the present research.

2.2. Inequality and the environment nexus

Along with growing literature on poverty and environment nexus, parallel development is going on to explore the inequality and the environment nexus. Following the pioneering study of Boyce (1994) many studies have attempted to provide decisive outcomes on inequality and the environment nexus (Langnel et al., 2021; Baloch et al., 2020a; Uzar and Eyuboglu, 2019; Masud et al., 2018; Jorgenson et al., 2017a,b; Grunewald et al., 2017; Wolde-Rufael and Idowu, 2017; Zhang and Zhao, 2014). The key argument behind this thread of the literature is that it is not just income growth, but relative income growth also plays a key role in explaining environmental issues. Theoretical literature proses the following theories to explain the inequality-environment nexus. First, the "political economy approach (PEA)" focuses on power allocation between the wealthy and the impoverished people and its interaction with the environmental reforms (Boyce, 1994). Second, "marginal properties to emit (MPE)" evaluates households' consumption responses to income changes which influence the inequality-environment nexus (Ravallion et al., 2000). Third, Veblen (1899) proposes "Emulation Theory (ET)" to explain the inequality-environment nexus. Theory, however, predicts conflicting outcomes of higher inequality on environmental loss. Higher inequality supports environmental conservation as the rich can invest in green and modern technologies and they value the environment and demand higher environmental quality. Contrary to this, the rich exploit the environment as they mainly focus on production activities instead of the negative external effects of such activities on the environment.

The empirical literature is also providing conflicting outcomes. One strand of the literature has shown the environmental hazard of increasing inequality in society (Uzar and Eyuboglu, 2019; Baloch et al., 2020a; Zhang and Zhao, 2014; Masud et al., 2018; Jorgenson et al., 2017a,b). Another strand of the literature found a favorable impact of inequality on the economy (Langnel et al., 2021; Grunewald et al., 2017). Further, some studies do not find it as a significant determinant of environmental changes (Wolde-Rufael and Idowu, 2017).

Using the ARDL approach over the period 1984–2014, Uzar and Eyuboglu (2019) showed that income inequality boosts carbon emissions in Turkey. Their finding authenticates the political economy approach. Baloch et al. (2020a) also confirmed the detrimental impact of inequality on environmental quality for 40 African countries covering the period from 2010 to 2016. They consider inequality as responsible for enhancing carbon emission in African economies. Zhang and Zhao (2014) revealed that inequality aggravates carbon emissions in China and contended that efforts to mitigate carbon emissions should consider a more equitable income distribution. Similarly, Masud et al. (2018) also showed the adverse influence of the income gap on the environment in ASEAN-5 countries using the data from 1985 to 2015. Comparable results are shown by Jorgenson et al. (2017a,b) for the USA. Ekeocha (2021) reported that income inequality raises the level of EFP in Africa covering the period 1996–2014. However, Langnel et al. (2021) reported that income inequality mitigates EFP in ECOWAS member countries. Grunewald et al. (2017) argued that the connection between inequality and carbon emission depends on the income level. Based on a panel of 158 economies from 1980 to 2008, their findings suggest that the income gap increases CO2 emission in upper-income economies while decreasing the emission in lower-income economies. However, Wolde-Rufael and Idowu (2017) claimed that inequality is not a significant driving force of carbon emissions in China and India.

The literature on poverty, inequality, and the environment nexus exhibits certain limitations. First, the literature is fairly limited in the arena of environmental effects of poverty and inequality incidence. Second, the literature is not yet conclusive as the results are sensitive to the environmental proxy, country choice, and estimation method. Third, the studies generally rely on CO2 emission as a measure of environmental loss or a single dimension of the natural resource. Fourth, the empirical outcomes of the aforementioned studies exhibit divergent and conflicting conclusions. In this milieu, the present research aims to contribute to the empirical stream of the literature by determining the effects of poverty and inequality on environmental quality for a global panel of 70 countries and segregated panels of high and middle-income economies by employing CO2 emissions as well as EFP as the proxy of environmental quality which is more comprehensive and representative in the case of poverty and inequality issues.

3. Methodology and data

3.1. Model specification

To determine the impacts of income inequality and poverty on environmental degradation, this study employs the following model which is consistent with the extant literature (Wolde-Rufael and Idowu, 2017; Khan, 2019; Baloch et al., 2020a; Langnel et al., 2021):

$$ENV_{it} = \alpha_0 + \alpha_1 ENV_{it-1} + \alpha_2 GINI_{it} + \alpha_3 POV_{it} + \alpha_4 GDP_{it} + \alpha_5 ENC_{it} + \varepsilon_{it} \quad (1)$$

where ENV = environmental degradation (proxy by CO2 emissions in metric tons per capita as well as ecological footprint of consumption per capita), ENV_{it-1} = one period lagged of environmental degradation, $GINI$ = income inequality (proxy by Gini index), POV = poverty (proxy by poverty headcount ratio at $1.90 a day as % of population, and alternatively by poverty headcount ratio at national poverty lines as % of population), GDP = real GDP per capita (in 2010 constant USD), ENC = energy consumption (in kg of oil equivalent per capita), ε = error term. We use carbon emissions and ecological footprint as proxies of environmental degradation to aptly capture different dimensions of environmental degradation. For instance, carbon dioxide emissions is deemed as the greatest contributor to the mounting greenhouse gases that degrade the environment, exacerbate global warming and climate change (Ehigiamusoe et al., 2020). Moreover, carbon emissions occupy vital position in the on-going debates on the mitigation of climate change, environmental protection and sustainable development (Charfeddine and Khediri, 2016; Ehigiamusoe et al., 2019). However, some studies contended that carbon dioxide emissions does not encapsulate other aspects of environmental degradation (Ulucak and Apergis, 2018; Usman & Hammar, 2021). Therefore, we complement carbon dioxide emissions with ecological footprint. The latter is a reliable tool to evaluate the environmental pressure exerted by human activities in the ecosystem for consumption and waste absorption (Rudolph and Figge, 2017). It has been argued that ecological footprint is a comprehensive proxy of environmental degradation since human activities influence the ecological atmosphere, deteriorate the land and water quality (Wang and Dong, 2019). Precisely, the ecological footprint is calculated by assessing the effects of human activities on six bioproductive types of land use (i.e., cropland, grazing land, forest land, build-up land, fishing grounds and carbon sequestration land).

In line with the extant literature, we proxy income inequality with GINI index (Masud et al., 2018; Uzar and Eyuboglu, 2019; Zhang and Zhao, 2014). Similarly, following the existing literature, we proxy

poverty by poverty headcount ratio at $1.90 a day as % of population (Baloch et al. (2020a). For robustness check, we use another proxy namely, poverty headcount ratio at national poverty lines as % of population which is consistent with some previous studies (Khan, 2019; Masron & Subramaniam, 2019). The Environment-Energy-Output (EEO) model employed in this study is appropriate to determine the impacts of poverty and income inequality on environmental degradation. The EEO model contends that energy consumption and output growth are significant determinants of environmental degradation (Ang, 2007; Itkonen, 2012). Empirical literature opined that an expansion in the economy or output growth has the capacity to worsen environmental degradation (e.g. Charfeddine and Khediri, 2016; Ehigiamusoe, 2020c). Similarly, energy consumption has the propensity to aggravate environmental degradation especially when energy are sourced from non-renewable resources such as fossil fuels (e.g. Dogan and Seker, 2016; Ehigiamusoe, 2020b). We augmented the EEO model with poverty and income inequality in line with some previous studies (e.g., Baloch et al., 2020a; Masron and Subramaniam, 2019; Khan, 2019; Uzar and Eyuboglu, 2019; Langnel et al., 2021). To capture persistency in environmental degradation, we added one period lagged of environmental degradation to the model, which is consistent with some previous studies (Baloch et al., 2020a; Ehigiamusoe, 2020a).

3.2. Estimation technique

This research uses the dynamic panel system Generalized Method of Moments (GMM) estimator developed by Arellano and Bover (1995). The justification for choosing this estimator is because it can control for potential endogeneity, country-specific effect and autocorrelation. This is fundamental because the addition of the lagged dependent variable in the model triggers autocorrelation concerns. Compared to the first-difference GMM suggested by Arellano and Bond (1991), the system GMM estimator blends the difference equation and level equation, as well as utilizes additional moment conditions as instruments. Since environmental degradation, income inequality, poverty, GDP, and energy consumption are fairly persistent, the system GMM is suitable for this research. To ascertain the consistency of the system GMM estimator, this study conducts two tests namely: Sargan test of over-identifying restriction to ascertain the joint validity of the instruments, and the Arellano and Bond test for autocorrelation to determine the presence of serial correlation. To unveil the causal relationship between the variables, this study utilizes the Dumitrescu and Hurlin (2012) Granger non-causality technique. This bivariate framework can control for heterogeneity and cross-sectional dependence.

3.3. Data description and sources

This study uses panel data of 70 countries covering the 2000–2018 period. The number of cross-section (N) is large relative to the number of time (T), which is appropriate for the GMM estimator that requires large number of N and small number of T. Roodman (2009) noted that the use of a small number of N relative to T could raise the number of instruments and cause too many instruments' problems. This study conducts the analysis in two levels. First, we run the analysis for the entire panel of 70 countries. These countries were selected based on availability of data on poverty and income inequality for the period. Second, we split the countries into two panels of high-income group ($12,536 or above) and middle-income group ($1,036–$12,535) based on World Bank (2020) classification of countries according to their income levels. Thus, our sample consists of 35 high-income countries and 35 middle-income countries. The selected countries are representatives of the income groups since our sample covers most of the high-and middle-income countries from different geographical regions (e.g., Asia, Africa, Europe, South America, North America, Australia/Oceania) of the globe. The low-income countries ($1,035 or below) were excluded from the study due to unavailability of data on poverty and income inequality for almost all countries. Besides, the scope of this study is dictated by data availability. The appendix Table A1 contains the lists of countries included in this study. Regarding data sources, the data of carbon dioxide emissions, income inequality, poverty, real GDP per capita and energy consumption were obtained from the World Development Indicators (2021) published by the World Bank, whereas the data of EFP were sourced from the Global Footprint Network, 2020.

4. Empirical results

4.1. Descriptive statistics and correlation analysis

Table 1 illustrates the descriptive statistics and correlation analysis of the variables. It shows widespread discrepancies in the variables across the income groups. The average carbon emissions, EFP, income inequality and poverty are 6.0 metric tons per capita, 4.1 global hectare per person, 37.9 and 4.7% respectively. The corresponding standard deviations of 4.5, 2.4, 9.4, and 9.5 reveal that the variables are quite spread around the means. When the panel was split into high- and middle-income groups, we observed that carbon emissions and EFP are higher in high-income group while income inequality and poverty are higher in middle-income group. The correlation analysis shown in the lower panel of Table 1 indicates that income inequality and poverty have negative relationships with carbon emissions and EFP in all the panels, whereas GDP and energy consumption have positive correlations with carbon emissions and EFP.

Figs. 1–4 show the graphical analysis of carbon dioxide emissions, ecological footprint, income inequality and poverty in all the panels. The trends indicate that CO2 emissions and EFP were higher in high-income countries compared to middle-income countries. However, CO2 emissions and EFP gradually decreased in high-income countries but

Table 1
Descriptive statistics and correlation analysis.

	CO2	EFP	GINI	POV	GDP	ENC
Full panel						
Mean	6.012	4.117	37.911	4.709	20483.8	2603.9
Min.	0.154	0.099	23.700	0.100	765.18	359.60
Max.	24.824	17.777	64.800	65.800	111968	9428.8
Std. Dev	4.502	2.439	9.403	9.479	22232	1895.3
CO2	1					
EFP	0.885	1				
GINI	−0.428	−0.464	1			
POV	−0.408	−0.430	0.545	1		
GDP	0.649	0.792	−0.448	−0.355	1	
ENC	0.908	0.876	−0.504	−0.414	0.778	1
High-income						
Mean	8.457	5.668	33.004	0.736	35898.3	3799.7
Min.	1.775	0.099	23.700	0.100	4899.1	799.3
Max.	24.824	17.777	56.700	15.400	111968	9428.8
Std. Dev	4.242	2.334	5.867	1.504	22450.4	1785.6
CO2	1					
EFP	0.847	1				
GINI	−0.179	−0.260	1			
POV	−0.315	−0.333	0.640	1		
GDP	0.518	0.685	0.312	−0.359	1	
ENC	0.843	0.795	−0.331	−0.360	0.670	1
Middle-income						
Mean	3.568	2.566	42.818	8.681	5069.4	1408.1
Min.	0.154	0.769	24.000	0.100	765.18	359.6
Max.	15.646	8.046	64.800	65.800	15190	5167
Std. Dev	3.257	1.280	9.712	12.082	3061.1	1066.5
CO2	1					
EFP	0.835	1				
GINI	−0.246	−0.200	1			
POV	−0.341	−0.412	0.448	1		
GDP	0.533	0.551	0.163	−0.404	1	
ENC	0.943	0.791	−0.266	−0.343	0.573	1

Notes: CO2 = carbon dioxide emissions, EFP = ecological footprint, GINI = income inequality, POV = poverty, GDP = real GDP per capita, ENC = energy consumption.

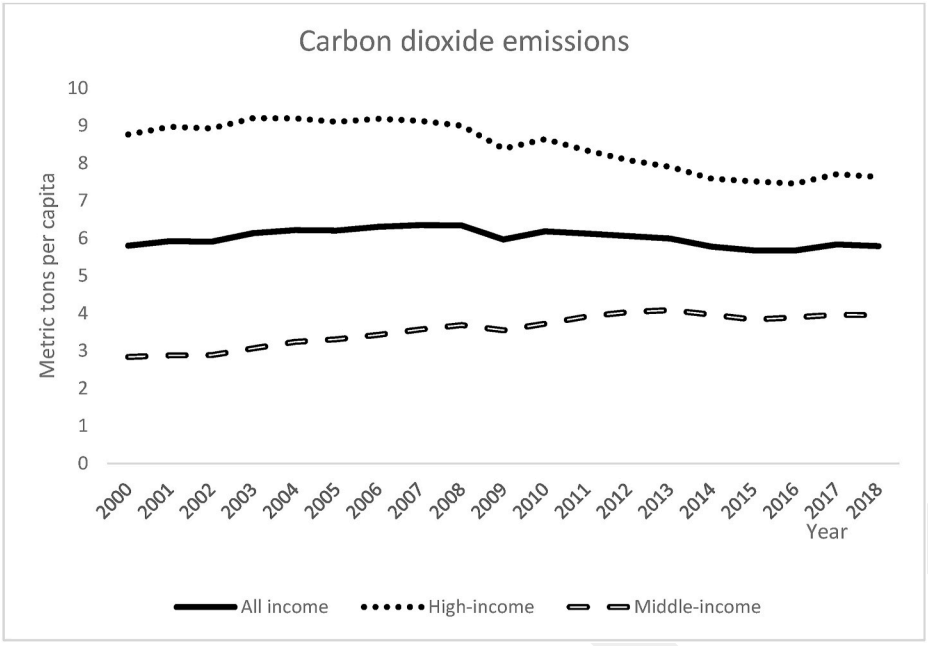

Fig. 1. Graphical analysis of CO2 emissions in high- and middle -income countries
Source: Drawn by the authors from data obtained from the World Development Indicators.

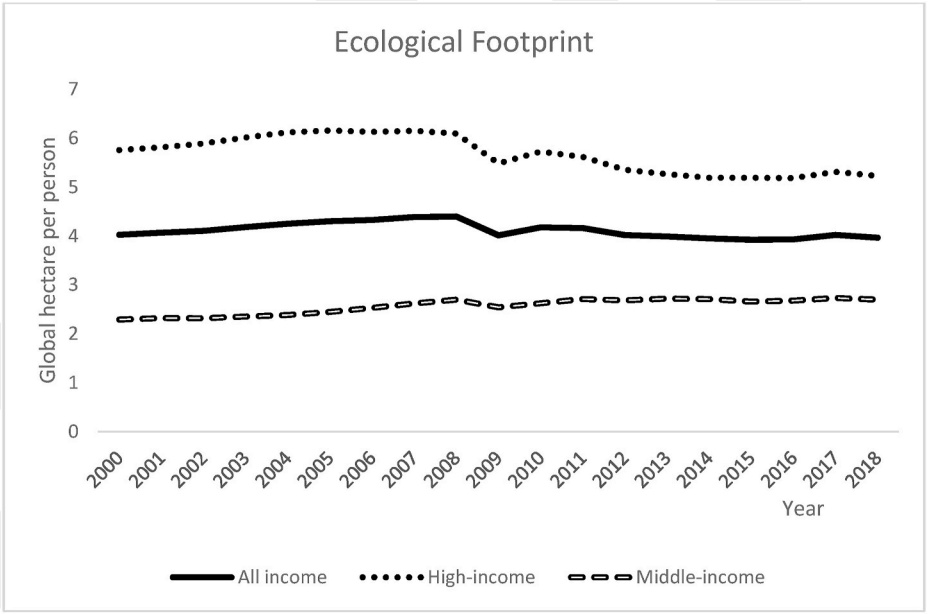

Fig. 2. Graphical analysis of ecological footprint in high- and middle -income countries
Source: Drawn by the authors from data obtained from the Gl
obal Footprint Network.

marginally increased in middle-income countries during the period. Conversely, income inequality and poverty were higher in middle-income countries relative to high-income countries. Though income inequality marginally fell in high- and middle-income countries, poverty declined significantly in middle-income countries compared to high-income countries during the period.

4.2. GMM estimations

4.2.1. Carbon dioxide emissions, income inequality and poverty

Table 2 displays the GMM estimations of the impact of income inequality and poverty on carbon emissions in heterogeneous panels. In Column 1, the results show that income inequality has a positive and significant impact on carbon emissions in the entire panel. Specifically, one percent increase in income inequality will increase carbon emissions by 0.037 percentage points. However, when the panel is split (Columns 2 & 3), the coefficients of income inequality is negative and significant in high-income group but positive and significant in middle-income group. This suggests that one percent increase in income inequality will diminishes carbon emissions by 0.144 percentage points in high-income group but exacerbates carbon emissions by 0.265 percentage points in middle-income group. The detrimental effect of income

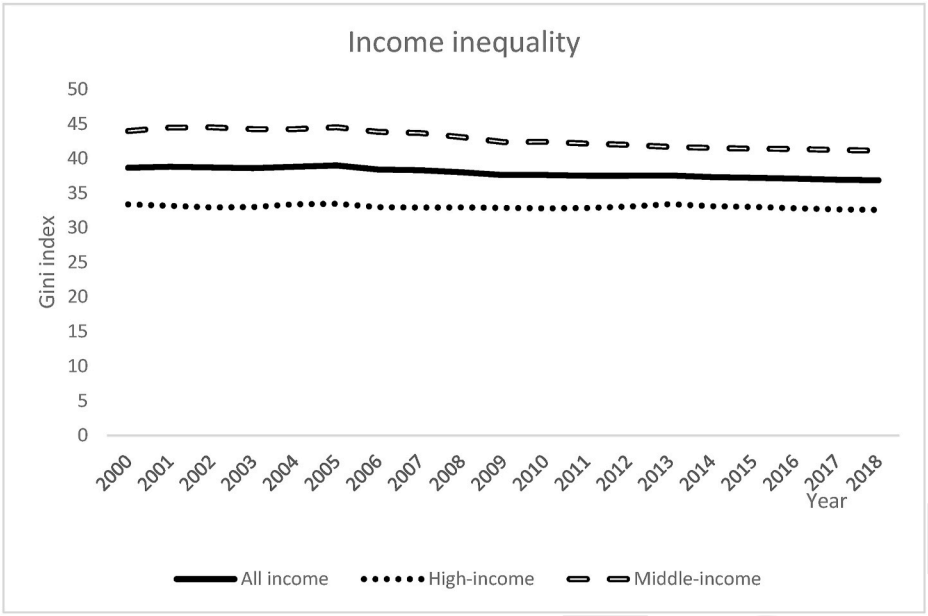

Fig. 3. Graphical analysis of income inequality in high- and middle -income co
Source: Drawn by the authors from data obtained from the World Development Indicators.

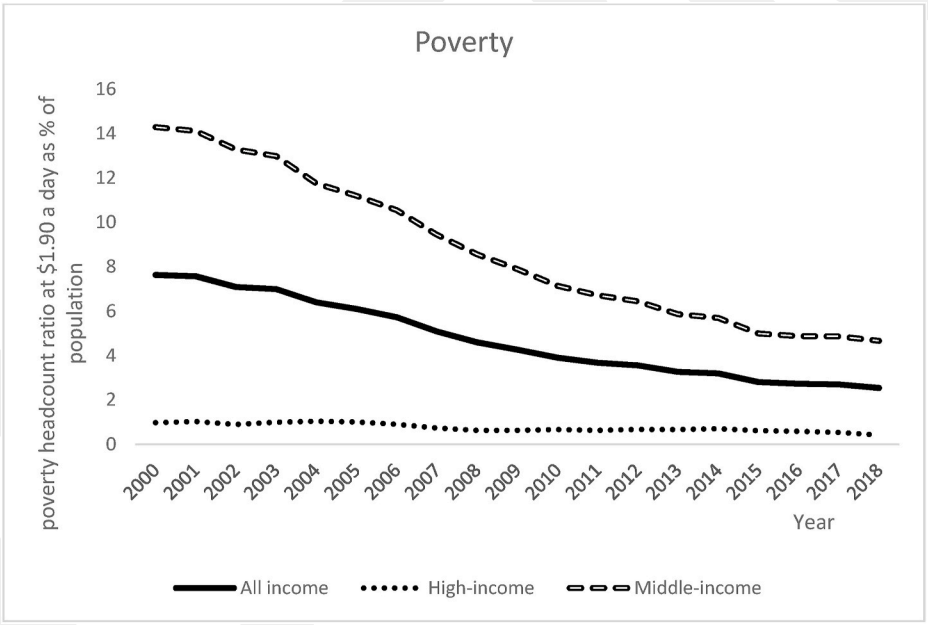

Fig. 4. Graphical analysis of poverty in high- and middle -income countries
Source: Drawn by the authors from data obtained from the World Development Indicators.

inequality found in our study is consistent with Baloch et al. (2020a) in 40 African nations. Uzar and Eyuboglu (2019) also revealed that income inequality has a detrimental impact on carbon emissions in Turkey. They argued that a deterioration in income distribution will degrade the environment. Zhang and Zhao (2014) revealed that income inequality aggravates carbon emissions in China, and contended that efforts to mitigate carbon emissions should consider a more equitable income distribution. However, Wolde-Rufael and Idowu (2017) posited that income inequality is not a significant determinant of carbon emissions in China and India. The negative coefficient of income inequality found in high-income group is consistent with Masud et al. (2018) in ASEAN-5 and Jorgenson et al. (2017a,b) in USA.

Furthermore, our results indicate that poverty has a positive and significant impact on carbon emissions in the entire panel and middle-income group, while the impact is insignificant in high-income group. Precisely, one percent rise in poverty will raise the level of carbon emissions by 0.007 percentage points and 0.015 percentage points in the entire panel and middle-income group respectively. However, variations in poverty cannot explain variations in carbon emissions in high-income group. The detrimental impact of poverty found in our study agreed with some studies (Baloch et al., 2020a). The harmful impact of poverty on carbon emissions found in middle-income group is consistent with Masron and Subramaniam (2019) who noted that comprehensive environmental policies should also target poverty alleviation to ensure environmental sustainability in 50 developing nations. Khan (2019) reported that poverty aggravates environmental degradation in ASEAN.

Table 2
Dynamic panel GMM estimations (Dependent variable: carbon dioxide emissions).

Variables	Full panel	High-income	Middle-income
Lagged dependent variable	0.387***	0.254***	0.294***
	(0.001)	(0.007)	(0.014)
GINI	0.037***	−0.144***	0.265***
	(0.008)	(0.025)	(0.066)
POV	0.007***	0.002 (0.001)	0.015***
	(0.001)		(0.005)
GDP	−0.147***	−0.187***	0.034***
	(0.007)	(0.013)	(0.008)
ENC	1.064***	1.186***	0.868***
	(0.011)	(0.021)	(0.019)
Constant	−5.928***	−5.710***	−6.757***
	(0.093)	(0.192)	(0.290)
Sargan Test (p-value)	65.339 (0.328)	31.928 (0.999)	30.247 (0.999)
First order serial	−4.008	−3.431	−2.452
correlation test (p-value)	(0.000)	(0.000)	(0.014)
Second order serial	−1.832	−1.246	−1.505
correlation test (p-value)	(0.067)	(0.212)	(0.132)
No. of countries	70	35	35

Notes: ***, ** and * indicate statistically significant at 1%, 5% and 10%, respectively. Standard errors are reported in parenthesis.

He argued that poverty contributes to carbon emissions probably because the poor are unskilled, often utilize natural resources in unsustainable way for survival, thereby heightening deforestation and emissions. The poor may lack fuel-efficiency, green vehicles/practices in their operations, and rather rely on fossil fuel consumption that produce higher carbon emissions and other greenhouse gases that degrade the environment. Overall, our findings on the inequality-environment nexus in heterogenous panels are consistent with Grunewald et al. (2017) who argued that the link between inequality and carbon emissions depends on the income level.

As for the control variables in the model, the results show that GDP mitigate carbon emissions in high-income group but aggravate carbon emissions in middle-income group. This finding is consistent with Ehigiamusoe and Lean (2019) who noted that GDP reduces carbon emission in high-income group but increases emissions in middle- and low-income groups. Energy consumption is detrimental to carbon emissions in all income groups. This finding agreed with Ehigiamusoe et al. (2019) and Majeed et al. (2021a) who showed that energy consumption is deleterious to carbon emissions in 64 countries and OECD countries, respectively. Expectedly, the one-period lagged carbon emissions has a detrimental impact on the current level of carbon emissions, suggesting persistence. Ehigiamusoe (2020a) revealed that the past value of carbon emissions influences the current level of carbon emissions in 31 African countries. Some studies have also reported similar empirical outcomes (Khan, 2019: Masron & Subramaniam, 2019).

In all the models, the Sargan test of over-identifying restriction indicate that the insruments are valid. Since the p-value is greater than 5 percent, we cannot reject the null hypothesis of joint soundness of the instruments. Likewise, the Arellano and Bond test for autocorrelation indicate absence of 2nd type serial-correlation. Moreover, the null hypothesis of no second order serial correlation is not rejected since the p-value is greater than 5 percent.

4.2.2. Ecological footprint, income inequality and poverty

To capture other dimensions of environmental pollution, this study use EFP as our dependent variable and redo the analysis. The results displayed in Table 3 are similar to the results shown in Table 2 in term of signs and significance. First, the results indicate that income inequality increases EFP in the entire panel. However, when the panel is split, income inequality mitigates EFP in high-income group but raises the level of EFP in middle-income group. Our finding in middle-income group is consistent with Ekeocha (2021) who reported that income inequality raises the level of EFP in Africa. The mitigating effect of income inequality on EFP in high-income group is consistent with some studies (Langnel et al., 2021).

Table 3
Dynamic panel GMM estimations (Dependent variable: ecological footprint).

Variables	Full panel	High-income	Middle-income
Lagged dependent variable	0.483***	0.355***	0.371***
	(0.011)	(0.022)	(0.038)
GINI	0.024***	−0.131***	0.213***
	(0.009)	(0.025)	(0.035)
POV	0.014***	0.011***	0.016***
	(0.001)	(0.001)	(0.003)
GDP	−0.061***	−0.028***	0.062***
	(0.004)	(0.005)	(0.015)
ENC	0.621***	0.814***	0.435***
	(0.024)	(0.038)	(0.026)
Constant	−3.592***	−4.844***	−3.878***
	(0.173)	(0.384)	(0.218)
Sargan Test (p-value)	66.034 (0.307)	32.821 (0.998)	32.157 (0.999)
First order serial	−4.223	−3.043	−2.728
correlation test (p-value)	(0.000)	(0.002)	(0.006)
Second order serial	1.641 (0.101)	0.703 (0.481)	−1.286
correlation test (p-value)			(0.198)
No. of countries	70	35	35

Notes: ***, ** and * indicate statistically significant at 1%, 5% and 10%, respectively. Standard errors are reported.

Second, our results show that poverty raises the level of EFP in all panels. Baloch et al. (2020b) showed that poverty increases ecological footprint in 46 African nations. Third, the study indicates that GDP mitigates EFP in the entire panel and high-income group but aggravates EFP in middle-income group. The latter finding agreed with Uddin et al. (2017) who revealed that GDP aggravates EFP in 27 countries. Fourth, our results show that energy consumption has a harmful impact on ecological footprint in all panels, a finding consistent with some studies (Charfeddine and Mrabet, 2017; Wang and Dong, 2019). Finally, the diagnostic tests indicate that the Sargan test of over-identifying restriction and the Arellano and Bond test for autocorrelation are satisfactory.

4.3. Robustness checks

We employ alternative proxy of poverty namely, poverty headcount ratio at national poverty lines as % of population (Khan, 2019; Masron & Subramaniam, 2019) and redo the analysis. The empirical outcomes

Table 4
Dynamic panel GMM estimations (alternative proxy of poverty).

Variables	Full panel	High-income	Middle-income
Lagged dependent variable	0.385***	0.318***	0.281***
	(0.002)	(0.016)	(0.013)
GINI	0.060***	−0.106**	0.263***
	(0.007)	(0.061)	(0.017)
POV_line	0.001***	0.008 (0.020)	0.018***
	(0.001)		(0.003)
GDP	−0.153***	−0.137***	0.008 (0.007)
	(0.007)	(0.020)	
ENC	1.069***	1.148***	0.843***
	(0.012)	(0.034)	(0.029)
Constant	−5.991***	−6.224***	−6.389***
	(0.104)	(0.355)	(0.177)
Sargan Test (p-value)	64.012 (0.371)	27.204 (0.393)	31.306 (0.999)
First order serial	−4.099	−3.299	−2.454
correlation test (p-value)	(0.000)	(0.001)	(0.014)
Second order serial	−1.856	−1.228	−1.527
correlation test (p-value)	(0.063)	(0.219)	(0.126)
No. of countries	70	35	35

Notes: ***, ** and * indicate statistically significant at 1%, 5% and 10%, respectively. Standard errors are reported in parenthesis. Dependent variable = carbon dioxide emissions.

displayed in Table 4 are consistent with the estimations reported in Table 2 in terms of sign and significance (albeit the size somewhat differ). In summary, poverty increases carbon emissions in the entire panel and middle-income group but has no significant influence on emissions in high-income group.

Furthermore, we experiment with another proxy of poverty such that $1.90 per day. The estimation results[1] are similar to the empirical outcomes reported in Tables 2 and 4 This implies that the impact of poverty on carbon emissions is not sensitive to the proxy used to measure poverty. By employing EFP as a proxy for environmental pollution, we run separate regressions using poverty headcount ratio at national poverty lines as % of population and poverty gap at $1.90 a day. The empirical outcomes[2] are similar to the results reported in Table 3. This confirms that the impact of poverty on EFP is not sensitive to the proxy used to measure poverty.

4.4. Dumitrescu-Hurlin Granger non-causality

The results of the Dumitrescu-Hurlin Granger non-causality test reported in Table 5 can be summarized as follows: (i) a bidirectional causal relationship between income inequality and carbon emissions in the entire panel. But when the panel was split, there was no evidence of any causality between income inequality and carbon emissions in high-income panel, whereas a bidirectional causality exists between the two variables in middle-income panel. (ii) a bidirectional causality between poverty and carbon emissions in the entire panel. However, when we split the panel, there was no causality from poverty to carbon emissions in high-income panel, although the reverse causality was detected. Conversely, we find a bidirectional causality between poverty and carbon emissions in middle-income panel. (iii) a unidirectional causality from income inequality to EFP in the entire panel and middle-income group, but no causality in high-income panel. (iv) a unidirectional causality from poverty to ecological footprint in the entire panel and middle-income group, whereas a bidirectional causality between the variables in high-income panel. (v) Evidence of unidirectional causality from GDP to carbon emissions and EFP in all the panels. (vi) Evidence of bidirectional causality between energy consumption and carbon emissions (ecological footprint) in the entire panel and high-income panel, whereas one-way causality from energy use to both carbon emissions and EFP in middle-income group.

Fundamentally, a unidirectional causal relationship from income inequality or poverty to environmental degradation suggests that variations in income inequality or poverty can cause variations in environmental degradation. Hence, policies that reduce income inequality or poverty can mitigate environmental degradation. Conversely, a bidirectional causal relationship between income inequality (or poverty) and environmental degradation suggests that the variables reinforce each other.

Table 5
Dumitrescu-Hurlin panel Granger non-causality tests.

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Conclusion
Full Panel				
GINI ≠ CO2	3.237	2.383	0.017	GINI ↔ CO2
CO2 ≠ GINI	3.276	2.494	0.012	
GINI ≠ EFP	2.762	2.031	0.053	GINI → EFP
EFP ≠ GINI	2.272	0.932	0.351	
POV ≠ CO2	3.507	3.152	0.001	POV ↔ CO2
CO2 ≠ POV	3.940	4.390	0.000	
POV ≠ EFP	3.491	3.107	0.001	POV → EFP
EFP ≠ POV	2.998	1.704	0.556	
GDP ≠ CO2	5.508	8.847	0.000	GDP → CO2
CO2 ≠ GDP	2.606	0.587	0.000	
GDP ≠ EFP	5.408	8.564	0.000	GDP → EFP
EFP ≠ GDP	2.462	0.176	0.859	
ENC ≠ CO2	3.414	2.886	0.003	ENC ↔ CO2
CO2 ≠ ENC	3.437	2.952	0.003	
ENC ≠ EFP	4.650	6.404	0.000	ENC ↔ EFP
EFP ≠ ENC	3.517	3.180	0.001	
High- income				
GINI ≠ CO2	3.232	1.674	0.094	GINI ≠ CO2
CO2 ≠ GINI	3.215	1.641	0.100	
GINI ≠ EFP	2.544	0.209	0.771	GINI ≠ EFP
EFP ≠ GINI	2.949	1.106	0.268	
POV ≠ CO2	3.096	1.401	0.161	POV ≠ CO2
CO2 ≠ POV	3.974	3.168	0.001	
POV ≠ EFP	4.187	3.596	0.000	POV ↔ EFP
EFP ≠ POV	3.527	2.360	0.018	
GDP ≠ CO2	5.408	6.054	0.000	GDP → CO2
CO2 ≠ GDP	2.441	0.084	0.933	
GDP ≠ EFP	4.998	5.230	0.000	GDP ↔ EFP
EFP ≠ GDP	2.255	−0.291	0.770	
ENC ≠ CO2	3.475	2.164	0.030	ENC ↔ CO2
CO2 ≠ ENC	6.959	4.634	0.000	
ENC ≠ EFP	5.216	5.669	0.000	ENC ↔ EFP
EFP ≠ ENC	4.010	3.241	0.001	
Middle- income				
GINI ≠ CO2	3.242	2.696	0.049	GINI ↔ CO2
CO2 ≠ GINI	3.337	1.886	0.059	
GINI ≠ EFP	2.980	2.168	0.062	GINI → EFP
EFP ≠ GINI	2.505	0.212	0.831	
POV ≠ CO2	3.919	3.057	0.002	POV ↔ CO2
CO2 ≠ POV	3.911	3.041	0.002	
POV ≠ EFP	2.796	2.797	0.045	POV → EPF
EFP ≠ POV	2.425	0.050	0.959	
GDP ≠ CO2	5.608	6.458	0.000	GDP → CO2
CO2 ≠ GDP	2.771	0.747	0.454	
GDP ≠ EFP	5.818	6.881	0.000	GDP → EFP
EFP ≠ GDP	2.668	0.541	0.588	
ENC ≠ CO2	3.352	1.917	0.055	ENC → CO2
CO2 ≠ ENC	2.239	−0.322	0.747	
ENC ≠ EFP	4.083	3.388	0.007	ENC → EFP
EFP ≠ ENC	3.024	1.256	0.209	

Notes: ≠ = does not homogeneously cause, → = unidirectional causality, ↔ = bidirectional causality.

5. Conclusions and policy implications

This paper analyzes the impacts of income distribution and poverty on environmental pollution employing a panel of global economies over the period 2000–2018. The panel is then classified into high- and middle-income groups and environmental quality is measured by CO2 emissions and EFP. To tackle the potential endogeneity, unobserved country-related effects, and correlation among errors, the study uses the dynamic panel system GMM. To analyze the causal association between the series, the study employs the Dumitrescu - Hurlin Granger non-causality technique which can control for heterogeneous and cross-sectionally dependent nature of the variables. The empirical outcomes show that both income inequality and poverty degrade the environment by increasing carbon emissions and EFP in the aggregate panel. However, a disaggregated analysis for two different income groups reveals heterogeneous outcomes for poverty and inequality effects on environmental quality. Income inequality supports environmental quality by mitigating carbon emissions and EFP in the high-income group. However, it also disrupts environmental quality in the middle-income group. Similarly, poverty decreases environmental quality in the middle-income group. However, its effect turned out be insignificant in high-income group.

These findings imply that both income inequality and poverty have a significant influence on environmental quality. Thus, global, and national efforts for environmental sustainability also need to pay due attention to these variables to ensure environmental sustainability. Particularly, low-income group countries need to streamline inequality and poverty issues in their macroeconomic policy framework in view of

[1] The empirical outcomes are not reported for the sake of space but available upon request.

[2] The empirical outcomes are not reported for the sake of space but available upon request.

their implications for environmental sustainability. This research offers further insights for academic scholars and policymakers. Many policy implications can be drawn from the empirical outcomes. First, given that inequality and poverty matter for global environmental loss, it is of prime importance that domestic governments need to tailor their policy choices considering real local circumstances to collaboratively eradicate poverty and scale down environmental loss generated by emissions and resources pressure caused by EFP. Second, since high-income group exhibits favorable effects of inequality on the environment, these countries can tolerate inequality given that other economic and social effects are not compromised. Nevertheless, this group needs to adjust their welfare programs in such a manner that environmental sustainability is also integrated with welfare policy option choices. Third, as middle-income group exhibits unfavorable effects of both inequality and poverty on the environment. Addressing redistribution policy is an urgent need of this group. The countries in this group can achieve the twin objective of lowering poverty and environmental degradation by initiating poverty reduction programs, particularly such programs which are also environmentally viable. Fourth, redistribution policy needs to be grounded in rigorous forecast analysis and ecological impact assessment and coordination among various settings relating to the market structure, welfare regime, and social outcomes. Fifth, environmental awareness programs can be embedded with social support programs.

Besides, the high-income group needs to enhance the quality of growth by decoupling it from emissions and improving their redistribution systems. They can foster their ongoing efforts from energy-saving technologies. Since middle-income may face the issue of pollution haven from the high-income group, they need to strengthen their environmental rules and regulation and need to encourage environmentally-friendly foreign investment. Our study has succeeded in unveiling the impacts of poverty and income inequality on environmental degradation proxied by carbon emissions and ecological footprint. It is suggested that future study should employ other indicators of environmental degradation such as water quality, social quality, habitat destruction, methane (CH4), nitrous oxide (N2O), sulfur dioxide (SO2), fluorocarbons gases, etc, for purpose of inferences. Further research needs to consider other available indicators of inequality and poverty. The spatial spillover impacts of inequality and poverty for different groups of the economies need to be explored. Our research considers the linear association between inequality and the environment, future research can test whether there is a threshold level for the favorable effects of inequality on environmental sustainability in the high-income group. Thus, a threshold analysis can be helpful to determine the optimal level of inequality.

CRediT authorship contribution statement

Kizito Uyi Ehigiamusoe: Methodology, model, methodology, writings, Writing – original draft, Writing – review & editing. **Muhammad Tariq Majeed:** Writing – review & editing, introduction, literature review. **Eyup Dogan:** Writing – original draft, Writing – review & editing, Supervision, writings, supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix. Table A1: List of countries

S/N	High-income countries	S/N	Middle-income countries
1	Australia	1	Albania
2	Austria	2	Argentina
3	Belgium	3	Armenia
4	Canada	4	Belarus
5	Chile	5	Brazil
6	Cyprus	6	Bulgaria
7	Czech Rep	7	China
8	Denmark	8	Colombia
9	Estonia	9	Costa Rica
10	Finland	10	Dominican Republic
11	France	11	Ecuador
12	Germany	12	Georgia
13	Greece	13	Indonesia
14	Hungary	14	Iran
15	Ireland	15	Kazakhstan
16	Israel	16	Malaysia
17	Italy	17	Mexico
18	Korea Republic	18	Namibia
19	Latvia	19	Paraguay
20	Lithuania	20	Peru
21	Luxembourg	21	Russia
22	Malta	22	South Africa
23	Netherlands	23	Thailand
24	Norway	24	Turkey
25	Panama	25	Bolivia
26	Poland	26	Egypt
27	Portugal	27	El Salvador
28	Romania	28	Honduras
29	Slovak Rep.	29	Mongolia
30	Slovenia	30	Pakistan
31	Spain	31	Philippines
32	Sweden	32	Sri Lanka
33	Switzerland	33	Ukraine
34	United Kingdom	34	Vietnam
35	United States	35	Zambia

Source: World Bank (2020) classification of countries according to their income levels.
High-income group ($12,536 or above) and middle-income group ($1,036–$12,535).

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