Chapter

Inequality and the Environment: Impact and Way Forward

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Abstract

Economic and financial crisis thwarts the process of global economic growth, development, integration, and efforts to promote a sustainable environment. The onset of the recent crisis aggravates the problem of inequality and more resources need to be channeled for economic recovery. This study attempts to examine the impact of income inequality on environmental pollution in a sample of an unbalanced panel of 120 countries which consist of 42 high-income, 35 upper-middle-income, and 43 lower-middle- and low-income countries. The sample period runs from 1985 to 2019. The empirical results are quantitatively robust to a different alternative of proxy. Results affirmed an inverted *U*-shaped relationship between income inequality and environmental pollution for lower-middle- and low-income countries. The Environmental Kuznets Curve (EKC) hypothesis is present in the case of upper-middle, lower-middle- and low-income countries but not for high-income countries. The policy implication based on these findings is policies must be coordinated to cushion the impact of income inequality to enable more allocation for environmental protection such as measures to reduce carbon dioxide (CO2) emissions. Despite the crisis and economic slowdown, countries should take the opportunity to review their recovery plans by incorporating environmental concerns.

Keywords: CO_2 emission, methane, income inequality, environmental protection expenditure

1. Introduction

The persistent international community's attention and urgency towards reducing carbon impact on the environment have prompted various efforts from countries in the form of green policies, green financing, green investments, recycling, upcycling, and even the promotion of a circular economy. These efforts were briefly thwarted by the sudden COVID-19 outbreak. Following the COVID-19 pandemic, lockdowns in various parts of the world saw a significant reduction in carbon dioxide emissions from vehicles and factories. But this is only for a short-lived period. As vaccine rollout continues, economic activities begin to move towards full force albeit with major changes in the working mechanisms to comply with the new norms. In 2022, the Russian-Ukraine war disrupted the supply chain in the region, coupled with the rise in oil and commodity prices, the stock market bull-run, crypto winter, and inflation, recovery is further challenged [1–5]. As most countries pave their way towards recovery along with these challenges, the green agenda needs to align with the current situation such that policymakers could deploy bold measures to ensure sustainability in both the economy and the environment.

One of the major concerns is the possibility of inequality worsening as countries continue to recover. Some countries are rebounding faster than others although uncertainties are high due to the recurrence of pandemic waves and newfound COVID-19 variants. On one hand, the pandemic drove 120 million people to poverty as part of the consequences of the global recession. On a different note, the pandemic saw an increase in the wealth of billionaires and the emergence of post-COVID-19 billionaires and millionaires which illustrates the unequal effect of the pandemic on different groups of people. To partially cushion the impact of the recession and to reduce inequalities, governments have responded by introducing various policies, programs, grants, and subsidies for the marginalized groups and all sectors affected by the pandemic. Rescue packages along with vaccination rollouts are the main economic recovery agenda for all countries. Whether the green agenda will remain imperative or be temporarily put aside to focus more on economic recovery would depend on how inequalities affect expenditures on environmental protection. Thus, understanding the nature of how income inequality affects environmental pollution based on experience and historical data would assist future economic planning. As such, this study examines the impact of income inequality on environmental pollution in a sample of 120 countries.

The contribution of this study is twofold. First, the sample is disaggregated according to the level of income to better understand how income inequalities in countries with similar income thresholds affect environmental pollution. Second, to capture the possible indirect effects of inequality on environmental pollution, three multiplicative interactive interaction terms between income inequality vis-à-vis GDP, trade, and government environment expenditures. If income inequality is the product of economic growth or trade, then policies should be coordinated accordingly to account for such interactions. Therefore, understanding these issues is vital to ensure appropriate policy formulation to cope with post-pandemic development.

This study is organized in the following manner. The next section briefly reviews selected literature on environmental pollution and income inequalities. The third section narrates the theoretical consideration for this study, the estimation method, and discusses the nature of the data. The penultimate section provides the results and discussion, and the final section concludes.

2. Review of selected literature

In earlier literature, income inequality and environmental pollution are by-products of economic development and growth. The Kuznets Curve theory is often used to describe the relationship between income inequality and economic growth whilst the Environmental Kuznets Curve (EKC) is used to describe the relationship between environmental pollution which is normally captured by carbon dioxide (CO2) emission. The original Kuznets Curves hypothesized an inverted U-shaped association between economic growth and income inequality. The main assumption of this model is that at earlier stages of economic development income inequality is expected to increase as income levels increase. After reaching a certain threshold or inflection point, economic growth would lead to lower inequality as more redistribution takes place. This model implies that sustained economic growth and development would eventually reduce the problem of income inequality [6]. This model has been empirically tested extensively using different estimation methods, different sample periods, and a different sample of countries. Kuznets hypothesis was present in regional and country-specific studies, such as Thailand [7], Latin American countries [8], Africa [9], and counties in the US [10].

EKC proposed an inverted U-shaped relationship between economic growth denoted by income and environmental pollution as captured by CO2 emission. The EKC purports that as economic development makes its way, environmental pollution will increase due to higher production in the manufacturing, energy, and agriculture sector. After reaching a certain point, the relationship reverses as industries embrace renewable energy and more sustainable production mechanism. The efficacy of EKC is tested in various studies (*inter alia* [11–14]) and results infer the existence of EKC. Farhani and Ozturk [15], however, found a positive monotonic association between real GDP and CO2 emission which negates the existence of EKC. Shahbaz et al. [14] find mixed results where certain African countries like Tunisia, Zambia follows the EKC hypothesis whilst others such as Sudan and Tanzania experienced a *U*-shaped relationship between per capita CO2 and GDP.

Based on the previous literature, studies on the impact of income inequality on environmental pollution can be divided into three categories. The first group of studies found that income inequality lowers environmental quality, whilst the second group found evidence that income inequality improves environmental qualities. The third category argues that both positive and negative effects exists, such that the results are inconclusive. Differences may be due to the use of various data sets, econometric methods, or indices of income inequality, the results are mixed. Based on data from Turkey from 1984 to 2014, Uzar and Eyuboglu [16] demonstrate that income inequality has a positive impact on CO2 emissions and that the EKC is applicable in Turkey. The same conclusion is drawn by Baek and Gweisah [17] and Kasuga and Takaya [18]. In a sample of 217 countries, Wan et al. [19] found that the relationship between income inequality and CO_2 emissions is negative in high-income economies vis-à-vis the middle-high-income, middle-low-income, and low-income economies. Demir et al. [20] and Khan et al. [11] echoed the same conclusion. On the other hand, Uddin et al. [21], found that in the case of G7, the effect of income inequality on CO_2 emissions was significantly positive for the years 1870–1880 but significantly negative for the years 1950–2000. According to Belaïd et al. [22], who conducted a cross-sectional analysis of 11 Mediterranean nations, there is a long-term, significant and negative relationship between income inequality and per capita carbon emissions. This relationship suggests that greater inequality may prevent environmental degradation. Results, however, indicate that there is a short-term, positive, and significant correlation between income disparity and CO2 emissions.

Government expenditures are often viewed as a means to partly remedy the problems of inequality and environmental pollution. Government environment protection expenditure, for example, is a vital tool to ensure environmental quality (inter alia [23, 24]). The effect of government environment expenditures and environmental policies may be direct and indirect. Lopez et al. (2011) identified four main channels through which government expenditures may affect levels of pollution which are (i) the need for economic growth expands production which pressures the environment, (ii) human-intensive production harms the environment more vis-à-vis capital-intensive production, (iii) better use technology improves the technique of production, hence, causing less harm to the environment and (iv) higher income and better awareness of the environment raise the demand for better environmental quality and sustainable production. Empirical results are mixed with evidence of larger government expenditure lowering pollution (for example [25, 26]) and some showing higher pollution (for example [27, 28]). Grossman and Krueger [29] argue that differences in results may be due to countries being at different points of the EKC. However, it should be noted that the majority of earlier studies use total government expenditure as a proxy which is for other uses and not specifically for environmental protection. More data on environmental protection expenditure would enable more specific analysis. Existing studies do not account for the interactive effect of government expenditures and income inequality which could be a possible explanation of the indirect effect of government environment expenditure and pollution. This gap is addressed in this study.

3. Methodology

This section explores some theoretical considerations based on the EKC model to identify the baseline empirical model. The next sub-section identifies the estimation method followed by a discussion on the data sources, control variables, and variables for robustness tests.

3.1 Theoretical considerations

The Environmental Kuznets Curve (EKC) describes the possibility of an inverted *U*-shaped relationship between environmental pollution and economic growth. As the economy progress via an increase in income, pollution is hypothesized to increase until it reaches a certain inflection point where pollution began to decrease [29]. In the early stages of economic development, it is assumed that industrialization would take place and contribute a large percentage towards GDP growth. Industrialization is expected to use large amounts of energy which results in environmental pollution in the form of CO2 emissions. CO2 emission stems from (i) burning of fossil fuels such as burning solid, liquid, gas fuel, or gas flaring, or from the production of cement, (ii) production of electricity and heat production, (iii) liquid fuel consumption for example the use of petroleum-derived fuels, (iv) combustion of fuels from the manufacturing (for example from coke inputs to blast furnaces) and construction sectors, (v) solid fuel consumption from the use of coal, (vi) transport activities such as aviation, domestic navigation, road, rail and pipeline transport, and (vi) use of natural gas. In the agriculture sector, greenhouse gas emissions from livestock, such as cows, rice, wheat, and corn production contribute to pollution. Other forms of pollution include methane which is emitted during the production and transport of coal or natural gas, from livestock such as cows, and the decay of waste in the soil.

As the economy progressed and began wealth accumulation, countries would be able to invest in research and development (R&D) towards the production of machines and mechanisms that could minimize the impact on the environment. Examples include the use of green technology in production. As a result, even as the economy continues to progress, the impact on the environment is minimized. Another reason for the possible decline in pollution is due to both public and private awareness of the negative impact of pollution left unchecked. International organizations such as the United Nations, World Bank, and the International Monetary Funds have made concerted efforts on environmental sustainability such as the use of renewable energy and the promotion of a circular economy. Governments have come together towards embracing green policies and the adoption of greener technologies to reduce CO2 emissions. At a micro level, non-governmental organizations (NGOs) are also propagating reduction in environmental pollution via recycling, upcycling, and more recently, replacing the end-of-life concept with the restoration which leads to changes in business models, operations, systems, use of materials, and reduction in the use of harmful chemicals. In other words, producers are responsible for the whole lifecycle of the products.

In countries where inequality and poverty are prevalent, the poorer segment of the economy are more concerned with their survival, therefore, have less interest in environmental policies or programs [30] unless they can monetize from the policies. For example, via the collection of paper, glass, or tin that could be sold to recycling industries. According to the Median Voter Theory, poorer societies are more concerned with material wellbeing and would be less interested to support environmental related policies [31]. Ridzuan [32] (2019) suggests that society's interest in environmental protection could be downplayed if income inequalities are predominant within the society. On a similar note, Franzen and Meyer [33] and Facchini et al. [34] argued that when income inequality is high, the public is more concerned focused on economic growth and redistribution compared to environmental issues. Consequently, income inequality reduces government expenditures on environmental protection [35]. On the other hand, the richer segment of the society could easily fulfill their daily needs and have excess wealth which could be directed towards the consumption of environmentally friendly products and comply with other environmentally friendly policies.

3.2 Estimation method

The System GMM (S-GMM) is used in this study to examine the impact of inequality and other control variables on environmental pollution. S-GMM overcomes the shortcomings of the standard GMM where biases increase the number of instruments proliferate and weak instrument problems, and the problem of poor finite sample properties in terms of bias and precision in Difference GMM and the problem of lagged levels [36]. S-GMM corrects endogeneity such as in *CO2* and *GDP* by introducing more instruments to considerably improve efficiency and transforms the instruments to make them uncorrelated (exogeneous) with the fixed effects, permits a certain degree of endogeneity in the other regressors and optimally combines information on cross country variation in levels with that on within-country variation in changes [37].

The baseline empirical model can be described as follows:

$$\begin{aligned} CO2_{it} = {} & \alpha_1 CO2_{it-1} + \beta_2 \log GDP_{it-1} + \beta_3 GDP^2_{it-1} + \beta_4 GDP_{gr_{it-1}} \\ & + \beta_5 Dom_{Credit_{it-1}} + \beta_6 Trade_{it-1} + \beta_7 Gini_{disp_{it-1}} + \rho_{it} + \varepsilon_{it} + v_{it} \end{aligned} \quad (1)$$

where $CO2_{it}$ denotes environmental pollution proxied by CO2 and methane emission for individual i in period t, $CO2_{i,t-1}$is the lagged of environmental pollution in the previous period and $\rho_{it} + \varepsilon_{it} + v_{it}$ represents the error components decomposition of the error term which allows for unobserved heterogeneity (ε_{it} hereafter). Other assumption includes $v_{i,t}$ is serially uncorrelated. The control variables include growth of GDP (*gdp_gr*), trade openness (*trade*), domestic credit (*dom_credit*), and a measure of inequality (*Gini_disp*). To empirically examine whether the effect of income inequality on CO2 emission is conditional on GDP, trade, and government environment expenditure, the baseline model is modified to incorporate a multiplicative interaction term of income inequality and the three variables which are the (i) size of the economy and income inequality ($GDP \times Gini\_disp$), (ii) the impact of trade on income inequality ($Trade \times Gini\_disp$) and (iii) the interaction of government expenditure on environment protection and income inequality ($GE \times Gini\_disp$) and (iv) the combined effect of economic growth and financial development on income inequality ($GDP \times Dom\_credit \times Gini\_disp$). The interaction models are as follows:

$$\begin{aligned} CO2_{it} = {} & \alpha_1 CO2_{it-1} + \beta_2 \log GDP_{it-1} + \beta_3 GDP^2_{it-1} + \beta_4 GDP_{gr_{it-1}} \\ & + \beta_5 Dom_{Credit_{it-1}} + \beta_6 Openness_{it-1} + \beta_7 Gini_{disp_{it-1}} \\ & + \beta_8 \left(GDP \times Gini_{disp}\right)_{it-1} + \rho_{it} + \varepsilon_{it} + v_{it} \end{aligned} \tag{2}$$

$$\begin{aligned} CO2_{it} = {} & \alpha_1 CO2_{it-1} + \beta_2 \log GDP_{it-1} + \beta_3 GDP^2_{it-1} + \beta_4 GDP_{gr_{it-1}} \\ & + \beta_5 Dom_{Credit_{it-1}} + \beta_6 Openness_{it-1} + \beta_7 Gini_{disp_{it-1}} \\ & + \beta_8 \left(Trade \times Gini_{disp}\right)_{it-1} + \rho_{it} + \varepsilon_{it} + v_{it} \end{aligned} \tag{3}$$

$$\begin{aligned} CO2_{it} = {} & \alpha_1 CO2_{it-1} + \beta_2 \log GDP_{it-1} + \beta_3 GDP^2_{it-1} + \beta_4 GDP_{gr_{it-1}} \\ & + \beta_5 Dom_{Credit_{it-1}} + \beta_6 Openness_{it-1} + \beta_7 Gini_{disp_{it-1}} + \beta_8 (GE \\ & \times Gini_{disp})_{it-1} + \rho_{it} + \varepsilon_{it} + v_{it} \end{aligned} \tag{4}$$

3.3 Data

A panel of unbalanced data from 120 countries was chosen based on the availability of the focal variables which are CO2 and income inequality data. The sample ranges from 1985 to 2019, drawn from various datasets. The sample was further disaggregated according to the level of income to control for the effect of income and to ensure that inferences were made based on samples that belong to some similar criteria which is in this case, the level of income. The segregated sample consists of 42 high-income, 35 upper-middle-income, and 43 lower-middle- and low-income countries. Segregation of the sample allows analysis and comparison of the impact of the different variables on CO2. In addition, more specific results can be obtained based on the characteristics, conditions, and resources of countries with similar income levels. This would allow understanding the nature and degree of association amongst the variables. The sample was segregated into three categories of income which are high-income countries, upper-middle-income countries, and lower-middle- and low-income countries. The categorization is based on The World Economic Situation and Prospects (WESP), United Nations [38]. The list of countries is listed in Appendix I. Data on CO2 and methane were derived from the WDI, World Bank and Emissions Database for Global Atmospheric Research (EDGAR), European Commission.

Income inequality (*gini_disp*) is represented by the Gini coefficients derived from the Standardized World Income Inequality Database (SWIID) V9.1 originally by Solt [39, 40]. SWIID is the best available proxy for income inequality since it covers the longest period and the largest number of countries compared to other databases.

SWIID 9.1 provides Gini coefficients for market incomes and net incomes (disposable Gini) which allows for international comparison. For the purpose of this study, only disposable Gini is used since it is an after-tax Gini which is calculated after taking out the effect of taxes and after considering the effect of transfer payments. It should be noted that Gini coefficients are not available for all countries for the stipulated time, hence, regression is based on unbalanced panel data. Alternative measures of income inequality such as wage inequality or ratio inequality, market income (income before taxes and transfers), disposable income (household income after pensions, unemployment insurance, social assistance transfers, and other government cash benefits), post-tax income (gross income minus all direct and indirect taxes) and gross income (market income plus government cash benefits) are available albeit calculated differently. Nevertheless, the range of countries offered by these alternative proxies is limited to a few countries only, making extensive international comparison difficult. Therefore, SWIID is the best available proxy.

The proxy for income is real GDP from the World Development Indicator (WDI) database, World Bank which serves the role to control for the size of the economy and the EKC effects. GDP growth controls for the effect of the level of development where wealthier economies are presumed to have a larger public sector which is bound to affect the design of fiscal policy and redistribution. Wagner's Law stipulates that higher economic development would result in greater redistribution, which subsequently suppresses the problem of income inequality. According to Wagner, as economies developed, more resources are available for redistribution which later, promotes economic growth through higher income and increase aggregate demand [41]. Other control variables include domestic credit to capture financial development and trade openness to represent globalization and the effects of international market integration. Trade openness is defined as total imports plus export as a percentage of GDP. Both data were drawn from the WDI database. The role of government expenditure on the environment is captured by the amount of government expenditure on environment protection as a percentage of total government expenditure. Data is extracted from the Expenditure by Functions of Government (COFOG), Government Finance Statistics, and the International Monetary Fund (IMF).

4. Results and discussion

The descriptive and correlation statistics for all variables for 120 countries over the period of 1985 to 2019 are reported in **Tables 1** and **2**. Real GDP (*gdp*) and government environment protection expenditure (*gov_env*) are expressed in the logarithm. The correlation statistics in **Table 2** shows no high correlation amongst the variables.

Table 3 displays the overall results for the whole sample and high-income countries. The lagged values of CO2 emission are consistently significant across all models in the overall sample and the high-income countries. The proxy for economic growth, gdp is significant except for eq. 4 but gdp^2 is negative but insignificant. The results suggest that economic growth continues to increase CO2 emission in the overall sample and high-income countries. The presence of an inverted U-shaped EKC could not be established based on these results. The rate of economic growth is positive and significant for all regression but the same could be generalized in the case of high-income countries. The positive and significant impact of financial development as proxied by domestic credit (*dom_credit*) indicates how improvement in credit access, for example, promotes more production and hence, higher CO2 emission. Results are

Variable	Obs	Mean	Std. Dev.	Min	Max
CO_2	3722	4.9745	6.8144	0.0209	70.0422
methane	2893	23.4996	18.6431	−1.9	100.7621
gdp	4062	26.8479	28.0095	0.00	30.5379
gdp_gr	4044	43.4591	442.2550	−50.2481	6310.1350
dom_credit	3934	78.7938	54.0776	9.1358	442.6200
trade	3027	53.4148	47.7398	0	308.9784
gini_disp	3749	37.9002	8.8526	17.5	67.1000
gov_env	599	6.0662	7.2042	0	9.6216

Notes: gdp and gov_env are expressed in a logarithmic term.

Table 1.
Descriptive statistics.

	CO_2	Methane	gdp	gdp_gr	dom_credit	Trade	gini_disp	gov_env
CO_2	1							
methane	0.5722	1						
gdp	0.1001	0.1807	1					
gdp_gr	0.5339	0.3702	0.142	1				
dom_credit	0.1452	−0.1203	0.3716	−0.0664	1			
trade	0.0385	0.1689	−0.1557	0.1199	0.0637	1		
gini_disp	−0.1096	0.1022	−0.1187	0.0309	−0.1864	−0.0387	1	
gov_env	0.0158	−0.032	−0.1306	−0.0474	−0.0193	0.0768	−0.0807	1

Table 2.
Correlation.

consistent for the overall sample and high-income countries; results are significant for eqs. 1–3. International trade (*trade*) is not significant except for eq. 3 in the overall sample.

Table 4 illustrates the results for upper-middle and lower-middle- and low-income countries. In the case of upper-middle-income countries, lagged term of CO2 emission is positively related to CO2 emission which is in line with the use of S-GMM. Evidence of an inverted *U*-shaped EKC is present implying the existence of a certain threshold point where reduction of CO2 emission takes place with better use of technology and more sustainable production techniques. These results are consistent with Le and Nguyen [13], Shahbaz et al. [14], and Le et al. [12]. More financial development implies higher emission of CO2. For lower-middle- and low-income countries, *gdp* is positive and significant and *gdp2* is negative and significant which suggests the existence of an inverted U-shaped relationship between economic growth and CO2 emission. Domestic credit and trade openness have the expected sign which both positive and significant, indicating the growth of trade and financial development leads to increased CO2 emission, hence, environmental pollution. Results are fairly consistent across all specifications.

Dependent variable: CO2 Emission								
Variable	**Overall sample**				**High-income countries**			
Panel	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
$CO2_{t-1}$	0.0942*** (0.0042)	0.9515*** (0.0053)	0.7211*** (0.0060)	0.9415*** (0.0095)	0.9412*** (0.0080)	0.9513*** (0.0095)	0.7312*** (0.0098)	0.9744*** (0.0287)
gdp	0.0670*** (0.0000)	−0.0552* (0.0000)	0.0441*** (0.0000)	0.0009 (0.0018)	0.0529** (0.0000)	0.0500* (0.0000)	0.0337*** (0.0000)	−0.0004 (0.0012)
gdp^2	−0.0098 (0.0120)	−0.0091 (.0121)	−0.0080 (0.0200)	−0.0060 (0.0120)	−0.0082 (0.0170)	−0.0065 (0.0150)	−0.0055** (0.0100)	−0.0025 (0.0101)
gdp_gr	0.0092** (0.0038)	0.0139* (0.0043)	0.0056** (0.0027)	0.0214 (0.0138)	0.0070 (0.0107)	0.0255* (0.0141)	0.0006 (0.0076)	0.0085 (0.0474)
dom_credit	0.0064*** (0.0010)	0.0065*** (0.0010)	0.0058*** (0.0007)	0.0077*** (0.0024)	0.0062*** (0.0016)	0.0058*** (0.0016)	0.0069*** (0.0011)	−0.0041 (0.0055)
trade	0.0010 (0.0008)	−0.0009 (0.0008)	0.0270*** (0.0008)	0.0029 (0.0019)	0.0011 (0.0013)	0.0013 (0.0013)	0.0269*** (0.0013)	0.0022 (0.0049)
gini_disp	0.0015* (0.0079)	0.0145** (0.0080)	0.0082 (0.0057)	1.3052*** (0.0329)	0.0130 (0.0218)	0.0080 (0.0221)	0.0366** (0.0157)	0.9024 (0.1316)
constant	1.0568*** (0.3338)	1.0011*** (0.3403)	2.6500*** (0.2454)	6.0514*** (1.3698)	1.1744* (0.6068)	0.9330 (0.6242)	1.8222*** (0.4356)	−1.9225 (5.8957)
gdp × gini_disp	—	0.0051*** (0.0001)		—	—	0.0326*** (0.0038)	—	—
trade × gini_disp	—		0.0052*** (0.0013)	—	—	—	0.0036** (0.0018)	—
gov_env × gini_disp	—	—	—	−0.5431*** (0.0153)	—	—	—	−0.695*** (0.0363)
Obs.	2376	2376	2376		862	862	862	98
Inst.	502	503	503		502	503	503	99

*Notes: Panels 1–4 are based on Eqs. 1–4. Standard errors are in parentheses. ***, ** and * denote 1%, 5%, and 10% significant levels.*

Table 3.
Impact of inequality on CO2 emission – Overall sample and high-income countries.

Dependent variable: CO2 emission								
Variable	**Upper middle-income countries**				**Lower middle- and low-income countries**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
$CO2_{t-1}$	0.9421*** (0.0161)	0.9533*** (0.0158)	0.9421*** (0.0161)	0.9671*** (0.1816)	0.8839*** (0.0116)	0.6183*** (0.0108)	0.1499*** (0.0076)	0.5932*** (0.0216)
gdp	0.0244*** (0.0000)	0.0211*** (0.0000)	0.0115*** (8.000)	0.0079* (0.0000)	0.0021 (0.0000)	−.0042** (0.0018)	0.0001*** (0.0000)	0.0001*** (0.0000)
gdp^2	−0.0088*** (0.0000)	−0.0074*** (0.0000)	−0.0067*** (0.0000)	−0.0011** (0.0000)	−0.0021 (0.0000)	−0.0061** (0.0000)	−0.0055*** (0.0000)	−0.0005*** (0.0000)
gdp_gr	−0.0043 (0.0068)	−0.0031 (0.0068)	−0.0043 (0.0068)	−0.0254*** (0.0077)	0.0134*** (0.0023)	−0.0150*** (0.0019)	−0.0030*** (0.0008)	0.0551*** (0.0086)
dom_credit	0.0019** (0.0010)	0.0016* (0.0010)	0.0019** (0.0010)	−0.0002 (0.0022)	0.0047*** (0.0013	0.0068*** (0.0009)	0.0078* (0.0004)	0.0231*** (0.0031)
trade	0.00074 (0.0009)	0.0007 (0.0009)	0.0007 (0.0009)	0.0008 (0.0025)	0.0025*** (0.0008)	0.0005 (0.0006)	0.0090*** (0.0000)	−0.0006 (0.0028)
gini_disp	0.0022 (0.0048)	0.0022 (0.0048)	0.0022 (0.0048)	0.0043 (0.0087)	0.0270*** (0.0075)	0.0454*** (0.0057)	0.0182*** (0.0022)	0.1473*** (0.0177)
constant	0.0548 (0.2477)	0.0579 (0.2493)	0.0548 (0.2477)	−0.2871 (0.4236)	0.8999*** (0.3317)	—	1.3652*** (0.1179)	6.4432*** (0.8850)
gdp × gini_disp	—	0.0031*** (0.0001)		—	—	0.0218*** (0.0029)	—	—
trade × gini_disp	—		0.0027*** (0.0011)	—	—	—	0.0032** (0.0016)	—
gov_env × gini_disp	—	—	—	−0.3512*** (0.0153)	—	—	—	−0.0559*** (0.0243)
Obs.	691	691	691	177	823	823	823	118
Inst.	499	498	499	167	488	489	489	126

*Notes: Panels 1–4 are based on Eqs. 1–4. Standard errors are in parentheses. ***, ** and * denote 1%, 5%, and 10% significant levels.*

Table 4.
Impact of inequality on CO2 emission – Upper Middle, Lower Middle- and Low-Income Countries.

Dependent variable: CO2 emission								
Variable	**Overall sample**				**High income countries**			
Panel	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
methane$_{t-1}$	0.9118*** (0.0175)	0.9118*** (0.0175)	0.8548*** (0.0512)	0.9086*** (0.0176)	0.9605*** (0.0158)	0.8573*** (0.0138)	0.6221*** (0.1020)	0.9553*** (0.0158)
gdp	0.0075* (0.0100)	0.0063*** (0.0010)	0.0044*** (0.0011)	0.0025* (0.0011)	0.0069*** (0.0000)	0.0060*** (0.000)	0.0039 (0.0000)	0.0022*** (0.0000)
gdp^2	−0.0063** (0.0031)	−0.0045 (0.0100)	−0.0032 (0.0049)	−0.0011 (0.0079)	−0.0061** (0.0030)	−0.0042** (0.0030)	0.0034 (0.0060)	0.0010 (0.0030)
gdp_gr	0.0881*** (0.0174)	0.0961*** (0.0188)	0.0376 (0.0791)	0.0890*** (0.0174)	0.0291 (0.0269)	0.0483 (0.0367)	0.0049 (0.0783)	−0.0307 (0.0269)
dom_credit	0.0158** (0.0063)	0.0159** (0.0063)	0.0114 (0.0163)	0.0061** (0.0063)	0.0047 (0.0043)	0.0042 (0.0044)	−0.0006 (0.0150)	0.0053 (0.0043)
trade	0.0008 (0.0057)	0.0013 (0.0019)	0.0063 (0.0318)	−0.0028 (0.0063)	0.0036 (0.0032)	0.0037 (0.0032)	0.0120 (0.0303)	−0.0019 (0.0037)
gini_disp	0.1513*** (0.0432)	0.1516 (0.0432)	0.7270*** (0.1436	0.1624*** (0.0440)	0.0145 (0.0567)	0.0135 (0.0567)	0.8107 (0.8877)	0.0139 (0.0565)
constant	−4.1768** (1.7505)	−4.2485** (1.7507)	−4.0502*** (7.8713)	−4.5688 (1.7723)	1.1979 (1.7054)	1.2955 (1.7107)	−2.1245 (3.6437)	1.1483 (1.7013)
gdp × gini_disp	—	0.0063*** (0.0011)		—	—	0.0055*** (0.0027)	—	—
trade × gini_disp	—		0.0047*** (0.0022)	—	—	—	0.0041** (0.0023)	—
gov_env × gini_disp	—	—	—	−0.6429*** (0.2556)	—	—	—	−0.4761*** (0.0876)
Obs.	1557	1557	123	1557	544	544	36	544
Inst.	282	283	75	283	282	283	31	283

*Notes: Panels 1–4 are based on Eqs. 1–4. Standard errors are in parentheses. ***, ** and * denote 1%, 5%, and 10% significant levels.*

Table 5.
Impact of inequality on CO2 emission – Overall Sample and High-Income Countries.

Dependent variable: CO2 emission								
Variable	**Upper middle-income countries**				**Lower middle- and low-income countries**			
Panel	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
$methane_{t-1}$	0.8421*** (0.0239)	0.8420*** (0.0239)	0.8547*** (0.1325)	0.8420*** (0.0239)	0.8288*** (0.0256)	0.8292*** (0.0256)	0.7350*** (0.0786)	0.8332*** (0.0257
gdp	0.0055*** (0.0010)	0.0041*** (0.0010)	0.0030*** (0.0011)	0.0029** (0.0014)	0.0033*** (0.0015)	0.0030*** (0.0015)	0.0021*** (0.0000)	0.0010*** (0.0000)
gdp^2	−0.0041*** (0.0003)	−0.0038*** (0.0000)	−0.0035*** (0.0002)	−0.0010*** (0.0001)	−0.0035** (0.0030)	−0.0027** (0.0030)	0.0026*** (0.0001)	0.0009*** (0.0000)
gdp_gr	0.0047 (0.0082)	0.0032 (0.0642)	0.1045 (0.1309)	0.0032 (0.0642)	0.0803*** (0.0239)	0.0865*** (0.0267)	0.0388 (0.2934)	0.0710*** (0.0243)
dom_credit	0.0032* (0.0642)	0.0228** (0.0097)	0.0255 (0.0513)	0.0228** (0.0097)	0.0666*** (0.0200)	0.0686*** (0.0205)	0.0309 (0.1228)	0.0458*** (0.0224)
trade	0.0210** (0.0087)	0.0210** (0.0087)	0.0285 (0.0513)	0.0210* (0.0139)	0.0384*** (0.0116)	0.0396*** (0.1181)	0.0448 (0.1003)	0.0239* (3.7864)
gini_disp	0.1423** (0.0648)	1.4232** (0.0648)	0.00766 (0.2556)	1.4232** (0.0648)	0.4845*** (0.0870)	0.4829*** (0.0871)	1.8993*** (0.3646)	0.5215*** (0.0889)
constant	7.8854** (3.0638)	7.8854** (3.0638)	4.3003 (14.0168)	7.8854** (3.0638)	1.2699*** (3.75551)	1.2939*** (3.7581)	0.2749*** (17.2062)	2.2438 (3.7864)
gdp × gini_disp	—	0.0021*** (0.0001)		—	—	0.0019*** (0.0001)	—	—
trade × gini_disp	—		0.0024*** (0.0010)	—	—	—	0.0018** (0.0009)	—
gov_env × gini_disp	—	—	—	−0.0787*** (0.0332)	—	—	—	−0.0481*** (0.0111)
		—						
Obs.	446	446	48	446	567	567	39	567
Inst.	283	283	38	283	282	283	31	283

*Notes: Panels21qq 1–4 are based on Eqs. 1–4. Standard errors are in parentheses. ***, ** and * denote 1%, 5%, and 10% significant levels.*

Table 6.
Impact of inequality on CO2 emission – Upper Middle, Lower Middle- and Low-Income Countries.

The conditional effect of economic growth on income inequality ($gdp \times gini\_disp$) is positive and significant, inferring that CO2 emission could be aggravated if income inequality is high coupled with economic growth in all samples. The interaction between trade and income inequality is also positive and significant for all samples inferring the combined effects of international market integration and income inequality leads to more pollution. The third interaction variable between government environment expenditures and income inequality is negative and significant, suggesting the possibility of lower government environment expenditure given income inequality could increase CO2 emission. Results seem to support the Median Voter Theory that purported lower income inequality would lead to more interest in environmental pollution-related policies and public spending, hence, leading to lower pollution. These results are parallel to Magnani [35] and Kempf and Rossignol [31] albeit different sample, estimation technique, and data span. These results are also in line with Uzar [42] who suggests that a decline in income inequality will enhance the usage of renewable energy, leading to lower environmental pollutions due to CO2, SO2, methane, and other harmful emissions (**Table 5**).

Table 6 shows the modified estimations using methane to proxy for environmental pollution as a measure of robustness. Results are relatively consistent with the baseline results. Using methane as a proxy, high-income countries show some support of the inverted *U*-shaped EKC. Trade has positive and significant effect on methane emission in for upper-middle income countries and lower-middle and low-income countries. In tandem with the results in the baseline regression, financial development is consistently positive and significant, inferring increase financial development promotes more production and consumption, hence, increasing emission of methane.

5. Conclusion

This study re-examines the EKC by controlling for the level of development and growth, financial development, international market integration, and government expenditure on environment protection. Overall, the results lend support to the inverted *U*-shaped EKC in the case of upper-middle countries, lower-middle- and low-income countries. The same could not be concluded for high-income countries. In the case of high-income countries, the combination of public policies in the form of environmental regulations, indirect government subsidies, and continuous technological innovation to reduce pollution allows the non-contradictory co-existence between economic growth and checked environmental pollution. Moreover, the inverted *U*-shaped EKC appears to be non-applicable to high-income countries as these countries would have experienced the *U*-shaped phenomenon earlier than the period covered in this study. Higher-income inequality resulting in higher environmental pollution is statistically evident for the overall sample, high-income, and lower-middle- and low-income countries. Financial development is a vital indicator for CO2 emission, lending support for higher emissions as the financial sector develops and matures. International market integration as represented by trade openness is significant across all equations for lower-middle and low-income countries but only partially significant for other samples.

In conclusion, economic growth and development are partly fueled by financial development and trade leading to higher production and consumption which translates into environmental pollution. To curb pollution, government environmental expenditure should be the catalyst along with other green policies such as the use of renewable energy, responsible production, and consumption, implementation of the circular economy-type of policies, and enforcement. Reducing income inequality indicates better income and wealth redistribution. Thus, more government expenditure could be allocated and spent on maintaining and sustaining the environment rather than used to provide subsidies or transfers to the poorer section of the economy. Failure to address income inequality could impede efforts to reduce CO2 emissions and other efforts to reduce environmental degradation as the post-COVID-19 fiscal policies mostly focused on economic recovery with various efforts aimed to remedy the high unemployment, production, and supply chain disruptions due to the pandemic. Nevertheless, this can be viewed as an opportunity to restart production and the whole supply chain ecosystem in a more environmentally sustainable manner.

Appendix I. List of countries

High-Income countries

Australia, Austria, Barbados, Belgium, Canada, Croatia, Cyprus, Czech, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherland, New Zealand, Poland, Portugal, Qatar, South Korea, Singapore, Hong Kong, Hungary, Israel, Norway, Panama, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States, Uruguay.

Upper middle-income countries

Albania, Algeria, Argentina, Armenia, Belarus, Botswana, Brazil, Bulgaria, China, Colombia, Costa Rica, Dominican Republic, Ecuador, Fiji, Georgia, Guatemala, Iran, Jamaica, Jordan, Kazakhstan, Malaysia, Mauritius, Mexico, Namibia, North Macedonia, Paraguay, Peru, Romania, Russian Federation, Serbia, South Africa, Sri Lanka, Thailand, Turkey, Venezuela.

Lower middle- and low-income countries

Bangladesh, Bolivia, Djibouti, Egypt, El Salvador, Ghana, Honduras, India, Indonesia, Kenya, Kyrgyzstan, Lao, Lesotho, Mauritania, Mongolia, Morocco, Nicaragua, Nigeria, Pakistan, Philippines, Senegal, Sudan, Tunisia, Ukraine, Vietnam, Zambia, Zimbabwe.

Burkina Faso, Burundi, Ethiopia, Gambia, Guinea, Madagascar, Malawi, Mozambique, Nepal, Niger, Rwanda, Sierra Leone, Tajikistan, Uganda, Tanzania, Yemen.

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