Impact of Income Inequality on CO_2 Emissions

—Empirical Evidences from 60 Countries between 2005 and 2019

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Abstract. Since the 21st century, income inequality and carbon emissions have become huge challenges for countries around the world. Based on the panel data of 60 countries from 2005 to 2019 as samples, this paper analyzes the impact of income inequality on CO2 emissions using the moderating effect model. Not only it analyzes the moderating effect of opening degree, foreign investment level, and economic structure in the impact of income inequality on CO2 emissions, but it also classifies and studies the heterogeneity of population aging and economic development. The results show that the increase in income inequality will inhibit CO2 emissions. This inhibition will weaken with the improvement of the opening degree, but it will strengthen with the improvement of foreign investment and the increase of manufacturing share. According to the age structure, income inequality has a restraining effect on CO2 emissions when the country is in the aging stage, while the restraining effect is not obvious for countries not in the aging stage. Further, according to different income levels, it is found that the impact of income inequality and CO2 emissions in low and middle-income countries is not obvious. Income inequality will promote CO2 emissions in upper middle-income countries, while it will decrease CO2 emissions in high-income countries.

Keywords: income inequality; carbon emissions; economic development; environmental pollution; aging

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1 Introduction

With the development of economy, people have paid more and more attention to environmental issues in recent years. Climate change is one of the most serious challenges in the world, which could lead to sea level rise, extreme weather events, infectious diseases, and even threaten human survival (1). Greenhouse gas emission is one of the main cause of climate change and it also closely relate with CO2 emissions. In terms of the contribution percentage of global warming, CO2 accounts for the largest proportion about 55% (2). To address the negative impact of this problem, some countries signed The Paris Agreement in 2016, promising to control the global average temperature rise below 2 °C, and taking measures to control the temperature rise within 1.5°C of the pre-industrial level (3).

In addition, income inequality is also a serious challenge for countries around the world. According to the statistics of the World Inequality Database, the world Gini index in 2016 was already 0.65. The problem of income inequality has not improved significantly until now: the pre-tax income share of the bottom 50% of the world's population is less than 9% of the total income, but that of the top 1% of the population has reached 19% of the total income (5). Wealth is firmly in the hands of a few people. Serious income inequality will have a negative impact on people's well-being and social stability (6).

Moreover, reducing poverty and controlling climate change are extremely important for all countries over the world, which are also indispensable components of the Sustainable Development Goals (SDGs). However, it is very difficult to reduce poverty and CO2 emission at the same time in the context of income inequality. Research shows that high income inequality hinders economic growth (16) and poverty reduction (24). On the one hand, income inequality has further expanded the dependence of low-income groups on natural resources (27). Developing countries often choose to develop industry to stimulate the economy rapidly in the short term, thus they lead to sharply increasing the consumption of non-renewable resources. However, low-income groups often manipulate natural resources in an unsustainable manner, leading to the neglect of CO2 emissions (15) . On the other hand, high-income groups not only have higher political rights to bargain with policy makers about their pollution behavior (26), but also have the ability to avoid the harm caused by CO2 emissions like migration and rent-seeking. They transfer the cost of pollution to low-income groups, and further increase income inequality (13).

2 Literature Review

After the Environmental Kuznets Curve(EKC) was issued in the 1990s, the non-linear relationship between economy and environmental pressure was explained, then the basic theoretical framework of the relationship between economic activities and ecological environment system was proposed and widely applied (11). According to the EKC, Torres and Boyce prove that the equitable distribution of power and income tends to produce better environmental quality, especially in low-income countries (14). Ravallion explores the impact of income inequality on CO2 emissions (9). The existing research conclusions are not uniform, which can be roughly divided into three aspects: income inequality and CO2 emissions have positive relationship; income inequality and CO2 emissions have nagative relationship; impact of income inequality on CO2 emissions is uncertain.

Some studies have found that increasing income inequality will aggravate CO2 emissions. Qu and Zhang confirm this conclusion by studying 36 countries for 20 years (12). By studying the data of N-11 countries from 1971 to 2013, Padhan finds that the rise in income inequality, economic development and energy consumption per capita will increase CO2 emissions in the long run (25). Some scholars also think the widening income gap will increase CO2 emissions by changing the environmental preferences of consumers, enterprises and governments(13).

Some studies believe that increasing income inequality will reduce CO2 emissions. Based on the data from 78 countries between 1990 and 2017 and using various panel regression models (FMOLS, DOLS and ARDL method), Wu finds that this relationship exists in both OECD and non-OECD countries, especially in low-income non-OECD countries(11). Heerink convinces that when the relationship between environmental damage and household income is as concave as the Environmental Kuznets Curve, income inequality is negatively correlated with total environmental damage (19). Jorgenson’s study shows that income concentration is positively correlated with CO2 emissions, because the poor will increase their consumption of energy and products when they enter the upper class (20). Scruggs believes that the rich people's demand for environmental quality is greater than their income, so income inequality would improve the environmental quality (21).

Other studies have shown that the impact of income inequality on CO2 emissions is uncertain. Md. Main Uddin uses LLDVE method to research G7 countries from 1870 to 2014, and he find that the relationship between income inequality and CO2

emissions changed with the impact of global special events (10). Eriksson's research shows that income inequality will aggravate CO2 emissions in areas with a high degree of democracy (22). Chen uses the improved EKC model to study G20 countries and finds that income inequality has a negative impact on CO2 emissions for developing countries and it hardly affects CO2 emissions for most developed countries (23). The individual studies believe that the impact of income inequality on CO2 emissions is insignificant (24).

In addition to income inequality, CO2 emissions are also affected by other factors. Wang confirms that population, urbanization, and GDP per capita will lead to an increase in CO2 emissions (4). Besides, energy and economic performance (18), technological innovation, and low-carbon technology import (17) are all important factors affecting CO2 emissions.

3 Model and Data

3.1 Model

3.1.1 Basic Model.

Nowadays, it has become an objective fact that the income gap between countries in the world is large. Especially in recent years, more and more countries have paid attention to environmental issues and the trend of industrial transfer is more obvious. To more accurately estimate the impact of income inequality on CO2 emissions around the world, we build the following basic models based on existing research:

$$C_{it} = \alpha + \beta_1 Gini_{it} + \varphi X_{it} + \mu_i + \sigma_t + \varepsilon_{it} \qquad (1)$$

i： country or region

t： year

C_{it}： the CO2 emission per capita

$Gini_{it}$: the Gini index

μ_i&σ_t： country fixed effects and year fixed effects. To avoid fixed technical differences caused by country differences and macroeconomic shocks caused by time differences.

ε_{it}： fixed effects

α: intercept term

Then we introduce control variables into the model. We measure the degree of affluence with GDP per capita and the degree of population aggregation with urbanization rate. Considering the moderating effect of trade level, foreign direct investment and industrial structure on CO2 emissions, we also include these variables in the model. The variables are shown in **Table 1.**

Table 1. Collection and arrangement of explained variables, explanatory variables, control variables, moderator variables, grouping variables and dummy variables

Variable Type	Variable Name	Symbol	Data Description	Data Sources
Explained Variable	CO2 emissions (kilogram per capita)	C_{it}	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	the World Development Indicators database
Explanatory Variable	Gini index	$Gini_{it}$	Gini index measures the extent to which the distribution of income (or consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.	

Control Variable	GDP per capita, PPP (constant 2017 international $)	GDP	PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. GDP at purchaser's prices is the sum of gross value added by all resident producers in the country plus any product taxes and minus any subsidies not included in the value of the products. Data are in constant 2017 international dollars.
Control Variable	The square term of GDP per capita (constant 2017 international $)	GDP^2	/
Control Variable	Urban population (% of total population)	URB	Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by United Nations Population Division.
Control Variable	The square term of Urban population (% of total population)	URB^2	/
Moderator Variable	Trade (% of GDP)	TRA	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.

Moderator Variable	Foreign direct investment, net inflows (% of GDP)	FDI	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments.
Moderator Variable	Manufacturing, value added (% of GDP)	MNF	Manufacturing refers to industries belonging to ISIC divisions 15-37. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator.
Grouping Variables	Population ages 65 and above (% of total population)	AGE	Population ages 65 and above as a percentage of the total population. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.
Dummy Variable	Low and middle-income group aggregate	LMI	Low and middle-income economies are those in which 2021 GNI per capita was less than $13,205.

Dummy Variable	Upper middle income group aggregate	UMI	Upper-middle-income economies are those in which 2021 GNI per capita was between $4,256 and $13,205.	
Dummy Variable	High income group aggregate	HI	High-income economies are those in which 2021 GNI per capita was more than $13,205	

3.1.2 Moderating Effect Model.

When the independent variable X has some relationship with the dependent variable Y, if the variable Z affects the relationship between X and Y, then Z is called the moderator variable. The relationship between variables is shown in Figure 1 (7).

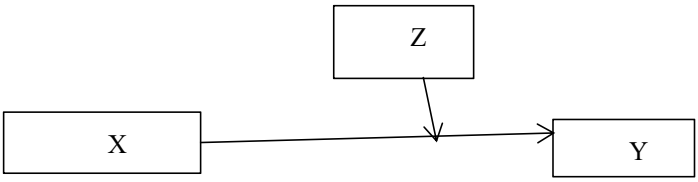

Fig. 1. Diagram of moderating effect

The moderating effect is mainly determined by testing whether the estimate of the interaction term is significant. When there is only one moderator variable, the moderating effect model is as follows:

$$C_{it} = \alpha + \beta_2 Gini_{it} + \varphi X_{it} + \beta_3 Z_{it} + \beta_4 Z_{it} Gini_{it} + \mu_i + \sigma_t + \varepsilon_{it} \quad (2)$$

Z_{it}: Moderator variable

$Z_{it}Gini_{it}$: Interaction item of Moderator variable

3.2 Data

We make a preliminary analysis based on a large number of national panel data (from 1960 to the latest 266 countries). Because of the availability of data, we finally choose 60 countries from 2005-2019 as a sample, which include 900 groups of data and each of them cover 10 statistical values. The data of Gini index, carbon dioxide emissions

per capita, real GDP per capita, Urban population, trade share, foreign direct investment share, Manufacturing share, population aging share and income level are all from the World Development Indicators database.

It is noteworthy that some years' data are missing or not included, since some countries have different statistical standards. Therefore, we use mean interpolation and linear interpolation to replace the missing data.

Table 2. Statistical information of variables

Descriptive Statistics

Variables	Unit	Obs	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
Carbon Emission	kg per capita	900	5977.52	4068.20	620.16	25604.20	1.31	5.32
GINI	/	900	36.29	8.13	23.20	59.50	0.62	2.46
GDP	constant 2017 international $	900	30345.63	19993.05	3517.72	120647.80	1.40	6.35
URB	%	900	70.84	14.11	35.28	98.04	-0.21	2.52
TRA	%	900	95.69	55.39	22.11	380.10	1.97	8.43
FDI	%	900	8.32	30.53	-57.53	449.08	9.05	102.85
MFT	%	900	14.60	5.28	3.89	34.90	0.94	4.47
AGE	%	900	13.08	5.08	3.82	23.01	-0.20	1.75

4 Empirical Results

4.1 Baseline Regression and Robustness Tests

Based on literature review, we select "Gini index" as the target explanatory variable. Before selecting the functional form of the regression model, we first test and analyze the control variables. In model (1), we preliminarily verify the impact of income inequality on CO2 emissions per capita. Then in the model (2) to model (4), we add the control variables GDP per capita, urbanization rate and the square of the two variables one by one. We also find that the target explanatory variables are more significant and the control variables are significant. Therefore, we select model (4) as the form of baseline regression.

In Table 3, the model (4) shows that income inequality has a significant negative correlation with CO2 emissions. Each percentage point increase in the Gini index will reduce the average CO2 emissions per capita by 57.80 kg. This may be due to the higher demand of high-income groups for high-level environmental quality when the degree of income inequality is large. This will help alleviate the negative impact of income inequality on CO2 emissions.

In the empirical results of the control variables, we confirm the EKC hypothesis, that is GDP per capita and CO2 emissions are significantly positively correlated, and the square term of GDP per capita and CO2 emissions are significantly negatively correlated. At the same time, we also confirm the conclusion of Wan and Wang (39), which means that the relationship between urbanization rate and CO2 emissions is inverted U-shaped.

In addition, we conduct the robustness tests. The reliability of the results is determined by shortening the time period of sample. Model (5) and model (6) are analyzed using data from 2010 to 2019 and 2005 to 2014 respectively. The Table 2 shows that the results of model (4) are robust.

Table 3. Baseline regression results

	Dependent Variable: Carbon Emission					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**（6）**
GINI	-38.12**	-84.73** *	-58.80** *	-57.80** *	-54.08**	-50.70** *
	(15.85)	(17.00)	(17.20)	(16.22)	（23.75）	（16.56）

GDP		-.06***	.09***	.08***	-.038	.16***
		(.01)	(.03)	(.02)	（.03）	（.03）
URB				705.27***	771.31***	748.22***
		-58.74***	-91.67***			
		(18.96)	(19.35)	(79.92)	（134.04）	（99.79）
GDP2			-1.54e-06***	-1.33e-06***	-2.80e-07	-6.90e-07**
			(2.54e-07)	(2.41e-07)	（2.75e-07）	（3.35e-07）
URB2				-6.11***	-6.19***	-6.87***
				(.60)	（.97）	(.77)
Constant	7361.09***	14892.58***	13941.52***	-10564.19***	-13029.86***	-12994.56***
	(575.91)	(1602.83)	(1577.70)	(2817.60)	（4906.85）	(3348.86)
Observations	900	900	900	900	600	600
Fix effect	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2 Analysis of Moderating Effect

To study the moderating effect, we have introduced the trade share, foreign direct investment share, manufacturing share and their interaction term (with Gini index) on the basis of baseline regression.

4.2.1. Moderating Effect Test and Analysis of Opening Degree.

As shown in Table 4, we add the trade share and interaction term in models (5) to (7) one by one. The results show that the explanatory variables and the trade share in the model (5) remain significant within the 99% confidence interval. In model (6), the explanatory variables are not significant, but the interaction item are significant

within the 99% confidence interval. In model (7), the explanatory variables are significant within the 95% confidence interval, while the trade share and interaction item are not significant. Due to the significant problem of model (7), we continue to adjust the form of moderator variable in model(8) to model (10). Finally, we choose the model (8) with all variables significant within the 99% confidence interval as the moderating effect model of opening degree.

Table 4. Analysis of the moderating effect of opening degree

	Dependent Variable: Carbon Emission						
	(4)	**（5）**	**(6)**	**(7)**	**(8)**	**（9）**	**(10)**
GINI	-57.80***	-45.23***	-6.90	-55.35**	-95.97***	8.61	-102.71
	(16.21)	（15.851）	(17.51)	(26.28)	(21.31)	（19.48）	(72.95)
GDP	.08***	.0647615***	.0649012***	.0650197***	.0672594***	.0654746***	.0702146***
	(.02)	（.02）	(.02)	(.02)	(.02)	（.02）	(.02)
URB	705.27***	603.93***	591.07***	609.70***	629.40***	596.58***	629.67***
	(79.92)	（78.87）	(79.69)	(79.80)	(78.66)	（79.64）	(80.59)
GDP2	-1.33e-06***	-1.01e-06***	-1.08e-06***	-1.00e-06***	-9.55e-07***	-1.08e-06***	-1.18e-06 ***
	(2.41e-07)	（2.38e-07）	(2.37e-07)	(2.39e-07)	(2.37e-07)	（2.37e-07）	(2.40e-07)
URB2	-6.11***	-5.34***	-5.25***	-5.38***	-5.48***	-5.26***	-5.61***
	(.60)	（.59）	(.60)	(.60)	(.59)	（.59）	(.60)
TRA		-17.08***		-21.04	-32.61***		
		（2.38）		(8.53)	(4.99)		

TRA2			-.43***	.11		-.61***	
			(.06)	(.23)		(.12)	
lnTRA						844.39*	-3192.24
						(467.47)	(2682.01)
lnTRA2					1850.30***		2027.26
					(523.87)		(2695.30)
Constant	-10564.19***	-6305.55**	-7373.12***	-6136.48**	-18949.82***	-11410.44***	-8264.19
	(2817.6)	（2799.15）	(2785.79)	(2822.26)	(4532.62)	（3568.67）	(7702.60)
Observations	900	900	900	900	900	900	900

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

It can be seen that the inhibition effect of income inequality on CO2 emissions will weaken with the improvement of opening degree. This means that the opening degree has a moderating effect on the relationship between income inequality and CO2 emissions. The increase in the trade share leads to an increase in logistics, including air, sea and land transportation, which will increase CO2 emissions. At the same time, when the opening degree is low, high-income people usually choose to reduce CO2 emissions by investing in industries that use environmental protection technologies or influencing legislation to improve their living environment. However, at a higher level of openness, high-income people will choose a cheaper and more efficient way to obtain a better living environment. For example, they choose to go to countries with higher environmental quality for vacation, or import high-quality resources from other countries for daily life. As a result, the high-income people no longer pay attention to environmental protection as before, and eventually lead to the weakening of the inhibition.

4.2.2. Moderating effect test and analysis of foreign investment.

As shown in Table 5, we add the foreign investment share and the interaction term in models (11) to (13) one by one. The results show that the explanatory variables in the model (11) are significantly negative within the 99% confidence interval, and the proportion of foreign investment is significantly positive within the 95% confidence interval. In model (12), the explanatory variable is significantly negative within the 99% confidence interval, and the interaction item is significantly positive within the 95% confidence interval. In model (13), the explanatory variable is significantly negative within the 99% confidence interval, the foreign investment share is significantly positive within the 99% confidence interval, and the interaction item is significantly negative within the 95% confidence interval.

Table 5. Analysis of the moderating effect of foreign investment

Dependent Variable: Carbon Emission				
	(4)	**（11）**	**(12)**	**(13)**
GINI	-57.80***	-55.85***	-56.81***	-47.09***
	(16.22)	（16.20）	(16.19)	(16.51)
GDP	.07***	.08***	.08***	.08***
	(.02)	（.02）	(.02)	(.02)
URB	705.27***	693.34***	695.23***	687.48***
	(79.92)	（79.87）	(79.91)	(79.65)
GDP2	-1.33e-06***	-1.34e-06***	-1.34e-06***	-1.37e-06***
	(2.41e-07)	（2.40e-07）	(2.40e-07)	(2.40e-07)
URB2	-6.11***	-6.03***	-6.04***	-5.99***
	(.60)	（.60）	(.60)	(.59）
FDI		2.79**		32.26***
		（1.19）		(11.78)
FDI2			.08**	-.98**
			(.039)	(.39)
Constant	-10564.19***	-10434.72***	-10438.16 ***	-10574.82***
	(2817.60)	（2810.57）	(22812.65)	(2802.20)
Observations	900	900	900	900

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Based on the significance of variables, we select model (13) as the moderating effect model of foreign investment. It is obvious that the inhibition of income inequality on CO2 emissions will strengthen with the improvement of foreign investment. This means that the foreign investment has moderating effect on the relationship between income inequality and CO2 emissions. The rising level of foreign investment means that enterprises will bring positive effects like employment opportunities, advanced technology and economic growth to the invested areas. For example, to build factories enterprises will improve the infrastructure construction in the region, including electricity and roads, etc. It not only increases the number of jobs in factories and the potential employment opportunities in regional infrastructure construction, but it also disseminates advanced knowledge such as wind power generation and hydropower generation. This will rapidly improve the regional economic development and strengthen the inhibition of CO2 emissions.

4.2.3.Moderating effect test and analysis of economic structure.

As shown in Table 6, we add manufacturing share and interaction term in models (14) to (16) one by one. The results show that the explanatory variables and the proportion of manufacturing industry in the model (14) are significant within the 99% confidence interval. In model (15), explanatory variables and interaction terms are significant within 99% confidence interval. In model (16), manufacturing share and interaction items are significant within the 99% confidence interval, and explanatory variables are not significant.

Table 6. Analysis of the moderating effect of economic structure

	Dependent Variable: Carbon Emission			
	(4)	**（14）**	**(15)**	**(16)**
GINI	-57.80***	-46.67***	-93.50***	42.79
	(16.22)	（15.95）	(17.40)	(34.14)
GDP	.08***	.13***	.11***	.13***
	(.02)	（.03）	(.03)	(.03)
URB	705.27***	684.36***	716.56***	628.35***
	(79.92)	（78.21）	(78.75)	(80.11)
GDP2	-1.33e-06***	-2.03e-06***	-1.86e-06***	-2.09e-06***

	(2.41e-07)	（2.60e-07）	(2.58e-07)	(2.60e-07)
URB2	-6.11***	-5.69***	-5.91***	-5.42***
	(.60)	（.59）	(.59)	(.59)
MFT		130.66***		339.10***
		（20.75）		(73.37)
MFT2			3.07***	-6.17***
			(.59)	(2.09)
Constant	-10564.19***	-14241.68***	-13250.46***	-14713.52***
	(2817.60)	（2815.79）	(2823.24)	(2807.30)
Observations	900	900	900	900

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

We choose model (16) as the moderating effect model of economic structure. Although the estimated value of Gini index is not significant, the manufacturing share and interaction term are significant. The impact of income inequality on CO2 emissions will increase as the proportion of manufacturing rises. This means that economic structure has moderating effect on the relationship between income inequality and CO2 emissions. Compared with the primary and tertiary industries, the manufacturing industry usually has a higher level of pollution. For example, manufacturing industries like steel, cement and paper, mostly rely on burning fossil fuels, resulting in high CO2 emissions. When the manufacturing share is at a high level, individuals will consume more goods than services. At the same time, the expansion of income inequality leads to higher income groups more inclined to choose environmentally friendly products. This will promote manufacturers to carry out production mode reform, and finally it reduces CO2 emissions.

4.3 Heterogeneity Analysis

4.3.1. Heterogeneity Test and Analysis of Population Aging.

Population aging is also an important factor affecting the relationship between income inequality and CO2 emissions. In 1956, the United Nations issued the "The ageing of populations and its economic and social implications", which defined the

criteria for dividing regions into aging. When the proportion of the elderly aged 65 and above in the total population in a country or region more than 7%, it means that the country or region is aging. We group the countries in the statistical data according to the proportion of aging population greater than 7% and less than or equal to 7%. As shown in table 7, model (17) and model (18) are divided into aging countries and non-aging countries. The results show that the explanatory variables in the model (17) are significant within the 90% confidence interval. The explanatory variables in model (18) are not significant.

Thus, when the country is aging, income inequality has a restraining effect on CO2 emissions. When a country has a large proportion of the elderly population, the polarization of income will make local people more concerned about the quality of living environment. This may be due to the pursuit of quality of life and sense of social responsibility of wealthy elderly people, which urges them to choose a lifestyle beneficial to the environment, thus reducing CO2 emissions.

However, we find that the results of explanatory variables were not significant when studying non-aging countries. To explore the reasons, we set up the variable income to quantify the income difference by assigning values to the dummy variables respectively:

$$\text{income} = HI*3+UMI*2+LMI*1 \tag{3}$$

Then we study the relationship between population aging and income and GDP respectively. As shown in Table 8, the proportion of population aging is significant within the 99% confidence interval. This shows that there is a positive correlation between population aging and regional income and economic level. When the proportion of aging is less than 7%, it indicates that the regional income level is low and the economic development is relatively backward. Because the living standards, consumption levels and ideologies of low-income countries are not very different. In the case of underdeveloped economy, the gap between rich and poor caused by income inequality is not very different. Therefore, income inequality has little impact on CO2 emissions.

Table 7. Heterogeneity analysis of population aging

Dependent Variable: Carbon Emission			
	(4)	**（17）**	**(18)**

GINI	-57.80***	-40.59*	-14.55
	(16.22)	（22.13）	(13.83)
GDP	.08***	.06**	.45***
	(.02)	（.03）	(.10)
URB	705.27***	968.95***	-127.67
	(79.92)	（94.13）	(98.98)
GDP2	-1.33e-06***	-1.06e-06 ***	-.000014***
	(2.41e-07)	（2.65e-07）	(3.03e-06)
URB2	-6.11***	-8.85***	.94
	(.60)	（.72）	(.74)
Constant	-10564.19***	-14159.39***	4766.58
	(2817.60)	（3343.81）	(3058.89)
AGE>7	NO	YES	NO
AGE<=7	NO	NO	YES
Observations	900	724	176

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8. Relationship between population aging and income and GDP

	income	**GDP**
AGE	.10***	2239.18***
	(.003)	(107.97)
Constant	1.14***	1068.33
	(.04)	(1514.44)

4.3.2. Heterogeneity test and analysis of economic development.

Previous studies have shown that there are differences in CO2 emissions among countries with different levels of economic development (1). As shown in Table 9, this paper discusses low and middle-income countries, upper middle-income countries and high-income countries one by one in models (19) to (21). The results show that the explanatory variables in the model (19) are not significant. In model (20), the explanatory variable is significantly positive within the 99% confidence interval. In

model (21), the explanatory variable is significantly negative within the 99% confidence interval.

The explanatory variables of model (19) are not significant, which may be due to the limited material life condition of low and middle-income countries. Even if there is income inequality, the living standards of the poor and the rich are difficult to open too wide a gap. In model (20), the positive correlation between income inequality and CO2 emissions may be due to the fact that high-income people in upper middle-income countries pay more attention to wealth accumulation than the quality of life. Because the citizens of upper middle-income countries want to develop their economy as soon as possible, so that the country to catch up with the world's top countries. Therefore, increasing income inequality in upper middle-income countries will promote CO2 emissions. In model (21), we find that the coefficient of explanatory variables in high-income countries is negative and significantly smaller than that in all countries under discussion. This may be due to the fact that high-income people in high-income countries pay more attention to environmental quality, and their high spiritual pursuit urges them to make contributions to global environmental protection. Therefore, the expansion of income inequality in high-income countries will strengthen the suppression of CO2 emissions.

Table 9. Heterogeneity analysis of economic development

Dependent Variable: Carbon Emission				
	(4)	**（19）**	**(20)**	**(21)**
GINI	-57.80***	-23.19	50.55***	-109.20***
	(16.22)	（17.28）	(16.03)	(33.71)
GDP	.077***	.16	.36***	.0058
	(.025)	（.23）	(.069)	(.031)
URB	705.27***	-199.51	143.58**	1042.37***
	(79.92)	（146.61）	(60.96)	(247.45)
GDP2	-1.33e-06***	.0000116	-7.45e-06***	-5.53e-07*
	(2.41e-07)	（.0000106）	(1.59e-06)	(2.91e-07)

URB2	-6.11***	1.01	-1.06**	-10.33***
	(.60)	（1.15）	(.45)	(1.62)
Constant	-10564.19***	9432.91	4766.58***	-6351.92
	(2817.60)	（3892.99）	(3058.89)	(9707.30)
Lower middle income	NO	YES	NO	NO
Upper middle income	NO	NO	YES	NO
High income	NO	NO	NO	YES
Observations	900	105	270	525

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

5 Conclusion

This paper uses the panel data of 60 countries from 2005 to 2019 as a sample to analyze the impact of income inequality on CO2 emissions from a global perspective. The descriptive data analysis in this paper shows that the intensification of income inequality will curb CO2 emissions. This paper confirms the EKC hypothesis that the initial stage of economic development will stimulate environmental degradation, and the environmental quality will be improved later with economic growth. At the same time, this paper also confirmed the inverted U-shaped relationship between urbanization rate and CO2 emissions. At the same time, this paper conducts a robustness test to verify this relationship.

More importantly, this paper analyzes the moderating effect. The results show that the inhibition effect of income inequality expansion on CO2 emissions will weaken with the increase of opening degree, because the increase of opening degree will lead to the increase of logistics and transportation, and the reduction of environmental protection attention of high-income people. Conversely, income inequality has a stronger inhibitory effect on CO2 emissions with the increase of foreign investment, since the enterprises will bring employment opportunities, advanced technology and economic growth to the invested areas. Meanwhile, the increase in the manufacturing

share enhances the inhibition of the impact of income inequality on CO2 emissions, because high-income people consume more environmentally friendly goods.

Finally, this paper analyzes the heterogeneity. The result shows that income inequality has a restraining effect on CO2 emissions when the country is aging. The wealthy elderly are encouraged to choose a lifestyle that is beneficial to the environment owing to the pursuit of quality of life and social responsibility. However, income inequality has little impact on CO2 emissions when the country is not aging on account of the positive correlation between population aging and regional income and GDP. When discussing the economic development, this paper finds that the impact of income inequality and CO2 emissions in low and middle-income countries is not obvious, in upper middle-income countries has the expansionary effect, while in high-income countries has restrain effects, because of the small gap in the living standards of citizens in low and middle-income countries, the desire of citizens in upper middle-income countries for a higher level of economic development, and the desire of citizens in high-income countries to enjoy a better living environment.

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