International Area Studies Review
2024, Vol. 27(3) 267–288

https://doi.org/10.69473/iasr.2024.27.3.267

Article

The Influence of Income Inequality on Air Environmental Quality: An Analysis of the Inland Region in China

Tao Liu
College of Local Administration, Khon Kaen University, Khon Kaen, Thailand
School of Economics and Management, Ningde Normal University, Ningde, China

Grichawat Lowatcharin*
College of Local Administration, Khon Kaen University, Khon Kaen, Thailand

Peerasit Kamnuansilpa
College of Local Administration, Khon Kaen University, Khon Kaen, Thailand

Lingtong Liu
College of Local Administration, Khon Kaen University, Khon Kaen, Thailand

Abstract

The influence of income inequality on air quality is a multifaceted matter that involves society, economy, and the environment. Although the inland region of China has achieved rapid economic development and fully utilized their abundant natural resources, it has also been accompanied by widening income disparities and environmental pollution issues. Especially the frequent occurrence of haze and sandstorms poses serious challenges to the sustainable development and residents' lives in inland areas. To gain a deeper understanding of this issue, this paper is based on panel data from 20 provinces, cities, and autonomous regions in the inland region from 2006 to 2020 and uses the pooled Ordinary Least Squares regression (POLS) to conduct an in-depth analysis of the repercussions of income inequality on air quality. By studying the relationship between the two, this paper aims to provide policy makers with scientific and reasonable policy recommendations, better balance income distribution differences and environmental governance, and attain a sustainable and robust development of the economy and environment in inland areas.

Keywords

Income inequality, Air quality, Pooled ordinary least squares regression, Inland region

Corresponding author:
* Email: grichawat@kku.ac.th

Introduction

The inland region of China has become the engine of national development due to the abundant natural resources and key economic status (Zhao & Zou, 2018). The economy has achieved significant development, with a total GDP growth of 837.1% from 6.2 trillion in 2003 to 58.1 trillion in 2022 (the data is from the *Statistical Yearbook of China*, 2000-2020). However, the growth of economy is accompanied by urgent social and environmental challenges, including significant income inequality and air quality issues, which significantly influence residents' quality of life and the sustainable development of society. In addition, the presence of high-income inequality can undermine the strength of institutional frameworks, complicating government efforts to enforce environmental regulations. This challenge arises as wealthier individuals and corporations often possess greater leverage in policy-making processes, potentially leading to a prioritization of their interests over those of the environment. Consequently, governments in such regions may struggle to implement and sustain environmental initiatives, ultimately exacerbating environmental degradation and compromising the effectiveness of their policies (Boyce, 2003).

The harm of income inequality in inland region involves multiple aspects such as economy, society, and environment, which may have serious negative impacts on individuals, society, and countries. Excessive income inequality can easily lead to social conflicts and dissatisfaction, which may lead to social unrest and instability (Hao et al., 2021). Social unrest or political instability, which can, in turn, hinder environmental initiatives (Pata et al., 2022). For instance, social tensions driven by inequality may cause governments to shift their focus and resources away from environmental priorities (Shah et al., 2023). In addition, as the main battlefield of Chinese industrialization, the inland region has injected vitality into economic growth through industrial processes (Zhang et al., 2022). However, this process is accompanied by large-scale industrial emissions, exhaust emissions, and environmental pollution. The decline in air quality has become a prominent issue in inland region, and the frequent occurrence of haze weather has aroused widespread concern (Agarwal et al., 2020). The impact of industrial emissions on the atmosphere, especially the emissions of fine particulate matter and harmful gases, directly threatens the health and living environment of residents (Yousuf et al., 2022). Therefore, studying the influence of income inequality in inland areas on air quality holds profound significance for attaining social equity, environmental justice, and sustainable development goals, which helps to provide more effective policies and action plans for governments, enterprises, and society.

The correlation between income inequality and air quality has always been a concern within the framework of the Sustainable Development Goals (SDGs) (Khan et al., 2022; Zhao et al., 2020). The Sustainable Development Goals provide a clear guiding framework for addressing income inequality and air quality issues in inland areas (Cernev & Fenner, 2020). SDG 10 emphasizes achieving inclusive economic growth at the global, national, and regional levels, reducing inequality among different social groups (Menyelim et al., 2021). Meanwhile, SDG 11 requires the construction of sustainable cities and communities, with a focus on improving the quality of life of residents and protecting the environment (Yamasaki & Yamada, 2022). Placing research within the framework of Sustainable Development Goals (SDGs) helps to better understand and address the interrelationships between society, economy, and environment.

In light of China's long-term goals for 2035, including the improvement of income and wealth distribution patterns alongside the double carbon objectives of reaching a carbon peak by 2030 and achieving carbon neutrality by 2060, addressing the income gap and environmental challenges arising from economic development is of utmost importance (Zhuang & Dou, 2023). The Chinese government faces the urgent task of developing a more equitable and sustainable socioeconomic model. This paper focuses on analyzing how income inequality affects air quality in inland regions. Its objective is to investigate the correlation between narrowing income disparities and enhancing environmental conditions. By doing so, the study aims to offer policymakers evidence-based insights for making informed decisions that align with the Sustainable Development Goals, encompassing economic growth, social equity, and ecological preservation.

Literature Review

Building upon the groundwork laid by Grossman and Krueger (1991), Panayotou (1993) introduced the environmental Kuznets curve (EKC), a pivotal model that analyzes the correlation between income per capita and environmental degradation. This framework has evolved into a foundational cornerstone for exploring the correlation between income and environment issues. Since then, scholars from various backgrounds have delved into this subject, leading to the development of three primary perspectives on the connection between income inequality and air quality.

The negative impact of income inequality on air quality

The prevailing viewpoint, widely embraced by scholars, asserts that income inequality exacerbates air quality issues. Kasuga and Takaya (2017) explored the impact of income inequality on environmental degradation in Japan, establishing not only a correlation but also a causal effect. Their empirical tests revealed a negative impact of income inequality on air quality. Mahalik et al. (2018) delved into the relationship between income inequality and environmental quality across various BRICS economies. Their findings suggested that, apart from South Africa, income inequality contributed to an increase in CO_2 emissions. Padhan et al. (2019) observed that the wealth gap decreased CO_2 emissions when income inequality exceeded 45%, but expanded CO_2 emissions when income inequality was below 40%. They emphasized that countries with more equal income distribution policies experienced a negative impact when exacerbating inequality, whereas countries adopting more unequal income distribution policies to reduce inequality degraded the environment. Baloch et al. (2020) explored the relationship between income inequality and CO_2 emissions in 40 Saharan and South African countries from 2010 to 2016. Their empirical results suggested that increasing income inequality exacerbated CO_2 emissions, negatively impacting the environmental quality of the study subjects. Alataş and Akın (2022) explored the impact of income inequality on sectoral CO_2 emissions in 28 OECD economies, identifying income inequality as a key factor in sectoral emissions. The rise of the Gini index led to varying degrees of increase in CO_2 emissions in sectors such as electricity, construction, and transportation. Rai and Rawat (2022) explored the impact of technological innovation, income inequality, and industrialization on the environmental quality of BRICS countries from 1996 to 2016. Their results indicated that a 1% increase in income inequality led to a 1.54% increase in CO_2 emissions. Khademolhosseini et al. (2022) investigated the impact of the Gini coefficient on suspended particulate matter and SO_2, finding that as the Gini coefficient increased and income inequality intensified, the emissions of suspended particulate matter and SO_2 showed varying degrees of increase. Gao and Fan (2023) analyzed the impact of income inequality on CO_2 emissions in the Belt and Road countries, and the results showed that income inequality significantly led to increased carbon emissions and decreased environmental quality.

The positive impact of income inequality on air quality

The alternative viewpoint regarding the correlation posits that an increase in income inequality may contribute to the enhancement of air environmental quality. Grunewald et al. (2017) found that for low- and middle-income economies, higher income inequality was associated with lower carbon emission. Liu et al. (2018) conducted a comprehensive examination of the relationship between income and environmental degradation across 31 provinces in China from 1996 to 2015. According to their research, a certain range of income inequality proved beneficial for enhancing environmental quality. Liu et al. (2019) analyzed the impact of income inequality on carbon emissions in various states of the United States and found that higher income inequality is beneficial for carbon reduction in the long run. Hailemariam et al. (2020) analyzed the impact of income inequality on CO_2 emissions in OECD countries and found that an increase in inequality on the Gini index is related to a decrease in CO_2 emissions. Yameogo and Dauda (2022) delved into the intricate relationship between income inequality, carbon emission rates, and economic growth. Their study indicated that income inequality was found to decrease CO_2 emissions in Nigeria in the short term. Wan et al. (2022) analyzed data from 217 countries since 1960 and found that rising income inequality can reduce CO_2 emissions by reducing energy consumption.

The unclear impact of income inequality on air quality

Some research indicated that the impact of income inequality on environmental outcomes is nuanced, exhibiting variations across different time periods and regions, and in some instances, showing no discernible relationship. Wolde-Rufael and Idowu (2017) found that income inequality was the least important factor determining CO_2 emissions, and there is no direct causal relationship between carbon dioxide emissions and income inequality in these two countries. Hübler (2017) found through fixed effects regression that there was no correlation between income inequality and CO_2 emissions. Li (2017) introduced the concept of a threshold effect in the impact of income inequality on the Chinese environment. His theoretical model, supported by empirical evidence, revealed a clear income threshold for China. When a region's per capita income is below the average level, an increase in urban-rural income gap can, to some extent, reduce the emission of environmental pollutants and enhance environmental quality. However, when the per capita income level exceeds the average, it tends to worsen environmental quality. Mader (2018) challenged the conclusions drawn by Knight et al. (2017) and Jorgenson et al. (2017) regarding the promoting effect of income inequality on CO_2 emissions. Mader argued that the selected regions, time spans, and indicators to measure inequality in these studies were limited in persuasiveness. In his further research, he found no discernible relationship between social inequality and CO_2 emissions. Wang, Yang, et al. (2023) pointed out that under the influence of the threshold effect of income inequality, the relationship between economic growth and per capita carbon emissions presents an N-shaped curve, rather than the traditional inverted U-shaped curve. In the stage of low-income inequality, economic growth has a significant promoting effect on carbon emissions. As income inequality deepens, economic growth in turn suppresses the increase of carbon emissions. However, in the stage of high-income inequality, the impact of economic growth on carbon emissions becomes positive again.

Except direct effects, income inequality may also indirectly affect air pollution through a series of socio-economic mechanisms. These mechanisms include industrial structure (Liu et al., 2020; Wang & Chen, 2024), energy consumption patterns (Duarte et al., 2021; Rojas-Vallejos & Lastuka, 2020; Wang et al., 2021), and environmental regulation (Jorgenson et al., 2017; Qin et al., 2021; Zhou & Li, 2020). Resident health plays an important role as a mediating variable in the process of income inequality affecting air pollution. Air pollution has a serious impact on human health, and the health status of residents is closely related to their income level (Chen & Wang, 2024). Due to limited economic conditions, low-income groups are often more susceptible to the impact of air pollution and have poorer health conditions. And the deterioration of health status will affect their labor ability and income level, further exacerbating income inequality. This vicious cycle makes residents' health an important mediating effect of income inequality on air pollution (Wang, Li, et al., 2023; Yang & Liu, 2018).

Methodology

Selection of EKC econometric model

The convex-concave nature of the EKC shapes the influence of income inequality on environmental quality (Wang & Lv, 2022). Therefore, it is essential to test the shape of EKC first. The most used econometric models for EKC currently include traditional linear models and logarithmic models. For example:

$$y_{it} = \alpha_i + \beta_1 \chi_{it} + \beta_2 \chi_{it}^2 + \beta_3 \chi_{it}^3 + \beta_4 z_{it} + \varepsilon_{it} \qquad \text{(1) (Dinda, 2004)}$$

$$lnPC_{it} = \alpha_0 + \alpha_1 lngini_{it} + \alpha_2 (lngini_{it})^2 + \alpha_3 (lngini_{it})^3 + \beta lnX_{it} + \mu_i + \nu_t + \varepsilon_{it} \qquad \text{(2) (Zhan, 2018)}$$

This paper uses a linear model to conduct empirical research as follows:

$$E_{i,t} = \alpha_0 + \beta_1 IN_{i,t} + \beta_2 IN_{i,t}{}^2 + \beta_3 Z_{i,t} \cdots + \varepsilon_{i,t} \qquad (3)$$

Where, E is the dependent variable for measuring environmental quality; IN is a variable that measures income inequality; Z is the control variable. α_0 is a constant, ε is a random error, where i and t correspond to province and year.

As shown in Table 1 above, the coefficient sign before the proxy variable of income inequality in Model (3) and the conclusion can provide reference for the judgment of subsequent empirical results.

Table 1. The Coefficient symbol and conclusion

Coefficient symbol	Conclusion
$\beta_1=\beta_2=0$	Environmental quality is not affected by income inequality
$\beta_1>0, \beta_2=0$	A positive linear relationship
$\beta_1<0, \beta_2=0$	An inverse linear relationship
$\beta_1>0, \beta_2<0$	An inverted U-shaped curve
$\beta_1<0, \beta_2>0$	A U-shaped curve

Source: Author's compilation based on Zaatari (2022)

Data sources and variable descriptions

Data sources

This study utilizes panel data encompassing the Inland region of China (excluding Xizang) over the period from 2006 to 2020. The data sources include the *Statistical Yearbook of China, China Regional Economic Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook*, and *Provincial-level Statistical Yearbooks*.

Dependent variable

The primary indicators used for measuring air pollution encompass carbon emissions, SO_2 emissions, smoke, and dust emissions, and PM2.5 levels (Luo et al., 2022; Pata, 2021; Zhao et al., 2023). In the contemporary discourse, climate change has gained global attention, with the substantial release of greenhouse gases, predominantly carbon emissions, identified as a leading contributor to this phenomenon. Consequently, many scholarly works have adopted carbon emissions as a key metric for assessing environmental quality (Wolde-Rufael & Idowu, 2017). Presently, China holds the position of the world's largest carbon emitter, placing immense pressure on the nation to reduce emissions. Therefore, this study designates carbon emissions as the principal explanatory variable for evaluating environmental quality.

Unlike indicators such as wastewater, sulphur dioxide, and smoke (powder) dust, there is currently no direct carbon emission statistical data in China. However, the United Nations Intergovernmental Panel on Climate Change (IPCC) provides a standardized method for calculating statistical carbon emissions. The IPCC posits that the surge in carbon emissions is primarily attributable to the utilization of fossil fuels. Hence, this paper adopts the initial method outlined by the IPCC, deemed straightforward and easily calculable. This approach entails estimating CO_2 emissions by considering the quantity of energy fuels consumed along with their respective carbon emission coefficients. Notably, this approach aligns with the common practice among Chinese scholars, as observed in the works of Chen (2009), who predominantly employ this method for estimating carbon emissions across diverse regions in China. For the scope of this research, the same method is applied to estimate carbon emissions data.

The primary energy data required for computing carbon emissions for the 30 provinces from 2006 to 2020 are derived from the *China Energy Statistical Yearbook*. This comprehensive yearbook offers data on eight fossil fuels, encompassing inputs for energy processing and conversion, along with fossil fuels utilized for non-energy purposes. To streamline calculations and avert redundancy, energy balance tables for the 30 provinces from 2006 to 2020 were specifically chosen for computation. This process included excluding inputs and losses occurring during energy processing and conversion procedures, as well as portions used as raw materials and materials in industrial production.

This paper calculates carbon emissions based on provincial terminal energy consumption data over the years. The method is based on the IPCC Guidelines for National Greenhouse Gas Emissions Inventory (IPCC, 2006) . As shown in formula (4):

$$CE_{it} = \sum (EC_{jit} \times \eta_j) \tag{4}$$

Where, CE is the total carbon emissions; EC is the j energy consumption; η_j is the carbon emission coefficient of the j energy source; i denotes the province; t signifies the year.

The original statistical data on the consumption of diverse energy sources is presented in physical units, necessitating their conversion into standardized statistics when estimating carbon emissions. In accordance with the categorization specified in the China Energy Statistical

Table 2. The equivalent coal coefficient and conversion coefficient of 9 types of energy

Energy Name	Equivalent coal coefficient	Carbon dioxide conversion coefficient
Coal	0.7143kgce/kg	1.9003
Coke	0.9714kgce/kg	2.8604
Crude oil	1.4286kgce/kg	3.0202
Gasoline	1.4714kgce/kg	2.9251
Kerosene	1.4714kgce/kg	3.0179
Diesel oil	1.4571kgce/kg	3.0959
Fuel oil	1.4286kgce/kg	3.175
Liquefied petroleum gas	1.7143kgce/kg	3.1013
Natural gas	1.33kgce/m^3	21.622

Source: General Principles for Calculation of Comprehensive Energy Consumption (GB/T 2589-2020), 2021

Yearbook, the final energy consumption is divided into nine categories: coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, liquefied petroleum gas, and natural gas. The corresponding equivalent coal coefficients and conversion coefficients for these nine energy types are detailed in Table 2 below.

In addition, SO_2 is one of the main atmospheric pollutants formed by industrial fuel combustion, and fuel use is usually considered as the environmental effect of energy consumption. Therefore, the robustness testing section of this paper will replace carbon emissions with sulfur dioxide indicators.

Independent Variables

At present, the main indicators for measuring income inequality include the Gini coefficient, the Thiel index, and the urban-rural income ratio (Consoli et al., 2023; Tang et al., 2022). This paper uses the Thiel index to measure income inequality.

The value of the Thiel index is positively correlated with income inequality, that is, the larger the Thiel index, the greater the income inequality. This paper refers to the specific calculation formula used in the Wang and Ouyang's research for the calculation method of the Thiel index (Wang & Ouyang, 2008).

The formula is as follows:

$$Theil_{it} = \sum_{j=1}^{2}\left(\frac{I_{it,j}}{I_{it}}\right)ln\left(\frac{I_{it,j}}{P_{it,j}} / \frac{I_{it}}{P_{it}}\right) \tag{5}$$

Where, j takes values 1 and 2 representing urban and rural areas, respectively; $Theil$ is the Theil index; I represents the total income, calculated by multiplying the total population by per capita income; P is the total population; i denotes the province; t signifies the year.

The Theil index, computed with this formula, incorporates the population shares of urban and rural areas as weights, considering the evolving urban and rural population structures. This approach is particularly apt for capturing the nuances of the current income landscape amid the dual structure of urban and rural areas in China. One of the salient features of the Theil index lies in its versatility to encapsulate both "inter-regional" and "intra-regional" income disparities. At the inter-regional level, it adeptly measures the variations in average income levels across diverse geographical areas. Conversely, delving into the regional level, the Theil index dissects income gaps among individuals or subgroups within a particular region. This dual-faceted decomposition capability renders the Theil index an invaluable tool for exploring multi-layered and multi-dimensional income inequality dynamics (Heng, 2011).

This paper primarily delves into the influence of inter-regional income distribution on air quality. One plausible reason for this focus stems from the practical challenges associated with gathering intra-regional income distribution data, particularly when encompassing vast numbers of individuals or segmented groups. To ensure the study's feasibility and efficiency, the article likely opted for the more readily accessible and manageable inter-regional data.

Moreover, the study's emphasis rests on elucidating the macro-level impact of income inequality on air quality. Consequently, regional disparities, as a pivotal aspect of macro-inequality, naturally emerged as the central research focus. Additionally, regional disparities encompass broader policy, economic, and social dimensions, which are crucial for comprehending the intricate relationship between overall inequality and air quality.

Nonetheless, this methodological choice bears notable limitations. Firstly, overlooking intra-regional income distribution may skew the overall inequality picture, potentially under- or overestimating it, thereby compromising the precision of research findings. Secondly, intra-regional income inequality might exert its influence on air quality through distinct mechanisms, such as shaping consumption habits or influencing environmental policy implementation, which might remain elusive in an inter-regional analysis.

Future research should aim to include more detailed geographical data and develop multi-level Theil indices. This would enable a comprehensive view of income distribution's influence on air quality, uncovering cross-strata relationships and informing targeted policies.

Control variables

This paper mainly uses economic development level, urbanization level, industrial structure indicators, and export dependence as control variables.

Economic development level. Economic growth, reflected in increased residents' disposable income, exerts influence on environmental quality by impacting GDP and environmental investment. In this study, the economic development level of each region is represented by per capita GDP. The issues of income disparity and environmental quality are inherently linked to economic development, with a discernible relationship existing among the level of economic development, income inequality, and environmental outcomes. The necessary GDP and population data are sourced meticulously from the *Statistical Yearbook of China*.

Urbanization level. The degree of urbanization plays a crucial role in influencing environmental quality. In contrast to developed nations, China is presently undergoing a phase of swift urbanization, marked by a substantial migration of rural residents to urban areas. However, China's Hukou system has led to the underestimate of the population actually living in the city but not moving in with registered residence, which affects the accuracy of urbanization data (Wang et al., 2022). This deviation in data further affects the accurate assessment of environmental effects such as environmental pressure and resource consumption caused by urbanization. In future research, multi-channel data collection and comprehensive analysis should be conducted to more comprehensively evaluate the level of urbanization and its impact on environmental quality. Some scholars believe that the relationship between urbanization and environmental pollution may not be single linear, but rather that with the development of urbanization, environmental quality will undergo a process of first deteriorating and then improving, which will present an inverted U-shape. This paper gauges the degree of urbanization development by calculating the percentage of the urban population in various regions, expressed as a proportion of the total population at the year's conclusion. The essential data for this measurement is diligently sourced from the *Statistical Yearbook of China*.

Industrial structure indicator. Industrial structure factors constitute important variables, given their close connection to energy consumption, which, in turn, influences environmental quality (Li & Yang, 2017). Regions with a higher proportion of the industrial sector tend to exhibit greater energy consumption, resulting in more pronounced environmental pollution. Prevailing research on industrial structure and environmental quality indicates that an excessive share of the secondary industry contributes to an imbalanced industrial structure, exacerbating environmental issues. Analyzing the repercussions of industrial upgrading on the ecological environment within the Yangtze River Economic Belt, Li (2018) contends that the rationalization and elevation of industrial structure have a positive impact on enhancing the ecological environment. This underscores a symbiotic relationship between industrial upgrading and environmental amelioration. This paper utilizes the percentage of added value from the secondary industry in the province's GDP (*psi*) as the indicator for assessing industrial structure. Data for this analysis is derived from the National Bureau of Statistics website and the *Statistical Yearbook of China*.

Export dependency. There is still no consensus on the impact of export dependence on environmental quality. Some scholars believe that with the increasing openness of export trade, enterprises continuously expand their production scale to seize the international market, resulting in environmental damage (Xue & Ding, 2020). However, there are also studies that hold different perspectives. Some scholars believe that in recent years, international trade competition has intensified, and countries have raised the admission standards for imported goods and formulated strict environmental regulations, especially developed countries that have higher requirements for environmental protection. Therefore, to avoid export risks, Chinese export enterprises are poised to advocate for clean production and prioritize the development of environmentally friendly products through innovations in environmental technology. On the one hand, this can ensure that the product meets the environmental access standards established by the exporting country, reduce restrictions on China's export goods, increase export volume to compensate for increased environmental costs, and on the other hand, it is conducive to enhancing the environmental awareness of enterprises in China and improving the environmental quality of China (Chen, 2012). In addition, foreign direct investment also affects environmental conditions through various factors, such as the introduction of new technologies and environmental concepts, which directly affect the level of environmental pollution control and thus the degree of environmental pollution. Li et al. (2017) believed that foreign direct investment has promoted the development of China's scientific and technological level, especially environmental protection technology, by exerting its "demonstration effect" and "spillover effect" on pollution control and has a restraining effect on China's environmental pollution. However, according to Han et al. (2019), while foreign direct investment (FDI) may stimulate short-term enhancements in China's environmental quality, its long-term effects are characterized by a suppressive influence on sustained environmental improvement, ultimately yielding a negative impact on overall environmental quality. Therefore, this paper uses the proportion of total import and export volume of foreign-invested enterprises to GDP to measure export dependence. The total import and export figures for foreign-invested enterprises are adjusted using the average exchange rate for the respective year. All data originate from the *Statistical Yearbook of China*.

Detailed descriptions of the variables are presented in Table 3 below.

Descriptive statistics

To have a preliminary understanding of the basic characteristics of the variables used in the model, Table 4 below provides the descriptive statistical characteristics of each variable.

Table 3. Description of related variables

Variables	Symbol	Unit of measurement	Variable description
Per capita carbon emissions	*pce*	ton/person	The ratio of carbon emissions to the total population
Per capita SO_2 emissions	*pso*	ton/person	The proportion of SO_2 emissions to the total population
Theil index	*thirl*	—	Measuring the urban-rural income gap
Per capita GDP	*pgdp*	10000 yuan/ person	The proportion of GDP to the total population
Urbanization rate	*ur*	%	The urban population to the total population
Per capita added value of the secondary industry	*psi*	10000 yuan/ person	The ratio of the added value of the secondary industry to the total population
Proportion of total import and export volume of foreign-invested enterprises	*tied*	%	The total import and export volume of foreign-invested enterprises to GDP
Ratio of completed investment in waste gas treatment projects	*rwg*	%	The completed investment in waste gas treatment projects to GDP

Source: Author's compilation

Table 4. Statistical description of variables

Variable	Obs	Mean	Std. Dev.	Min	Max
pce	300	10.377	9.085	0.677	49.474
pso	300	0.017	0.014	0.001	0.064
thirl	300	0.128	0.05	0.04	0.281
pgdp	300	3.38	1.577	0.614	7.803
ur	300	0.502	0.094	0.275	0.722
psi	300	1.438	0.642	0.258	3.159
tied	300	0.039	0.045	0	0.259
rwg	300	0.001	0.001	0	0.009

Source: Stata Corp2021

Findings

Empirical findings

This section first uses the pooled Ordinary Least Squares regression (pooled OLS) to empirically test the impact in the inland region, and then conducts a robustness testing on the measurement results.

Regression results

As shown in Table 5 above, the coefficient of the *thirl* is 218.525, which is a positive number, while the coefficient of its square term ($thirl^2$) is -395.191, reflecting a negative value. Both coefficients have passed the 1% significance test. This indicates that in inland region, there is an inverted U-shaped relationship between *pce* and the *thirl*, which means there is an inverted U-shaped EKC curve in inland China.

Furthermore, further observation of the regression results of the control variables revealed that:

Per capita GDP (*pgdp*): The results of the regression analysis reveal an inverse relationship between *pgdp* and environmental pollution in inland region, that is, as *pgdp* increases, per capita carbon emissions (*pce*) will decrease, and environmental quality will improve.

Urbanization rate (*ur*): The outcomes of the regression analysis indicate a negative impact of the urbanization rate on environmental quality in inland areas, that is, the higher the level of *ur*, the more pollutants are emitted.

Per capita added value of the secondary industry (*psi*): The regression analysis results show a positive relationship between *psi* and environmental pollution in inland areas, that is, as *psi* increases, the amount of pollutant emissions increases.

The proportion of total import and export volume of foreign-invested enterprises to GDP (*tied*): The regression analysis results show a positive relationship between *tied* and environmental quality in inland areas, that is, as *tied* increase, environmental quality gradually improves.

Robustness testing

To enhance the credibility of the research findings, this paper performs robustness testing using four distinct methods. The first method is replacing the dependent variable, the second method is adding variable, the third method is reducing variable, and the fourth method uses a lag of one period for robustness detection.

Replacing variables

As shown in Table 6, after replacing the dependent variable, the regression results and significance of the independent variables align closely with the regression results (Table 5). However, there are slight variations in the magnitudes of the coefficients and the extent of their

Table 5. Regression results

pce	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
thirl	218.525	44.793	4.88	0	130.369	306.681	***
thirl2	-395.191	134.103	-2.95	0.003	-659.118	-131.263	***
pgdp	-5.239	0.967	-5.42	0	-7.142	-3.337	***
ur	114.826	9.828	11.68	0	95.485	134.168	***
psi	11.426	2.158	5.29	0	7.178	15.673	***
tied	-87.315	10.578	-8.25	0	-108.133	-66.497	***
Constant	-63.073	6.718	-9.39	0	-76.296	-49.851	***

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

Source: Stata Corp2021

Table 6. The result with pso as the dependent variables

pso	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
thirl	0.396	0.072	5.51	0	0.254	0.537	***
thirl2	-0.732	0.215	-3.40	0.001	-1.156	-0.309	***
pgdp	-0.014	0.002	-9.07	0	-0.017	-0.011	***
ur	0.15	0.016	9.49	0	0.119	0.181	***
psi	0.02	0.003	5.90	0	0.014	0.027	***
tied	-0.077	0.017	-4.51	0	-0.11	-0.043	***
Constant	-0.073	0.011	-6.81	0	-0.095	-0.052	***

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

Source: Stata Corp2021

Table 7. Increasing ratio of completed investment in waste gas treatment projects (rwg)

pce	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
thirl	177.037	40.911	4.33	0	96.519	257.554	***
thirl2	-335.789	121.731	-2.76	0.006	-575.371	-96.207	***
pgdp	-2.871	0.924	-3.11	0.002	-4.689	-1.052	***
ur	92.027	9.343	9.85	0	73.638	110.416	***
psi	7.375	2.019	3.65	0	3.401	11.349	***
tied	-63.504	10.03	-6.33	0	-83.244	-43.765	***
rwg	2867.209	355.924	8.06	0	2166.708	3567.71	***
Constant	-53.448	6.203	-8.62	0	-65.657	-41.239	***

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

Source: Stata Corp2021

impact. The coefficient of *thirl* is 0.396, which is positive, while the coefficient of its square term is -0.732, which is negative, and both pass the 1% significance test.

Adding variables

As shown in Table 7, after adding the control variable *rwg*, all variables passed the 1% significance test.

Reducing variables

As shown in Table 8, after reducing the control variable *tied*, *pgdp and psi* exhibited significance at the 5% level, while other variables demonstrated significance at the 1% level.

Lagged regression results for one period

As shown in Table 9, after a lag of one period, all variables passed the 1% significance test.

The robustness testing conducted through the four methods affirms the overall reliability of the empirical results presented in this paper.

Table 8. Reducing the proportion of total import and export volume of foreign-invested enterprises to GDP (*tied*)

pce	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
thirl	285.529	48.822	5.85	0	189.443	381.615	***
thirl2	-566.313	146.842	-3.86	0	-855.308	-277.317	***
pgdp	-2.184	.99	-2.21	0.028	-4.132	-0.236	**
ur	94.942	10.56	8.99	0	74.159	115.724	***
psi	5.674	2.264	2.51	0.013	1.218	10.129	**
Constant	-63.919	7.445	-8.59	0	-78.572	-49.266	***

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

Source: Stata Corp2021

Table 9. Lagged regression results for one period

pce	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
thirl	206.271	43.78	4.71	0	120.074	292.468	***
thirl2	-369.236	135.413	-2.73	0.007	-635.85	-102.622	***
pgdp	-5.233	0.9	-5.82	0	-7.004	-3.462	***
ur	112.9	9.414	11.99	0	94.365	131.436	***
psi	11.597	1.996	5.81	0	7.667	15.527	***
tied	-88.619	10.113	-8.76	0	-108.53	-68.709	***
Constant	-61.951	6.425	-9.64	0	-74.601	-49.301	***

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

Source: Stata Corp2021

Regression fitting graphs

As shown in Figure 1 above, during the quadratic fitting of *pce* and *thirl*, the estimated coefficient of *thirl* is 58.333, while the estimated coefficient of $thirl^2$ is -308.66. The fitting results indicate the existence of an inverted U-shaped EKC curve in inland China.

As shown in Figure 2 below, the quadratic fitting results of *pce* and *pgdp* indicate an inverted U-shaped curve between *pce* and *pgdp* in inland areas. Based on the quadratic fitting function of *pce* and *pgdp*, $pce = 1.4797 + 3.5973\ pgdp - 0.23466\ pgdp^2$. Setting $pce' = 0$, i.e., $3.5973 - 0.46932\ pgdp = 0$, obtain: $pgdp = 7.6649$, which means that the inflection point of *pce* is around *pgdp* equals 7.6649. The *pgdp* in 2018 was 5.0895, 5.4697 in 2019, and 5.6304 in 2020 (data from 2018 to 2020 is calculated based on *the Statistical Yearbook of China*). This indicates that *pgdp* is in the ascending stage to the left of the inflection point, that is, as *pgdp* increases, *pce* will increase.

As shown in Figure 3 below, the quadratic fitting results of *pce* and *ur* indicate a U-shaped relationship between *pce* and *ur* in inland areas. Following the approach of calculating the inflection point above, the inflection point of *ur* is 29.68%. In 2018, the *ur* was 56.59%, 57.98% in 2019, and 59.23% in 2020 (data from 2018 to 2020 is calculated based on *the Statistical Yearbook of China*). It is evident that the *ur* has surpassed the inflection point and is currently in an ascending phase on its right, that is, as *ur* increases, *pce* will increase.

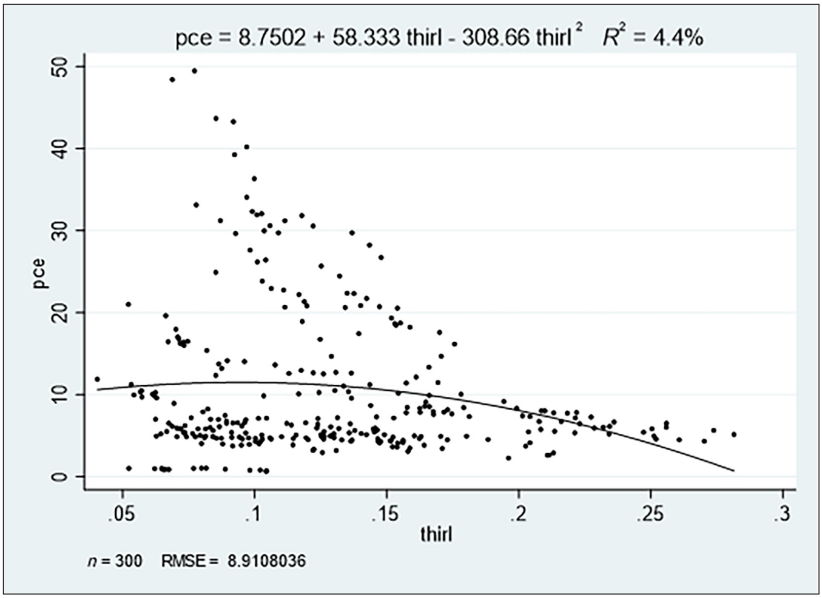

Figure 1. Quadratic fitting graph between *pce* and *thirl* in inland region
Source: Stata Corp2021

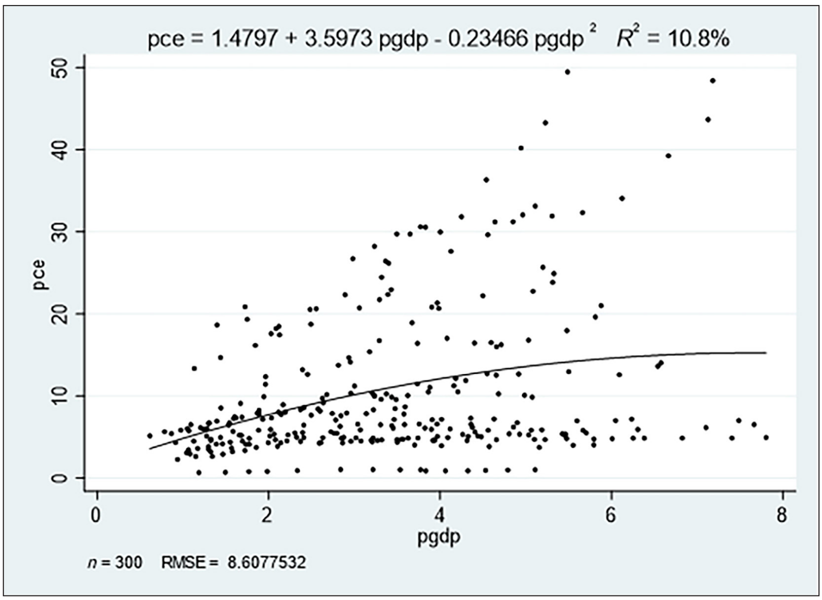

Figure 2. Quadratic fitting graph between *pce* and *pgdp*
Source: Stata Corp2021

As shown in Figure 4 above, the quadratic fitting results show an inverted U-shaped relationship between *pce* and *psi* in inland areas. Following the approach of calculating the

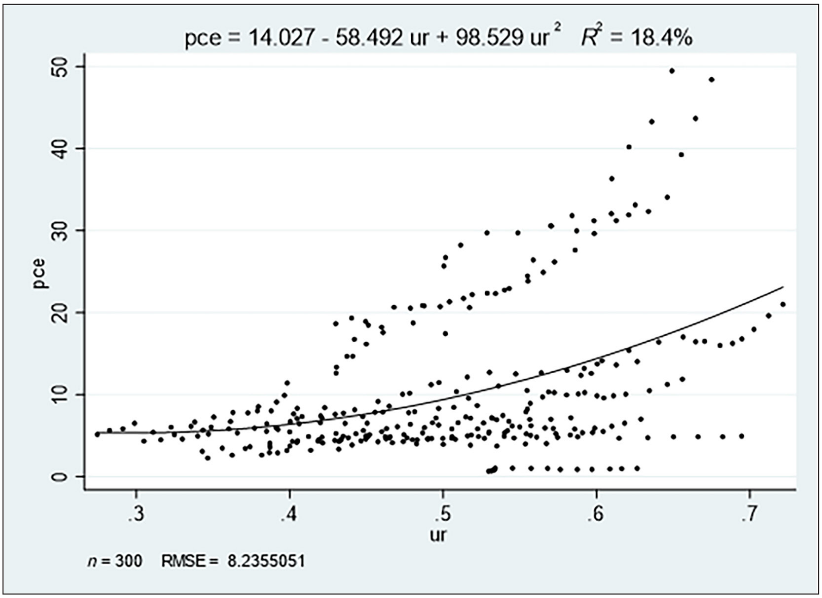

Figure 3. Quadratic fitting graph between *pce* and *ur*
Source: Stata Corp2021

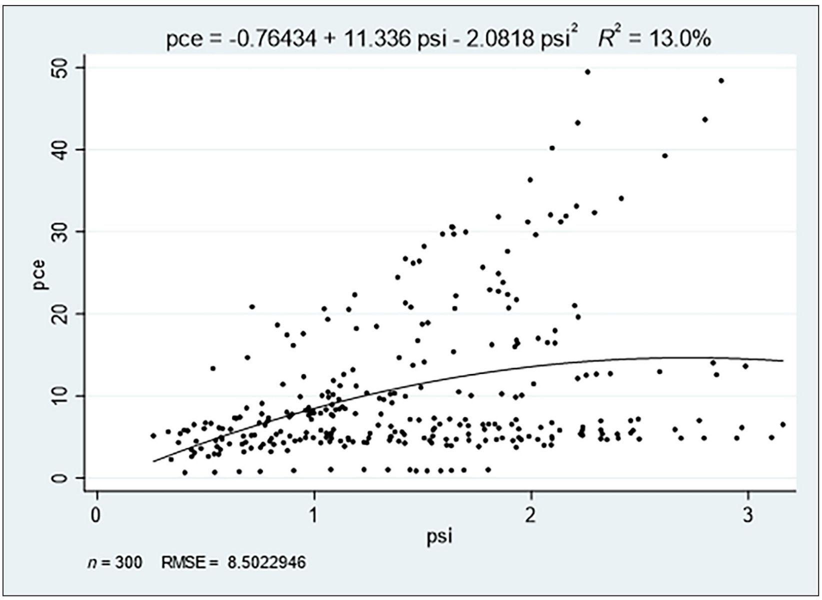

Figure 4. Quadratic fitting graph between *pce* and *psi*
Source: Stata Corp2021

inflection point, the inflection point of *psi* is 2.7226. The *psi* in 2018 was 2.0555, 2.182 in 2019, and 2.1715 in 2020 (the data from 2018 to 2020 is calculated based on *the Statistical Yearbook of*

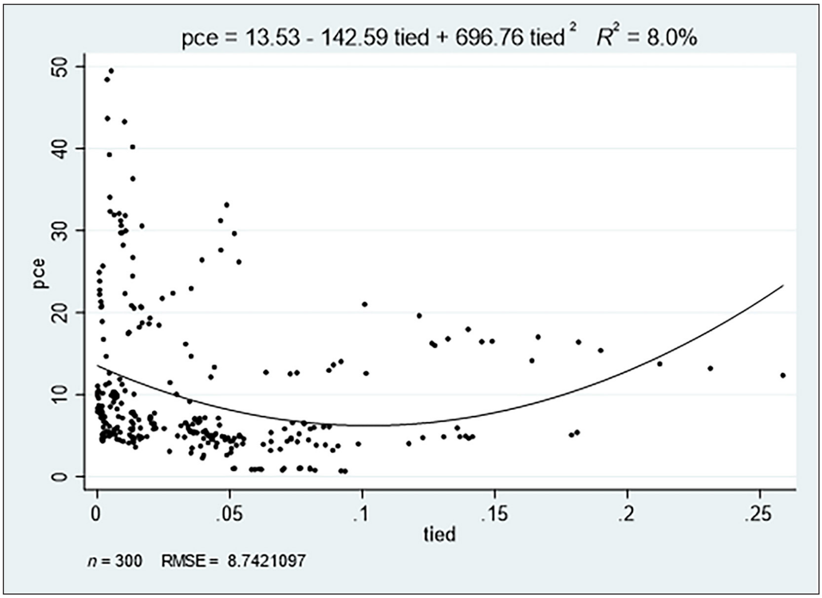

Figure 5. Quadratic fitting graph between *pce* and *tied*
Source: Stata Corp2021

China). It is obvious that *psi* has not yet reached the inflection point and is in the rising stage on its left side, that is, as *psi* increases, *pce* will increase.

As shown in Figure 5 below, the quadratic fitting results of *pce* and *tied* indicate a U-shaped relationship between *pce* and *tied* in inland areas. Following the approach of finding the inflection point, it can be concluded that the inflection point is 10.23%. In 2018, the *tied* was 5.21%, 4.88% in 2019, and 5.09% in 2020 (data from 2018 to 2020 is calculated based on *the Statistical Yearbook of China*). It is obvious that the *tied* has not yet reached the inflection point, which is the descending stage on its left side, that is, as the *tied* increases, the *pce* will decrease.

Conclusions and Implications

In general, an inverted U-shaped EKC exists in inland China, which first increases and then decreases. This indicates that the EKC hypothesis is applicable in inland China.

Conclusions

The regression analysis and quadratic fitting results consistently indicate an inverted U-shaped relationship between the environmental quality and the income inequality.

Per capita GDP: The regression analysis results reveal a negative correlation between per capita GDP and air environmental pollution in inland areas, that is, as per capita GDP increases, per capita carbon emissions will decrease, and air environmental quality will improve. Furthermore, by further calculating the inflection point, it was found that per capita GDP is in the rising stage to the left of the inflection point of the fitting curve.

Urbanization rate: The regression analysis results show that urbanization rate has a negative effect on environmental quality in inland areas, that is, the higher the level of urbanization rate, the more pollutants are emitted. The quadratic fitting graph illustrates a U-shaped relationship between urbanization rate and air environmental quality.

Per capita added value of the secondary industry: The regression analysis results show a negative relationship between per capita added value of the secondary industry and air environmental quality in inland areas. The quadratic fitting graph illustrates an inverted U-shaped curve.

The proportion of total import and export volume of foreign-invested enterprises to GDP: The regression analysis results show a positive relationship between *tied* and environmental quality in inland areas, that is, as the proportion of total import and export volume of foreign-invested enterprises to GDP increase, environmental quality gradually improves.

Implications

Strengthening green technology to promote clean energy development

Enhancing green technology and implementing clean energy policies represent crucial strategies in addressing both income inequality and environmental quality concerns (Liu et al., 2022). It is imperative for the government to actively promote, and support research and application of green technologies aimed at reducing environmental pollution and resource consumption. Investment in clean energy sources, such as solar and wind energy, is essential for mitigating reliance on highly polluting energy. Moreover, increased funding in green technologies and clean energy infrastructure, encompassing power networks, energy storage facilities, and charging stations, can significantly contribute to the sustainability of clean energy (Razmjoo et al., 2021). Furthermore, boosting investment in research and development within the realms of green technology and clean energy is vital for expediting the development and commercialization of new technologies (Kong, 2022). This can be achieved through government funding, collaborative research and development initiatives, and innovation funds.

Enhancing education and skill training

Reinforcing education and skill training policies stands as a crucial strategy for mitigating income disparities and enhancing environmental quality in inland areas. Elevating the education level and skill literacy of residents not only fosters increased employment opportunities but also facilitates the creation of high-value industries. Moreover, it cultivates a deeper understanding and a heightened sense of responsibility toward the environment among individuals (Wei et al., 2020).

Facilitating local government cooperation

Facilitating collaboration among governments at various levels is pivotal for coordinating the execution of environmental policies, especially concerning cross-regional environmental issues such as watershed management and air quality improvement. The establishment of cross-regional planning agencies can effectively coordinate development plans and policies across different regions, ensuring the judicious allocation of resources and mitigating inequality (Gao et al., 2022). Encouraging local governments to share resources and best practices promotes sustainable development and environmental protection initiatives. Collaborative efforts on cross-regional environmental protection projects, encompassing water resource management, air pollution control, and ecological preservation, can collectively address environmental challenges and enhance environmental quality (He et al., 2022).

Setting long-term plans and goals

To attain the objective of diminishing income inequality and enhancing environmental quality over the long term, the government can craft comprehensive, enduring plans and policies with a focus on nurturing the tourism industry in inland areas (Xiao et al., 2022). Inland regions, characterized by abundant natural and cultural tourism resources, have experienced relatively sluggish development in this sector due to factors such as lagging overall development and inconvenient transportation (Ma et al., 2023). To alleviate income inequality, stimulate economic growth in inland areas, and enhance environmental quality, the government can implement a series of policies aimed at fostering the development of the inland tourism industry.

In conclusion, to narrow the income disparity in inland regions while concurrently enhancing environmental quality, the government should enact comprehensive policies. In inland areas, emphasis can be placed on bolstering infrastructure construction, fostering enterprise investment, advancing tourism development, fortifying education and training, and elevating residents' skill levels. Simultaneously, there should be a concerted effort to prioritize environmental protection and formulate sustainable development plans.

AI Acknowledgment

Generative AI or AI-assisted technologies were not used in any way to prepare, write, or complete essential authoring tasks in this manuscript.

Conflict of Interests

The author(s) declare that there is no conflict of interest.

Funding

The author(s) declare that there is no funding.

ORCID iD

Tao Liu https://orcid.org/0009-0008-4772-9786
Grichawat Lowatcharin https://orcid.org/0000-0002-2623-1769
Peerasit Kamnuansilpa https://orcid.org/0000-0001-6994-4809
Lingtong Liu https://orcid.org/0009-0000-5591-406X

References

Agarwal, A., Kaushik, A., Kumar, S., & Mishra, R. K. (2020). Comparative study on air quality status in Indian and Chinese cities before and during the COVID-19 lockdown period. *Air Quality, Atmosphere & Health, 13*(10), 1167–1178. https://doi.org/10.1007/s11869-020-00881-z

Alataş, S., & Akın, T. (2022). The impact of income inequality on environmental quality: A sectoral-level analysis. *Journal of Environmental Planning and Management*, *65*(10), 1949–1974. https://doi.org/10.1080/09640568.2022.2050684

Baloch, M. A., Danish, Khan, S. U. D., Ulucak, Z. Ş., & Ahmad, A. (2020). Analyzing the relationship between poverty, income inequality, and CO_2 emission in Sub-Saharan African countries. *Science of the Total Environment*, *740*, 139867. https://doi.org/10.1016/j.scitotenv.2020.139867

Boyce, J. K. (2003). *Inequality and Environmental Protection* (PERI Working Paper Series, No. 52). Political Economy Research Institute.

Cernev, T., & Fenner, R. (2020). The importance of achieving foundational Sustainable Development Goals in reducing global risk. *Futures*, *115*, 102492. https://doi.org/10.1016/j.futures.2019.102492

Chen, S. Y. (2009). Energy consumption, CO_2 emission and sustainable development in Chinese industry. *Economic Research Journal*, *4*(4), 41–55.

Chen, T. L., & Wang, M. (2024). Environmental regulation, endowment characteristics and income inequality: A general equilibrium analysis. *Journal of Environmental Management*, *368*, 122118. https://doi.org/10.1016/j.jenvman.2024.122118

Chen, Y. (2012). The impact and countermeasures of international environmental regulations on China's export trade. *Practice in Foreign Economic Relations and Trade*, *5*, 43-45.

Consoli, D., Castellacci, F., & Santoalha, A. (2023). E-skills and income inequality within European regions. *Industry and Innovation*, *30*(7), 919–946. https://doi.org/10.1080/13662716.2023.2230222

Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics*, *49*(4), 431–455. https://doi.org/10.1016/j.ecolecon.2004.02.011

Duarte, R., Miranda-Buetas, S., & Sarasa, C. (2021). Household consumption patterns and income inequality in EU countries: Scenario analysis for a fair transition towards low-carbon economies. *Energy Economics*, *104*, 105614. https://doi.org/10.1016/j.eneco.2021.105614

Gao, D., Li, G., & Li, Y. (2022). Government cooperation, market integration, and energy efficiency in urban agglomerations—Based on the quasi-natural experiment of the Yangtze River Delta Urban Economic Coordination Committee. *Energy & Environment*, *33*(8), 1679–1694. https://doi.org/10.1177/0958305X211047480

Gao, X., & Fan, M. (2023). The effect of income inequality and economic growth on carbon dioxide emission. *Environmental Science and Pollution Research*, *30*(24), 65149–65159. https://doi.org/10.1007/s11356-023-27009-x

Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American free trade agreement* (NBER Working Papers Series, No. 3914). National Bureau Of Economic Research. https://doi.org/ 10.3386/w3914

Grunewald, N., Klasen, S., Martínez-Zarzoso, I., & Muris, C. (2017). The trade-off between income inequality and carbon dioxide emissions. *Ecological Economics*, *142*, 249–256. https://doi.org/10.1016/j.ecolecon.2017.06.034

Hailemariam, A., Dzhumashev, R., & Shahbaz, M. (2020). Carbon emissions, income inequality and economic development. *Empirical Economics*, *59*(3), 1139–1159. https://doi.org/10.1007/s00181-019-01664-x

Han, Y. H., Li, Z. W., Zhang, F., & Shen, C. (2019). Environmental effects of bidirectional FDI in China. *Resource Science*, *41*(11), 2043–2058. https://doi.org/10.18402/resci.2019.11.08

Hao, Y., Liu, J., Lu, Z. N., Shi, R., & Wu, H. (2021). Impact of income inequality and fiscal decentralization on public health: Evidence from China. *Economic Modelling*, *94*, 934–944. https://doi.org/10.1016/j.econmod.2020.02.034

He, Y., Liu, X., & Wang, X. (2022). How can environment get better? A research review of pollution governance. *Management of Environmental Quality: An International Journal*, *33*(2), 406–418. https://doi.org/10.1108/MEQ-08-2021-0187

Heng, Y. (2011). Characteristics of inter-regional income disparities in China. *Social Sciences in China*, *32*(3), 123–144. https://doi.org/10.1080/02529203.2011.598305 https://doi.org/10.1007/s10668-022-02802-9

Hübler, M. (2017). The inequality-emissions nexus in the context of trade and development: A quantile regression approach. *Ecological Economics*, *134*, 174–185. https://doi.org/10.1016/j.ecolecon.2016.12.015

IPCC (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Jorgenson, A., Schor, J., & Huang, X. (2017). Income inequality and carbon emissions in the United States: A state-level analysis, 1997-2012. *Ecological Economics*, *134*, 40–48. https://doi.org/10.1016/j.ecolecon.2016.12.016

Kasuga, H., & Takaya, M. (2017). Does inequality affect environmental quality? Evidence from major Japanese cities. *Journal of Cleaner Production*, *142*, 3689-3701. https://doi.org/10.1016/j.

jclepro.2016.10.099
Khademolhosseini, J., Mousavi, S. N., & Khodaparast Shirazi, J. (2022). The effect of income inequality on SO_2 and SPM emissions. *Iranian Journal of Agricultural Economics and Development Research*, *53*(2), 539–551. https://doi.org/10.22059/ijaedr.2022.325416.669050
Khan, S., Wang, Y., & Zeeshan, A. (2022). Impact of poverty and income inequality on the ecological footprint in Asian developing economies: Assessment of Sustainable Development Goals. *Energy Reports*, *8*, 670–679. https://doi.org/10.1016/j.egyr.2021.12.001
Knight, K. W., Schor, J. B., & Jorgenson, A. K. (2017). Wealth inequality and carbon emissions in high-income countries. *Social Currents*, *4*(5), 403–412. https://doi.org/10.1177/2329496517704872
Kong, F. (2022). A better understanding of the role of new energy and green finance to help achieve carbon neutrality goals, with special reference to China. *Scienzce Progress*, *105*(1). https://doi.org/10.1177/00368504221086361
Li, J. K., Cheng, L. Y., & Zhang, T. B. (2017). Does foreign direct investment have a "pollution halo" effect? *Chinese Population, Resources and Environment*, *27*(10), 74–83.
Li, Q. (2018). Has industrial upgrading promoted ecological environment optimization? Based on panel data analysis of 108 cities in the Yangtze River Economic Belt. *Finance and Trade Research*, *12*, 39–47. https://doi.org/10.19337/j.cnki.34-1093/f.2018.12.004
Li, Z. H. (2017). The income threshold effect of income gap on environmental pollution: theoretical and empirical research. *Inquiry into Economic Issues*, *3*, 63–72.
Li, Z., & Yang, S. Y. (2017). Science and technology innovation, industrial upgrading, and economic growth: Interactive mechanism and empirical test. *Jilin University Journal Social Sciences Edition*, *57*(3), 41–52, 204-205. https://doi.org/10.15939/j.jujsse.2017.03.004
Liu, C., Jiang, Y., & Xie, R. (2019). Does income inequality facilitate carbon emission reduction in the US? *Journal of Cleaner Production*, *217*, 380–387. https://doi.org/10.1016/j.jclepro.2019.01.242
Liu, H., Anwar, A., Razzaq, A., & Yang, L. (2022). The key role of renewable energy consumption, technological innovation, and institutional quality in formulating the SDG policies for emerging economies: evidence from quantile regression. *Energy Reports*, *8*, 11810–11824. https://doi.org/10.1016/j.egyr.2022.08.231
Liu, Q., Wang, S., Zhang, W., & Li, J. (2018). Income distribution and environmental quality in China: A spatial econometric perspective. *Journal of Cleaner Production*, *205*, 14–26. https://doi.org/10.1016/j.jclepro.2018.09.090
Liu, Z., Zhang, H., Zhang, Y. J., & Qin, C. X. (2020). How does income inequality affect energy efficiency? Empirical evidence from 33 Belt and Road Initiative countries. *Journal of Cleaner Production*, *269*, 122421. https://doi.org/10.1016/j.jclepro.2020.122421
Luo, Y., Sun, F., Yan, X., & Sun, T. (2022). Research on comprehensive assessment of effect on environmental pollution collaborative treatment: Taking China's Yangtze River Delta urban agglomeration as an example. *Polish Journal of Environmental Studies*, *31*(6), 5151–5162. https://doi.org/10.15244/pjoes/151494
Ma, L., Zhu, Z., Li, S., & Li, J. (2023). Analysis of spatial and temporal changes in human interference in important ecological function areas in China: The Gansu section of Qilian Mountain National Park as an example. *Environmental Monitoring and Assessment*, *195*(9), 1029. https://doi.org/10.1007/s10661-023-11633-8
Mader, S. (2018). The nexus between social inequality and CO_2 emissions revisited: Challenging its empirical validity. *Environmental Science & Policy*, *89*, 322–329. https://doi.org/10.1016/j.envsci.2018.08.009
Mahalik, M. K., Mallick, H., Padhan, H., & Sahoo, B. (2018). Is skewed income distribution good for environmental quality? A comparative analysis among selected BRICS countries. *Environmental Science and Pollution Research*, *25*(23), 23170–23194. https://doi.org/10.1007/s11356-018-2401-8
Menyelim, C. M., Babajide, A. A., Omankhanlen, A. E., & Ehikioya, B. I. (2021). Financial inclusion, income inequality and sustainable economic growth in sub-Saharan African countries. *Sustainability*, *13*(4), 1780. https://doi.org/10.3390/su13041780
Padhan, H., Haouas, I., Sahoo, B., & Heshmati, A. (2019). What matters for environmental quality in the

Next Eleven countries: Economic growth or income inequality? *Environmental Science and Pollution Research*, *26*(22), 23129–23148. https://doi.org/10.1007/s11356-019-05568-2

Panayotou, T. (1993). *Empirical tests and policy analysis of environmental degradation at different stages of economic development*. International Labour Organization. http://www.ilo.org/public/libdoc/ilo/1993/93B09_31_engl.pdf

Pata, U. K. (2021). Renewable and non-renewable energy consumption, economic complexity, CO_2 emissions, and ecological footprint in the USA: Testing the EKC hypothesis with a structural break. *Environmental Science and Pollution Research*, *28*(1), 846–861. https://doi.org/10.1007/s11356-020-10446-3

Pata, U. K., Yilanci, V., Hussain, B., & Naqvi, S. A. A. (2022). Analyzing the role of income inequality and political stability in environmental degradation: Evidence from South Asia. *Gondwana Research*, *107*, 13–29. https://doi.org/10.1016/j.gr.2022.02.009

Qin, M., Fan, L. F., Li, J., & Li, Y. F. (2021). The income distribution effects of environmental regulation in China: The case of binding SO_2 reduction targets. *Journal of Asian Economics*, *73*, 101272. https://doi.org/10.1016/j.asieco.2021.101272

Rai, S. K., & Rawat, A. (2022). Exploring the nexus between environment quality, economic development, and industrialization in BRICS nations: The role of technological innovation and income inequality. *Environmental Science and Pollution Research*, *29*(25), 37842–37853. https://doi.org/10.1007/s11356-021-18181-z

Razmjoo, A., Kaigutha, L. G., Rad, M. V., Marzband, M., Davarpanah, A., & Denai, M. (2021). A technical analysis investigating energy sustainability utilizing reliable renewable energy sources to reduce CO_2 emissions in a high potential area. *Renewable Energy*, *164*, 46-57. https://doi.org/10.1016/j.renene.2020.09.042

Rojas-Vallejos, J., & Lastuka, A. (2020). The income inequality and carbon emissions trade-off revisited. *Energy Policy*, *139*, 111302. https://doi.org/10.1016/j.enpol.2020.111302

Shah, M. I., Shuaibu, M. S., AbdulKareem, H. K., Khan, Z., & Abbas, S. (2023). Inequality consequences of natural resources, environmental vulnerability, and monetary-fiscal stability: A global evidence. *Environmental Science and Pollution Research*, *30*(4), 10329–10345. https://doi.org/10.1007/s11356-022-22788-1

Tang, J., Gong, J., & Ma, W. (2022). Narrowing urban-rural income gap in China: The role of the targeted poverty alleviation program. *Economic Analysis and Policy*, *75*, 74–90. https://doi.org/10.1016/j.eap.2022.05.004

Wan, G., Wang, C., Wang, J., & Zhang, X. (2022). The income inequality-CO_2 emissions nexus: Transmission mechanisms. *Ecological Economics*, *195*, 107360. https://doi.org/10.1016/j.ecolecon.2022.107360

Wang, F., Yang, J., Shackman, J., & Liu, X. (2021). Impact of income inequality on urban air quality: A game theoretical and empirical study in China. *International Journal of Environmental Research and Public Health*, *18*(16), 8546. https://doi.org/10.3390/ijerph18168546

Wang, L., & Chen, L. (2024). Resource dependence and air pollution in China: Do the digital economy, income inequality, and industrial upgrading matter? *Environment, Development and Sustainability*, *26*(1), 2069–2109.

Wang, Q., Li, L., & Li, R. (2023). Uncovering the impact of income inequality and population aging on carbon emission efficiency: An empirical analysis of 139 countries. *Science of the Total Environment*, *857*, 159508. https://doi.org/10.1016/j.scitotenv.2022.159508

Wang, Q., Yang, T., & Li, R. (2023). Does income inequality reshape the Environmental Kuznets Curve (EKC) hypothesis? A nonlinear panel data analysis. *Environmental Research*, *216*, 114575. https://doi.org/10.1016/j.envres.2022.114575

Wang, S., & Ouyang, Z. (2008). The threshold effect of the urban-rural income disparity on real economic growth in China. *Social Sciences in China*, *29*(3), 39–53. https://doi.org/10.1080/02529200802288005

Wang, Y., Wang, J., Liu, Y., & Li, J. (2022). Calibrations of urbanization level in China. *China CDC Weekly*, *4*(6), 111–115. https://doi.org/10.46234/ccdcw2022.007

Wang, Z., & Lv, D. (2022). Analysis of agricultural CO_2 emissions in Henan province, China, based on EKC

and decoupling. *Sustainability*, *14*(3), 1931. https://doi.org/10.3390/su14031931
Wei, H., Nian, M., & Li, L. (2020). China's strategies and policies for regional development during the period of the 14th five-year plan. *Chinese Journal of Urban and Environmental Studies*, *8*(2), 2050008 . https://doi.org/10.1142/S2345748120500086
Wolde-Rufael, Y., & Idowu, S. (2017). Income distribution and CO_2 emission: A comparative analysis for China and India. *Renewable and Sustainable Energy Reviews*, *74*, 1336–1345. https://doi.org/10.1016/j.rser.2016.11.149
Xiao, Y., Tang, X., Wang, J., Huang, H., & Liu, L. (2022). Assessment of coordinated development between tourism development and resource environment carrying capacity: A case study of Yangtze River economic Belt in China. *Ecological Indicators*, *141*, 109125. https://doi.org/10.1016/j.ecolind.2022.109125
Xue, J., & Ding, J. (2020). The influence of economic growth and export trade on environmental pollution. *Economic Forum, 10*, 34–42.
Yamasaki, K., & Yamada, T. (2022). A framework to assess the local implementation of Sustainable Development Goal 11. *Sustainable Cities and Society*, *84*, 104002. https://doi.org/10.1016/j.scs.2022.104002
Yameogo, C. E., & Dauda, R. O. (2022). The effect of income inequality and economic growth on environmental quality: A comparative analysis between Burkina Faso and Nigeria. *Journal of Public Affairs*, *22*(3), e2566 . https://doi.org/10.1002/pa.2566
Yang, T., & Liu, W. (2018). Does air pollution affect public health and health inequality? Empirical evidence from China. *Journal of Cleaner Production*, *203*, 43–52. https://doi.org/10.1016/j.jclepro.2018.08.242
Yousuf, S., Donald, A. N., & Hassan, A. B. U. M. (2022). A review on particulate matter and heavy metal emissions; Impacts on the environment, detection techniques and control strategies. *MOJ Ecology & Environmental Sciences , 7*(1), 1–5. https://doi.org/10.15406/mojes.2022.07.00239
Zaatari, R. (2022). *The green economy of Morocco* [Doctoral dissertation]. University of Glasgow. http://theses.gla.ac.uk/id/eprint/83070
Zhan, H. (2018). The effect of income inequality on environmental pollution: Reassessment of the environmental Kuznets curve of China. *Economic Review*, *214*(6), 102–114, 168. https://doi.org/10.19361/j.er.2018.06.08
Zhang, W., Shi, P., & Huang, W. (2022). Research on spatial and temporal pattern evolution and driving factors of county carbon emissions in underdeveloped regions: Gansu province of Western China as an example. *Sustainability*, *15*(1), 291. https://doi.org/10.3390/su15010291
Zhao, K., Yu, B., Du, H., & Zhang, Y. (2023). Will air pollution affect entrepreneurial activity? Evidence from China. *Applied Economics Letters*, *30*(17), 2396–2400. https://doi.org/10.1080/13504851.2022.2097177
Zhao, W., & Zou, Y. (2018). Hefei: An emerging city in inland China. *Cities*, *77*, 158–169. https://doi.org/10.1016/j.cities.2018.01.008
Zhao, Y., Tan, Y., & Feng, S. (2020). Does reducing air pollution improve the progress of sustainable development in China? *Journal of Cleaner Production*, *272*, 122759. https://doi.org/10.1016/j.jclepro.2020.122759
Zhou, A., & Li, J. (2020). Impact of income inequality and environmental regulation on environmental quality: Evidence from China. *Journal of Cleaner Production*, *274*, 123008. https://doi.org/10.1016/j.jclepro.2020.123008
Zhuang, G., & Dou, X. (2023). Energy base for carbon peaking and carbon neutrality. In G. Zhuang & H. Zhou (Eds.), *China's road to carbon peaking and carbon neutrality* (pp. 61–86). Springer Singapore. https://doi.org/10.1007/978-981-99-3122-4_4