Research on the Impact of Income Gap on Environmental Pollution Based on Balanced Panel Data of 48 Countries

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Abstract. Reconciling economic development with ecological environmental protection has always been a hot issue of the whole society. However, existing studies only consider the impact of per capita income on environmental pollution, while ignoring the existence of income gap and its possible impact on environmental pollution. Therefore, the paper focuses on the specific analysis of the relationship between income gap and environmental pollution in 48 countries and revising the EKC theory. The empirical analysis results show that: there is an M-shaped relationship between the income gap and the per-capita carbon emissions, and the three turning points are 0.27, 0.36 and 0.52; there is an N-shaped relationship between the per-capita income and the per-capita carbon emissions, and the two turning points are 5218.65 and 13766.50 international dollars; the per-capita carbon emissions increases significantly as the per-capita energy consumption increases; and there is a significant negative relationship between the urbanization rate and the per-capita carbon emissions, which provide theoretical reference for the government to formulate corresponding policy measures.

1. Introduction

The rapid economic growth has significantly improved the living quality of residents, which has also caused environmental degradation. Reconciling economic development with ecological environmental protection has always been a hot issue of the whole society. Therefore, the relationship between economic growth and environmental pollution has attracted considerable interest of academic circles [1], and is considered as one of the most important empirical relationships tested in the economic literature [2].

Grossman and Kruger found that there is an "inverted U" relationship between per capita income and environmental pollution. Based on this, the classic EKC (Environmental Kuznets Curve) hypothesis was proposed. Since then, the link between economic growth, energy use and carbon dioxide emissions has been an active area of research [3-6].

The current research on the Environmental Kuznets Curve has roughly formed two views, supporters agree that the Environmental Kuznets Curve is in the “inverted U” shape [7-8], while opponents believe the shape of the Environmental Kuznets Curve is not “inverted U”, but “U”, linear, and even “N” [9-
11]. Some scholars believe that the relationship between economic development and environmental pollution depends on the data used and the indicators that measure environmental pollution [12-13].

Studies have shown that for most countries, energy consumption has a positive impact on carbon dioxide emissions [1], and there is a one-way causal relationship between energy use and environmental pollution [14-16]. Some scholars believe urbanization has a positive impact on carbon dioxide emissions, while some hold the opposite view.

However, existing studies only consider the impact of per capita income on environmental pollution, while ignoring the existence of income gap and its possible impact on environmental pollution. In countries around the world, income inequality prevails in urban and rural areas, between industries, and between regions, adding unfavorable factors to long-term stable economic growth and social stability [17]. Therefore, on the basis of existing research, the paper focuses on the specific analysis of the relationship between income gap and environmental pollution in 48 countries from the perspective of income distribution, and focuses on revising the EKC (Environmental Kuznets Curve) theory from the perspective of income distribution, in order to explore whether the reduction of income gap can play a positive effect on improving the environment, which may provide theoretical reference for the government to formulate corresponding policy measures.

2. Research hypothesis
Based on the above analysis of existing research, we tested the following null hypotheses:

Hypothesis 1: There is a positive correlation between the energy consumption and the carbon dioxide emissions [18].

Hypothesis 2: There is a negative correlation between the urbanization and the carbon dioxide emissions.

Hypothesis 3: There is a non-linear relationship between the per capita income and the carbon dioxide emissions.

Hypothesis 4: There is a non-linear relationship between the income gap and the carbon dioxide emissions.

3. Variables and models
The explanatory variable is environmental pollution, which is measured by per-capita carbon emissions. Combined with the literature, this paper includes the explanatory variable income gap and three control variables: per-capita income, urbanization rate and per-capita energy consumption in the empirical model. The variable interpretation table is shown in Table 1.

| Variable Name | Variable Description |
|---------------|----------------------|
| PC            | Per-capita carbon emissions |
| gini          | Gini coefficient |
| y             | Per-capita income, which is dealt with the CPI deflator, taking 2010 as the base year |
| urb           | Urbanization rate |
| ene           | Per-capita energy consumption |

Furthermore, in order to study the phased impact of income gap on environmental pollution, we introduce the Gini coefficient squared, cubed, and to the power of four into the measurement model. Referring to relevant literature at home and abroad [19], the multiple regression model of the factors affecting the environmental pollution is as follows:

\[
\ln PC_{it} = \alpha_0 + \alpha_1 \ln gini_{it} + \alpha_2 (\ln gini_{it})^2 + \alpha_3 (\ln gini_{it})^3 + \alpha_4 (\ln gini_{it})^4 + \beta \ln X_{it} + \mu_i + v_t + \varepsilon_{it} \tag{1}
\]

where \(X\) represents control variables, \(i\) represents country, \(t\) represents year, \(\alpha_0\) is the intercept term, \(\alpha_n\) (\(n=1,2,...\)) and \(\beta\) are coefficients of explanatory variable and each control variable, \(\mu_i\) is the national fixed-effect variable, \(v_t\) is the time fixed-effect variable, and \(\varepsilon_{it}\) is the random error term.
In order to reduce the possibility of heteroscedasticity, except for the proportional variables, other variables were processed by taking the logarithm. In order to avoid negative results, we added one to the two variables per-capita carbon emissions and Gini coefficient respectively before taking the logarithm.

In order to obtain balanced panel data, we collected data of 48 countries from 2006 to 2014, which is from the World Bank statistical database. The countries include: (1) 6 countries in Asia, which are Armenia, Georgia, Kazakhstan, Kyrgyzstan, Thailand and Turkey; (2) 5 countries in North America, which are Costa Rica, Dominican Republic, Honduras, Panama and Salvador; (3) 7 countries in South America, which are Bolivia, Brazil, Colombia, Ecuador, Peru, Paraguay and Uruguay; (4) 30 countries in Europe, which are Austria, Belgium, Bulgaria, Switzerland, Cyprus, Czech Republic, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, Ireland, Iceland, Italy, Lithuania, Luxembourg, Latvia, Moldova, Netherlands, Norway, Portugal, Romania, Russia Federation, Slovak Republic, Slovenia, Sweden and Ukraine.

The descriptive statistics of the variables, including the mean, median, maximum, minimum, and standard deviation are shown in Table 2.

| Variable | Mean | Median | Maximum | Minimum | Std. Deviation |
|----------|------|--------|---------|---------|----------------|
| PC       | 1.727229 | 1.805194 | 3.21939 | 0.517349 | 0.623291 |
| gini     | 0.307409 | 0.294533 | 0.454255 | 0.212689 | 0.063083 |
| y        | 9.859174 | 9.981683 | 11.44592 | 7.799065 | 0.785504 |
| ene      | 7.66669 | 7.813318 | 9.807975 | 6.161231 | 0.807423 |
| urb      | 0.696458 | 0.686865 | 0.97833 | 0.35284 | 0.135888 |

4. Empirical analysis

4.1. Stationary test

First, the stationary test was performed on the regression model using unit root test to avoid spurious regression [19]. As shown in Table 3, in the multiple regression model, each horizontal variable is a stationary series. The model passed the stationarity test, and there is no need to perform the cointegration test.

| Variable | LLC | Breintung | IPS | ADF-Fisher | PP-Fisher |
|----------|-----|-----------|-----|------------|-----------|
| PC       | -20.58*** | -2.47*** | -2.73*** | 195.51*** | 268.89*** |
| gini     | -10.00*** | - | -2.30*** | 144.44*** | 160.91*** |
| y        | -12.38*** | - | -1.83*** | 134.10*** | 107.35 |
| urb      | -7.01*** | - | -3.05*** | 203.35*** | 472.20*** |
| ene      | -4.31*** | - | - | 148.41*** | 268.97*** |

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

4.2. Multiple regression analysis

The sample data were subjected to full-sample regression analysis using Eviews8.0 statistical software [19]. The redundant fixed effects test result is shown in Table 4, and the correlated random effects-Hausman test result is shown in Table 5. As shown in Table 4 and 5, the fixed effects model should be used in the study, and the results of which are shown in Table 6.

**Table 4. Redundant fixed effects test result.**

| Effects test | Statistic | Prob. |
|--------------|-----------|-------|
| Cross-section F | 278.07 | 0.0000 |
| Cross-section Chi-square | 1546.29 | 0.0000 |
Table 5. Hausman test result.

| Test summary               | Statistic | Prob. |
|----------------------------|-----------|-------|
| Cross-section random       | 22.11     | 0.0085|

Table 6. Fixed effects model results.

| Variable | Coefficient | Standard errors | t-statistic |
|----------|-------------|-----------------|-------------|
| gini     | 102.68***   | 43.21           | 2.38        |
| (gini)^2 | −509.18**   | 201.93          | −2.52       |
| (gini)^3 | 1093.22***  | 412.34          | 2.65        |
| (gini)^4 | −856.55**** | 310.35          | −2.76       |
| y        | 13.34***    | 4.11            | 3.24        |
| y^2      | −1.48***    | 0.43            | −3.41       |
| y^3      | 0.05***     | 0.02            | 3.59        |
| ene      | 0.90***     | 0.03            | 26.91       |
| urb      | −0.86***    | 0.23            | −3.69       |
| C        | −52.20****  | 14.21           | −3.67       |

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

Findings of the empirical results are as follows.

There is an M-shaped relationship between the income gap and the per-capita carbon emissions. The three turning points are 0.27, 0.36 and 0.52. This shows that when Gini coefficient is between 0 and 0.27, environmental pollution increases with the increase of income gap. When Gini coefficient is between 0.27 and 0.36, environmental pollution decreases with the increase of income gap. When Gini coefficient is between 0.36 and 0.52, environmental pollution increases with the increase of income gap. When Gini coefficient is between 0.52 and 1, environmental pollution decreases with the increase of income gap.

There is an N-shaped relationship between the per-capita income and the per-capita carbon emissions. The two turning points are 5218.65 and 13766.50. This shows that when per-capita income is between 0 and 5218.65 international dollars, environmental pollution increases with the increase of per-capita income. When per-capita income is between 5218.65 and 13766.50 international dollars, environmental pollution decreases with the increase of per-capita income. When per-capita income is more than 13766.50 international dollars, environmental pollution increases with the increase of per-capita income.

The coefficient of the energy consumption is 0.90, and the statistical result is significant at the 1% confidence level, which indicates that there is a positive correlation between the per-capita energy consumption and the per-capita carbon emissions. This shows that energy consumption should be reduced in order to alleviate the problem of environmental pollution.

The coefficient of urbanization is −0.86, and the statistical result is significant at the 1% confidence level, which indicates that there is a negative correlation between the urbanization rate and the per-capita carbon emissions. This shows that in order to reduce environmental pollution, something should be done to increase the urbanization rate.

5. Results

This study used macro- and balanced panel data to empirically analyze the factors influencing environmental pollution using multivariate statistical regression analysis. Multivariate regression statistics revealed the following.

There is an M-shaped relationship between the income gap and the per-capita carbon emissions, and the three turning points are 0.27, 0.36 and 0.52, which shows that the impact of income gap on environmental pollution can be divided into four stages. Since the income gap may be different when a country is in different periods, the economic policies to be adopted by the relevant government may also
be different, in order to reduce environmental pollution. As well, though at the same time, different countries might adopt different economic measures, for the purpose of protecting environment.

Both linear and nonlinear terms (Y, Y², and Y³) provide evidence in supporting an N-shaped relationship between the per-capita income and the per-capita carbon emissions, by revealing that the carbon emissions increase in the initial stage of the per capita GDP. The two turning points are 5218.65 and 13766.50 international dollars, which shows that different countries should adopt different economic measures according to the current economic level, in order to protect environment.

There is a positive correlation between the per-capita energy consumption and the per-capita carbon emissions. Since energy use increases the carbon emissions significantly, we suggest that the policy makers make efforts to reduce carbon emissions and strengthen the management of energy and carbon in order to fight energy waste, and take corrective measures to replace the fossil fuel with renewable energy for consumption and production purposes.

Carbon emissions tend to decrease as urbanization rate increases, which shows that the policy makers should make efforts to improve the construction of the urban system, strengthen the construction of urban infrastructure, attach importance to rural reform and development, vigorously develop the secondary and tertiary industries, and expand the scale of urban agglomerations to drive the development of surrounding areas and promote the process of urbanization.

6. Conclusion
This paper takes into account the macro- and balanced panel data to empirically analyze the factors influencing environmental pollution using multivariate statistical regression analysis, aiming to provide theoretical reference for the government to formulate corresponding policy measures to protect environment. The study found that there is an M-shaped relationship between the income gap and the per-capita carbon emissions, and the three turning points are 0.27, 0.36 and 0.52. There is an N-shaped relationship between the per-capita income and the per-capita carbon emissions, and the two turning points are 5218.65 and 13766.50 international dollars. There is a positive correlation between the per-capita energy consumption and the per-capita carbon emissions. There is a negative correlation between the urbanization rate and the per-capita carbon emissions.

However, the research in this paper still has some limitations, which are as follows.

First, in terms of sample data, due to limitations in the availability of raw data, Gini coefficients of some countries in relevant years are incomplete. In order to obtain balanced panel data, the research in this study covers 48 countries from 2006 to 2014. When relevant data is counted, the data will continue to be enriched. In the future, relevant research on the factors affecting the environmental pollution can be further developed to better provide a decision-making reference for government.

Second, in terms of the influencing variables, the variables in this paper have certain limitations, and it is impossible to incorporate all the factors into the research model. As the World Bank statistical database continues to improve, the research on the factors affecting the environmental pollution will be more comprehensive and systematic.

Finally, in terms of research categories, since there are regional differences in the relationship between income gap and environmental pollution in various countries, which can be reflected in many levels, such as geographic location and economic development. In the future, relevant research can be further developed to provide theoretical basis for governments in different regions to formulate corresponding policies and measures.

7. Author Contributions
All authors contributed extensively to the work presented in this paper. Methodology, formal analysis and writing – original draft, Li Luo; Supervision, Xiaoming Ma.

8. Conflicts of Interest
The authors declare no conflict of interest.
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