provisional edition

Analysis of environmental inequality influencing factors in China based on STIRPAT model

DAI JUANJUAN

Abstract:

Since the reformation and the opening-up policy of Chinese in 1978, China has achieved a high economic growth for about 30 years. However, the problem of economic disparity in China has been worsened than ever before, and the environment inequality is beginning be more noticeable. China faces the challenge this environmental inequality. In this paper, we first calculated the Green Contribution Coefficient in the 31 provinces in 2000 and 2014, and then clarified the fact that there existed regional environmental inequality in China. Based on the STIRPAT model, various factors affecting environmental inequality in China from 2000 to 2014 were analyzed by the regression analysis, using the panel data on industrial air emissions published by each ministry. We examined the hypothesis that the increase in GDP, secondary industry ratio, the energy industry investment has a negative influence on Chinese environment. The environmental inequality is to be balanced by the progress of industrial structures in the various regions of China.

Keywords:

Environmental inequality, Green contribution coefficient, STIRPAT model.

1. Introduction

In 1982, national attention was drawn to a large protest over the siting of a PCB[1] landfill in Warren County, North Carolina[2]. Since then, the study on “environmental inequality” has become very popular. In the research on environmental inequality, it is

---

[1] PCB refers to polychlorinated biphenyl and causes skin damage and liver damage to the human body.

[2] Robert D. Bullard ed. (1994)

mainly divided into two areas: social inequality and regional inequality. The social inequality refers to the difference between groups of people that are hierarchical in nature. It refers to the hierarchical distribution of social, political, economic and cultural resources. As for the regional inequalities, it is mainly inequalities between developing and developed countries, in urban and rural areas, or in coastal and inland areas.

China's economic reform in 1978 originated in rural areas, but by 2000 the emphasis on the reformation and opening-up of the market was in urban areas, especially in the coastal areas. Consequently, China has achieved a remarkable economic growth since the 1980s, but there still remain some problems about openness, industrialization, and urbanization among regions. New social stratifications have also been formed within the city, which has drawn more attention to the studies on regional inequality than social inequality in China.

The Chinese nominal GDP was only 364.5 billion yuan in 1978 when the reformation and opening policy began, but after the high growth for 30 years, it became “the world’s factory” and afterward, transformed the figure to “the world market” with high growth rate[3]. In 2010, the nominal GDP reached 39,800 billion Yuan, 110 times larger than the amount in 1978, and accounted for 9.5% of the whole world[4]. In the last 40 years, China ranked from 10th to 2nd in the world GDP ranking. The share in the total amount of the world economy increased from 1.8% in 1978 to 15% in 2017[5]. According to the World Bank standards, now China can be listed as a middle-income country rather than a low-income country.

On the other hand, although China has maintained a high economic growth, environmental issues are one of the side effects of the economic development. Particularly, the air pollution, caused by the smokes emitted in the air from chimneys of factories is damaging her environment. Her economic activities have been the sources of global warming, water contamination and its shortage. But in order to realize sustainable society, it is necessary to clarify which factors negatively affect the environment in our economic activities. With the background information in mind, this study will examine the regional environmental inequality in China.

Based on the STIRPAT model, using data of population (1990~2006), per capita

3 National Bureau of Statistics of China
4 IMF "World Economic Outlook, (April 2011)
5 International Monetary Fund World Economic Outlook (October 2018)

GDP, and urbanization rate of Jiangxi province, Liu (2008) studied and found that the main factor affecting environmental inequality in the province is population [1]. Lu (2011) examined that the economic growth of Suzhou City, Wuxi City, and Changzhou City from 1991 to 2008 has an impact on the increase of carbon energy consumption [2]. Yan (2007) analyzed the correlation between carbon dioxide emissions and population, wealth, urbanization and technology in Shanghai City. Their study results showed that the change of population and urbanization rate would affect the environment inequality of Shanghai City. The carbon dioxide emissions impact increases by 0.6% when population increase by 1%. The carbon dioxide emissions impact increases by 0.8% when urbanization rate increase by 1% [3]. Jia (2009) analyzed the impact factors of the environment inequality in Henan Province from 1983 to 2006, using the STIRPAT model and method of PLS, which verified that the main factor is the population increase [4]. Long (2006) analyzed the impacts of population, wealth, and technology on environmental inequality of China in 2000, and clarified that the main affecting factor is population [5]. Wang (2008) revealed that a change of 1% in population and the energy consumption would affect China's environment by 2% and 0.8% respectively [6].

In the previous studies, researchers focused on the provincial ratio in China. There was very little research on China as a whole. Moreover, the factors for environmental inequality in China could be examined only by population and economy. Now, this study focuses on environmentally affecting determinants in 30 provinces of China (except Hong Kong, Macao, Taiwan and Tibet), and attempts to hypothesize which determinant strongly impacts on environmental inequality.

This paper consists of 4 chapters. The first chapter introduces the research background and purpose. Chapter 2 introduces the Green Contribution Coefficient and the STIRPAT model. In Chapter 3, we perform coefficient tests of China's regional Green Contribution Coefficient in 2000 and 2014, and then we analyze the factors that affect environmental inequality in China. The final chapter 4 is the summary and the results of this research. In addition, we would like to suggest a possible policy on the industrial structure advancements.

2. Methodology

2.1. Green contribution coefficient.

According to the concept of environmental Gini coefficient (Wang, 2006). The green contribution coefficient is used as an indicator to evaluate the fairness of internal unit pollutant emissions or resource consumption [7]. Green contribution coefficient (GCC)= Economic contribution rate/Pollution emissions ratio (Resource consumption ratio). The calculating formula is as shown below:

$$\mathrm{GCC} = \frac{G_{\mathrm{i}}}{G} / \frac{P_{\mathrm{i}}}{p} \qquad (1)$$

G_i and P_i represents the regional GDP and pollution emissions (resource consumption), G and P represents the national GDP and pollutant emissions (resource consumption).

The Green contribution coefficient is used as the basis for judging unfair factors. If GCC < 1, it shows that the contribution rate of pollution emissions is greater than the contribution rate of GDP. Fairness is relatively poor. If GCC > 1, it shows that the contribution rate of pollution emissions is less than the contribution rate of GDP. It is relatively fair. It embodies a green development model, which serves as a basis for judging the unfair factors of the national resource environment Gini coefficient.

2.2 The STIRPAT model

Ehrlich and Holdren (1971) established a famous method called the IPAT (Human Impact, Population, Affluence and Technology) equation to uncover the influence of environmental pressure among population growth, economic development, and technological advancements [8].

$$Impact(I) = Population(P) \times Affluence(A) \times Technology(T) \qquad (2)$$

This model cannot consider non-monotonic or non-proportional effects of the variables and it is not useful for statistical analysis since statistic associations don't reflect causal relationship [9]. To overcome these imperfections, the STIRPAT (Stochastic Regression on Population, Affluence and Technology) was developed by Dietz and Rosa (1997) allowing for empirical hypothesis test [10]. The STIRPAT model is shown as follows:

$$I_t = aP_t^b A_t^C T_t^d \mathrm{e} \qquad (3)$$

Where I_t indicates the environment impact, a is the constant term and P represents the number of populations. A represents affluence measured by GDP. T represents the technology, e denotes the error term, b, c, and d are the coefficients of P, A, and T respectively, which can be obtained by regression, t represents time. STIRPAT is non-linear program model, in order to elimination model Heteroscedasticity, Eq. (3) takes the following form for time-series data after taking logarithms to be linear:

$$\mathrm{In}\, I_t = a + b\, \mathrm{In} P_t + c\, \mathrm{In}\, A_t + d\, \mathrm{In} T_t + e \qquad (4)$$

3. Empirical analysis

Fig 1 shows the distribution map of environmental green contribution coefficients in China in 2000 (left) and 2014(right), As shown in Fig.1 (left), Xinjiang Uygur Autonomous Region, Qinghai Province, Gansu Province, Ningxia Hui Autonomous Region, inner Mongolia Autonomous Region, Heilongjiang Province, Liaoning Province, Guizhou Province, Guangxi Zhuang Autonomous Region, Henan Province, Shandong Province, Hebei Province, Shanxi Province and Hubei Province, green contribution coefficients of these 14 provinces are less than one.

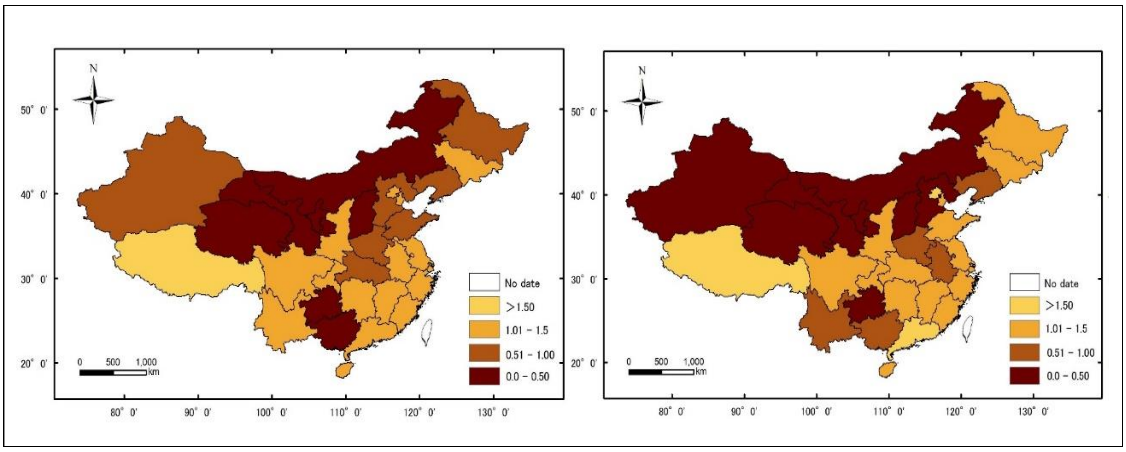

Fig.1 The distribution map of Green contribution coefficient (2000 and 2014)

As shown in Fig.1 (right), Xinjiang Uygur Autonomous Region, Qinghai Province, Gansu Province, Ningxia Hui Autonomous Region, inner Mongolia Autonomous Region, Yunnan Province, Liaoning Province, Guizhou Province, Guangxi Zhuang

Autonomous Region, Henan Province, Hebei Province, Shanxi Province and Anhui Province, green contribution coefficients of these 14 provinces are less than one.

According to Fig.1, we can find there existed regional environmental inequality in China. Looking at the changes over the past 15 years, the 14 cities are negatively affecting Chinese environment, mainly the areas in western less economically developed regions and central regions. Also, compared to the northern and southern regions, the northern region is more polluted than the southern region.

What causes the environmental inequality in China? This paper attempts to investigate the impact of GDP, population, secondary industry ratio, the urban consumption ratio and the energy industry investment on industrial air emissions by using the STIRPAT model. We will examine the data for 4 years between 2000 and 2014 on 30 provincial-ratio administrative units of mainland China, excluding Hong Kong, Macao, Taiwan and Tibet. Data used in this paper is given by China Statistical Yearbook (2001-2015), where GDP and energy industry investment data is given by the hundred million yuan. Industrial air emissions data is in hundred million m^3. Population is calculated in ten thousand. Secondary industry ratio and the urban consumption ratio data is given by %. For the absence of industrial air emissions data in some areas, this paper examines only China's 30 provincial-ratio administrative units. These abbreviations are used in this paper to study the impacts of emissions: I (industry air emissions) indicates influence by the driving factors. A indicates GDP, P (population), S (secondary industry ratio), C (urban consumption ratio) and E (energy industry investment). The specific description of the variables used in this paper is showed in Table 1.

Table.1 Description of the variables used in the analysis.

Variable	Definition	Unit of measurement	Symbol
Industry air emissions	Total Volume of Industrial Waste Gas Emissions	100 million m^3	I
GDP	Gross domestic product	hundred million yuan	A
Population	Total population	ten thousand	P
Secondary industry ratio	Ratio of Secondary sector of the economy	Percent	S
Urban consumption ratio	Ratio of urban residents' consumption in the total residents	Percent	C
Energy industry investment	investment of the energy industry	hundred million yuan	E

This is the value used for the estimation of the STIRPAT model using SAS 9.4 software. After building STIRPAT model, the fitting results shown in Table.2. The

R-squared has the useful property that its scale is intuitive: it ranges from zero to one, with zero indicating that the proposed model does not improve prediction over the mean model, nor one indicating perfect prediction. In other words, the R-squared value is an indicator of how well the model fits the data. According to Table.2, the model fits well with R-squared more than 0.83.

Table.2

Fit Statistics				
SSE	MSE	DFE	Root MSE	R-Square
14.5461	0.0328	444	0.181	0.8297

Table.3 is the description of the parameter estimates. As the results in Table.3 show, we find that GDP, population, secondary industry ratio, the urban consumption ratio, and the energy industry investment had some influence on industrial air pollution. However, there are differences in the influence, degree and saliency of each factor. From Table.3, the objective variable is I, the intercept is 3.84, GDP, population, secondary industry ratio, urban consumption ratio, the elastic coefficient for energy industry investment are respectively 0.03, 0.55, 0.79, 0.28, 0.16. From the value of Prob> | T |, it is shown that only GDP, secondary industry ratio and energy industrial investment are statistically significant at a ratio higher than 1%.

Table.3 Description of the parameter estimates

Variable	DF	Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	3.839559	0.6095	6.3	<.0001
lnA	1	0.550156	0.0455	12.09	<.0001
lnP	1	0.032149	0.0891	0.36	0.7183
lnS	1	0.788528	0.1151	6.85	<.0001
lnC	1	0.278473	0.1612	1.73	0.0848
lnE	1	0.158222	0.0289	5.48	<.0001

From Table.3, the final equation achieved is:

$$\text{In } I_t = 3.84 + 0.55\text{In } A_t + 0.79\text{InS}_t + 0.16\text{In}E_t + e \quad (5)$$

$$I_t = 3.84 A_t^{0.55} S_t^{0.79} E_t^{0.16}\text{e} \quad (6)$$

4. Conclusions

In this paper, we developed the theoretical and the analytical framework of the STIRPAT model to analyze the determinants of industrial air emissions and to investigate the impact of GDP(A), population(P), secondary industry ratio(S), urban consumption ratio(C) and energy industrial investment(E) on industrial air emissions in the 30 provincial-ratio administrative units of China. The analysis has resulted in getting the following conclusions:

(1) In relation to environmental impact in China, secondary industry ratio has the highest regression coefficient of 0.789, followed by GDP and the energy industry investment. The environmental impact increases by 0.79% when secondary industry ratio increases by 1% from 2000 to 2014. It has a biggest effect on environmental impact.

(2) The GDP has the second highest regression coefficient of 0.55. The environmental impact increases by 0.55% when the GDP increase by 1%.

(3) The regression coefficient of energy industry investment is 0.16 which is around one third of that for the GDP. The environmental impact increases by 0.16% when the energy industry investment increases by 1%.

At present the biggest aim for China to achieve is an economic development to eliminate poverty from her society. However, industrial advancement would increase pollutants and exhaust emissions, if she should accept them as inevitable negative impacts on the environment. It now is the time when changes should happen in its economic growth patterns and advancement of industrial structures. More consideration should be given to the environment in each region of China. Different regions should take different measures to decrease air pollution with the consensus of the local people with their own economic and environmental conditions.

References

[1] LiuX, Xiong X-B, Jia J-S(2008). Effects of social and economic factors on environmental stress in midland of China : A case study in Jiangxi Province. Population Research, 32(3):75-78

[2] Lu N, Qu F-T, Feng S-Y, et al. (2011), Trends and determining factors of energy consumption carbon footprint: An analysis for Suzhou- Wuxi-Changzhou region based on STIRPAT model. Journal of Natural Resources,26(5):814-824

[3] Yan H, Guo Y-G, Lin F-C (2007), Analyzing the development model of Chinese cities under the control of CO_2 emissions using the STIRPAT model: A case study of Shanghai. Acta Geographica Sinica, 20(1):118-122

[4] Jia JS, Deng FB, Duan J, et al. (2009), Analysis of the major drivers of the ecological footprint using the STIRPAT model and the PLS method: A case study in Henan Province, China. Ecological Economics, 68: 2818-2824.

[5] Long A-H, Xu Z-M, Wang X-H (2006), et al. Impacts of population, affluence and technology on water footprint in China. Acta Ecologica Sinica, 26(10): 3358-3365

[6] Wang L-M, He K-L (2008), Analysis of spatial variations in environmental impact based on the STIRPAT model: A case study of energy consumption. Acta Scientiae Circumstantiae, 28(5):1032-1037.

[7] Wang L-M, He K-L (2006), Analysis on temporal variation of environmental impact based on STIRPAT model: A case study of energy consumption of China. Journal of Natural Resources, 21(6):862-869.

[8] Paul R. Ehrlich; John P. Holdren (1997), Impact of Population Growth Science, New Series, 171(3977), 1212-1217.

[9] Aguir Bargaoui, S., Liouane, N. and Nouri (2014), 'Environmental Impact Determinants: An Empirical Analysis based on the STIRPAT Model', Procedia – Social and Behavioral Sciences, 109, 449-458.

[10] Dietz T, Rosa E A. Effects of population and affluence on CO2 emissions (1997), Proceedings of the National Academy of Sciences of the United States of America, 94:175-179.

[11] T. Dietz, E.A. Rosa (1994), Rethinking the environmental impacts of population, affluence, and technology, Human Ecology Review, 277-300.

[12] R. York, E.A. Rosa, T. Dietz (2003), STIRPAT, IPAT and IMPACT: analytic tools for unpacking the driving forces of environmental impacts, Ecological Economics, 351-365.

[13] Zheng, H., Hu, J., Guan, R., Wang, S. (2016), Examining Determinants of CO2 Emissions in 73 Cities in China. Sustainability, 1296. 2.

[14] Shuai, S., Yang, L.L., Cao, J.H. (2010), Study on Influencing Factors of CO2 Emissions from Industrial Energy Consumption: An Empirical Analysis Based

on STIRPAT Model and Industrial Sectors' Dynamic Panel Data in Shanghai. Finance. Econ. 36, 17-28.

[15] Claudia Sheinbaum, Belizza J. Ruíz, Leticia Ozawa (2011), Energy consumption and related CO2 emissions in five Latin American countries: changes from 1990 to 2006 and perspectives, Energy, pp. 3629-3638.

[16] TIAN X., CHANG M., SHI F., TANIKAWA H. (2014), How does industrial structure change impact carbon dioxide emissions? A comparative analysis focusing on nine provincial regions in China. Environmental Science & Policy, 37, 243.

[16] LI H., MU H., ZHANG M., GUI S. (2012), Analysis of regional difference on impact factors of China's energy – Related CO2 emissions. Energy, 39, 319.

[17] WANG Z., YIN F., ZHANG Y., ZHANG X. (2012), An empirical research on the influencing factors of regional CO2 emissions: Evidence from Beijing city, China. Applied Energy, 100, 277.

[18] Huanan Li, Hailin Mu, Ming, Zhang, Shusen Gui (2012), Analysis of regional difference on impact factors of China's energy – Related CO2 emissions. Energy. 39(1): 319-326.

[19] Keith, KILTY (2004), Poverty, Exclusion, and Racial and Ethnic Minorities in the United States. Journal of Education and social work.No.10-(1).75.

[20] Robert D. Bullard (1994), Environmental Justice for All, in UNEQUAL PROTECTION: ENVIRONMENTAL JUSTICE & COMMUNITIES OF COLOR 5,44-46.

[21] National Bureau of Statistics of China. China statistical yearbook (2001–2015)