Research on the Balanced Development of Economic Efficiency and Environmental Protection--Empirical Verification Based on Chinese Data

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Abstract. It is essential to explore the effects of China's economic efficiency on environmental protection as the Chinese economy moves into a civilized stage of development. This paper adopts simple linear regression model to explore the impact of per capita gross regional product on sulfur dioxide emissions based on China's inter-provincial panel data from 2004 to 2022, and further adopts a heterogeneity analysis approach to regress groups through different regional, temporal, and industrial development classification perspectives. The results of this paper conclude that (1) economic efficiency has a negative relationship with environmental protection. (2) China's economic efficiency has the greatest effect on environmental protection in the eastern region, followed by the central region, and has less effect on the level of environmental protection in the western and northeastern regions. (3) During the period of 2004-2008, China's economic efficiency has a positive relationship with environmental protection, and during the period of 2008-2022, it has a negative relationship. (4) Rising economic efficiency in the service sector has the greatest positive impact on environmental protection, followed by agriculture, with the lowest impact coming from industry. This paper provides three policy recommendations based on the findings of this paper: (1) The government should strengthen the enforcement of environmental laws and regulations. (2) Green technology development should be promoted. (3) Optimize the industrial structure and encourage the development of sustainable industries. The relationship between the economy and the environment has been studied continuously for several years so far, but this paper uses the latest data to analyze it, which is highly current and based on the actual situation in China, and has a significant impact on the study of environmental economy in China as well as in the world.

Keywords: Economic Efficiency, Environmental Protection, Regression Model

1 Introduction

Since the reform and opening up of China in 1978, China has achieved a high rate of economic efficiency, successfully developed from a poor and backward country with a

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large population into the world's second-largest economy, the largest developing country, and won the title of "the world's factory". This shows that China's economic efficiency has very important research value. However, China's economic efficiency also comes at the cost of environmental pollution. In the early stages of China's development, there were a number of incidents such as the construction of the Three Gorges Dam and the coal mining in Shanxi Province, where the pursuit of rapid development caused irreversible damage to cultural heritage, natural landscapes, and ecological environments. Nowadays, Chinese society has stepped into the stage of civilized development, paying more attention to the treatment of pollution and the protection and restoration of the environment. That is why China has put forward strategies such as "Carbon Peaking and Carbon Neutrality Goals" in the 21st century.

Therefore, the study of the relationship between economic efficiency and environmental protection in China can better provide important references on how to realize the coexistence of environmental and economic development in China in the future, and furthermore, it can provide valuable development experience for other developing countries in the world, and more importantly, it can provide important inspirations for environmental protection in the world. This paper will utilize China's inter-provincial panel data from 2004-2022 to empirically analyze the relationship between economic efficiency and environmental protection using simple linear regression and Heterogeneity analysis, so as to provide a Chinese case study and a Chinese strategy for the research related to economic efficiency and environmental protection.

2 Literature Review

The most relevant research to this paper is the study of the relationship between environmental protection and economic efficiency. Lei Yi [1] analyzes the current problems faced by environmental protection. Lai Jiongping et al [2] pointed out that watershed management can bring certain economic, environmental and social benefits. Wei Jiaqi [3] fully explored the increase in environmental protection costs of enterprises, the impact on economic efficiency and coping strategies.

Some environmental protection studies will further focus on water resources. Liu Huiyu et al [4] analyze the impact of the environmental protection tax on the local economy and environment by describing the situation before and after the introduction of the ecological tax system in the United States and the water pollution tax system in Germany, which is more successful in the introduction of environmental taxes. Tan Haixia et al [5] proposed the optimization path of guiding the green development of marine economy with ecological concept, constructing marine innovation system to promote the optimization and upgrading of marine industry in Hebei, and strengthening the synergistic and efficient policy system to promote the cooperation of marine economy. Qin Wenpan et al [6] comprehensively analyzed the environmental and economic benefits of rural wastewater resource utilization.

In addition, there is also a portion of related research that focuses on exploring the environmental protection and economic efficiency of a particular industry. Yan Jing et al [7] took the environmental impact assessment of an industrial park planning as an

example and sorted out the planned environmental pollution control measures, energy saving and carbon reduction projects. Sun Chi [8] elaborated on the concept of environmental protection in enterprises and analyzed the value of good environmental protection work from the perspectives of enterprises and the country respectively. Yang Lijuan [9] explored the relationship between environmental protection and energy saving and emission reduction development content and enterprise economic efficiency. Dai Weike [10] explored and researched on the technical strategies to realize the win-win situation of environmental protection and economic efficiency in the paper industry.

Based on the above literature, there are four possible contributions of the text. First, in terms of research methodology, the paper conducts three types of heterogeneity analysis, namely, regional heterogeneity analysis, temporal heterogeneity analysis, and industrial heterogeneity analysis. Second, in terms of subject matter, few articles have focused on the assessment and analysis of China's economic efficiency on environmental protection. This paper takes GDP per capita as a proxy for economic efficiency, and explores its impact on China's sulfur dioxide emissions, i.e., China's environmental protection situation, and provides countermeasures. Third, in terms of research data, this paper uses data from China's National Bureau of Statistics from 2004-2022, which is comprehensive, relatively new and close to the reality, which is conducive to reflecting China's overall problems since the twenty-first century, and helps to draw more accurate and more current economic conclusions. Fourth, in the context of China's booming economic development, the study of environmental protection is particularly important, so the conclusions and policy recommendations of this paper are of great theoretical significance and practical value, and can provide other developing countries in the world with valuable Chinese cases, Chinese experiences and Chinese solutions.

3 Characteristic Facts

Fig. 1 presents the development trend of China's GDP per capita since the 21st century. As can be seen from Fig. 1, based on the perspective of development trend, China's per capita GDP has been increasing year by year, i.e., China presents the important fact that economic efficiency is progressing steadily. This is mainly due to the fact that since 1978, China has implemented positive policies such as reform and opening up, promoting urbanization and modernization, strengthening infrastructure construction and focusing on scientific and technological innovation, which have effectively contributed to China's sustained economic growth and development. Based on the perspective of development speed, China's per capita GDP growth rate has been relatively stable in the past 20 years, but it has slowed down significantly in 2019-2020, mainly due to the outbreak of the COVID-19 epidemic at the end of 2019. During the epidemic, services such as tourism, entertainment and catering, as well as industries such as construction and manufacturing, were greatly affected, leading to the closure of many businesses and an increase in unemployment, which seriously affected people's willingness and ability to consume. After 2020, China's GDP per capita resumed its steady upward trend

as the epidemic was effectively controlled and the service and industrial sectors, which had been strongly affected during the epidemic, rebound.

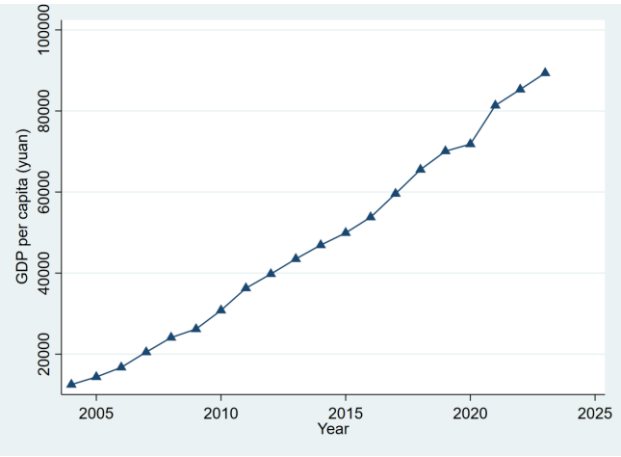

Fig. 1. Trends in the development of GDP per capita in China.

4 Research Design

4.1 Variable Selection

The explained variable in this paper is environmental protection, and sulfur dioxide emissions are used as a proxy variable. The higher the value of sulfur dioxide emissions[1], the heavier the pollution of organic pollutants in the water and the higher the importance of environmental protection. The explanatory variable in this paper is economic efficiency, using gross regional product per capita as a proxy variable. Gross domestic product per capita is the ratio of the absolute value of GDP to the average population for the year, and is a measure of the economic contribution or value created in a country or region by each of its inhabitants to that country or region. Higher per capita Gross Regional Product indicates higher economic performance of the region.

Furthermore, this paper will use gross regional product per capita and NOx emissions for robustness testing. This paper will also use sulfur dioxide emissions from eastern, central, western, and northeastern China for regional heterogeneity analysis, sulfur dioxide emissions from 2004-2008, 2008-2020, and 2020-2022 for temporal heterogeneity analysis, and sulfur dioxide emissions from agriculture, sulfur dioxide emissions from industry, and sulfur dioxide emissions from the service industry for industrial heterogeneity analysis.

[1] Sulfur dioxide emissions: Sulfur dioxide emissions refer to the sum of industrial SO2 emissions and domestic SO2 emissions during the reporting period.

4.2 Source of Data

The empirical part of this paper selects 31 provinces, cities or autonomous regions in China as the object of empirical analysis, the observation period is from 2004-2022, and the sample data used are from the National Bureau of Statistics of China. The descriptive statistics of this paper are shown in Table 1.

Table 1. Results of descriptive statistics.

Variable	Unit	Obs	Mean	Std.Dev.	Min	Max
Gross regional product per capita	Yuan/person	589	44585	31167	4244	189988
Sulfur dioxide emissions	10 kilo-tons	589	51.05	45.83	0.100	200.2
Gross domestic product	billions	589	19912	20780	217.9	129514
Nitrogen oxide emissions	10 kilo-tons	372	51.52	38.61	3.410	180.1
Value added of primary industry	billions	589	1638	1366	42.10	6297
Value added of secondary industry	billions	589	8440	8987	51.30	54886
Value added of tertiary industry	billions	589	9834	11170	124.5	71543

4.3 Model Design

The research model in this paper is a simple linear regression as follows:

$$Y = \alpha X + \beta + \varepsilon \tag{1}$$

where Y is the explained variable sulfur dioxide emissions, X is the core explanatory variable gross regional product per capita, and ε is the random error term.

5 Empirical Analysis

5.1 Correlation Analysis

Fig. 2 depicts the relationship between economic efficiency and environmental protection. A preliminary indication of the trend on the graph is that sulfur dioxide emissions decrease with the growth of GDP per capita. The relationship between economic efficiency and environmental protection still needs to be confirmed by regression analysis in this study.

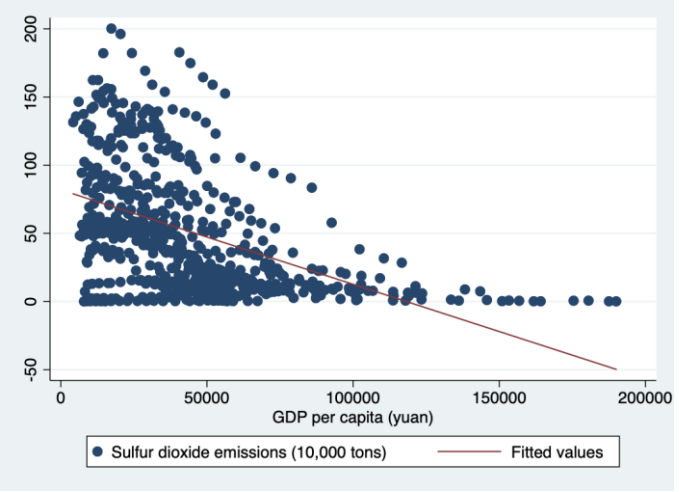

Fig. 2. Correlation between education level and consumption of the population.

5.2 Benchmark Regression

Table 2 Model (1) reports the main regression results of GDP per capita affecting sulfur dioxide emissions. Specifically, the estimated coefficient on the core explanatory variable of the model is -1.1217, which is significantly negative at the 1% significance level. The regression results preliminarily indicate that for environmental protection, the economic efficiency at present in general has a positive and positive impact on it.

Table 2. Benchmark regression and robustness tests.

	(1)	(2)	(3)
	y	y	y
x	-1.1217***	-0.9649***	-1.1568***
	(-23.0239)	(-20.3174)	(-31.7988)
_cons	24.1968***	21.4872***	16.1852***
	(43.4411)	(44.3864)	(38.3415)
N	589	589	372
R2	0.4886	0.5008	0.7539

Note: ***, **, * denote statistical values that are significant at the 1%, 5% and 10% significance levels, with z-values in parentheses. Same as below.

5.3 Robustness Checks

In order to test the stability and reliability of the benchmark regression estimates, this paper conducts a robustness analysis by replacing the measures of economic efficiency and environmental protection. Since both per capita Gross Regional Product (GRP) and Gross Regional Product (GRP) are measures of economic efficiency, sulfur dioxide (SO2) emissions and nitrogen oxide (NOx) emissions are measures of environmental

protection. Then this paper starts with the Gross Regional Product in the model, replacing the core explanatory variable Gross Regional Product per capita for robustness testing; Secondly, Nitrogen oxides emissions, instead of the core explanatory variable sulfur dioxide emissions, are tested for robustness. The empirical results of models (2) and (3) in Table 2 show that after replacing the measures of economic efficiency and environmental protection respectively, the effect of economic efficiency on environmental protection is still significantly negative and the baseline model is robust.

5.4 Heterogeneity Analysis

5.4.1 Regional Heterogeneity Analysis.

Based on the National Bureau of Statistics 2011 classification, all provinces in China are divided into four regions[2]: East, Central, West, and Northeast, in order to reveal the regional characteristics of China's economic performance affecting environmental protection. Table 3 Models (1), (2), (3), and (4) report the regression results of GDP per capita affecting sulfur dioxide emissions in eastern, central, western, and northeastern China, respectively, with estimated coefficients of the explanatory variables of -1.7301, -1.0760, -0.8408, and -0.9804, and the regression results are all significantly negative at the 1% significance level. The regression results indicate that, for China, China's economic efficiency has the greatest effect on the improvement of environmental protection in the eastern region, followed by the central region, and has less effect on the level of environmental protection in the western and northeastern regions.

Table 3. Regional heterogeneity analysis.

	(1) East	(2) Central	(3) Western	(4) North-Eastern
	y	y	y	y
x	-1.7301***	-1.0760***	-0.8408***	-0.9804***
	(-15.0363)	(-12.3208)	(-14.0185)	(-6.7183)
_cons	31.0015***	24.0861***	20.9726***	22.8817***
	(23.2372)	(26.4460)	(27.7332)	(15.0371)
N	190	114	228	57
R2	0.5582	0.5846	0.4787	0.5027

[2] The eastern region includes a total of 10 provinces, including Beijing, Hebei, Tianjin, Shandong, Shanghai, Jiangsu, Zhejiang, Guangdong, Hainan, and Fujian; the central region includes a total of 7 provinces, including the Inner Mongolia Autonomous Region, Shanxi, Henan, Anhui, Jiangxi, Hubei, and Hunan; and the western region includes a total of 11 provinces, including the Xinjiang Uygur Autonomous Region, Tibet Autonomous Region, Gansu, Qinghai, Sichuan, Yunan Province The western region includes 11 provinces including Xinjiang Uygur Autonomous Region, Tibet Autonomous Region, Gansu, Qinghai, Sichuan, Yunnan, Guangxi Zhuang Autonomous Region, Ningxia Hui Autonomous Region, Guizhou, Chongqing and Shaanxi. The Northeast Region includes three provinces: Heilongjiang, Jilin and Liaoning.

5.4.2 Temporal Heterogeneity Analysis.

This paper analyzes the temporal heterogeneity of the sample period by dividing the sample period into three time periods based on the major influencing events since the 21st century, taking the subprime mortgage crisis in the United States in 2008 and the proposal of China's "dual-carbon" goal in 2020 as the time nodes. Table 4 Models (1), (2), and (3) report the regression results of GDP per capita affecting sulfur dioxide emissions for 2004-2008, 2008-2020, and 2020-2022, respectively, with estimated coefficients of the explanatory variables of 0.2386, -1.4453, and -1.4049, respectively, and the regression results of model (1) are significantly positive at the 1% significance level were significantly positive, and the regression results of models (2) and (3) were significantly negative at 1% significance level. The regression results indicate that economic efficiency inhibits environmental protection in China during 2004-2008 and enhances it after 2008. In addition, economic efficiency has the greatest effect on environmental protection during the period 2008-2020, and a lesser effect during the period 2020-2022.

Table 4. Temporal heterogeneity analysis.

	(1) 2004-2008 y	(2) 2008-2020 y	(3) 2020-2022 y
x	0.2386***	-1.4453***	-1.4049***
	(4.3579)	(-17.2216)	(-8.8566)
_cons	10.8687***	27.8950***	26.6789***
	(18.6642)	(30.4540)	(14.9258)
N	124	372	93
R2	0.1693	0.4710	0.5360

5.4.3 Industrial Heterogeneity Analysis.

This paper analyzes the heterogeneity of China's industrial development into agriculture, industry, and services based on the classification of industrial development. Table 5 Models (1), (2), and (3) report the results of regression analysis of GDP per capita on sulfur dioxide emissions from agriculture, industry, services, respectively, with estimated coefficients of the explanatory variables of -0.8344, -0.8029, and -0.9243, respectively, and the regressions are all significantly negative at the 1% level of significance. The regression results illustrate that rising economic efficiency in the service sector has the greatest positive impact on the environmental protection situation, followed by agriculture, with the lowest impact coming from industry.

Table 5. Industrial heterogeneity analysis.

	(1) Agriculture y	(2) Industry y	(3) Services y
x	-0.8344***	-0.8029***	-0.9243***
	(-11.9317)	(-14.2535)	(-23.6612)

_cons	18.2037***	19.2531***	20.3971***
	(35.5861)	(37.8211)	(52.0413)
N	589	589	589
R2	0.5582	0.4872	0.5484

6 Summary

Based on the above empirical results, this study concludes that economic efficiency has a negative relationship with environmental protection; Based on the perspective of China's four major regional divisions, China's economic efficiency presents a positive enhancement of environmental protection in the eastern region, a weaker enhancement of environmental protection in the central region, and a smaller impact on environmental protection in the western and northeastern regions; Based on the perspective of different time intervals, economic efficiency inhibits China's environmental protection during the period of 2004-2008 and enhances it after 2008, with the greatest enhancement during the period of 2008-2020 and a smaller enhancement during the period of 2020-2022; In terms of China's industrial development, rising economic efficiency in the service sector has the greatest positive impact on the environmental protection situation, followed by agriculture, with the lowest impact coming from industry.

The implications of the above conclusions lie in the following three points. First, the government should strengthen the enforcement of environmental laws and regulations, and adopt corresponding policies to effectively restrain the pollution emissions of enterprises and individuals. Secondly, we should promote the development of green technology, such as new energy sources and pollution treatment technologies. This will not only solve the residual problems of the past, but also reduce the environmental damage caused by future development. Thirdly, we should optimize the industrial structure and stimulate the development of sustainable industries. We should promote industrial transformation, gradually phase out traditional industries that cause a great deal of pollution, and develop low-carbon and environmentally friendly sustainable industries.

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