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Spatial and Heterogeneity Analysis of Environmental Taxes' Impact on China's Green Economy Development: A Sustainable Development Perspective

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Abstract: Environmental taxation is an important tool used by governments to promote resource conservation and environmental protection. Given the current global constraints on resources and increasing environmental degradation, exploring how environmental taxes can effectively stimulate the development of a green economy is of utmost importance. This study utilized panel data from 30 provinces, autonomous regions, and municipalities in China, covering the period from 2006 to 2020. The research findings indicate a spatial correlation between environmental taxes and green economic efficiency in China, with the former significantly promoting the development of the latter. A heterogeneity analysis revealed varying impacts of different taxes on the efficiency of green economic development in different regions. Controlling for variables, the study results demonstrated a negative correlation between industrial structure and green economic efficiency, with a significance level of 1%. Additionally, no correlation was found between pollution control efforts and green economic benefits. The effects of different taxes on regional efficiency varied, and industrial structure exhibited a negative correlation with green economic efficiency. This study recommends strengthening intergovernmental coordination, improving tax policies, optimizing industrial structure, and enhancing the pollution control efficiency of local governments to promote China's green economy.

Keywords: environmental tax; green economic efficiency; spatial lag model; resource conservation; environmental protection; sustainable development

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1. Introduction

Since the beginning of the industrial civilization era, mankind, while driving rapid global economic growth, has also accelerated the seizure of natural resources, disrupting the balance of the Earth's ecosystem and increasingly revealing deep-seated conflicts between man and nature. According to the 2019 Global Resource Outlook report by the United Nations Environment Programme, the exploitation of natural resources has increased from 27 to 92 billion tons over the last 50 years. This has led to 90% of biodiversity loss and water scarcity and is responsible for about half of the effects of climate change. The 2022 Global Air Quality Report shows that 97.3% of the world's population now lives in areas where air pollution exceeds health standards. Given the increase in resource and environmental problems, "developing a green economy" has become a necessary requirement for governments to break the resource and environmental constraints, accelerate the transformation of economic development, and achieve sustainable socio-economic development [1].

A green economy is an economic development model that seeks to ensure both the natural environment and human well-being can coexist without causing ecological crises or social divisions resulting from the relentless pursuit of economic growth; it aims to avoid unsustainable socio-economic growth caused by the depletion of natural resources [2]. Achieving green economic development hinges on finding solutions to energy use inefficiency and environmental pollution, which often accompany socio-economic development [3]. In this regard, economist BiGu pioneered the concept of "government regulation of environmental pollution through macro taxation". This approach involves taxing emitters based on the difference between private and social costs of emissions, thereby internalizing the negative externalities of pollution. This theoretical foundation supports governmental intervention and management of environmental problems. Environmental taxes, as a crucial tool for the government to protect the environment and conserve resources, have multiple benefits. In the short term, they directly restrict polluters' emission behavior and encourage rational use of environmentally friendly production materials [4]. In the long term, they incentivize technological innovation, leading to improved production efficiency and enhanced market competitiveness [5].

A well-defined environmental taxation system can effectively curb environmental destruction and excessive resource consumption, thus promoting the development of a green economy. The Chinese government has been gradually establishing a comprehensive environmental taxation system while promoting green economic transformation. This system encompasses taxes related to environmental protection, resources, urban construction and maintenance, vehicles, vehicle purchases, urban land use, and arable land occupation.

Considering the competitive behaviors among local governments and regional economic development disparities, it is important to examine the spatial correlation between environmental taxes and the level of green economic development in each region. It is essential to determine whether the current environmental tax system in China effectively fosters the development of a green economy and whether there is heterogeneity in the impact of various environmental taxes on green economic development across regions. Clarifying these questions holds great theoretical and practical significance for the government in reforming and improving the environmental tax system while promoting the development of a green economy.

2. Literature Review

Green economic efficiency serves as a significant indicator for measuring the progress of green economic development. It addresses the limitations of traditional socio-economic development, which focuses solely on increasing factor inputs without considering environmental costs. Evaluating high-quality socio-economic development now includes the consideration of green economy efficiency, as it has become a consensus for sustainable development worldwide.

Many studies have examined green economic efficiency at various spatial scales using data envelopment analysis (DEA) within the input-output framework. For example, Zhao Jinkai et al. (2021) utilized a four-stage disaggregated DEA approach excluding the impact of external environmental variables and employed a bootstrap-DEA model to account for random shocks [6]. Their study focused on measuring the green development efficiency of Chinese provinces and regions. Similarly, Qianqian Geng (2023) assessed industrial green total factor productivity in China from 2004 to 2020 using the slacks-based measure (SBM) approach [7]. Zhao P.J. (2020) and Shen Y. (2022) employed a similar approach to measure green economic efficiency in 30 Chinese provinces [8,9]. Additionally, Fangmei Liu (2023) evaluated provincial green economic efficiency in China by employing the stochastic non-smooth data envelope (StoNED) model [10]. Furthermore, Liu's study examined the gradient differences in green economic efficiency among the eastern, central, and western regions of China.

The analysis of the impact mechanism of environmental tax on green economic development primarily focuses on the micro-individual level. Firstly, environmental taxes influence the production and operational behavior of enterprises, thereby promoting energy conservation and emission reduction. According to Muhammad (2021), environmental taxes encourage cleaner production in industrial enterprises, leading to sustainable economic and environmental development [11]. Guangqiang Liu (2022) empirically examined the effects of environmental taxes on corporate environmental investment using data from Chinese listed companies between 2015 and 2019, revealing a significant increase in environmental investment due to the implementation of environmental taxes [12]. According to Akio Yamazaki (2022), rather than diverting resources from production, environmental taxes contribute to a net increase in firm productivity by encouraging investments in environmental protection [13]. Xu He (2022) analyzed data from a sample of listed companies in China from 2015 to 2020 and discovered that environmental tax reforms have a positive impact on corporate profitability while curbing corporate pollution behaviors [14]. Zastempowski (2023) analyzed business survey data collected from 13 EU member states in 2014 and discovered that the implementation of environmental taxes motivated companies to replace fossil fuel with renewable energy sources [15].

Secondly, environmental taxes can drive firms to innovate green technologies and enhance resource efficiency. Greaker (2018) explored how environmental policies can guide firms toward technological innovation, achieving both environmental and economic benefits [16]. Vitenu-Sackey (2021) argued that a significant increase in environmental taxes can incentivize firms to adopt green technologies, mitigating environmental pollution and improving their total factor productivity [17,18]. Zhangsheng Jiang (2023) and Xiaomin Zhao (2023) demonstrated that the implementation of environmental taxes stimulated firms to engage in green innovation, consequently driving business performance [19,20]. Min Fan (2022) discovered that environmental taxes indirectly contribute to regional green total factor productivity by fostering higher levels of green technological innovation among firms [21]. Johan Albrecht (2023) confirmed that environmental taxes largely determine the adoption of energy-efficiency-related technological innovations by small- and medium-sized enterprises (SMEs) [22]. Zhao X. (2022), using China's urban panel data from 2007 to 2018, studied the positive impact of green innovation on green economic efficiency [23].

Empirical studies on the impact of environmental taxes on green economic development have primarily focused on the influence of environmental regulations on green economy development. For example, Shuai S. and Fan Z. (2020) performed an empirical analysis using panel data from China's regions spanning from 2007 to 2018 [24]. They measured China's green economy efficiency using a super-efficient DEA model and found a nonlinear relationship between environmental regulation and green economy efficiency. Shang Y. et al. (2022) investigated the effect of environmental regulation on circular economy performance and discovered that it receives a linear contribution from environmental regulation [25]. Shen Y. and Zhang X. (2022) utilized provincial-level panel data from China spanning from 2004 to 2020 and employed a two-way fixed-effects model to analyze the impact of environmental taxes on industrial green transformation [8]. They found that broad environmental taxes such as taxes on vehicles and boats, resources, and urban land use had a significant positive impact on industrial green transformation. Zhao Xin (2023) tested the impact of environmental policies on energy use by using provincial panel data from 2005 to 2019 [26]. Syed Abdul (2022) identified a significant positive relationship between environmental policies and green total factor productivity through empirical analysis of data from a sample of 12 cities in China [17].

Upon reviewing the existing literature, it is evident that there is a wealth of research on measuring green economy efficiency and analyzing the micro-mechanisms of environmental taxes on green economy development. This body of work has laid a strong foundation for our study. However, there are certain limitations in the existing research that need to be addressed. Firstly, most studies primarily focus on analyzing the impact of environmental regulations or policies on green economy efficiency, with fewer studies examining the influence of environmental taxes on green economy development. Furthermore, there is a scarcity of research exploring the differential effects of various environmental taxes on green economy development across different regions. Secondly, in terms of research methodology, many studies rely on general panel models to empirically analyze the relationship between environmental taxes and the green economy. However, it is crucial to consider the spillover effects of environmental taxes on green economy development, especially considering the strong geographical and economic correlations observed in local environmental tax policies and the green economy (C. Cindy Fan, 2004) [27].

Taking into account these shortcomings in the existing research, our study assumes that environmental taxes have a spatial spillover effect on green economic efficiency and aims to contribute in the following ways: Firstly, in terms of methodology, we employed a spatial econometric model to empirically analyze the impact of environmental taxes on green economic efficiency. This approach allowed us to consider the spatial relationships and potential spillover effects in our analysis. Secondly, in terms of content, we comprehensively analyzed the impact of environmental taxes as a policy tool on green economic development. Moreover, we explicitly examined the diverse effects of different environmental taxes on green economic development across different regions. This provides valuable insights for formulating region-specific environmental tax policies that are conducive to promoting sustainable and green economic growth.

3. Model Setting and Variable Selection

3.1. Model Setting

Spatial econometrics is specialized field that incorporates the concepts of spatial autocorrelation and spatial heterogeneity (Anselin, 2010) [28]. One of its key features is the explicit consideration of spatial interdependence and variability among different units of analysis. Unlike standard econometric approaches that primarily focus on testing heterogeneity, spatial econometrics places significant emphasis on detecting and analyzing spatial dependence. Moreover, spatial econometric models often employ the maximum likelihood estimation (MLE) method, which is known for its high precision and reliability. In order to investigate the potential spatial relationship between environmental tax policies and the efficiency of green economics, the present study incorporated spatial variables while analyzing the link between the two. A spatial lag model was constructed that combined a spatial weighting matrix with relevant variables. This model builds upon the spatial lag model proposed by Shao Yanfei (2022) and represents an improvement in our study. We selected this model due to its simplicity and accuracy, which align with the structure of our paper. The model construction is as follows [29]:

$$Y_{it} = \alpha_i + \rho \sum_{j=1}^{N} WY_{it} + \beta X_{it} + \varepsilon_i \quad (1)$$

In the above equation, i denotes different provinces, t denotes the year, W represents the spatial weight, X_{it} characterizes the explanatory variable, Y_{it} denotes the explanatory variable (green economic efficiency), β is the explanatory variable regression coefficient, and ρ is the explanatory variable spatial regression coefficient.

3.2. Variable Selection

3.2.1. Explanatory Variables

(1) Measurement Model

Many studies currently measure green economy efficiency using DEA within the input-output framework, conducted at various spatial scales. However, the traditional DEA model often overlooks non-desired outputs, leading to imprecise efficiency assessments. To address this limitation, we adopted the SBM model, which accounts for non-desired outputs, to measure green economic efficiency.

In our research, we referred to the book *Data Envelopment Analysis Method and MaxDEA Software* by Cheng-Gang [30], which provides a detailed derivation of the super-efficient SBM model. Building upon the works of scholars such as Tone (2001), we further summarized and expanded upon the existing research to obtain a more concise formula for the SBM model [31]. Given that our measurement software and calculation procedures were based on Cheng-Gang's (2014) book, we made appropriate modifications to the super-efficiency SBM formula presented by Cheng-Gang (2014) to suit our specific needs [30]:

$$\rho = \min \frac{1 + \frac{1}{m}\sum_{i=1}^{m} \frac{s_i^x}{x_{i_0}}}{1 - \frac{1}{s_1+s_2}\left(\sum_{k=1}^{s_1} \frac{s_k^y}{y_{k_0}} + \sum_{l=1}^{s_2} \frac{s_l^z}{z_{l_0}}\right)}$$

$$\text{S.T.} \begin{cases} x_{i_0} = \sum_{j=1}^{n} \lambda_j x_j - s_i^x, \forall i; \\ y_{k_0} = \sum_{j=1}^{n} \lambda_j y_j + s_k^y, \forall k; \\ z_{l_0} = \sum_{j=1}^{n} \lambda_j z_j - s_l^z, \forall l; \\ 1 - \frac{1}{s_1+s_2}\left(\sum_{k=1}^{s_1} \frac{s_k^y}{y_{k_0}} + \sum_{l=1}^{s_2} \frac{s_l^z}{z_{l_0}}\right) > 0 \\ s_i^x \geq 0, s_k^y \geq 0, s_l^z \geq 0, \lambda_j \geq 0, \forall i, j, k, l; \end{cases} \quad (2)$$

where x, y, and z are slack in the inputs, desired outputs, and non-desired outputs, respectively, and w is the weighting vector, which indicates that the variable returns to scale (VRS) if its sum is 1, and the constant returns to scale (CRS) otherwise; the greater the objective function, the higher the efficiency.

(2) Variable Descriptions

To determine appropriate input-output indicators for quantifying the efficiency of green economic practices, we referred to the findings of Qingmin et al. (2020), which integrate existing research and available data, and selected total energy consumption, the number of employed population, and capital stock by region as input variables [32]. One of the methods employed in the computation of capital stock was the perpetual inventory approach, which relies on gross fixed capital formation as a basis. Gross domestic product (GDP) was selected as the desired output variable, which was obtained by deflating the consumer price index of each region, with 2006 as the base period. Chemical oxygen demand in industrial wastewater and SO_2 emissions in industrial waste gas were selected as non-desired output variables (as shown in Table 1). The data inputs and outputs used in this study were sourced from several Chinese statistical yearbooks spanning from 2007 to 2021.

Table 1. Green economic efficiency evaluation index system.

Indicators	Variables	Variable Description	Data Sources
Input indicators	Energy input	Total energy consumption	China Energy Statistical Yearbook for the years 2007 to 2021
	Labor input	Employed population by region	China Statistical Yearbook for the years 2007 to 2021
	Capital input	Capital stock	China Fixed Assets Statistical Yearbook for the years 2007 to 2021
Desired output indicators	Economic benefits output	Regional GDP	China Statistical Yearbook for the years 2007 to 2021
Non-desired output indicators	Wastewater emissions	Industrial wastewater emissions	China Environmental Statistical Yearbook for the years 2007 to 2021
	Exhaust emissions	Industrial waste gas emissions	China Environmental Statistical Yearbook for the years 2007 to 2021

3.2.2. Core Explanatory Variables

Existing studies classify environmental taxes into integrated and independent environmental taxes, including taxes on resources, urban maintenance and construction, and other fiscal systems related to environmental protection. Independent environmental taxes include only the environmental protection tax implemented in 2018. Considering that the environmental protection effect of taxation was generated by the integrated environmental tax before the environmental protection tax was introduced in China, this study referred to Zhanlei et al. (2022) to measure the environmental taxation system using environmental tax indicators [5]. It adopted six taxes as the components of environmental tax: environmental protection, resource, vehicle, urban maintenance and construction, arable land occupation, and urban land-use taxes. The ratio of revenue from these six taxes to GDP was used as a proxy variable.

3.2.3. Control Variables

In addition, the following control variables were used: (1) Economic development level: Green economic efficiency measures both green and economic aspects, and the level of economic development affects such efficiency, as shown by the fact that as the economic level increases, green economic efficiency also significantly increases. In this study, GDP per capita was used to indicate the level of economic development, and the GDP deflator was used to deflate the value, with 2003 as the base period to exclude the price trend. (2) Industrial composition: Social production encompasses three primary sectors—primary, secondary, and tertiary industries—each with varying degrees of efficiency in resource utilization and pollutant emissions. In particular, secondary industries have higher resource consumption and pollutant emission rates, which negatively impact green economy's efficacy. Therefore, this study employed the output value proportion of secondary industry to GDP as the index for measuring industrial composition. (3) Environmental pollution control measures: These are essential government environmental regulatory methods aimed at mitigating environmental pollution and promoting the development of a green economy. The level of investment in pollution control serves as a significant indicator of the government's commitment and efforts in controlling environmental pollution. A higher investment amount signifies a stronger dedication to reducing pollutant emissions and supporting sustainable environmental practices. In this study, we chose the investment amount in pollution control as a reliable metric for assessing the strength of environmental pollution control measures. (4) External openness degree: An increase in external openness levels can potentially lead to a robust green technology spillover effect among enterprises, enhancing the efficiency of the green economy. However, external openness may result in the influx of more polluting enterprises and increase environmental pollution due to low tax rates. Therefore, we used the amount of foreign investment to gauge the degree of regional external openness. (5) Population concentration: High-population-density areas are prone to elevated levels of wastewater, waste gas, solid waste, and noise pollution. However, areas with high population density usually imply a high level of urbanization, which results in more efficient use of energy and, consequently, a higher level of economic development. Here, population density was measured by dividing the area by the number of permanent residents in that area.

3.3. Data Source

We carefully selected a set of panel data comprising 30 provinces, regions, and municipalities, spanning from 2006 to 2020, based on the criteria of data validity, consistency, and availability. The sample data utilized for empirical research were sourced from reputable publications such as the China Energy Statistical Yearbook, China Statistical Yearbook, China Fixed Assets Statistical Yearbook, and China Environmental Statistical Yearbook. Considering the seamless transition of the current environmental protection tax from an emissions-fee system, we utilized the principle of "tax burden shifting" to measure the environmental protection tax indicators of each province from 2006 to 2017 based on emission-fee data. Missing data were interpolated. Excel 2021 and Stata 17 were used to generate descriptive statistics (Table 2).

Table 2. Descriptive statistics of variables.

	Variable	Average	Standard Deviation	Minimum	Maximum
Dependent variable	Green economy efficiency	0.470	0.250	0.150	1.300
Explanatory variables	Environmental taxes	583.360	423.140	61.230	3159.500
Control variables	Economic development level	4.628	2.805	0.612	16.489
	Industry structure	44.880	8.740	15.800	61.500
	Pollution control efforts	20.420	19.630	0.050	141.600
	Openness to the outside world	157.883	291.873	1.998	2744.956
	Population density	2839.240	1207.910	597.840	6307.380

Note: Stata17 software was used to conduct descriptive statistics of the variables.

4. Empirical Results and Analysis

4.1. Spatial Panel Model Testing and Analysis

4.1.1. Spatial Autocorrelation Test

In the application of spatial econometric methods, it is essential to assess the presence of spatial dependence in the data. This step is crucial, as it serves as a prerequisite for employing spatial econometric methods. One commonly used approach for evaluating spatial dependence is Moran's I test. Moran's I value ranges between −1 and 1, with positive values greater than 0 indicating high-high (H-H) and low-low (L-L) agglomeration, while negative values less than 0 indicate high-low (H-L) agglomeration. Positive correlation is generally more prevalent. A value approaching 0 suggests a random spatial distribution, indicating the absence of spatial autocorrelation among the variables. To ensure the applicability of spatial econometric methods in this study, spatial autocorrelation tests were conducted on both the dependent and independent variables.

Prior to the construction of the spatial econometric model, the spatial autocorrelation between the explanatory variable of green economic efficiency and environmental tax was assessed, utilizing provincial panel data from China between 2006 and 2020. The global Moran's I index for each year was computed using Stata17 software (Table 3).

Table 3. Global Moran's I of green economy efficiency and environmental taxes from 2006–2020.

Year	Spatial Weighting Matrix of Geographic Distance		Spatial Weighting Matrix of Neighborhood		Spatial Weighting Matrix of Economic Geographic Distance		Spatial Weighting Matrix of Economic Distance	
	Green Economy Efficiency	Environmental Taxes	Green Economy Efficiency	Environmental Taxes	Green Economy Efficiency	Environmental Taxes	Green Economy Efficiency	Environmental Taxes
2006	0.090	0.297 ***	0.430 ***	0.251 **	0.336 ***	0.688 ***	−0.046	−0.095
2007	0.174 **	0.297 ***	0.494 ***	0.297 ***	0.487 ***	0.680 ***	−0.013	−0.101
2008	0.180 **	0.308 ***	0.475 ***	0.301 ***	0.491 ***	0.621 ***	−0.019	−0.121
2009	0.169 **	0.279 ***	0.458 ***	0.307 ***	0.470 ***	0.555 ***	−0.023	−0.140
2010	0.207 ***	0.272 ***	0.235 **	0.192 *	0.574 ***	0.432 ***	0.057	−0.155
2011	0.228 ***	0.230 ***	0.205 **	0.235 **	0.583 ***	0.475 ***	0.054	−0.164
2012	0.233 ***	0.181 **	0.204 **	0.248 **	0.588 ***	0.374 ***	0.060	−0.131
2013	0.243 ***	0.227 ***	0.202 **	0.169 *	0.604 ***	0.295 ***	0.063	−0.143
2014	0.262 ***	0.211 ***	0.210 **	0.126	0.616 ***	0.281 ***	0.064	−0.127
2015	0.268 ***	0.089	0.217 **	−0.045	0.619 ***	0.248 ***	0.072	−0.074
2016	0.295 ***	0.089	0.239 **	−0.058	0.639 ***	0.259 ***	0.057	−0.076
2017	0.274 ***	0.096	0.211 **	0.053	0.622 ***	0.290 ***	0.070	−0.010
2018	0.284 ***	−0.108	0.260 ***	−0.111	0.730 ***	0.055	0.043	−0.077
2019	0.278 ***	0.052	0.253 ***	0.183 *	0.736 ***	0.250 ***	0.051	0.028
2020	0.340 ***	0.011	0.399 ***	0.206 **	0.753 ***	0.212 **	0.015	0.038

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively. The statistics are in parentheses.

Based on the results presented in Table 3, the Moran's I index was calculated for green economic efficiency and environmental taxation using three different spatial weighting matrices: geographic distance, neighborhood, and economic geographic distance. The results indicate that there is significant positive autocorrelation between green economic efficiency and environmental taxation across all regions in China for all years.

To visually demonstrate the spatial correlation between environmental taxes and green economic efficiency, Moran scatter plots were generated using the spatial weighting matrix based on economic geographic distance. These scatter plots were created for the years 2006 and 2020 to explore the spatial clustering pattern of each province (Figures 1 and 2). Most of the sample fell within H-H and L-L agglomerations, indicating strong spatial dependence of environmental taxes among neighboring provinces. This coincides with the fact that there is tax competition behavior among local governments, which leads to the characteristics of mutual emulation among local governments in setting environmental tax collection standards, tax collection, and behavioral regulation.

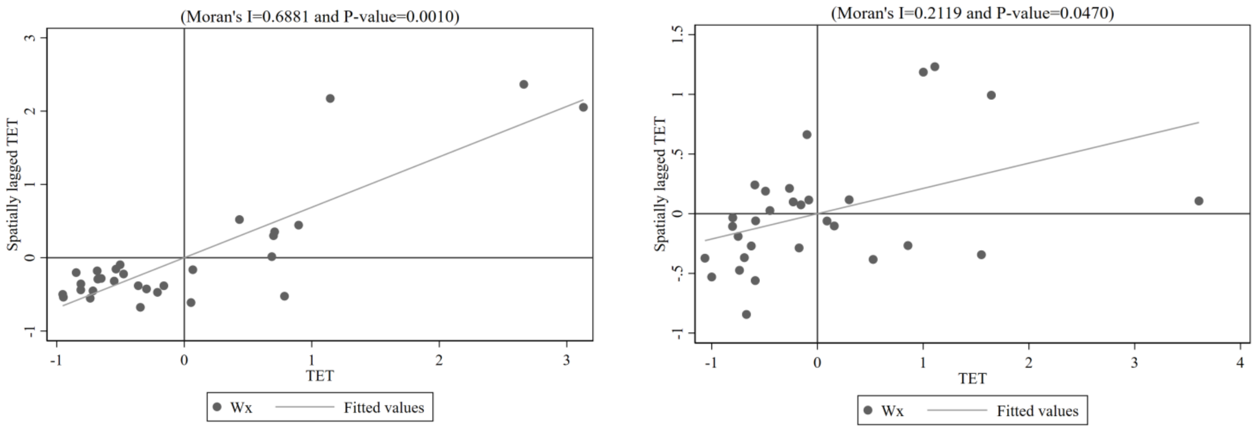

Figure 1. Scatterplot of local Moran's I of green economy efficiency in 2006 and 2020.

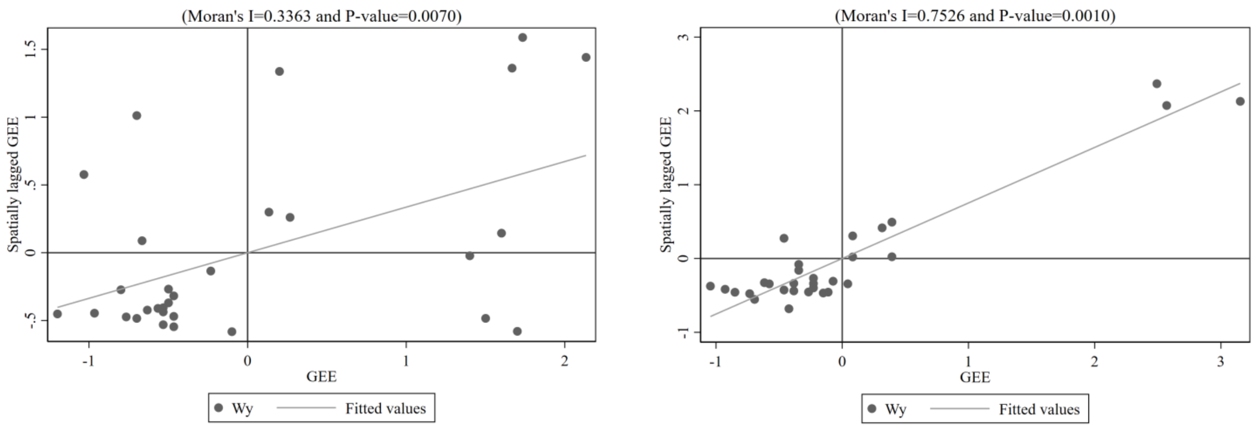

Figure 2. Scatterplot of local Moran's I of environmental tax in 2006 and 2020.

Upon further examination of Figures 1 and 2, it is evident that the scatter points representing green economic efficiency and environmental tax in both 2006 and 2020 are mainly concentrated in the first and third quadrants. However, there are differences in the level of dispersion between the two time periods. In 2020, the dispersion of green economic efficiency was lower compared to 2006, and it expanded to include the second quadrant (H-L agglomeration). Despite this expansion, the overall concentration still remains primarily in the first and third quadrants.

By contrast, the concentration of environmental taxes in the first and third quadrants is higher in 2020 compared to 2006. These characteristics align with the numerical changes observed in the Moran's I index for the years 2006 and 2020.

4.1.2. Analysis of Spatial Effect Regression Results

The standard deviation is a measure that quantifies the dispersion or variability of a set of values. In the context of regression results, the standard deviation of the estimated values reflects the spread or deviation of individual data points from the average estimated value. A smaller standard deviation indicates that the estimates are tightly clustered around the mean, indicating higher accuracy and consistency in the regression analysis.

Considering the nature of standard deviation, we first examined the values within brackets in Table 4. We observed that none of the values exceeded 0.1. This observation suggests that the standard deviations associated with the regression results are very small, indicating the precision and reliability of the estimated regression coefficients.

Table 4. Regression results of spatial effects of environmental taxes on green economic efficiency.

Variable	Spatial Weighting Matrix of Geographic Distance	Spatial Weighting Matrix of Neighborhood	Spatial Weighting Matrix of Economic Geographic Distance
Environmental taxes	0.093 *** (0.030)	0.110 *** (0.031)	0.102 *** (0.029)
Economic development level	0.235 *** (0.029)	0.243 *** (0.029)	0.201 *** (0.033)
Industry structure	−0.384 *** (0.036)	−0.374 *** (0.038)	−0.365 *** (0.037)
Pollution control efforts	−0.007 (0.007)	−0.005 (0.007)	−0.008 (0.007)
Openness to the outside world	0.069 *** (0.007)	0.070 *** (0.007)	0.072 *** (0.007)
Population density	0.071 *** (0.014)	0.068 *** (0.014)	0.064 *** (0.014)
rho	0.143 * (0.073)	0.043 (0.040)	0.124 *** (0.042)
sigma2_e	0.012 *** (0.001)	0.012 *** (0.001)	0.012 *** (0.001)
Observations	450	450	450
R-squared	0.250	0.282	0.281
Log likelihood	360.458	359.291	362.896

Note: *** and * indicate that the variables are significant at the 1% and 10% levels, respectively. The statistics are in parentheses.

The results in Table 4 demonstrate that the impact of environmental taxes on green economic efficiency can be estimated using spatial lag models. Specifically, rho values of 0.143 and 0.124 were found for the geographic distance and economic geographic distance weighting matrices, respectively. These values were found to be statistically significant at the 10% and 1% levels, consistent with the Moran index results. This suggests that green economic efficiency is influenced not only by local environmental tax factors but also by neighboring regions' green economic efficiency, with significant spatial dependence between them. This dependence is related to geographical distance, economic levels, and adjacency and reflects the spatial correlation of the lagged term. Furthermore, the model's coefficients for each explanatory variable remained significant, indicating the model's validity and reliability.

The results of the model show that environmental taxes have a positive and significant impact on the green economy's efficiency according to all three weighting matrices. Additionally, economic development level, openness to the outside world, and population density were found to be significantly and positively associated with green economic efficiency across all three weighting matrices. This finding is in line with the results of Baek Jungho (2011) and Hashim Zameer (2020), who studied the relationship between environmental taxes and international trade. Hence, these factors are conducive to the development of the green economy. However, the proportion of GDP as secondary industry was negatively correlated with green economic efficiency at the 1% significance level, indicating that it hinders the improvement of green economic efficiency [33,34]. This conclusion aligns with the result of Muhammad Zahid Rafifique (2021) and Bingnan Guo

(2021), who found that environmental taxes can impact industrial structure [11,35]. Notably, the correlation between pollution control efforts and green economy efficiency was not found to be significant in the present study, suggesting that local governments' investments in environmental pollution control may not be efficient enough to promote economic development and achieve performance goals.

4.1.3. Analysis of Tax Heterogeneity

To analyze the potential variations in the impact of different taxes on carbon emission intensity, environmental taxes were partitioned into six categories: environmental protection tax, resource tax, vehicle and boat tax, urban maintenance and construction tax, arable land occupation tax, and urban land-use tax. The explanatory variables for each sub tax were determined by calculating the ratio of the tax revenue to GDP. The results are presented in Table 5.

Table 5. Impacts of environmental taxes on green economic efficiency by tax type.

Variable	Spatial Weighting Matrix of Geographic Distance	Spatial Weighting Matrix of Neighborhood	Spatial Weighting Matrix of Economic Geographic Distance
Environmental protection tax	−0.056 *** (0.012)	−0.056 *** (0.012)	−0.055 *** (0.012)
Vehicle tax	0.027 *** (0.010)	0.025 ** (0.010)	0.025 ** (0.010)
City maintenance and construction tax	−0.022 (0.013)	−0.020 (0.014)	−0.024 * (0.013)
Arable land occupation tax	−0.023 *** (0.007)	−0.026 *** (0.007)	−0.023 *** (0.007)
Urban land tax	−0.051 *** (0.013)	−0.058 *** (0.013)	−0.048 *** (0.013)
Resource tax	−0.007 (0.005)	−0.007 (0.005)	−0.006 (0.005)
Economic development level	0.235 *** (0.029)	0.243 *** (0.029)	0.201 *** (0.033)
Industry structure	−0.384 *** (0.036)	−0.374 *** (0.038)	−0.365 *** (0.037)
Pollution control efforts	−0.007 (0.007)	−0.005 (0.007)	−0.008 (0.007)
Openness to the outside world	0.069 *** (0.007)	0.070 *** (0.007)	0.072 *** (0.007)
Population density	0.071 *** (0.014)	0.068 *** (0.014)	0.064 *** (0.014)
rho	0.143 * (0.073)	0.043 (0.040)	0.124 *** (0.042)
sigma2_e	0.012 *** (0.001)	0.012 *** (0.001)	0.012 *** (0.001)
Observations	450	450	450
R-squared	0.250	0.282	0.281
Log likelihood	360.458	359.291	362.896

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively. The statistics are in parentheses.

According to Table 5, in terms of specific environmental taxes, the estimated coefficients of the model for all three matrices were positive and significant at the 1% or 5% level, indicating that the vehicle and vessel taxes levied at this stage effectively contributed to improving green economic efficiency. This conclusion, which is in line with Yang Shen (2022), is probably derived because vehicle and vessel taxes are levied on vehicles traveling on public roads and vessels navigating domestic rivers, lakes, and territorial sea ports [8]; their taxation can reduce people's use of motor vehicles and vessels and control the emission of pollutants. The results demonstrate that the environmental protection, arable land occupation, and urban land-use taxes have all exhibited negative and statistically significant regression coefficients at the 1% level. This suggests that the introduction of these taxes has an inhibitory effect on the development of the green economy, possibly due to the current costs associated with paying these taxes being outweighed by the revenue gained from increasing pollution emissions. This, in turn, has resulted in enterprises failing to reduce their pollution emissions and giving little attention to technological innovation in enterprise emission reduction, which is detrimental to promoting the green transformation of enterprises. Zhao X.'s (2022) research on enterprises also supports this viewpoint [36]. The regression coefficient of urban maintenance and construction tax for the spatial weighting matrix of economic geographic distance was found to be −0.024 and significant at the 10%

level. This indicates that at the economic level, the urban maintenance tax has negative utility for improving green economic efficiency in the region. The urban maintenance and construction tax, as an additional tax, has a large impact on the main industries such as traditional manufacturing and energy processing industries, increasing the tax burden of enterprises and reducing their green innovation investment. Although the estimated coefficients of resource tax for the three weightings were negative, the results are not significant, indicating that the levy of resource tax does not have the expected effect on local green economic development. This result is supported by Parry (2005), who studied gasoline tax collection in Britain and the United States [37]. A possible reason behind this conclusion is that the current scope of resource tax in China is relatively narrow, including only crude oil, natural gas, coal, and other non-metallic ores, which is insufficient to greatly influence enterprises' resource utilization and pollution emission behaviors, resulting in a slow green transformation process. Additionally, all the standard deviation values in Table 6 are below 0.1, indicating that the estimated empirical results are highly representative, affirming the accuracy of the equation's estimates.

Table 6. Spatial heterogeneity analysis of the effect of environmental taxes on green economic efficiency for the geographic distance matrix.

Variable	Eastern Region	Central Region	Western Region
Environmental taxes	0.136 * (0.073)	0.026 ** (0.012)	0.035 (0.049)
Economic development level	0.235 *** (0.060)	−0.046 *** (0.015)	0.049 (0.057)
Industry structure	−0.641 *** (0.087)	0.071 *** (0.017)	−0.181 ** (0.084)
Pollution control efforts	0.033 ** (0.015)	−0.002 (0.004)	−0.009 (0.010)
Openness to the outside world	0.085 *** (0.019)	0.011 (0.007)	0.057 *** (0.012)
Population density	0.199 *** (0.037)	−0.004 (0.011)	0.024 (0.017)
rho	−0.091 (0.145)	−0.286 ** (0.134)	−0.473 ** (0.211)
sigma2_e	0.018 *** (0.002)	0.000 *** (0.000)	0.003 *** (0.000)
Observations	180	135	135
R-squared	0.294	0.061	0.065
Log likelihood	104.330	350.627	191.536

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively. The statistics are in parentheses.

4.1.4. Analysis of Regional Heterogeneity

To examine whether environmental taxes have different impacts on green economic efficiency across regions, we divided China's 30 provinces into three regions: eastern, central, and western (National Bureau of Statistics of China, 2003). We then evaluated the spatial effects of environmental taxes on green economic efficiency, using the three different weighting matrices. To ensure the accuracy of the estimated results, we first analyzed the standard deviations of the regression results presented in Tables 6–8. A closer examination revealed that the standard deviation values were consistently small, suggesting that the estimated results of the spatial heterogeneity tests conducted using the three types of spatial weight matrices were highly precise. Hence, we moved on to further analysis. The findings presented in Table 6 suggest that environmental taxes had varying effects across the regions. Specifically, the environmental tax in the eastern region had a significant positive impact on green economic efficiency, but its rho value failed to meet the 10% level of significance. This suggests that the environmental tax policy in the eastern region primarily affects the region and does not have a spatial spillover effect. By contrast, the coefficient of the environmental tax in the central region was 0.026, it was significant at the 5% level, and its rho value was −0.286, which was also significant at the 5% level. These results indicate that the environmental tax in the central region is beneficial to improving green economic efficiency and has a spatial spillover effect. However, although the environmental tax in the western region had a significant rho value, indicating a spatial spillover effect, its coefficient was not large enough to produce a significant Impact on the region. Overall, while there are some differences among the three regions, the results show that environmental taxes are generally conducive to improving green economic efficiency.

Table 7. Spatial heterogeneity analysis of the effect of environmental taxes on green economic efficiency for the adjacent weighting matrix.

Variable	Eastern Region	Central Region	Western Region
Environmental taxes	0.132 * (0.077)	0.031 * (0.016)	0.037 (0.052)
Economic development level	0.234 *** (0.062)	0.050 *** (0.017)	0.108 * (0.062)
Industry structure	−0.654 *** (0.089)	−0.005 (0.022)	−0.263 *** (0.091)
Pollution control efforts	0.033 ** (0.015)	−0.024 *** (0.004)	−0.005 (0.011)
Openness to the outside world	0.089 *** (0.018)	−0.006 (0.008)	0.045 *** (0.014)
Population density	0.203 *** (0.039)	0.028 *** (0.007)	0.040 ** (0.020)
rho	−0.020 (0.071)	−0.422 *** (0.112)	0.300 (0.255)
sigma2_e	0.018 *** (0.002)	0.001 *** (0.000)	0.004 *** (0.000)
Observations	180	135	135
R-squared	0.267	0.220	0.036
Log likelihood	104.184	301.530	184.903

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively. The statistics are in parentheses.

Table 8. Spatial heterogeneity analysis of the effect of environmental taxes on green economic efficiency for the economic geography matrix.

Variable	Eastern Region	Central Region	Western Region
Environmental taxes	0.146 ** (0.069)	0.012 (0.008)	0.020 (0.040)
Economic development level	0.216 *** (0.057)	0.019 ** (0.009)	0.048 (0.046)
Industry structure	−0.629 *** (0.082)	−0.001 (0.011)	−0.133 * (0.069)
Pollution control efforts	0.033 ** (0.014)	−0.010 *** (0.002)	−0.008 (0.008)
Openness to the outside world	0.085 *** (0.016)	−0.003 (0.004)	0.041 *** (0.010)
Population density	0.192 *** (0.036)	0.014 *** (0.004)	0.026 * (0.014)
rho	−0.465 (0.305)	−4.020 *** (0.330)	−2.190 *** (0.468)
sigma2_e	0.016 *** (0.002)	0.000 *** (0.000)	0.002 *** (0.000)
Observations	180	135	135
R-squared	0.407	0.473	0.304
Log likelihood	101.6629	336.2340	203.1628

Note: ***, **, and * indicate that the variables are significant at the 1%, 5%, and 10% levels, respectively. The statistics are in parentheses.

Table 7 reports the findings of the neighboring weighting matrix's estimation, which indicate that the introduction of environmental tax in the eastern and central regions had a significant positive impact on the green economic efficiency at the 10% level, whereas in the western region, the effect was positive but not significant. Concerning the spatial spillover effect, our results suggest that only the provinces located in the central region exerted a significant influence on their neighboring provinces, whereas no significant spillover effects were found in the other regions.

Table 8 shows the estimation results for the weighting matrix of economic geographic distance, from which it may be seen that environmental taxation in the eastern, central, and western regions had positive effects on green economic efficiency, but the significance of the influence in the central and western regions was insufficient, probably due to disparities in the composition of industries between the eastern region and the central and western regions. Moreover, the central and western regions exhibited a significant spatial spillover effect. However, the p-value of rho in the eastern region was 0.127, indicating that the spatial correlation between provinces in the eastern region was not statistically significant, which implied a weaker spatial interdependence compared to the central and western regions.

5. Research Findings and Policy Recommendations

5.1. Research Conclusion

This research utilized panel data encompassing 30 Chinese provinces, including autonomous regions and municipalities directly controlled by the central government. The data cover the period from 2006 to 2020, providing a comprehensive temporal scope for the analysis. The study measured the efficiency of each province's green economy by utilizing a super-efficiency model. To investigate the impact of environmental tax policies on green economic development, a spatial lag model was employed, and three spatial weighting matrices were used. The following conclusions were drawn: (1) Environmental taxation exhibits a strong positive correlation with green economic efficiency and also has a positive spatial spillover effect on regional green economic efficiency. (2) The analysis of tax heterogeneity showed that vehicle and vessel taxes can promote improved green economic efficiency. Nevertheless, the implementation of taxes such as those for environmental protection, arable land occupation, and urban land use may hinder the growth of green economic ventures. Urban maintenance and construction taxes can also adversely affect green economic efficacy on an economic scale within the region. Conversely, resource taxation does not appear to significantly impact local green economic development. Further examination of regional heterogeneity revealed that the spatial ramifications of environmental taxation on green economic advancement vary among regions. (3) In light of China's current economic development, population distribution, and level of openness to external trade, favorable conditions exist for the advancement of the green economy. However, the industrial structure exhibits a negative correlation with green economic efficacy at the 1% level of significance. In addition, no correlation exists between pollution control efforts and green economic efficacy. This study has several limitations that should be considered. Firstly, the analysis primarily focuses on data from 30 provinces and autonomous regions in China, which may limit the generalizability of the findings to other countries. Economic development levels, population sizes, and national policies vary across countries, and therefore, the findings may not be directly applicable elsewhere. To address this limitation, future studies could expand the sample size to include a broader range of countries, specifically examining the impact of environmental tax policies on green economy development in five East Asian countries or sixteen East and Southeast Asian countries. By conducting such analyses and exploring the heterogeneity among countries at different stages of development, more comprehensive and general conclusions can be drawn.

5.2. Recommendations

Drawing from the aforementioned research results, we present the subsequent policy suggestions. Firstly, based on the spatial characteristics of environmental taxation and green economic efficiency, coordination and cooperation among governments should be strengthened. The spatial spillover effect of environmental taxation could potentially provoke neighboring governments into either free riding or blindly imitating such policies. Building a perfect information-communication and interest-coordination mechanism among governments can prompt local governments to target their policies, understand key points, and clarify targets, thus realizing inter-governmental cooperation in pollution control and accelerating the green transformation and development of enterprises. From a different perspective, it is clear that green economic efficiency exhibits positive autocorrelation; therefore, governments at all levels should understand the scientific basis of economic efficiency under current resource and environmental constraints, clarify the key industries in each region, form regional characteristics, and cooperate with neighboring regions to guide the development of industrial layout in the region to achieve green economic growth. Governments at all levels can play a crucial role by creating a platform for regional exchange and cooperation. This allows them to coordinate efforts with other regions and develop tailored environmental tax strategies that align with the specific attributes of each region. By doing so, governments can maximize the guiding potential and fiscal leverage of environmental taxes, leading to more effective and targeted outcomes in promoting sustainable development.

Secondly, environmental tax policy should be improved and a comprehensive environmental tax system constructed. We found that the environmental tax presently imposed encourages environmentally sustainable economic growth. However, some pre-existing environmental tax measures have yet to yield noticeable results, or they may have even led to adverse effects. Local governments should follow the current status of economic development and resource endowment of each region to further develop and improve the content of environmental tax policies suitable for local areas. After careful analysis, it is recommended that the resource tax levy be broadened, tax burden be increased for arable land occupation and urban land use, and environmental protection tax levy standards be adjusted to reflect the actual pollution emissions and economic development level of the region. It is advisable to levy taxes on all forms of pollutants to provide effective policy support. Simultaneously, consideration can be given to reducing the tax burden of other taxes such as VAT and corporate income tax in the form of green innovation incentives to reduce the cost effect of environmental taxes and thus promote development of the green economy. In response to this scenario, it is essential for nations worldwide, particularly those that have recently implemented or reformed environmental tax policies, to conduct a comprehensive analysis of the effects of these taxes on various regions and industries. This analysis will enable them to identify any necessary adjustments that need to be made in a timely manner, ensuring that environmental tax strategies effectively achieve their intended outcomes. By closely monitoring and adapting these strategies, governments can maximize the positive impact of environmental taxes and ensure their continued effectiveness in promoting sustainable development.

Thirdly, based on the results of the heterogeneity tests for different taxes and considering the negative impact of the industrial structure on green economy efficiency, it is crucial to focus on upgrading the industrial structure and enhancing the efficiency of local governments in environmental pollution control. By prioritizing these areas, policymakers can effectively address the challenges and improve the overall performance of the green economy. Although the current industrial structure of most Chinese provinces has entered the "three-two-one" mode because of the high level of pollution emissions in China's secondary industry, in order to promote economic development, there remains a need to prioritize the expansion of the tertiary sector while gradually diminishing the significance of the secondary sector. At the same time, in secondary industry, it is important to strengthen the capacity constraints of high-pollution and high-energy-consumption enterprises and use environmental tax policy to urge them to enhance their production technology and speed up transformation and upgradation. Regarding the issue of unremarkable pollution control effectiveness, in order to enhance the effectiveness of pollution control investment funds, local authorities must intensify their evaluations of investment projects, tailor investment plans to the unique characteristics of the region, and augment their oversight and monitoring of plan execution. Simultaneously, it is imperative to contemplate integrating the pollution mitigation level into the all-encompassing appraisal framework of economic and societal progress in every locality. This would ensure that the impact of pollution control investment is one of the pivotal assessment benchmarks for regional authorities. To prevent local officials from being trapped in the "GDP growth" mindset, it is essential to introduce measures that discourage industries with high pollution and energy consumption even if they offer economic benefits. As mentioned earlier, countries can customize their environmental tax objectives and standards to suit their specific circumstances and implement these policies nationwide. A cohesive national environmental tax strategy can effectively deter businesses from exploiting regional tax and policy differences to relocate their polluting industries. Additionally, the central government plays a crucial role in coordinating efforts and managing potential competition among regional governments. By adopting these approaches, countries can strike a balance between economic development and environmental protection, avoiding the negative impacts that unsustainable industries may have on the green economy.

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