

Measurement, Influencing Factors and Spatial Spillover Effect of China's Green Economy Development Level

-- Spatial econometric analysis based on provincial panel data

Ruolin Meng*, Jia Shao

School of Public Administration, Nanjing Agricultural University, Nanjing, China.

*Corresponding Author Email: mengruolin0526@163.com

Abstract. Based on the concept of green development under the new development pattern, the evaluation index system of China's green economy development is constructed from three dimensions: green production, green life and green ecology. Based on the panel data of 30 provinces from 2005 to 2020, the green economy development level of each province is calculated, and its influencing factors are considered from three aspects: economic development, social capital and governance efficiency, and its spatial spillover effect is analyzed. The conclusions of this study are as follows: (1) During the study period, the development level of green economy in each province generally presents a steady upward trend, but there are significant differences among the provinces, with Xinjiang, Hainan, Tianjin and other provinces experiencing the largest increase, while Yunnan, Guangxi and Shaanxi provinces experiencing the smallest increase. (2) The development level of China's green economy is obviously centralized and distributed. The level of science and technology, the development of the private economy and the degree of opening to the outside world are the key factors to promote the high-quality development of green economy in China. The extensive utilization of resources has hindered the development of the green economy. The degree of openness is the main factor to promote the development of the green economy in this region. Technological progress and energy consumption are not conducive to the promotion of green economic development level in other regions.

Keywords: Green economy; FHARA algorithm; Entropy weight Topsis method; Spatial econometric model.

1. Introduction

In recent years, China's economy has maintained a good development trend for a long time, but economic growth is accompanied by high pollution and high energy consumption, which breed serious resource and environmental problems. Green development is an important content of high-quality regional development under the new development pattern. However, due to the different economic, institutional, social, cultural and natural resource endowments of different regions and provinces in China, how to balance regional economic development with resources and environmental protection has always been a key issue. The new development model can not only emphasize the efficiency of economic development, but also take into account the quality of its development, especially the green and sustainable economic model. Based on the traditional measurement model and the new connotation of green development under the new development model, it is necessary to explore the measurement system and its influence mechanism of green economic development. Therefore, it is of great significance to establish a perfect evaluation index system for the development of green economy, scientifically measure the development level of green economy in various provinces in China, explore the key factors that influence the development of green economy, and analyze its internal influence mechanism for promoting the sustainable development of green economy in various regions in China.

The development of green economy has become a hot topic among scholars at home and abroad. The research fields are divided into national, provincial and regional level. Xu et al. measured the development level of China's green economy and explored its influencing factors, while others have chosen Guangxi and the Yangtze River Delta urban agglomeration, Yellow River Basin, North

China Plain、Beijing-tianjin-hebei region as the research object. On the research content, most scholars focus on the construction of evaluation system, the analysis of the temporal and spatial evolution trend and the influencing factors. At present, there are abundant research achievements on the construction of evaluation system. The existing studies are different in index selection and evaluation methods, and measures the green development level from different perspectives. Xu et al. have constructed a green development evaluation system from three perspectives: green production, green life and green ecology. Wang et al.、Yang et al. have used the non-oriented Super-SBM model and the non-expected output Super-SBM model to measure the green development efficiency, Ma et al. used entropy weight -Topsis method to evaluate the green development index, while others choose combination evaluation method and fixed-base range method. Based on different perspectives, the existing research have constructed various measurement models to explore the factors that affect the level of green development. Some scholars based on traditional econometric models, such as fixed effect model、Tobit model、Dynamic panel model, etc. However, most scholars pay more attention to the spatial correlation among variables and use spatial econometric models to study the spatial spillover effects of the influencing factors. From the perspective of spatial correlation, Feng et al. constructed a panel space dobbin model with two-way fixed individual time, and studies the effect of industrial synergy on urban green development, spatial spillover effect and attenuation boundary. From the perspective of spatial heterogeneity, most scholars use panel data to construct GWR model to explore the spatial differences of influencing factors.

To sum up, few scholars have studied the spatial spillover effect of the influencing factors of China's green economy development level from the perspective of spatial correlation. Therefore, based on the panel data of China (excluding Hong Kong, Macao, Taiwan and Tibet) from 2005 to 2020, this study uses FHARA algorithm to screen the evaluation indicators of green economic development level, and uses entropy weight -Topsis method to calculate the development level of green economy in various provinces of China. This paper constructs the Spatial Durbin Model, explores the spatial spillover effect of each explanatory variable, and puts forward relevant suggestions to promote the development of green economy, in order to provide effective reference for China's green coordinated development.

This research innovation mainly includes two points. Firstly, the innovation of research methods. In order to solve the problem of redundant attribute information, the FHARA algorithm is used to construct the evaluation system for green economic development index. Combining with the relevant connotation of green development under the new development pattern, the evaluation index system of green economy development level is constructed from three aspects: green production, green life and green ecology, and the development level of China's green economy is measured and analyzed. Considering its influencing factors from the perspectives of economic development, social capital and governance efficiency, this paper explores its spatial spillover effect and provides policy suggestions for the high-quality development of the green economy.

2. Measurement of China's Green Economy Development Level

2.1 Construction of Evaluation Index System for China's Green Economy Development

Based on the concept of green development under the new development pattern and referring to the research of Xu and other scholars, the study has constructed the evaluation index system of green economy development level from three aspects of production, life and ecology, and preliminarily determines the indicators of green economy development level based on this (Table 1). In this study, panel data of 30 provinces, municipalities directly under the central government and autonomous regions in China (Tibet Autonomous Region is not currently available) from 2005 to 2020 are selected. The data are from China Statistical Yearbook, China Environmental Statistics Yearbook, China Energy Statistics Yearbook and statistical yearbooks of various provinces and cities, where missing values are interpolated by linear interpolation or cubic polynomial interpolation.

Table 1. Indicators for Evaluating the Development Level of Green Economy

Primary index	Secondary index	Index meaning	Property
Green production	Sewage emission per unit GDP	Sewage emission / gross regional production	-
	Sulfur dioxide emission per unit GDP	Sulfur dioxide emission/ gross regional production	-
	Soot emission per unit GDP	Soot emission/ gross regional production	-
	The amount of agricultural pollutants used per unit cultivated land area	(plastic film usage + plastic film usage + pesticide usage)/cultivated area	-
	GDP per capita	Gross Regional Production/resident population	+
Green ecology	Elasticity Ratio of Energy Production	Annual average growth rate of energy consumption/annual average growth rate of GDP	-
	Forest coverage rate	Forest area/land area	+
	Total Investment in the Treatment of Environmental Pollution as Percent of GDP (%)	Investment amount of environmental pollution control/ gross regional production	+
	City appearance and environmental sanitation investment as Percent of GDP (%)	Total investment in urban environmental infrastructure construction/ gross regional production	+
	Reuse rate of urban sewage	Reuse of urban sewage/total sewage	+
Green life	City sewage disposal rate	Municipal sewage treatment/total sewage	+
	Green Covered Area as % of Completed Area	Green coverage area/built-up area	+
	Public Recreational Green Space Per Capita	Park green area/year-end total population	+
	Buses and Trolley Buses Per Capita	Number of buses/total population at year-end	+
	Special Vehicles for Environmental Sanitation Per Capita	Number of special vehicles for environmental sanitation /total population at year-end	+
	City garbage harmless disposal rate	Harmless disposal of household garbage / Total domestic waste	+

Considering the redundancy and repetition of information in the indicators selected by manual evaluation, the redundant indicators will cause a large amount of overall information collection and complicated model calculation, which is not conducive to the follow-up research. In this study, according to the FHARA algorithm proposed by liu et al., the reduced attribute set is generated. This method uses the greedy strategy to extract the attributes that can make the positive region contain the largest number of nodes from the unselected attribute set, and add them to the reduced attribute set until the positive region can't continue to increase with the addition of a single conditional attribute.

Considering that the neighborhood radius in the FHARA algorithm can be selected artificially, the neighborhood radius (θ) is 0.01-0.3 during the sampling test. In this process, the number of attribute sets generated by the FHARA algorithm and the proportion of positive region in all sample spaces are recorded.

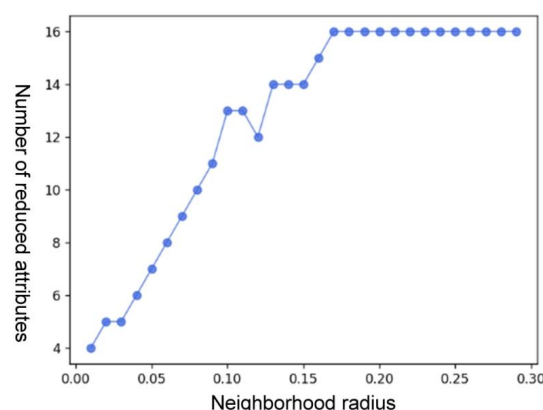


Figure 1. Number of attributes after reduction

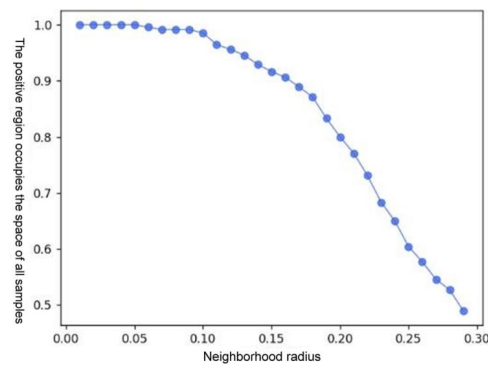


Figure 2. Proportion of Positive Region in All Sample Spaces

The proportion of positive area in sample space can represent the ratio of sample information contained in this attribute set under radius measurement. With the increase of radius, this constraint strength is stronger, and when the radius exceeds a certain value, the specific gravity displayed is no longer of reference significance. Considering that the attribute set generated by FHARA algorithm adopts greedy strategy, the result of the algorithm is not the optimal attribute set, so the optimal selection proportion is 95%. At this time, $\theta = 0.12$, a total of 12 indexes are finally selected (Table 2).

2.2 Measurement and Analysis of China's Green Development Level

Considering the influence of dimensions, the standard treatment is adopted to unify the indicators into positive indicators. Then, the entropy weight -Topsis method is used to measure the green development level of 30 provinces and cities in China from 2005 to 2020 (Table 3). From the analysis of the data in the table, it can be concluded that from the general trend, most of the provinces have shown a steady growth, with Xinjiang, Hainan, Tianjin and Guizhou showing the largest growth, with Xinjiang showing an increase of 109.3%, while Shaanxi showing the smallest increase, with an increase of 21.3%. The overall distribution has shown a great change. The development advantages of Beijing, Tianjin and the Pearl River Delta have been gradually established, with an overall increase higher than that of other regions. The development level of green economy in China's provinces is extremely unbalanced, and targeted measures should be taken to further promote the coordinated development of green.

Table 2. Index Weight

Primary index	Secondary index	Unit	Index direction	Weight
Green production	Sewage emission per unit GDP	Million tons/billion yuan	-	0.90%
	Soot emission per unit GDP	Tons/billion yuan	-	1.34%
	GDP per capita	Ten thousand yuan	+	17.91%
Green ecology	Green Covered Area as % of Completed Area	hektare	+	6.75%
	Public Recreational Green Space Per Capita	%	+	2.76%
	Special Vehicles for Environmental Sanitation Per Capita	unit	+	20.35%
	City garbage harmless disposal rate	%	+	3.09%
Green life	City sewage disposal rate	%	+	2.12%
	Reuse rate of urban sewage	%	+	5.45%
	City appearance and environmental sanitation investment as Percent of GDP (%)	%	+	18.78%
	Total Investment in the Treatment of Environmental Pollution as Percent of GDP (%)	%	+	8.34%
	Forest coverage rate	%	+	12.21%

Table 3. Grading of Green Economy Development Level

Region	2005	2006	2007	2008	2009	2010	2011	2012
Beijing	0.36	0.45	0.36	0.40	0.42	0.36	0.47	0.40
Tianjin	0.25	0.19	0.21	0.21	0.24	0.25	0.29	0.30
Hebei	0.22	0.17	0.17	0.18	0.21	0.22	0.24	0.23
Shanxi	0.20	0.16	0.17	0.18	0.19	0.20	0.22	0.23
Inner Mongolia	0.22	0.16	0.15	0.17	0.18	0.22	0.24	0.26
Liaoning	0.24	0.21	0.21	0.24	0.23	0.24	0.27	0.28
Jilin	0.23	0.23	0.21	0.20	0.22	0.23	0.23	0.23
Heilongjiang	0.22	0.20	0.21	0.22	0.22	0.22	0.24	0.25
Shanghai	0.28	0.22	0.24	0.26	0.28	0.28	0.29	0.31
Jiangsu	0.22	0.17	0.18	0.20	0.21	0.22	0.23	0.24
Zhejiang	0.30	0.26	0.27	0.29	0.30	0.30	0.31	0.32
Anhui	0.20	0.15	0.16	0.19	0.20	0.20	0.22	0.23
Fujian	0.31	0.28	0.29	0.29	0.30	0.31	0.32	0.32
Jiangxi	0.29	0.25	0.25	0.25	0.27	0.29	0.29	0.31
Shandong	0.22	0.18	0.19	0.20	0.21	0.22	0.23	0.24
Henan	0.17	0.14	0.15	0.15	0.17	0.17	0.18	0.19
Hubei	0.21	0.17	0.17	0.18	0.20	0.21	0.30	0.22
Hunan	0.22	0.18	0.19	0.20	0.22	0.22	0.23	0.25
Guangdong	0.35	0.26	0.26	0.28	0.32	0.35	0.34	0.34
Guangxi	0.27	0.21	0.21	0.22	0.26	0.27	0.28	0.28
Hainan	0.27	0.23	0.23	0.23	0.26	0.27	0.28	0.29
Chongqing	0.23	0.14	0.15	0.16	0.21	0.23	0.26	0.25
Sichuan	0.19	0.16	0.17	0.18	0.19	0.19	0.20	0.21
Guizhou	0.18	0.14	0.14	0.14	0.17	0.18	0.22	0.20
Yunnan	0.24	0.18	0.19	0.19	0.24	0.24	0.24	0.24
Shaanxi	0.24	0.17	0.18	0.20	0.22	0.24	0.24	0.24
Gansu	0.18	0.12	0.14	0.14	0.14	0.18	0.16	0.18
Qinghai	0.13	0.10	0.12	0.15	0.11	0.13	0.15	0.14
Ningxia	0.21	0.19	0.21	0.19	0.18	0.21	0.22	0.22
Xinjiang	0.13	0.07	0.09	0.10	0.13	0.13	0.16	0.22

Continuation of table 3. Grading of Green Economy Development Level

Area	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	0.56	0.63	0.49	0.61	0.55	0.52	0.52	0.50
Tianjin	0.31	0.36	0.35	0.37	0.38	0.39	0.42	0.44
Hebei	0.24	0.24	0.23	0.24	0.23	0.29	0.26	0.30
Shanxi	0.24	0.22	0.22	0.27	0.22	0.28	0.28	0.27
Inner Mongolia	0.29	0.29	0.31	0.32	0.30	0.31	0.31	0.31
Liaoning	0.26	0.26	0.27	0.27	0.30	0.28	0.29	0.30
Jilin	0.24	0.25	0.26	0.27	0.26	0.27	0.28	0.29
Heilongjiang	0.27	0.26	0.27	0.26	0.26	0.27	0.27	0.29
Shanghai	0.32	0.34	0.36	0.37	0.40	0.41	0.43	0.43
Jiangsu	0.26	0.27	0.29	0.29	0.31	0.32	0.33	0.35
Zhejiang	0.33	0.34	0.34	0.35	0.36	0.37	0.38	0.40
Anhui	0.25	0.25	0.25	0.26	0.27	0.25	0.27	0.28
Fujian	0.33	0.33	0.33	0.34	0.35	0.37	0.37	0.39
Jiangxi	0.29	0.29	0.30	0.30	0.31	0.33	0.37	0.37
Shandong	0.24	0.25	0.25	0.26	0.27	0.28	0.29	0.29
Henan	0.20	0.20	0.21	0.22	0.24	0.25	0.26	0.27

Hubei	0.25	0.26	0.27	0.28	0.28	0.28	0.29	0.30
Hunan	0.27	0.26	0.26	0.25	0.26	0.26	0.27	0.28
Guangdong	0.36	0.37	0.39	0.41	0.43	0.44	0.46	0.47
Guangxi	0.29	0.29	0.30	0.30	0.30	0.31	0.32	0.33
Hainan	0.28	0.29	0.29	0.36	0.38	0.43	0.49	0.51
Chongqing	0.26	0.26	0.26	0.27	0.28	0.30	0.29	0.32
Sichuan	0.21	0.22	0.22	0.23	0.24	0.25	0.26	0.28
Guizhou	0.23	0.23	0.23	0.26	0.25	0.26	0.27	0.29
Yunnan	0.25	0.26	0.26	0.27	0.27	0.28	0.29	0.30
Shaanxi	0.25	0.28	0.27	0.27	0.27	0.26	0.27	0.29
Gansu	0.21	0.20	0.20	0.20	0.21	0.22	0.22	0.23
Qinghai	0.16	0.18	0.19	0.21	0.19	0.18	0.21	0.20
Ningxia	0.25	0.25	0.27	0.28	0.28	0.31	0.30	0.30
Xinjiang	0.31	0.29	0.23	0.24	0.29	0.24	0.25	0.27

3. Spatial Autocorrelation Test of China's Green Economy Development Level

3.1 Spatial Weights Matrix

Considering that the connection between provinces and cities is an adjacent relationship, Queen adjacency is used to indicate the adjacent relationship between provinces and cities. Among them, Hainan Province is modified to be connected with Guangdong Province and Guangxi Province.

Queen adjacency space weight matrix is defined as follows:

$$W_{ij} = \begin{cases} 0, & \text{Province } i \text{ is not adjacent to province } j. \\ 1, & \text{Province } i \text{ is adjacent to province } j. \end{cases} \quad (1)$$

Note: when $i=j$, the weight is defined as 0.

3.2 Global Spatial Autocorrelation

Spatial autocorrelation can analyze the spatial correlation characteristics of a certain attribute, which is a measure of agglomeration degree in spatial domain. Studies have shown that economic geography has obvious polarization and diffusion effects, and the ecological environment has obvious characteristics of regional differentiation. In this paper, the Moran's I index is used to measure the spatial correlation degree of the development level of green economy in China's provinces. The calculation formula is as follows:

$$Moran's I = \frac{\sum_{i=1}^n \sum_{j=1}^n W_{ij} (x_i - \bar{x})(x_j - \bar{x})}{S^2 \sum_{i=1}^n \sum_{j=1}^n W_{ij}} \quad (2)$$

n is the number of counted provinces, W_{ij} is the Spatial Weights Matrix, $\bar{x}$ is the average value of green economy development in 30 provinces. Moran's I index is between $[-1,1]$. And the index above 0, which indicates that the development level of green economy has overall spatial positive correlation in space, and that the regions with higher development level of green economy in various provinces in China are clustered in space, and vice versa.

The green economic development scores of various provinces in China are imported into Geoda software to calculate the Global Moran's I index (Table 4), and a trend chart of Moran's I index from 2005 to 2020 is drawn (Figure 3). As can be seen from Table 4, the Moran's I index from 2005 to 2020 was far greater than 0, and all of them passed the significance level test of 5%. This shows that there is a significant global spatial positive correlation between the development levels of green economy, that is, the development levels of green economy in various provinces in China are clustered.

At the same time, from the time dimension analysis, the Moran's I index showed volatility from 2005 to 2020, but in recent years the Moran's I index was higher and showed an upward trend, showing a strong spatial correlation. This indicates that the development level of regional green economy has been greatly affected by the surrounding areas, so we can further try to build a spatial econometric model and explore its internal influence mechanism.

Table 4. Global Moran's I Index of Green Economy Development Level of China's Provinces from 2005 to 2020

Periods	Moran's I	z-value	p-value
2005	0.498	4.507	0.001
2006	0.279	2.851	0.006
2007	0.399	3.565	0.002
2008	0.357	3.334	0.002
2009	0.408	3.865	0.001
2010	0.498	4.507	0.001
2011	0.413	4.005	0.001
2012	0.459	4.221	0.001
2013	0.171	2.028	0.026
2014	0.230	2.823	0.006
2015	0.356	3.464	0.002
2016	0.277	3.102	0.007
2017	0.323	3.211	0.007
2018	0.468	4.379	0.001
2019	0.461	4.333	0.001
2020	0.502	4.633	0.001

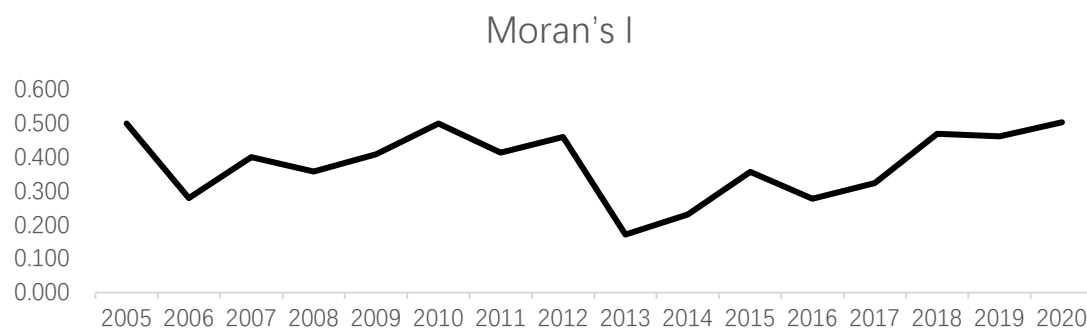


Figure 3. Global Moran's I Index Trend of Green Economy Development Level of China's Provinces from 2005 to 2020

3.3 Local Spatial Autocorrelation

The global spatial autocorrelation measures the spatial correlation characteristics of the whole research area, but it cannot clearly show the local spatial situation. Therefore, the local spatial autocorrelation is used to reveal the correlation features of the local space. Its essence is to decompose the global Moran's I index into each province, for spatial test individual I is:

$$I_i = \frac{Y_i - \bar{Y}}{S^2} \sum_{j=1}^n W_{ij} (Y_j - \bar{Y}) \quad (3)$$

Moran scatter plot can intuitively reflect the local spatial correlation characteristics of the development level of green economy in China's provinces. It is divided into four quadrants, each corresponding to a different type of spatial aggregation. The specific explanation is shown in Table 5.

Table 5. Interpretation of Each Quadrant of Moran Scatter Diagram

Quadrant	Aggregation type	Meaning
Frst quadrant	H-H	High scores are adjacent to areas with high scores.
Second quadrant	H-L	The scores of observation objects are high, while the scores of surrounding areas are low.
Third quadrant	L-H	The scores of observation objects are low, while the scores of surrounding areas are high.
Fourth quadrant	L-L	Low scores are adjacent to areas with low scores.

In order to more intuitively reflect the relationship between the neighboring provinces of the green economy development level, this study has drawn the Moran scatter diagram of the green economy development level. Due to the space limitation, only 2005, 2010, 2015 and 2020 are shown. Looking at the four graphs (a)(b)(c)(d) in Fig. 4, most of the counted provinces are clustered in the first and third quadrants, which indicates that there is a strong spatial positive correlation in most regions, and also indicates that the distribution of the development level of green economy shows significant spatial heterogeneity. Once again, it is proved that the spatial effect model used to study the impact of green economic development level is more in line with objective facts..

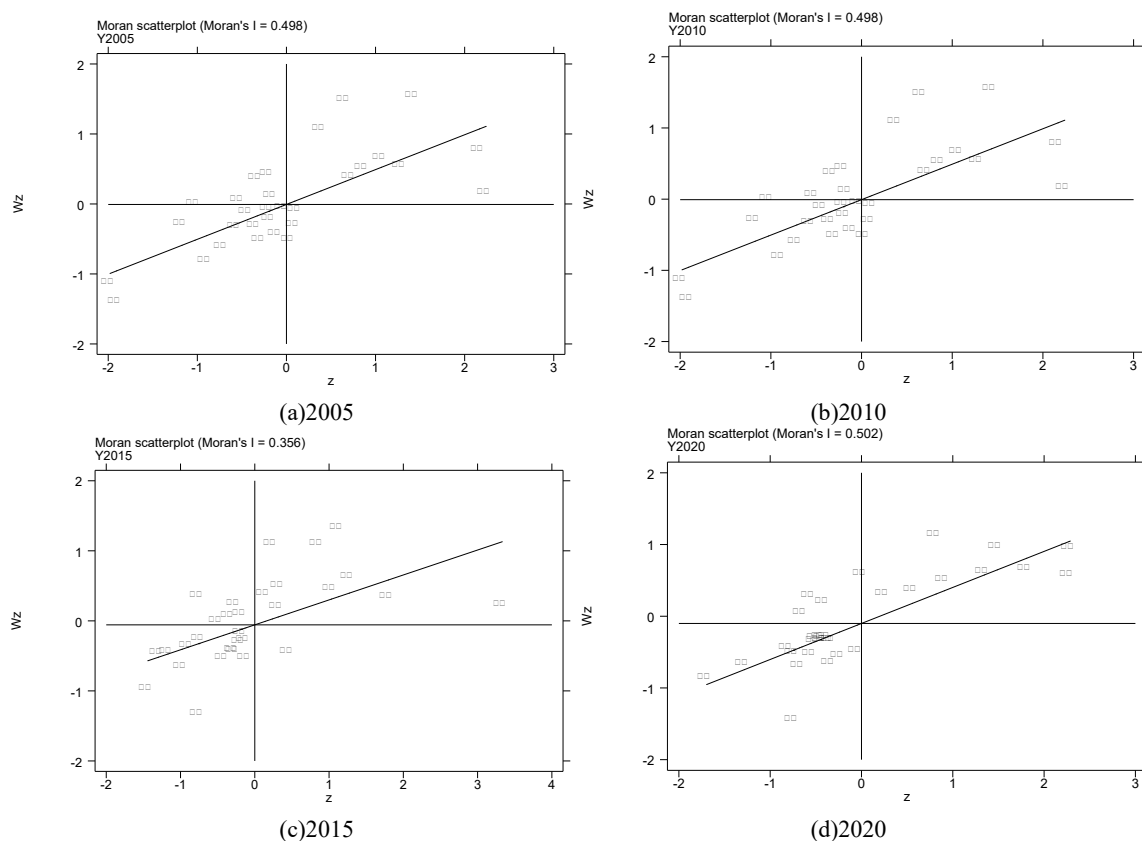


Figure 4. Moran Scatter Diagram of Green Economy Development Level in 2005,2010,2015 and 2020.

4. Analysis on Influencing Factors and Spatial Spillover Effect of China's Green Economic Development Level

4.1 Data Sources and Variable Selection

The data are from China Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook, China High-tech Industrial Statistical Yearbook, Provincial

Statistical Yearbook and RESSET database. Some missing data in the yearbook are filled by linear interpolation.

Table 6. Potential explanatory variables affecting the development level of green economy

Index	Explanatory variable
Economic development	Research and experimental development (R&D) Intensity of funding (x_1)
	Contribution rate of high-tech industry (x_2)
	The number of regional patents per 10, 000 people (x_3)
	Private economic development level (x_4)
	Consumption level of residents (x_5)
	Degree of opening to the outside world (x_6)
Social capita	Marriage and divorce rates (x_7)
	Number of labor dispute cases accepted in the current period (x_8)
Governance efficiency	Water-saving irrigation scale (x_9)
	Total energy consumption per unit of gross industrial output (x_{10})
	Water consumption per unit of gross industrial output value (x_{11})
	Coverage Rate of Urban Population with Access to Gas(%) (x_{12})
	Daily Treatment Capacity of City Sewage (x_{13})
	Per Capita Area of Paved Roads (x_{14})
	City garbage harmless disposal rate (x_{15})
	Urbanization level (x_{16})

Table 7. Screening of Multivariate Stepwise Regression Variables

Variables within the model (Adj $R^2=0.646$)	t	P> t	VIF
Research and experimental development (R&D) Intensity of funding (x_1)	11.883	0.000	3.373
Degree of opening to the outside world (x_6)	5.540	0.000	6.046
Daily Treatment Capacity of City Sewage (x_{13})	-2.366	0.018	1.985
Marriage and divorce rates (x_7)	6.666	0.000	1.629
Contribution rate of high-tech industry (x_2)	-2.548	0.011	2.496
The number of regional patents per 10, 000 people (x_3)	-5.231	0.000	3.984
Total energyconsumption per unit of gross industrial output (x_{10})	2.621	0.009	2.200
Urbanization level (x_{16})	4.538	0.000	6.985
Water consumption per unit of gross industrial output value (x_{11})	3.186	0.002	1.700
Private economic development level (x_4)	1.879	0.061	3.258

Due to the limitation of data, this study initially selects 16 explanatory variables from the perspectives of economic development, social capital and governance efficiency (Table 6): R&D expenditure intensity (x_1), which is expressed by the proportion of R&D expenditure to GDP in each province; The contribution rate of high-tech industry (x_2) which is expressed as the number of patents granted per 10,000 people, with reference to Li Z et al.; Private economic development level (x_4) is represented by the ratio of the total number of employees in individual and private enterprises to the resident population at the end of the year, referring to Huang H et al.; The degree of opening to the outside world (x_6), expressed as the proportion of foreign imports and exports of each province to the total population; Marriage and divorce rate (x_7), learning from the research of Wan et al., the ratio of log of marriage registration to log of divorce registration is adopted; Total energy consumption per unit of gross industrial output value (x_{10}), expressed as the ratio of total energy consumption (10,000 tons of standard coal) to gross industrial output value; Water consumption per unit of gross industrial output value (x_{11}), expressed as the ratio of total water consumption to gross industrial output value;

The urbanization level (x16) is expressed as the ratio of the urban population to the total population; The other explanatory variables are directly from each database. In order to eliminate the influence of dimension, standardized data is used in regression analysis.

In order to avoid the influence of multicollinearity of various influencing factors on the results, the stepwise regression method in SPSS 26.0 software was used to select the independent variables with weak significance. As shown in Table 7, P-values of explanatory variables selected by SPSS calculation are all less than 0.05, and VIF are all less than 7.0.

4.2 Data Sources and Variable Selection

4.2.1. Space Suitability Test

The traditional panel regression results are tested by LM and Robust LM to determine whether to conduct spatial panel analysis and determine the optimal Spatial econometric model. It can be seen from Table 8 that Moran's I passed the 5% significance test, indicating that it is suitable for spatial panel model analysis; The LM (lag) value is 36.809 and significant at the level of 1%, and the LM(error) value is 66.925 and significant at the level of 1%. It shows that the spatial durbin model (SDM) is superior to the spatial error model (SEM) and the spatial lag model (SAR), and is more suitable for the analysis in this research; The LR test results and Ward test results both rejected the original hypothesis at the significance level of 1%, indicating that SDM model cannot be degenerated into SEM and SAR model. The p-value result of Hausman test rejects the original hypothesis of random effect at the significance level of 1%. Therefore, this study chooses the fixed-effect spatial dobbin model for analysis.

Table 8. LM Test Results

Inspection type	Statistic	p-value
Moran's I (error)	1.763	0.078
Lagrange Multiplier (error)	43.436	0.000
Robust LM (error)	17.326	0.000
Lagrange Multiplier (lag)	28.461	0.000
Robust LM (lag)	2.324	0.127
LR_spatial_lag	23.19	0.0101
LR_spatial_error	25.72	0.0041
Wald_spatial_lag	38.74	0.000
Wald_spatial_error	38.60	0.000
Hausman	85.27	0.000

4.2.2. SDM Model Analysis of Fixed Effects

By analyzing the three SDM models with fixed space, fixed time and fixed time and space, the SDM model with the best fixed effect is determined. The results are shown in Table 9.

Compared with the three fixed-effect models, the R² value of SDM model with time-fixed effect is the largest (0.6187), which is significantly larger than the other two models, indicating that this model has the best fitting degree. In addition, the coefficients of most variables in the time-fixed effect test results have passed the significance test. Based on the results of the model, the spatial Dubin model with fixed time effect is the most suitable model for the study of the spatial effect of the national green economy development level.

By analyzing the regression results in Table 10, it can be seen that scientific and technological progress can significantly improve the development level of green economy in the region. From specific indicators, the level of green economic development will increase by 0.145% for every 1% increase in R&D expenditure. The development level of green economy will increase by 0.096% for every 1% increase in the number of patents granted. The scientific and technological progress can not only provide more advanced technical support for the treatment of pollutants, but also realize energy conservation and emission reduction at the source of pollution and promote the high-quality development of regional green economy. However, for every 1% increase in the contribution rate of high-tech industries, the level of the green economic development will drop by 0.089%. This indicates

that the high profit brought by the development of high-tech industry at the present stage has not promote the improvement of the green economy level. The reason may be that environmental governance requires a lot of investment, and the benefits obtained are hard to measure. Although the huge profits of high-tech industry have promoted the progress of the local economy, they have not effectively improved the local environmental quality, indicating that higher development requirements for green sustainability should be put forward for the high-tech industry. The level of opening to the outside world has significantly improved the level of the green economy development. From a nationwide perspective, the improvement in the level of opening to the outside world has promoted regional trade, thus promoting the rapid development of local economy. Social capital can significantly promote the development of green economy. Energy consumption plays an important role in restraining the development of the green economy in this region. Environmental improvement and urbanization level have no significant impact on the development level of green economy.

Table 9. Fixed Effect Estimation of SDM Model

variable	Fixed space		Fixed time		Space-time fixed	
Main	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
X ₁	0.145*	0.075	0.196***	0.048	0.122*	0.07
X ₂	-0.115***	0.035	-0.089**	0.04	-0.122***	0.032
X ₃	0.096**	0.042	0.195***	0.05	0.082**	0.039
X ₄	0.059*	0.036	0.090*	0.046	0.05	0.032
X ₆	-0.074	0.06	0.415***	0.06	-0.092	0.057
X ₇	-0.108***	0.034	0.235***	0.039	-0.117***	0.034
X ₁₀	0.019	0.035	-0.111***	0.04	0.034	0.031
X ₁₁	-0.068*	0.038	-0.108***	0.035	-0.106***	0.039
X ₁₃	0.048	0.044	0.067	0.044	-0.037	0.042
X ₁₆	-0.101	0.11	0.073	0.065	-0.457***	0.122
W x						
X ₁	0.093	0.149	-0.108	0.096	0.045	0.161
X ₂	0.062	0.072	0.314***	0.08	-0.087	0.074
X ₃	-0.034	0.075	-0.169	0.113	0.051	0.086
X ₄	0.144*	0.082	0.217**	0.105	0.118	0.086
X ₆	0.288***	0.109	-0.125	0.148	0.121	0.13
X ₇	-0.116*	0.064	-0.082	0.089	-0.064	0.069
X ₁₀	-0.215***	0.072	-0.111	0.09	-0.118*	0.065
X ₁₁	0.238***	0.079	-0.273***	0.073	0.072	0.087
X ₁₃	0.003	0.07	0.098	0.096	-0.351***	0.097
X ₁₆	0.042	0.177	0.022	0.154	-0.663***	0.254
Sigma ²	0.090***	0.006	0.238***	0.015	0.070***	0.005
R ²		0.229		0.6187		0.3538
Log-likelihood		-107.121		-336.4909		-43.709

Note: the upper corner marks * * *, * *, and * are significant at 1%, 5%, and 10%, respectively, the same below

From the perspective of the spatial lag effect of each variable, the spatial lag effect of R&D funding intensity, the number of patents granted, the degree of opening to the outside world, the marriage and divorce rate, and the energy consumption are negative, while the spatial lag effect of urban sewage daily treatment capacity and urbanization level are positive, but not significant, indicating that changes in the above variables in other regions will not have a substantial impact on the development level of green economy in this region. The spatial lag effect of the contribution rate of high-tech industries is significantly positive. The reason may be that the huge profits brought by the high-tech industries in the surrounding areas have driven the economic development of the surrounding areas. The spatial spillover effect of water consumption is significantly negative, which indicates that water consumption in other regions significantly inhibits the development of green economy in this region. The reason is that the conditions of water resources in adjacent areas often influence each other, and improper utilization of water resources in adjacent areas will affect the utilization of water resources in this area, thereby inhibiting the development of the green economy in this area.

4.2.3 Effect Decomposition of Spatial Dubin Model

As the spatial lag coefficient of some factors affecting the development level of green economy is not significant, the regression coefficient calculated above cannot directly reflect its spatial effect. This study further analyzed its direct, indirect and overall benefits. Among them, the direct effect indicates the influence of this influencing factor on the development level of green economy in the region, the indirect effect indicates the influence of this factor on the surrounding regions, and the total effect indicates the overall influence of this factor on the development level of green economy.

Table 10. Decomposition of Spatial Effects of SDM Model with Time-fixed Effects

variable	direct effect		indirect effect		total effect	
	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
x1	0.199***	0.049	-0.118	0.089	0.081	0.107
x2	-0.093**	0.039	0.315***	0.082	0.222**	0.097
x3	0.200***	0.049	-0.177*	0.107	0.023	0.112
x4	0.085*	0.044	0.215**	0.108	0.300***	0.105
x6	0.417***	0.057	-0.145	0.139	0.272*	0.158
x7	0.238***	0.037	-0.083	0.091	0.156	0.115
x10	-0.111***	0.041	-0.095	0.085	-0.206**	0.102
x11	-0.104***	0.035	-0.261***	0.069	-0.364***	0.077
x13	0.065*	0.039	0.088	0.088	0.153	0.115
x16	0.071	0.069	0.020	0.148	0.091	0.176

From the perspective of economic development, the total effect of contribution rate of high-tech industry, private economic development level and degree of opening to the outside world is significantly positive, indicating that the above three influencing factors promote the development of China's green economy macroscopically. Among them, the direct effect of each influencing factor is significant, the direct effect of contribution rate of high-tech industry is significantly negative, and the other four variables are significantly positive; This shows that technological progress, opening up to the outside world and the development of private economy can promote the development of green economy in the region, while the high profit brought by the development of high-tech industry does not promote the development of green economy in the region. The indirect effects of Contributing Rate of High-Tech Industry and Private Economic Development Level are significantly positive, while the indirect effects of The Number of Regional Patents Per 10,000 People are significantly negative; The reason may be that the industrial development in the region has driven the rapid economic development in the surrounding areas, while the index of patent license number indicates that large cities attract a large number of high-quality talents, resulting in the shortage of talents in the surrounding areas, thus inhibiting the development of green economy in the surrounding areas.

From the perspective of social capital, the direct effect of Marriage and divorce rates is positive and significant at 1%, while the indirect effect and total effect are not significant. From the perspective of governance efficiency, the total effect of water resources consumption and total energy consumption per unit of gross industrial output value is significantly negative, indicating that these three factors generally inhibit the development of green economy in China; The direct effect of resource consumption is significantly negative, while the direct effect of sewage treatment capacity is significantly positive, indicating that the inefficient use of resources inhibits the development of green economy in the region, and environmental management can promote its development; The indirect effect of the indicator of water resources consumption per unit of gross industrial output value is significantly negative. The reason is that the available water resources in the surrounding areas are often located in the same river basin, and the improper use of water resources in this area will seriously affect the surrounding areas.

5. Conclusions and Suggestions

5.1 Conclusions

Based on the panel data of 30 provinces in China from 2005 to 2020, this paper measures the development level of green economy in each province and city, and analyzes its spatial spillover effect by using spatial dobbin model, and draws the following main conclusions:

1). From 2005 to 2020, the development level of green economy in 30 provinces in China has a steady trend of improvement, with Xinjiang, Hainan, Tianjin and other places increasing more, Yunnan, Guangxi, Shaanxi and other places increasing less. In recent years, the top-ranked provinces are Beijing, Guangdong, Hainan, Shanghai, Tianjin, Zhejiang and other places.

2). The green economy development level of 30 provinces in China has a significant global spatial positive correlation. The development level of green economy in each province is clustered, mainly distributed in low-low clustering areas. This shows that the development level of the green economy is not only influenced by local economic development, social capital and governance efficiency, but also by related factors in the surrounding areas.

3). By constructing spatial dobbin model to decompose its spatial spillover effect, we can see that scientific and technological progress, private economy and the degree of opening to the outside world are the key factors to promote the high-quality development of China's green economy, while the extensive utilization of resources hinders the development of regional green economy. The direct effect of openness is the highest, followed by social capital and patent license. The profit of high-tech industry has positive spatial spillover effect with the development level of private economy. Under the close interaction of population, information, capital and materials, it can form the synergistic coupling effect of regional green economy development can be formed. Patent licensing and water resources consumption have negative spatial spillover effect. The spatial spillover effect of other factors is not significant.

5.2 Suggestion

At present, there is still much room for improvement in the development level of China's green economy. In terms of time, the overall development level has a tendency to improve steadily. From the perspective of space, the imbalance of green economy development is even more serious. The environmental planning formulated and implemented by the government needs to scientifically deal with the relationship between economic development and environmental protection scientifically. The following aspects should be paid attention to when formulating and implementing regulatory policies.

1). Strengthen the coordinated transformation and development of the regional economy, formulate ecological regulation policies considering financial development, and create a good living environment. The empirical results show that scientific and technological progress, opening to the outside world and the development of private economy all play a positive role in promoting the development of green economy, while the spatial spillover effect is obvious. This shows that a good green ecological environment and a better life for the people complement each other. All regions should promote the coordinated development of regional green economy from the perspective of new development, take the development of green economy as the guide, and promote the cooperation of enterprises and technical exchange between neighboring regions, so as to achieve a "win-win" situation between ecological environment protection and economic growth.

2). Emphasis on "green production", energy conservation and emission reduction, and adjustment of industrial structure. According to the empirical results, energy utilization efficiency and environmental governance capacity significantly affect the development level of regional green economy. Therefore, we should promote the effective utilization of resources, establish our own standards in the industry, build a low-pollution and low-consumption industrial development model, and form a circular economy model of the whole industrial chain.

3). Pay attention to the relationship between scientific and technological progress and environmental protection, so that technological progress can truly serve the development of green economy. According to the empirical results, the three indicators related to scientific and technological progress have significant direct and indirect effects on the development of regional green economy, which indicates that scientific and technological innovation is an important indicator for the development of green economy in this region and its surrounding areas. Among them, the total effect of contribution rate of high-tech industry is positive and significant, but the direct effect is negative and significant, which indicates that the related industries should be strictly supervised and the green sustainable development with high requirements should be put forward. Scientific and technological innovation plays a fundamental and strategic supporting role in the development of the green economy. Therefore, the government should pay attention to the investment of scientific research funds, but at the same time, it should standardize the ecological civilization of scientific research development, encourage the integration of the two, and build an ecological environment scientific and technological innovation system.

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