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Research on Ecological Efficiency of Industrial Structure

Jialong Wen[1]*, Weida He[1, 2], and Manyin Zhang[1]

[1]Donlinks School of Economics and Management, University of Science and Technology Beijing, No. 30, Xueyuan Road, Haidian District, Beijing 100 083, China

[2]National Academy of Economic Security, Beijing Jiaotong University

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This paper uses industrial structure as a critical reference frame for evaluating ecological efficiency. It calculates the industrial structures and ecological efficiency value of 29 municipalities, autonomous regions, and provinces of China for the period between 2005 and 2017. Analysis of the regional characteristics and development trends of ecological efficiency of China's industrial structure are conducted. The results show that the industrial structural ecological efficiency of China exhibits the phenomenon of spatial agglomeration, and gradient decrease, and gradually increasing gaps between the provinces.

Keywords: Spatial Agglomeration, Gradient Decrease, Spatial agglomeration, Gradient decrease

Introduction

The ecological efficiency is a critical part of the green development concept. Improving regional ecological efficiency is an important part of accelerating the improvement of the ecological environment, building a 'resource-saving and environment-friendly' society, and promoting high-quality development in China. Ecological efficiency mainly reflects the efficiency and quality of a region from the perspective of energy conservation, emission reduction, and pollutant treatment. In the recent years, many experts have also discussed ecological efficiency from different perspectives.[1–3] The influencing factors and solutions in different fields are analyzed.[4,5] To effectively promote the realisation of the new economic growth model, the vigorous development of the green economy with industry as the support point is necessary.[6,7]

Methodology

Evaluation model

This article combines concepts such as industrial structure, green development concepts, and ecological efficiency and calculate the ecological efficiency of industrial structure through the method of Resources and Environmental Performance Index[8] and Factorization. We add the industrial structure variable to the traditional concept of ecological efficiency, and decomposing the ecological efficiency of the industrial structure into two parts: energy efficiency of the industrial structure and environmental efficiency of the industrial structure. By comprehensively adjusting the industrial structure, consumption structure, resource utilisation, and pollutant discharge of the industrial sector, the ecological efficiency in a certain area and within a certain time range is calculated, and the trend and environmental quality of the ecological efficiency in the area are analysed.

$$EEIS = [EEIS_{en} \times EEIS_{ev}]^{(1/2)} \quad \ldots (1)$$

EEIS represents industrial structure ecological efficiency, $EEIS_{en}$ represents the energy efficiency of the industrial structure, and $EEIS_{ev}$ represents the environmental efficiency of the industrial structure.

$$EEIS_{en} = \sum_{\gamma=1}^{m} \frac{S_\gamma}{S_t} \times \frac{S_\gamma}{C_\gamma} \quad \ldots (2)$$

$\gamma=1,2,3$ represents the industrial sector divided by three industrial standards, m represents the number of industrial sectors, S represents the output value, C represents the energy consumption, C_γ represents the energy consumption of each industry, S_γ represents the output value of each industry, and S_t represents the total output value.

*Author for Correspondence
E-mail: wjl19920530@163.com

$$EEIS_{ev} = [\prod B_\theta]^{1/3} \quad \ldots (3)$$

θ=*WW*, *EG*, and *SW*, respectively, represent wastewater emissions, waste gas emissions, and national waste emissions, and *B* represents the environmental efficiency of each emission.

$$B_\theta = \sum_{\varphi=1}^{n} \frac{S_\varphi}{S_t} \times \frac{S_\varphi}{P_{\theta,\varphi}} \quad \ldots (4)$$

φ= *1, 2* represents the industrial sector divided by the industrial and non-industrial sectors, *n* represents the number of sectors, and *P* represents the amount of pollutant emissions. Exhaust gas emissions are divided into sulphur dioxide and dust, which must be calculated separately. Because solid waste has no data from the non-industrial sector, only the environmental efficiency of solid waste in the industrial sector is calculated. This paper assumes that *m*, *n* represents the division of industrial categories and that the value can be subdivided into different types according to the research object and research type.

Evaluation Indicators and Data Description

The economic output value is expressed by the output value of each industry and the GDP. Energy consumption is expressed by the energy consumption of each province. Pollutant emissions are expressed in terms of wastewater emissions, SO_2 emissions, soot emissions, and industrial solid waste emissions by province. The aforementioned data are from the website of the National Bureau of Statistics, the China Statistical Yearbook, and the statistical yearbooks of the provinces. The data in Ningxia Hui and Tibet are incomplete and thus eliminated.

Results and Discussion

We conducted calculations, and the results of the ecological efficiency of the industrial structure in each of the provinces over the years are listed in Table 1.

Table 1 — Evaluation value of the ecological efficiency of the industrial structure by province, 2005–2017

Region/Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Beijing	2.54	2.83	3.34	3.69	3.87	4.42	5.06	5.46	6.21	6.50	7.13	8.67	10.27
Tianjin	2.14	2.38	2.76	3.33	3.46	4.22	5.72	5.60	6.77	6.77	7.26	8.16	8.64
Hebei	1.21	1.36	1.53	1.64	1.74	1.81	2.22	2.15	2.39	2.23	2.21	2.47	2.93
Shanxi	0.81	0.86	1.03	1.12	1.04	1.24	1.41	1.47	1.54	1.48	1.52	1.76	1.95
Neimenggu	0.86	0.94	1.11	1.33	1.33	1.33	1.52	1.64	1.94	1.87	1.85	2.21	2.06
Liaoning	1.51	1.37	1.53	1.76	1.89	2.12	2.42	2.68	3.02	2.89	2.89	2.63	2.64
Jilin	1.26	1.36	1.56	1.75	2.22	2.47	2.91	3.25	3.48	3.36	3.35	4.18	3.90
Heilongjiang	1.64	1.56	1.80	2.18	2.00	2.50	2.13	2.12	2.21	2.33	2.14	2.23	2.29
Shanghai	2.36	2.24	2.42	2.57	3.36	3.72	4.99	5.24	6.07	7.10	7.63	9.25	9.45
Jiangsu	2.77	3.00	3.48	3.98	4.24	4.75	6.18	6.34	6.83	7.31	7.69	8.24	8.16
Zhejiang	5.00	3.26	3.73	4.06	4.31	4.85	6.00	6.36	6.74	7.18	7.59	8.04	9.63
Anhui	2.30	2.05	2.28	2.49	2.59	2.91	3.42	3.09	3.37	3.59	3.68	4.34	4.78
Fujian	2.45	2.17	2.53	2.73	2.87	3.37	4.24	4.25	5.02	5.87	6.17	6.84	7.14
Jiangxi	1.47	1.61	1.83	2.15	2.26	2.58	3.42	3.88	4.20	4.39	4.58	4.84	5.34
Shandong	1.90	2.04	2.32	2.66	2.78	3.09	3.22	3.57	3.69	4.61	4.70	4.61	4.95
Henan	1.80	1.87	2.11	2.36	2.42	2.56	2.79	2.93	3.33	3.24	3.27	4.30	5.21
Hubei	1.41	1.56	1.79	2.02	2.12	2.36	2.88	3.01	3.22	3.72	3.98	4.48	5.02
Hunan	1.41	1.56	1.76	1.98	2.12	2.31	3.08	3.18	3.44	3.94	4.11	4.85	5.55
Guangdong	3.66	4.06	4.06	4.12	4.16	4.34	6.11	6.24	6.72	7.37	8.10	11.36	9.83
Guangxi	1.89	2.07	2.25	2.67	2.68	2.70	3.60	3.66	3.92	3.97	4.27	4.27	4.60
Hainan	3.35	3.35	3.63	3.89	3.73	4.22	4.81	5.00	6.19	6.23	6.62	6.00	5.85
Chongqing	1.34	1.39	1.50	1.66	1.80	2.04	3.37	3.37	3.97	5.14	5.46	6.04	6.98
Sichuan	1.44	1.55	1.83	2.03	2.21	2.45	3.47	3.87	4.18	4.35	4.33	4.53	4.57
Guizhou	0.58	0.69	0.84	0.97	0.92	1.09	1.46	1.72	1.87	2.14	2.37	2.53	2.69
Yunnan	1.22	1.25	1.42	1.69	1.77	1.99	2.18	2.52	2.74	2.97	2.81	2.77	3.24
Shaanxi	1.16	1.34	1.58	1.96	2.09	2.25	2.54	2.78	3.02	3.07	3.06	3.69	3.94
Gansu	1.08	1.12	1.26	1.39	1.42	1.58	1.68	1.84	2.07	1.97	2.04	2.32	2.37
Qinghai	1.08	1.13	1.27	1.40	1.37	1.54	1.22	1.31	1.48	1.42	1.35	1.36	1.47
Xinjiang	1.02	1.08	1.17	1.27	1.25	1.48	1.56	1.55	1.65	1.69	1.68	1.70	1.89

We observe the following:

(1) From a national perspective: From 2005 to 2017, the ecological efficiency of China's industrial structure showed a decentralised upward trend. Among the cities, Beijing, Shanghai and Tianjin have the most obvious changes. Heilongjiang, Qinghai, and Shanxi posted the smallest gains. Some provinces, such as Heilongjiang, Guangdong, and Shandong, show a trend of rising volatility. We observe that the national ecological environment of resources has gradually improved with the development of society and the passage of time.

(2) From a regional perspective, in Table 1, the ecological efficiency of China's industrial structure is characterised by a gradual decrease from east to west and spatial concentration of neighbouring provinces. Among the provinces, those with high industrial structure and ecological efficiency are mostly concentrated in the eastern coast. Most of the provinces with low ecological efficiency in the industrial structure are concentrated in the northwest. Therefore, it can be found that the ecological efficiency of China's industrial structure has a decreasing gradient from east to west, and the neighbouring provinces have similar ecological efficiency values and have obvious spatial clustering characteristics.

(3) From an interprovincial perspective: the ecological efficiency of the industrial structure among the provinces has shown a trend of decentralised growth, which also shows that the gap in ecological efficiency between provinces is constantly expanding. In 2005, the provinces with the largest gaps were Zhejiang and Guizhou, with a difference of 4.42, by 2010, with a difference of 3.76 in evaluation values. By 2017, the provinces with the largest gaps were Beijing and Qinghai, with a difference of 8.79 in their evaluation values. Thus, there is a significant difference in the growth rate of industrial structure productivity between different provinces.

Conclusions

(1) From 2005 to 2017, the ecological efficiency of China's industrial structure steadily increased, fluctuations in individual provinces increased, and differences between provinces gradually expanded. The rate of change of the ecological efficiency values in the eastern coastal regions is also faster than western regions.

(2) At the regional level, the ecological efficiency of China's industrial structure has obvious spatial agglomeration characteristics and decreasing gradient characteristics. The spatial agglomeration feature refers to the similarity of the ecological efficiency of the industrial structure of neighbouring provinces or provinces within the same economic region. The characteristic of decreasing gradient refers to the distribution pattern of the ecological efficiency of China's industrial structure with a decreasing gradient from southeast to northwest, with the highest in the east and southeast, the second in the middle, and the worst in the west and northeast.

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