Research on Industrial Green Transformation Efficiency of Prefecture-Level Cities in Hebei Province

Rongyan Jia[1], Shuo Yang[2*]

{he_jry@163.com[1], 351350969@qq.com[2*]}

School of Economics and Management, Hebei University of Science and Technology, Shijiazhuang, China

Abstract. During the development period of the 14th Five-Year Plan, Hebei Province put forward the goal of focusing on adjusting and optimizing the industrial structure and establishing a sound economic system of green, low-carbon and circular development. Based on the panel data of prefecture-level cities in Hebei Province from 2016 to 2020, this paper uses SBM model and Malmquist-Luenberger index, combined with the input-output data of prefecture-level cities in Hebei Province, establishes evaluation indicators, and analyzes the industrial development efficiency of prefecture-level cities in Hebei Province from both static and dynamic perspectives. The main conclusions are as follows: In recent years, the overall industrial transformation efficiency of Hebei Province presents a positive trend, and both technical level and technical efficiency are important factors affecting industrial green transformation efficiency. According to the analysis, the following suggestions are made: the government should strengthen the organization guarantee; Promote technological progress and efficiency improvement; To the best, optimize the industrial layout.

Keywords: Efficiency of industrial green transformation; Circular development； DEA-SBM；Malmquist-Luenberger

1 Introduction

China has made major breakthroughs and remarkable results in the two aspects of building Chinese socialism and developing economic society, and has shifted from the characteristics of high-speed development to the characteristics of high-quality development. In the process of building a new development pattern, the concept of industrial green development is a profound reflection of China's economic development law, and has a profound practical significance. In the new era of the 14th Five-Year Plan, the high-end green transformation of China's manufacturing industry not only catches up with the wave of strategic decision-making, but also undertakes the important historical mission and task of promoting China's economic and social development and reform.

Hebei Province is the cradle of China's modern industry. Since New China, seven industries have become relatively complete in Hebei Province's industrial system and dominate other industries. However, there are still some problems in the current development of Hebei Province. The rising cost of production factors needs to be solved urgently. Various industries pay more and more attention to the impact on the environment and the protection of resources in the

ICEMME 2023, November 17-19, Beijing, People's Republic of China

DOI 10.4108/eai.17-11-2023.2342747

development process. The study of industrial green transformation of prefecture-level cities in Hebei Province is of great significance for promoting the coordinated development of Beijing, Tianjin and Hebei Province and building the blueprint of a beautiful Hebei province, and can also provide effective experience for other regions in the country.

2 Model establishment and index selection

2.1 Establishment and selection of evaluation model

DEA is the English abbreviation of data enveloping analysis method, a new efficiency evaluation method proposed in the 1970s, which was proposed by the famous operations research scientist A. harnes. This method is used to measure the relative efficiency of DMU, and it is widely used for multiple input and output variables. Using DEA model to measure efficiency can clearly represent the combination of input and output, and can evaluate the relative effectiveness of decision making units. It is a trustworthy model and can effectively avoid the influence of subjective judgment.

Tone constructed a new DEA model, namely the SBM model, in the literature published in 2001. In the evaluation and analysis of the decision-making unit, it will involve the orientation problem and radial and non-radial problems[1]. The so-called orientation refers to the analysis from the perspective of input or output. The so-called radial refers to the assumption that the input or output changes in the same proportion when using DEA analysis to evaluate efficiency[2]. The SBM model is a non-radial non-oriented DEA model. In classical DEA models, such as CCR or BBC models, it is the input-oriented radial DEA model. If there is excessive input or insufficient output, that is, there is non-zero Slack of input or output, the obtained efficiency value will be higher than the DMU efficiency value path; However, for this model, changes in two aspects must be ignored, so the results calculated by this model may not conform to the objective reality[3]. Therefore, in order to overcome the above problems, Tone (2001) created a Slacks-Based Measure of efficiency, namely the SBM model.

As mentioned earlier. The SBM model proposed by Tone(2001) is based on the DEA model, and the DEA model itself evaluates the relative efficiency measure of DMU, and its efficiency value takes a value in the range of 0 to 1. An efficiency value of 1 is considered as the most efficient, and an efficiency value of less than 1 is considered as no efficiency. It is not difficult to find that this method cannot effectively compare and evaluate DMU with an efficiency value of 1. To solve this problem, Tone(2002) built a super-efficiency SBM model [4].

In addition to the above problems, there are also different definitions of output indicators, such as desired output indicators and undesired output indicators. The earliest DEA model, when evaluating DMU, was based on the fact that the less the input, the more the output, the higher the efficiency value. However, with the deepening of the research problem, some indicators are not suitable for this analysis, such as three waste emissions: Waste water, waste gas, waste residue, these indicators are we do not want to output, in other words, the input must be, the less the output, the better, so we call this kind of output undesirable output. Nowadays, green environmental protection has become the theme of The Times, energy conservation and emission reduction, and green has become a requirement that cannot be ignored. Therefore, the most efficient production mode in today's society must be green production mode, that is, to

produce as much expected output as possible with as little input and produce less undesirable output. The green transformation efficiency studied in this paper can reduce the emission of three wastes and improve production efficiency. Under the condition of certain investment, it can reduce energy consumption and achieve energy conservation and emission reduction.Tone(2003) built a non-expected output SBM model based on Tone(2001)SBM model [5]. Suppose you have a decision unit, and each decision unit contains three elements: input, expected output, and unexpected output, each represented by three vectors. Similar to the superefficient SBM model, the non-expected superefficient SBM model calculates an efficiency value greater than 1.

The Malmquist index is the index used to measure the change in total factor productivity, which is usually suitable to measure the dynamic change of DMU time dimension of multi-input and multi-output indicators. Chung and Fare (1997) derived the M index with undesired output based on the Malmquist index based on the directional distance function of output orientation, and named it Malmquist_Luenberger index.

In this paper, Cheng Gang (2004) is referred to to directly use the efficiency value calculated by the non-expected output SBM and apply the M-index calculation formula to calculate the ML index.

$$\mathrm{ML}_{\mathrm{C}}^{t+1} = \mathrm{MLEC}_{\mathrm{C}} * \mathrm{MLTC}_{\mathrm{C}} \tag{1}$$

$$\mathrm{ML}_{\mathrm{C}}^{t+1}(x^t, y^t, z^t, x^{t+1}, y^{t+1}, z^{t+1}) = \left[\frac{E_C^t(x^{t+1},y^{t+1},z^{t+1})}{E_C^t(x^t,y^t,z^t)} \cdot \frac{E_C^{t+1}(x^{t+1},y^{t+1},z^{t+1})}{E_C^{t+1}(x^t,y^t,z^t)}\right]^{\frac{1}{2}} \tag{2}$$

$$\mathrm{MLEC}_{\mathrm{C}} = \frac{E_C^{t+1}(x^{t+1},y^{t+1},z^{t+1})}{E_C^t(x^t,y^t,z^t)} \tag{3}$$

$$\mathrm{MLTC}_{\mathrm{C}} = \left[\frac{E_C^t(x^{t+1},y^{t+1},z^{t+1})}{E_C^{t+1}(x^{t+1},y^{t+1},z^{t+1})} \cdot \frac{E_C^t(x^t,y^t,z^t)}{E_C^{t+1}(x^t,y^t,z^t)}\right]^{\frac{1}{2}} \tag{4}$$

2.2 Index system construction

Industrial green transformation is a dynamic process that changes the industry from extensive development to green and sustainable development. From the macro perspective, it is a comprehensive process, including a country or region's industry in the structural organization and technology oriented green transformation; From the micro point of view, it is the resource reallocation within an industry[6]. The analysis we conduct is of the first kind.The construction of evaluation index system is one of the most commonly used methods for comprehensive analysis, and the construction of comprehensive evaluation index system should follow the principles of purpose, completeness and independence [7].Total output is jointly determined by technological progress, capital, and labor, and the production function reflects the quantitative relationship between inputs and outputs. For the evaluation system of industrial green transformation, capital and skilled labor are selected as inputs, and output includes desired output and undesired output.

The capital input in this paper is expressed by the investment amount of fixed assets. The process of industrial green transformation is often accompanied by equipment updating, environmental protection transformation and so on. Taking this index as the input index to measure the

efficiency of industrial green transformation in Hebei Province meets the construction requirements of Hebei Province.

In this paper, the full-time equivalent of R&D personnel is used to represent the technical labor force, which refers to the workload of R&D personnel calculated according to the actual time engaged in R&D activities during the reporting period. It is an international index to compare human input in science and technology[8].Considering the availability and representativeness of data, the full-time equivalent of R&D personnel is selected, which reflects the talent input of a region in science and technology, and plays an extremely important role in the output and transformation of scientific and technological achievements. In the process of industrial transformation, the input of science and technology and the input of related talents are conducive to the development of the industry in the direction of green. The selection of this index can well represent the input of Hebei Province in labor force.

Hebei Province is a major manufacturing province, and its industrial system is dominated by the resource and energy processing industry, and efforts to optimize the industrial structure have become an important part of the development strategy of the 14th Five-Year Plan. The selection of the gross product of the secondary industry as the expected industry is in line with the development basis of prefecture-level cities in Hebei for many years, and the analysis of the secondary industry is also an important aspect of the transformation of industrial structure. In addition, the gross product of the tertiary industry is selected, which refers to the sector that provides various services for production and consumption in the process of reproduction. For the entire regional economy, the reasonable development of the tertiary industry has an important indicative role, reflecting whether the economy is sustained and healthy growth, but also reflects the quality of people's living standards.

Energy consumption per ten thousand yuan of GDP is the main index reflecting the level of energy consumption and energy saving and consumption reduction, as well as the index of energy utilization efficiency.Industrial smoke (powder) dust emissions, sulfur dioxide and nitrogen oxide are the main pollutants discharged in the process of industrial development, and reducing pollutant emissions as much as possible is also one of the important tasks of industrial green transformation. Referring to Zhu Chunhong [9] and Yu Qianqian [10] et al., the above three indicators are selected as pollution control indicators.

Based on the above analysis and collation, the evaluation index system of industrial green transformation efficiency is established, as shown in Table 1.

Table 1. Evaluation index system of industrial green transformation efficiency in Hebei Province

Primary index	Secondary index	Measurable index	unit	encoding
input	capital	Investment in fixed assets	Hundred million yuan	input1
	Skilled labor force	R&d personnel full-time equivalent	People per year	input2
output	Expected output	Gross value of secondary industry production	Hundred million yuan	output1

	Gross value of tertiary industry production	Hundred million yuan	output2
	Energy consumption per 10,000 yuan GDP	Tons of standard coal / 10,000 yuan	output3
Undesirable output	Industrial smoke (powder) dust emissions and sulfur dioxide and nitrogen oxide emissions	Tons	output4
			output5
			output6

3 Efficiency measurement and analysis evaluation

3.1 Static efficiency analysis of industrial green development in prefecture-level cities in Hebei province

According to the super efficiency SBM model, matlab software is used to calculate the super efficiency value of industrial development of each city in Hebei Province, **Table 2**, the efficiency value without considering the undesirable output, **Table 3**, the efficiency value considering the undesirable output.

Table 2. Efficiency value and ranking of industrial green transformation in prefecture-level cities of Hebei Province from 2016 to 2020

Region	2016	2017	2018	2019	2020	Average value
Shijiazhuang	0.6680	0.5850	0.6804	0.6804	1.0852	0.7398
Tangshan	1.1043	0.7713	0.7619	0.7619	0.7431	0.8285
Qinhuangdao	1.1625	1.0928	1.1282	1.1282	1.1040	1.1231
Handan	1.0558	1.2345	1.1919	1.1919	1.0241	1.1396
Xingtai	0.7963	0.7007	0.7798	0.7798	0.8945	0.7902
Baoding	1.1521	0.5171	0.5021	0.5021	0.4243	0.6195
Zhangjiakou	0.3010	0.3462	0.3163	0.3163	0.1745	0.2909
Chengde	0.8695	1.0153	1.2438	1.2438	1.1568	1.1058
Cangzhou	1.0627	1.0663	0.8767	0.8767	0.5998	0.8965
Langfang	1.0141	0.6908	0.7568	0.7568	0.8013	0.8040
Hengshui	0.9264	0.7961	0.9113	0.9113	1.1977	0.9485

According to the results in **Table 2**, from the average value of 2016 to 2020, Qinhuangdao, Handan and Chengde have better industrial green transformation efficiency, with the average value reaching DEA effectiveness. In recent years, under the guidance of the development strategy of Hebei Province, the output value of the secondary and tertiary industries in these three cities has increased significantly. In recent years, the efficiency of industrial green transformation in Zhangjiakou is at a low level in the province, and Zhangjiakou still needs to make great efforts to improve the output value. In the case of not considering the undesirable output, Shijiazhuang, as the provincial capital city, is at the lower middle level.

Table 3. Efficiency value and ranking of industrial green transformation in prefecture-level cities of Hebei Province from 2016 to 2020

Region	2016	2017	2018	2019	2020	Average value
Shijiazhuang	1.1169	1.1457	1.1377	1.1356	1.1146	1.1301
Tangshan	1.0336	1.0373	1.0562	1.0589	1.0411	1.0454
Qinhuangdao	1.0489	1.0421	1.0464	1.0421	1.0369	1.0433
Handan	1.0325	1.0750	1.0662	1.0476	1.0157	1.0474
Xingtai	0.5315	0.5706	0.6432	1.0324	1.0159	0.7587
Baoding	1.1357	1.0714	1.1309	1.0232	1.0628	1.0848
Zhangjiakou	0.3556	0.4366	0.4597	1.0139	0.2362	0.5004
Chengde	0.5858	1.0053	1.1150	1.1334	1.0777	0.9834
Cangzhou	1.1840	1.1342	1.1170	1.0122	0.6453	1.0185
Langfang	1.0296	1.0301	1.0974	1.1231	1.0713	1.0703
Hengshui	1.0906	1.2019	1.1182	1.1260	1.2875	1.1648

It can be seen from the results in **Table 3** that in the case of unexpected output, Hengshui has the highest efficiency of industrial green transformation in recent years. The overall trend is that the proportion of tertiary industry is gradually increasing, while the proportion of primary and secondary industry is gradually decreasing. By 2020, emerging industries have formed a basic pattern of coordinated development. New breakthroughs have been made in new materials, new technologies, high-end equipment manufacturing and other fields, focusing on key areas, increasing transformation and upgrading efforts, and gradually building Hengshui into an advanced city of provincial transformation and upgrading;

Shijiazhuang (1.1301) and Hengshui (1.1648) have no significant difference in their transformation efficiency and both reach DEA. Shijiazhuang city has a good effect in reducing the undesirable output, which is related to the strategic orientation of Shijiazhuang city to improve the environment comprehensively, optimize the industrial layout, and build a beautiful home decorated with landscape characteristic towns.

From the above analysis results, it can be seen that there is a big difference between the two scenarios without considering the undesirable output. Taking Shijiazhuang City, the provincial capital city, as an example, the efficiency value considering the undesirable output (1.1301) is 52.76% higher than the efficiency value without considering the undesirable output (0.7398) from 2016 to 2020.

To a certain extent, this shows the focus and direction of industrial green transformation efficiency in Hebei Province. This is related to the development strategy of Hebei Province. Energy and the three main pollutants with the expected output of ten thousand yuan of GDP are the key tasks of Hebei Province in the process of industrial structure transformation this year. Adhere to the priority of ecology and conservation, and adhere to the sustainable development strategy, strictly control production capacity, reduce energy consumption intensity, and build a green industrial structure system. In the process of industrial transformation, all cities also

follow the policy of Hebei Province, and have achieved great results in reducing energy consumption, reducing emissions and green transformation.

3.2 Results and analysis of industrial green TFP in Hebei province

According to the formula (1), (2), (3) and (4) of the Malmquist-Luenberger index model, MATLLAB software was used to calculate the industrial total factor productivity and its decomposition items of each city in Hebei Province. The specific results are shown in **Table 4**.

Table 4. ML index and decomposition of industrial green transformation in Hebei Province from 2016 to 2020

year	Undesired output is not considered			Consider the undesirable output		
	ML	EC	TC	ML	EC	TC
2016-2017	1.015	0.898	1.156	1.317	1.099	1.201
2017-2018	1.265	1.039	1.229	1.187	1.030	1.146
2018-2019	0.938	1.241	0.809	1.052	1.150	0.948
2019-2020	0.972	0.934	1.045	1.029	0.897	1.156
Average value	1.048	1.028	1.060	1.146	1.044	1.113

It can be seen from **Table 4** that when undesired output is not considered from 2016 to 2020, the ML index of industrial green transformation of cities in Hebei Province is less than 1 in 2018-2019 and 2019-2020, which are 0.938 and 0.972 respectively. This shows that the industrial TFP of Hebei Province in 2019 decreased by 6.2% compared with that in 2018, and that in 2020 decreased by 2.8% compared with that in 2019. From 2016 to 2018, the ML index is greater than 1, indicating that the industrial TFP is on the rise. From 2015 to 2020, the total factor productivity of industries excluding undesirable output increased by 4.8% on average. The ML index from 2016 to 2020 considering the unexpected output is greater than 1, and the total factor productivity of industries in Hebei Province has increased by 14.6% on average. The rise is not only the improvement of technical efficiency, but also the technical progress plays an important role and mainly because of the improvement of technical progress. This shows that from the overall situation, Hebei Province has a positive trend in industrial green technology and is moving forward in a good direction. On the whole, the technological progress index without considering the undesirable output is smaller than that without considering the undesirable output, which to a certain extent indicates that the green production of Hebei Province industry has developed to a certain extent in recent years, and the environmental protection technology has been improved to a certain extent. This is in sync with Hebei province's current industrial green transformation policy and the macro environment under the 14th Five-Year development. In recent years, the industry in Hebei Province has been making efforts to optimize the industrial structure, promote the green transformation of the industry, and accelerate the implementation of energy-saving technology transformation, and has established the goal of carbon peak and carbon neutrality.

However, it can be seen in **Table 4** that the technical efficiency of the industrial green transformation of cities in Hebei Province from 2019 to 2020 is 0.897. This shows that the improvement of technical level alone cannot promote the improvement of productivity in Hebei

Province, but also depends on the improvement of technical efficiency. Although the technical efficiency is on the rise on the whole, the overall innovation of Hebei Province is not high, and the lack of innovation vitality has become one of the difficulties that Hebei Province needs to face in the process of industrial Hu provisional implementation.

4 Conclusion

After research, this paper draws the following conclusions: first, most of the industrial green transformation efficiency of prefecture-level cities in Hebei Province without considering the unexpected output fails to reach DEA effectiveness, with an average value of 0.8442; Considering the undesirable output, only a few of the industrial green transformation efficiency values of prefecture-level cities in Hebei Province do not reach DEA effectiveness, and they are generally stable except for Zhangjiakou City. Second, in recent years, the overall industrial transformation efficiency of Hebei Province has shown a positive trend, and all prefecture-level cities are developing in line with the general development trend of Hebei Province. Thirdly, the industrial green transformation efficiency of prefecture-level cities in Hebei Province is quite different from that of the case of considering the undesirable output.

From the above analysis, we put forward the following suggestions, hoping to promote the further development of industrial green transformation in Hebei Province: First, the government should strengthen the organizational guarantee. Strengthen the government's evaluation and supervision role, the government should strengthen the supervision and inspection of the plan, ensure the transformation effect, timely supervision and guidance. Second, we need to advance technological progress and improve efficiency. All cities should strengthen the orientation of industrial green transformation, adhere to green production, sustainable development, increase investment in green innovation and technology, and promote technological progress and efficiency improvement. Third, the efficiency of industrial green transformation is not good enough prefecture level cities should be in line with the cities with better transformation, grasp the wave of the 14th Five-Year Plan, and strive to achieve greater achievements in optimizing the industrial layout and promoting the green transformation of industrial structure on the basis of the results achieved in the 13th Five-Year Plan.

References

[1] Abdul Waheed Siyal, Hongzhuan Chen, Fakhar Shahzad, Shaher Bano,Investigating the role of institutional pressures, technology compatibility, and green transformation in driving manufacturing industries toward green development,Journal of Cleaner Production,Volume 428,2023.

[2] Maximilian Palmié, Jonas Boehm, Jonas Friedrich, Vinit Parida, Joakim Wincent, Jonas Kahlert, Oliver Gassmann, David Sjödin,Startups versus incumbents in green industry transformations: A comparative study of business model archetypes in the electrical power sector,Industrial Marketing Management,Volume 96,2021,Pages 35-49.

[3] Wang Zhenyu, Jin Xiaokun. Research on construction of evaluation index system of industrial green transformation development in Qinling Mountains based on Analytic Hierarchy Process [J]. Science & Technology and Economy, 2021,34(06):1-5.

[4] Kaoru Tone. A slacks-based measure of super-efficiency in data envelopment analysis[J].

European Journal of Operational Research,2002,143(1).
[5] Kaoru Tone. Dealing with Undesirable Outputs in DEA: A Slacks-based Measure (SBM) Approach.Presentation at NAPW III, Toronto, 2003.
[6] Tu Fengna, Wang Li. Study on effect evaluation of industrial green transformation in Tianjin [J]. City,2022(02):3-16.
[7] ZHAO Xiuyun, Li Yejin, Li Qian, Liu Xiaoyi. Quantitative measurement of the interactive coupling relationship between industrial transformation and upgrading and ecological environment: A case study of Industrial transformation and upgrading demonstration zones in China [J]. China Market,2022(07):6-10.
[8] Zhao Y. Research on industrial green transformation efficiency of resource-based cities in China: Empirical analysis based on panel data of resource-based cities at prefecture level [J]. Exploration of Economic Issues,2019(07):94-101.
[9] Zhu Chunhong, Ma Tao. Research on effect evaluation of regional green industry development [J]. Economic and Management Research,2011,(03):64-70.
[10] Yu Q Q. Evaluation of green transformation and upgrading of industrial structure in Yangtze River Delta [D]. Nanjing University of Posts and Telecommunications,2020.