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Research on the Measurement and Influencing Factors of Innovation Efficiency of Listed Companies in the Energy Conservation and Environmental Protection Industry

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Abstract

Under the double carbon goal, the 14th Five Year Plan proposes to accelerate green and low-carbon development. The energy conservation and environmental protection industry has ushered in a period of strategic opportunities, and its driving role in economic growth will be further apparent. The further specialization and refinement of market demand for environmental protection products will force the energy conservation and environmental protection industry to carry out technological innovation. What is the efficiency of technological innovation in the energy conservation and environmental protection industry? Based on 2016-2020 data of 45 Chinese listed companies in this industry, this study uses DEA model and Malmquist index model to measure innovation efficiency from both static and dynamic aspects, and Tobit model to conduct regression analysis on the influencing factors of innovation efficiency. The results indicate that, from a static perspective, the overall innovation efficiency remained relatively stable from 2016 to 2019, and decreased in 2020 due to the impact of the epidemic. From a dynamic perspective, due to the decrease in scale efficiency and pure technological efficiency, the overall innovation efficiency decreased by 1% between 2016 and 2020; The main influencing factors of innovation efficiency are regional public budget revenue, the number of universities in the region, and the number of employees with master's degrees or above in the company.

Keywords

Energy Conservation and Environmental Protection Industry, Measurement of Innovation Efficiency, Influencing Factors, China

1. Introduction

The energy conservation and environmental protection industry is essentially an industry that provides a technological foundation and equipment guarantee for saving energy and resources, developing circular economy, and protecting the environment.

Environmental protection is a major socio-economic issue of common concern to people around the world today, which is related to the sustainable development of the economy and society (Geng & Cui, 2020). Governments around the world also attach great importance to environmental protection work, and have introduced a series of policies to promote the development of environmental protection (Li et al., 2022). The Chinese government proposed in the 14th Five Year Plan to accelerate green and low-carbon development, continuously improve environmental quality, enhance ecosystem quality and stability, and comprehensively improve resource utilization efficiency. The 20th National Congress once again emphasized the need to accelerate the green transformation of development methods. Guided by the goals of carbon neutrality and carbon peaking, the energy conservation and environmental protection industry has ushered in a new period of strategic opportunities, and its driving effect on economic growth will further manifest. The total output value of the energy conservation and environmental protection industry has increased from 4.5 trillion yuan in 2016 to 7.5 trillion yuan in 2020. The proportion of the total industrial output value to China's annual GDP has reached about 7%, becoming an important component of China's socialist economic system. The energy-saving and environmental protection industry is the most sensitive industry to respond to market demand. With the improvement of people's environmental awareness and knowledge, the demand for products will become more specialized and refined, and the demand for environmentally friendly products will be further diversified and personalized (Geng & Cui, 2020). The new market demand will force energy-saving and environmental protection enterprises to carry out technological innovation to meet the public's requirements for products. However, at the same time, there are still many problems in the innovation capacity of the energy-saving and environmental protection industry, such as the lack of key technologies with independent intellectual property rights, the relatively small number of patent authorizations, and the relatively low value of products and services, which seriously limit the further development of the energy-saving and environmental protection industry. This study selects the DEA model and Malmquist index model to measure the innovation efficiency of listed companies in the energy-saving and environmental protection industry from both static and dynamic aspects, analyzes the main influencing factors of innovation efficiency, and seeks ways to improve innovation efficiency.

Existing research mostly focuses on the measurement and influencing factors of regional innovation efficiency. Scholars have examined and compared the innovation efficiency of EU member states from the perspective of innovation input and output (Aytekin et al., 2022); Scholars have measured the efficiency of green technology innovation in Chinese provinces from different perspectives based on the dynamic network data envelopment analysis of Slack (Wang & Ren, 2022), and used a double-layer stochastic frontier model to decompose the positive and negative effects of outward direct investment on green innovation in different time periods and provinces (Song & Han, 2022); Scholars have also conducted research on the efficiency of green innovation in Chinese cities, believing that regional collaborative innovation, development of the Internet (Wang et al., 2022) and the agglomeration of innovation elements characterized by knowledge and technology (Yu et al., 2023) have promoted regional innovation efficiency, including financial agglomeration, industrial structure, knowledge sharing, economic activities, higher education, etc. The impact of openness and environmental regulations (Fan et al., 2020) on the overall efficiency and stage efficiency of green innovation in Chinese cities exhibits regional heterogeneity (Liao & Li, 2023). There is an inverted U-shaped relationship between enterprise size and innovation efficiency (Mei & Shao, 2016). Scholars have also conducted research from the perspective of the effectiveness of regional innovation efficiency, and believe that the innovation efficiency of 280 cities in China has an impact on the ecological footprint of different regions (Ke et al., 2021).

The research on the innovation efficiency of micro enterprises mainly focuses on two aspects. One is to explore the influencing factors. Scholars believe that gender diversity in R&D teams (Xie et al., 2020), artificial intelligence applications (Li et al., 2023), perceived economic policy uncertainty in enterprises (Zhou et al., 2023), high-speed rail (Yang et al., 2022), and financial technology development (Xu et al., 2023) have an impact on innovation efficiency in enterprises. The second is to explore a certain industry field. Scholars have measured the technological innovation efficiency of China's high-tech industries and believe that the overall efficiency of most of China's high-tech industries is relatively low, with significant differences between the five high-tech industries (Wang et al., 2020). The role of intellectual property rights in improving innovation efficiency in China's high-tech industries, mediating the development of technology markets, and regulating market segmentation (Wan et al., 2023). Competition will force Chinese manufacturing enterprises to focus on improving innovation efficiency, but it also undermines cooperation, leading to unpredictable research and development results (Huang, 2023). Green finance policies (Wang, 2023) and digital economy development (Hui et al., 2023) have a significant impact on the efficiency of green innovation in China's manufacturing industry. Diversified agglomeration and specialized agglomeration have different impacts on the innovation efficiency of China's pharmaceutical manufacturing industry (Shi, 2019). Scholars have also measured and evaluated the technological innovation efficiency of the Chinese electronic game industry

(Xi et al., 2022) and the China Industrial Technology Research Institute (Qin et al., 2023).

Based on existing literature, most experts and scholars have conducted in-depth and comprehensive research on regional innovation efficiency, including the measurement of national, provincial, and urban innovation efficiency and the exploration of influencing factors. There is relatively little research on the innovation efficiency of micro enterprises, mostly focusing on a certain influencing factor, lacking a comprehensive analysis of the influencing factors. The research on industry focuses on high-tech and manufacturing industries, without studying the innovation efficiency of energy-saving and environmental protection industries. Therefore, this study will attempt to make the following contributions: firstly, focus the research object on the energy-saving and environmental protection industry. The energy-saving and environmental protection industry, as a strategic emerging industry recognized by the country, has a very important strategic position and optimistic development prospects, attracting widespread attention from all sectors of society. This study measures the innovation efficiency of listed companies in the energy-saving and environmental protection industry, providing new ideas for the research of the energy-saving and environmental protection industry, and promoting the healthy development of the energy-saving and environmental protection industry. Secondly, conduct a comprehensive analysis of the influencing factors of innovation efficiency. This article studies the influencing factors of innovation efficiency in energy conservation and environmental protection industries from the perspectives of external economy, education, policy environment, as well as internal scale and human resources of enterprises, which helps to find more comprehensive paths to improve innovation efficiency.

2. The Current Status of Innovation Input-Output in Energy Conservation and Environmental Protection Industries

2.1. Current Status of Innovation Investment

2.1.1. Financial Expenditure

From 2016 to 2020, the total fiscal expenditure of China's energy conservation and environmental protection industry was 473.482 billion yuan, 561.733 billion yuan, 629.761 billion yuan, 739.02 billion yuan, and 633.34 billion yuan, respectively, showing an overall trend of first increasing and then decreasing, with local expenditure accounting for a large proportion. From 2016 to 2019, the total fiscal expenditure on the energy conservation and environmental protection industry has been increasing every year, with an increase of 18.64%, 12.11%, and 17.35%, respectively. In 2020, due to the impact of the epidemic, the central and local government's fiscal expenditure on the energy conservation and environmental protection industry has decreased compared to 2019, but the total investment remains at a relatively high standard. The central and local governments attach great importance to the energy conservation and environmental protection industry, Great support has been provided for innovative investment in the energy conservation and environmental protection industry (Figure 1).

2.1.2. R&D Personnel Investment

From the overall situation of R&D personnel investment in the three industries, the number of research and development personnel in the water management industry, ecological protection and environmental governance industries is showing an increasing trend year by year, reflecting the overall importance that the industry attaches to the introduction of innovative talents. The number of R&D personnel in the ecological protection and environmental governance industries has been significantly higher over the years compared to the other two industries, and the number of R&D personnel has maintained a growth trend in all other years except for a decrease in 2018. The introduction of innovative talents is in a leading position in the industry. The number of R&D personnel in the public facility management industry is relatively backward among the three industries, and the number of R&D personnel has been decreasing year by year from 2018 to 2020. The industry needs to strengthen the scale of introducing innovative talents and maintain consistency in the introduction (Figure 2).

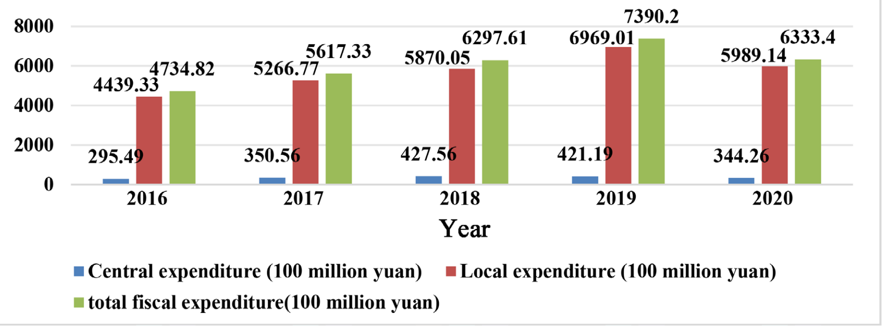

Figure 1. Financial expenditure of energy conservation and environmental protection industry.

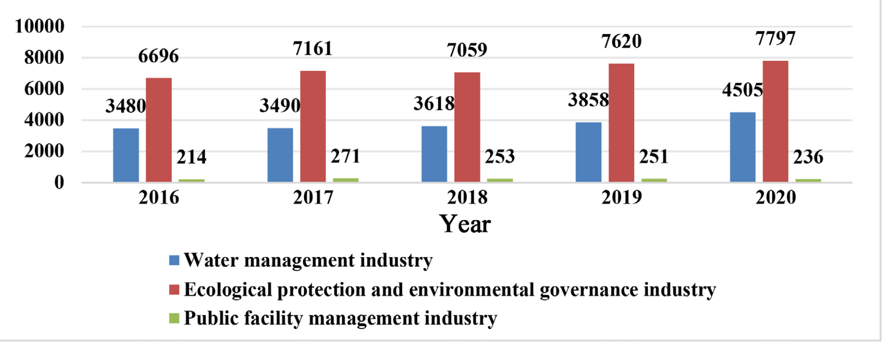

Figure 2. Investment of R&D personnel in energy-saving and environmental protection industries.

2.1.3. R&D Funding Investment

From the overall situation of internal investment in research and development funds in the three industries, the total investment in research and development funds in the three industries has been increasing year by year, and the overall investment in research and development funds in the industry is constantly increasing. From the perspective of various industries, the internal investment in research and development funds in the water management industry shows a trend of first decreasing and then increasing. The internal investment in 2017 and 2018 was lower than that in 2016, and the industry needs to maintain consistency in investment. The internal investment in research and development funds for ecological protection and environmental governance has been increasing year by year, with an increase rate of 13.99%, 19.05%, 15.3%, and 2.95%, respectively. Both the growth rate and investment scale are leading in the industry. The internal investment scale of research and development funds in the public facility management industry is lagging behind among the three industries, with relatively small annual investment amounts. It is necessary to appropriately expand the investment scale to support innovation activities in the industry (Figure 3).

2.2. Current Status of Innovation Output

2.2.1. Industrial Output Value

During the five-year period from 2016 to 2020, the output value of the energy conservation and environmental protection industry increased from 5.3 trillion yuan in 2016 to 7.5 trillion yuan in 2020, with growth rates of 9.43%, 15.52%, 8.96%, and 2.74%, respectively. The industrial output value has been increasing year by year, but the increase has slowed down, and the overall industry is in a relatively stable development stage. At the same time, based on the slightly higher GDP growth rate in 2017 and a decrease in its numerical value, the proportion of energy conservation and environmental protection industry output value to GDP has exceeded 7% in other years and shows a slight growth trend. The energy

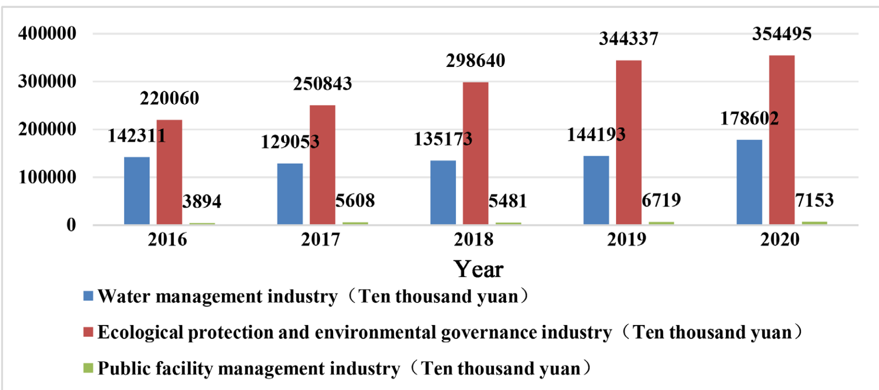

Figure 3. Internal investment of R&D funds in energy conservation and environmental protection industries.

conservation and environmental protection industry has become an indispensable force in China's economic development system (Figure 4).

2.2.2. The Patent Output

From 2018 to 2020, the number of patent applications in the energy conservation and environmental protection industry showed an increasing trend year by year, with an increase of 3.64% in 2019 compared to 2018 and 2.98% in 2020 compared to 2019. The overall innovation awareness of the industry has been enhanced. The number of patent authorizations shows a trend of first decreasing and then increasing, with the ratios of patent authorizations to patent applications over the years being 46.86%, 41.07%, and 41.51%, respectively. Only a small portion of patents can be granted. This can reflect that there are still some problems that need to be improved in the innovation system of the energy conservation and environmental protection industry, and there is still significant room for improvement in the overall innovation capacity of the industry (Figure 5).

2.2.3. Profit Situation

From 2017 to 2020, the operating profit of listed environmental protection enterprises showed a state of first decreasing and then increasing. Based on the

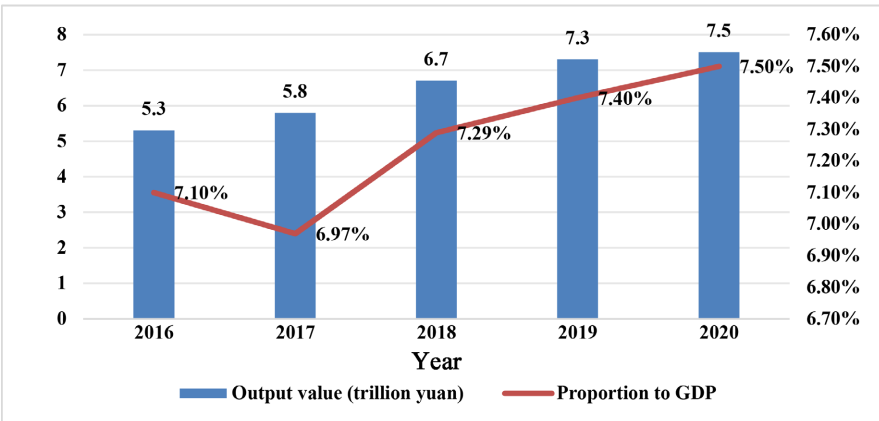

Figure 4. Energy conservation and environmental protection industry output value and it proportion to GDP.

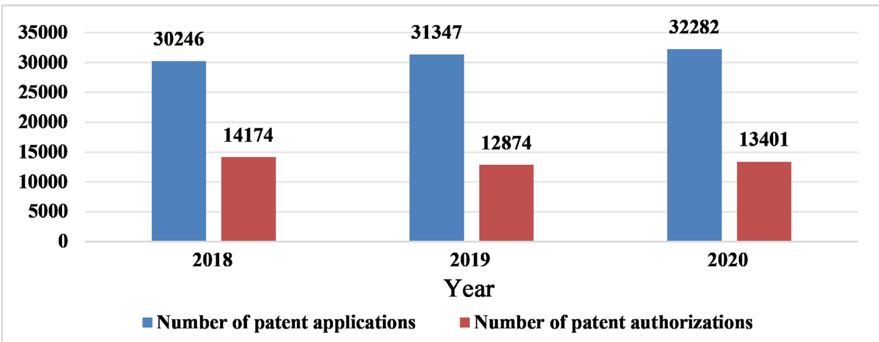

Figure 5. Patent output of energy conservation and environmental protection industry.

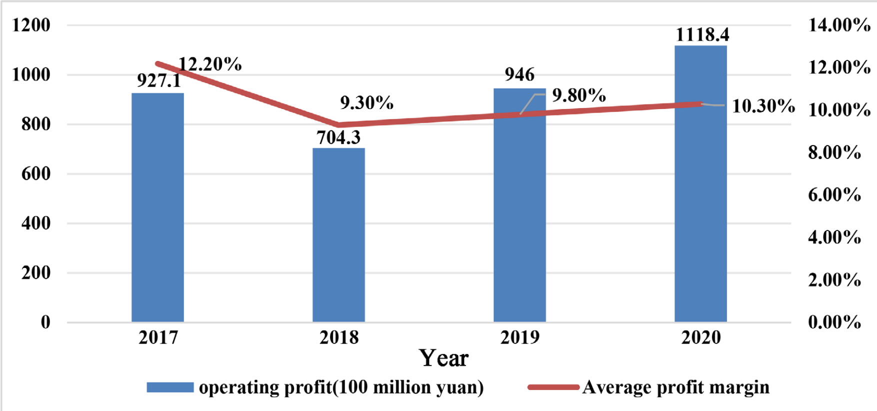

Figure 6. Profitability of energy conservation and environmental protection industry.

impact of declining operating income, the overall operating profit in 2018 showed a significant decrease compared to 2017, a decrease of 24.03%. Subsequently, the overall operating profit of the enterprise increased significantly in 2019 and 2020, reaching 94.6 billion yuan and 111.84 billion yuan, respectively (Figure 6). From the perspective of average profit margin, the overall average profit margin of the enterprise is relatively low, with the highest being only 12.20% in 2017. The overall profitability of the enterprise is weak, and the ability to obtain profits from innovation investment needs further improvement.

3. Measurement of Innovation Efficiency

3.1. Sample Selection and Data Sources

This article is based on the list of listed companies published by Dongfang Wealth Network. After excluding ST, *ST, and incomplete data listed companies, 45 energy-saving and environmental protection industry listed companies were ultimately selected. The relevant financial data of each listed company comes from the annual report; the patent authorization data is sourced from the National Intellectual Property Network.

3.2. Selection of Indicators

Based on the existing research results of other scholars [83], the investment indicators of this article mainly include human resource investment and financial investment. Among them, the number of R&D personnel (X1) is selected as human resource investment, while R&D funding (X2) and operating costs (X3) are selected as financial investment. The output indicators of this article mainly include knowledge output and economic output. The output of knowledge achievements is represented by the number of patent authorizations (Y1), while the output of economic achievements is reflected by two economic indicators: operating income (Y2) and net profit (Y3). This article adopts the efficiency coefficient method to correct the data in the indicators of net profit and patent authorization numbers that are less than or equal to 0.

3.3. Model Construction

3.3.1. DEA-BCC Model

This article uses the BCC model to statically measure the innovation efficiency of 45 listed companies in the energy-saving and environmental protection industry. The specific model is as follows:

$$\begin{cases} \min \theta - \varepsilon\left(e^{\mathrm{T}} s^{+} + e^{\mathrm{T}} s^{-}\right) \\ \sum_{j=1}^{n} Y_j \lambda_j - S^{+} = Y_0 \\ \sum_{j=1}^{n} \lambda_j = 1,\ j = 1,2,3,\cdots,n \\ \lambda_j \geq 0,\ S^{-}, S^{+} \geq 0 \end{cases} \tag{1}$$

$j = 1,2,3,\cdots,n$ represents each decision-making unit, X and Y represent input and output variables, S^{-} and S^{+} represent input and output relaxation variables of each listed company, respectively, ε Represents a non Archimedean infinitesimal quantity. If the pure technical efficiency and scale efficiency of a listed company reach 1, and the innovation efficiency of the listed company is 1, it indicates that the innovation efficiency of the listed company is effective. If the innovation efficiency does not reach 1, it indicates that the innovation efficiency of the listed company is in an invalid state.

3.3.2. Malmquist Index Model

The Malmquist index model can be represented as:

$$Tfpch = Effch \times Techch = \left(Pech \times Sech\right) \times Techch \tag{2}$$

Among them, *Tfpch* represents the total factor productivity of innovation efficiency, *Effch*, *Techch*, *Pech* and *Sech* represent the technical efficiency change index, technical progress index, pure technical efficiency change index, and scale efficiency change index, respectively. If *Tfpch* > 1, it indicates that the innovation efficiency of listed companies in energy-saving and environmental protection industries is on the rise, *Tfpch* = 1 indicates that the innovation efficiency remains unchanged, and *Tfpch* < 1 indicates that the innovation efficiency is decreasing.

3.4. Measurement Results of Innovation Efficiency

3.4.1. Correlation Analysis of Input-Output Variables

The DEA-BCC and Malmquist models require a positive correlation between input-output variables. This article analyzes the correlation between input-output indicators and finds that the correlation coefficients between R&D expenditure and patent authorization, operating revenue, and net profit are 0.64, 0.41, and 0.37, respectively, and are positively significant at a 1% confidence level; The correlation coefficients between the number of R&D personnel and the number of patent authorizations, operating revenue, and net profit are 0.62, 0.39, and 0.29, respectively, and are positively significant at a 1% confidence level; The correlation coefficients between operating costs and patent authorizations, operating revenue, and net profit are 0.52, 0.70, and 0.59, respectively, and are positively significant at a 1% confidence level, indicating a positive correlation between input and output variables, which meets the requirements of the model (Table 1).

3.4.2. Static Measurement of Innovation Efficiency

1) Analysis of Individual Innovation Efficiency

As shown in Table 2, the number of listed companies with innovation efficiency values of 1 in the energy conservation and environmental protection industry from 2016 to 2020 was 9, 6, 9, 8, and 8, respectively, accounting for 20.00%, 13.33%, 20%, 17.78%, and 20.00%, respectively. Only a very small number of listed companies are in an effective state of innovation efficiency each year. Among them, only four listed companies have an innovation efficiency value of 1 in five years, and one listed company has an innovation efficiency value of 1 in four years. These five listed companies have high and stable innovation efficiency, and their overall innovation efficiency is in a leading position in the industry. The innovation efficiency of 11 companies has reached 1 in one to three years, which is in an effective state, but it cannot be sustained. We should focus on improving the stability of our own innovation efficiency. The remaining 29 companies have not achieved an innovation efficiency value of 1 in a year, and there are serious problems in both scale efficiency and pure technical efficiency. Innovation efficiency is at a relatively backward level in the industry.

2) Analysis of overall innovation efficiency

As shown in Table 3, the overall average innovation efficiency, pure technical efficiency, and scale efficiency of listed companies in the energy conservation and environmental protection industry from 2016 to 2020 were 0.70, 0.84, and 0.83, respectively. The overall innovation efficiency maintained a high level, but did not reach 1 and was not in an effective state. From the average situation over the years, the average level of pure technical efficiency and scale efficiency was relatively stable from 2016 to 2019, without significant fluctuations. The average

Table 1. Correlation analysis of input-output variables.

	X1	X2	X3	Y1	Y2	Y3
X1	1					
X2	0.83***	1				
X3	0.55***	0.58***	1			
Y1	0.62***	0.64***	0.52***	1		
Y2	0.39***	0.41***	0.70***	0.39***	1	
Y3	0.29***	0.37***	0.59***	0.29***	0.44***	1

***Significantly at a 1% confidence level.

Table 2. Annual innovation efficiency values of listed companies in the energy conservation and environmental protection industry.

NO.	2016	2017	2018	2019	2020	NO.	2016	2017	2018	2019	2020
1	0.67	0.63	0.63	0.64	0.31	24	0.72	0.64	0.60	0.81	0.65
2	0.92	0.86	0.78	0.72	0.34	25	0.53	0.60	0.39	0.73	0.33
3	0.76	0.66	0.58	0.55	0.08	26	0.90	0.62	1	0.91	0.92
4	0.84	0.74	0.89	1	0.65	27	0.70	0.62	0.54	0.45	0.31
5	0.88	0.65	0.66	0.58	0.38	28	1	1	1	0.77	0.63
6	1	1	1	1	1	29	0.73	0.64	0.71	0.65	0.51
7	1	1	1	1	1	30	0.71	0.67	0.65	0.59	0.49
8	1	0.66	0.63	0.72	0.26	31	0.95	0.58	0.67	0.67	0.49
9	1	0.91	1	1	1	32	0.72	0.61	0.72	0.53	0.32
10	1	1	1	0.54	0.73	33	0.69	0.62	0.58	0.93	1
11	0.81	0.68	0.70	1	0.54	34	0.48	0.51	0.32	0.76	0.15
12	0.66	0.62	0.65	0.69	0.39	35	0.62	0.57	0.58	0.65	0.33
13	0.69	0.65	0.64	0.59	0.65	36	0.67	0.62	0.49	0.50	0.28
14	0.67	0.64	0.62	0.77	0.39	37	0.58	0.58	0.50	1	0.54
15	0.65	0.57	0.69	0.63	0.19	38	0.61	0.51	0.51	0.55	0.28
16	0.89	0.70	0.71	0.76	0.58	39	1	1	1	1	1
17	0.75	0.69	0.75	0.75	0.79	40	0.64	0.59	0.61	0.63	0.29
18	0.61	0.61	0.65	0.84	1	41	0.94	0.83	0.73	0.92	0.78
19	0.75	0.67	0.75	0.72	0.42	42	1	0.75	1	0.88	0.82
20	0.66	0.60	0.63	0.81	0.57	43	0.78	0.68	0.71	0.72	1
21	0.78	0.69	0.69	0.70	0.51	44	0.68	0.61	0.68	0.70	0.04
22	0.67	0.62	0.58	0.55	0.28	45	1	1	1	1	1
23	0.91	0.87	0.79	0.78	0.68						

values for each year were above 0.8, but there was a significant decline in 2020. Under the combined effect of the two, the average innovation efficiency of the industry decreased to 0.55. This is mainly due to the significant impact of the epidemic in 2020 on the entire energy-saving and environmental protection industry, resulting in a significant decrease in the overall innovation efficiency of the industry.

3) Analysis of regional differences in innovation efficiency

As shown in Table 3, the average innovation efficiency of listed companies in the energy conservation and environmental protection industries in the central, western, and eastern regions from 2016 to 2020 was 0.66, 0.74, and 0.70, respectively. The innovation efficiency values of listed companies in the western region

Table 3. Overall analysis of innovation efficiency of listed companies in the energy conservation and environmental protection industry.

Year/Region	Mean innovation efficiency	Mean pure technical efficiency	Mean scale efficiency
2016	0.78	0.87	0.89
2017	0.70	0.86	0.81
2018	0.71	0.87	0.82
2019	0.75	0.87	0.86
2020	0.55	0.72	0.77
population mean	0.70	0.84	0.83
Central region	0.66	0.81	0.82
Central region	0.74	0.82	0.89
Central region	0.70	0.85	0.82

were higher than those in the central and eastern regions, and they were in a leading position in the comparison between regions. However, the average innovation efficiency of the three regions is less than 1, which has not reached an effective state, and there is still significant room for improvement. From the perspective of various regions, the average pure technical efficiency of listed companies in the central and western regions is lower than the average scale efficiency. The low pure technical efficiency is the main factor hindering the improvement of innovation efficiency of listed companies in the western and central regions; The average pure technological efficiency in the eastern region is higher than the average scale efficiency, and the low scale efficiency is the main factor hindering the improvement of innovation efficiency of listed companies in the eastern region.

3.4.3. Dynamic Measurement of Innovation Efficiency

1) Analysis of Individual Innovation Efficiency

As shown in Table 4, there were 22 listed companies with an average total factor productivity of innovation efficiency greater than 1 from 2016 to 2020, accounting for 48.8%, indicating that nearly half of the listed companies in the industry are on the rise in innovation efficiency. From the perspective of the technical efficiency change index, the values of 5 listed companies are greater than 1, the values of 5 listed companies are equal to 1, accounting for 11.1% respectively, and the values of the other 35 listed companies are less than 1. This indicates that the technical efficiency of 35 companies is declining during this time period. Among them, 19 companies were caused by a decrease in pure technological efficiency, while 16 companies were caused by a decrease in scale efficiency due to investment scale and resource allocation. From the perspective of technological progress index, the value of 37 listed companies is greater than 1, accounting for 82.2%, indicating that the vast majority of energy-saving and

Table 4. Summary of innovation efficiency total factor productivity and its decomposition index mean of listed companies in the energy conservation and environmental protection industry.

NO.	effch	techch	pech	sech	tfpch	NO.	effch	techch	pech	sech	tfpch
1	0.83	1.23	0.80	1.03	1.02	24	0.98	1.09	1.01	0.97	1.06
2	0.78	1.16	0.93	0.84	0.91	25	0.89	1.12	0.88	1.01	1
3	0.56	1.62	0.65	0.87	0.91	26	1.01	1	1.01	1	1.01
4	0.94	1.02	1.01	0.93	0.95	27	0.82	1.30	0.89	0.92	1.06
5	0.81	1.17	0.87	0.94	0.95	28	0.89	0.99	0.89	1	0.88
6	1	0.84	1	1	0.84	29	0.91	1.17	1.02	0.90	1.06
7	1	0.94	1	1	0.94	30	0.91	1.10	0.94	0.97	1
8	0.71	1.05	0.72	0.99	0.75	31	0.85	1.05	1	0.85	0.89
9	1	1.24	1	1	1.24	32	0.81	1.14	0.81	1	0.92
10	0.93	0.96	0.93	1	0.89	33	1.10	1.29	1.04	1.06	1.41
11	0.90	1.06	0.99	0.91	0.96	34	0.74	1.12	0.79	0.94	0.83
12	0.88	1.15	1	0.88	1.01	35	0.85	1.33	1.04	0.82	1.14
13	0.98	1.15	1.07	0.92	1.13	36	0.80	1.20	0.80	1.01	0.97
14	0.87	1.18	1.04	0.84	1.03	37	0.99	0.97	1.08	0.91	0.96
15	0.73	1.42	0.75	0.98	1.04	38	0.83	1.24	0.87	0.96	1.02
16	0.90	1.16	0.98	0.92	1.04	39	1	0.97	1	1	0.97
17	1.01	1.07	0.99	1.02	1.08	40	0.82	1.21	0.86	0.96	0.99
18	1.13	1.15	1.08	1.05	1.30	41	0.95	1.01	0.95	1	0.96
19	0.87	1.28	0.91	0.95	1.11	42	0.95	0.95	1	0.96	0.91
20	0.96	1.09	0.96	1.01	1.05	43	1.06	1.08	1.06	1.01	1.15
21	0.90	1.17	1	0.90	1.05	44	0.50	1.38	0.48	1.04	0.69
22	0.80	1.28	0.91	0.88	1.03	45	1	0.80	1	1	0.80
23	0.93	1.13	0.99	0.94	1.05						

environmental protection industries can attach importance to the development of new technologies, actively introduce scientific research talents, and their scientific research and technological capabilities are rapidly developing.

2) Analysis of overall innovation efficiency

As shown in Table 5, the average total factor production index of innovation efficiency for listed companies in the energy conservation and environmental protection industry from 2016 to 2020 was 0.99, indicating a 1% decrease in overall innovation efficiency. From the perspective of each decomposition index, the average value of the technical efficiency change index is 0.90, which has decreased by an average of 10% and has a negative impact on the improvement of

Table 5. Overall analysis of innovation efficiency and total factor productivity of listed companies in the energy conservation and environmental protection industry.

Year/Region	effch	techch	pech	sech	tfpch
2016-2017	0.90	1.07	0.99	0.90	0.96
2017-2018	1.00	0.92	0.99	1.01	0.92
2018-2019	1.06	0.90	1.01	1.05	0.95
2019-2020	0.63	1.80	0.73	0.87	1.14
population mean	0.90	1.17	0.93	0.96	0.99
Central region	0.93	1.18	0.95	0.98	1.09
Central region	0.87	1.18	0.88	0.99	1.00
Central region	0.89	1.12	0.94	0.95	0.98

innovation efficiency; The average value of the technological progress index is 1.17, an average increase of 17%, which has a positive effect on improving innovation efficiency; The average change index of pure technological efficiency is 0.93, a decrease of 7% on average, which has a negative impact on the improvement of innovation efficiency; The average change index of scale efficiency is 0.96, which has decreased by 4% annually and has a negative impact on the improvement of innovation efficiency. It can be seen that the decline in industrial technological efficiency is caused by the decrease in scale efficiency and pure technological efficiency. Among them, the decrease in pure technological efficiency is greater than that of scale efficiency, and the decrease in pure technological efficiency is the main reason for the overall decline in innovation efficiency in the industry.

3) Analysis of regional differences in innovation efficiency

As shown in Table 5, from 2016 to 2020, the average innovation efficiency total factor productivity of listed companies in the central region was 1.09, with a 9% increase in efficiency. The average innovation efficiency total factor productivity of listed companies in the western and eastern regions was 1 and 0.98, respectively. The efficiency value in the western region remained stable, while in the eastern region it decreased by 2%. The innovation efficiency in the central region was significantly higher than that in the western and eastern regions. From the perspective of each decomposition index, the average technological progress index of listed companies in the three regions has exceeded 1, and the technological capabilities of each region are significantly improving. However, the average pure technological efficiency and scale efficiency index of the three regions are all less than 1, indicating a decline. There are problems with the establishment and daily management of innovation systems, investment scale, and resource allocation of listed companies in each region.

4. Research on the Factors Influencing Innovation Efficiency

4.1. Theoretical Analysis of Influencing Factors

4.1.1. Regional Economic Development Level (Z1)

The level of economic development in a region is an economic influencing factor in the PEST theory, and the impact of economic development level on innovation efficiency has been a hot topic of academic research in recent years. The development of innovation activities requires the support of economic foundation. The higher the level of economic development, the greater the investment of listed companies in innovation, and the greater the demand for innovative products by the public (Zhou & Xu, 2022). So, this article assumes a positive correlation between the level of regional economic development and the innovation efficiency of listed companies. Among them, Z1 is represented by the regional public budget revenue indicator.

4.1.2. Regional Education Level (Z2)

Regional education level is a social environmental influencing factor in PEST theory. The richer the educational resources in a region, the more innovative talents it can provide for technological innovation, resulting in more output of innovative achievements and more demand for innovation, promoting the improvement of innovation efficiency (Wan et al., 2023). So, this article assumes a negative correlation between regional education level and innovation efficiency of listed companies. Among them, Z3 is represented by the number of regional universities.

4.1.3. Government Support (Z3)

The government's support for energy conservation and environmental protection industries is a technological influencing factor in PEST theory. Generally speaking, the more government expenditure on energy conservation and environmental protection, the greater the local government's attention and support for the energy conservation and environmental protection industry. Listed companies can receive more external support to better carry out innovation activities. This article assumes a positive correlation between government support and the innovation efficiency of listed companies. Among them, the Z4 government's energy conservation and environmental protection expenditure indicator represents.

4.1.4. Company Size (Z4)

The size of a company is an internal influencing factor on its innovation efficiency. Generally speaking, larger enterprises have relatively strong financial strength, better innovation resources, can maintain the continuity of innovation investment, and have strong ability to resist risks. Large scale enterprises can effectively disperse innovation risks and reduce losses caused by R&D failures through diversification and large-scale R&D innovation (Li et al., 2023). So, this article assumes a positive correlation between company size and innovation efficiency of listed companies. Among them, Z2 is represented by the company's total asset indicator.

4.1.5. Labor Quality and Talent Introduction (Z5)

The quality of the company's labor force and the introduction of talent to a certain extent reflect the company's core competitiveness and are internal influencing factors for the company's innovation efficiency. Generally speaking, the higher the education level of the workforce, the stronger their ability to learn innovative knowledge and develop innovative technologies. On the other hand, the introduction of high-quality and highly educated talents by listed companies requires a significant amount of cost, and at the same time, there may be many problems such as mismatch between education and innovation ability, and unreasonable talent allocation in the company (Ahmad et al., 2022). So, this article assumes that there is a negative correlation between the quality of company labor and the introduction of talent and the innovation efficiency of listed companies. Among them, Z5 is represented by the number of employees with a master's degree or above in the company.

4.2. Model Construction

This article constructs a Tobit regression model as follows:

$$Crste_{it} = \beta_0 + \beta_1 \ln Z1_{it} + \beta_2 \ln Z2_{it} + \beta_3 \ln Z3_{it} + \beta_4 \ln Z4_{it} + \beta_5 \ln Z5_{it} + \mu \quad (3)$$

Among them, i represents the serial number of the enterprise, t represents the year, *Crste* represents the innovation efficiency value of the listed company, $\ln Z1$ represents the logarithm of regional public budget revenue, $\ln Z2$ represents the logarithm of regional universities, $\ln Z3$ represents the logarithm of government energy conservation and environmental protection expenditure, $\ln Z4$ represents the logarithm of company total assets, $\ln Z5$ represents the logarithm of the number of employees with master's degree or above, and μ represents the residual term.

4.3. Tobit Regression Analysis

From the Tobit regression results, it can be found that the regression coefficient of regional public budget revenue is positive and positively correlated with the innovation efficiency of listed companies, which is consistent with hypothesis 1. At the same time, the regional public budget revenue and the innovation efficiency of listed companies have passed the significance test at a 5% confidence level, and are the main influencing factors of innovation efficiency. The improvement of regional economic level has driven the improvement of innovation efficiency of local companies.

The regression coefficient of the number of universities in the region is negative and negatively correlated with the innovation efficiency of listed companies, which is consistent with hypothesis 2. At the same time, the number of regional universities and the innovation efficiency of listed companies have passed a significance test at a confidence level of 1%, which is the main influencing factor of innovation efficiency. The increase in the number of regional universities hinders the improvement of innovation efficiency of listed companies in their respective regions.

The regression coefficient of government energy conservation and environmental protection expenditure is positive and positively correlated with the innovation efficiency of listed companies, which is consistent with hypothesis 3. However, it did not pass the significance test and has only a weak impact on the innovation efficiency of listed companies, not the main influencing factor of innovation efficiency.

The regression coefficient of the total assets of the company is positive and positively correlated with the innovation efficiency of the listed company, which is consistent with hypothesis 4. However, it did not pass the significance test, indicating that the company size of the listed company only has a weak impact on the innovation efficiency of the company and is not the main influencing factor of innovation efficiency.

The regression coefficient for the number of employees with a master's degree or above in a company is negative and negatively correlated with the innovation efficiency of listed companies, consistent with hypothesis 5. At the same time, the number of employees with a master's degree or above in the company and the innovation efficiency of listed companies have passed a significance test at a 5% confidence level, which is the main influencing factor of innovation efficiency. Each listed company has paid high costs to attract highly educated talents, hindering the improvement of its own innovation efficiency (**Table 6**).

4.4. Robustness Testing

In order to verify the accuracy of Tobit regression results, this article adopts a variable substitution method for robustness testing. The number of employees in the company is used to replace the total assets of the company to reflect the size of the company. The test results are shown in **Table 7**.

From the results of the robustness test, it can be seen that the three indicators of regional public budget revenue, number of regional universities, and number of employees with master's degrees or above have passed the significance test

Table 6. Tobit regression results.

Variable	regression coefficient	S.D.	T	*P*
lnZ1	0.0802	0.0357	2.24	0.026**
lnZ2	−0.2495	0.0697	−3.58	0.000***
lnZ3	0.0430	0.0439	0.98	0.329
lnZ4	0.0170	0.0201	0.84	0.401
lnZ5	−0.0392	0.0180	−2.18	0.030**

***Significantly at a 1% confidence level, **Significantly at a 5% confidence level.

Table 7. Robustness test.

Variable	regression coefficient	S.D.	T	*P*
lnZ1	0.0865	0.0350	2.47	0.014**
lnZ2	−0.2668	0.0687	−3.88	0.000***
lnZ3	0.0501	0.0439	1.14	0.255
lnZ4	0.2588	0.0168	1.54	0.126
lnZ5	−0.0469	0.1762	−2.66	0.008***

***Significantly at a 1% confidence level, **Significantly at a 5% confidence level.

with the innovation efficiency of listed companies in the energy conservation and environmental protection industry, and are the main influencing factors of innovation efficiency of listed companies. At the same time, there is a positive correlation between regional public budget revenue and innovation efficiency, while there is a negative correlation between the number of universities in the region and the number of employees with master's degrees or above and innovation efficiency, which is consistent with previous conclusions. The average number of students in higher education per 100,000 population in the region, government expenditure on energy conservation and environmental protection, and the innovation efficiency of listed companies in the energy conservation and environmental protection industry have not passed the significance test, and are not the main influencing factors of innovation efficiency. At the same time, the average number of students in higher education per 100,000 population in the region is negatively correlated with the innovation efficiency of listed companies, and the government's energy conservation and environmental protection expenditure is positively correlated with the innovation efficiency of listed companies, which is consistent with previous conclusions. Therefore, the results of Tobit regression have high reliability.

5. Conclusion and Suggestions

5.1. Conclusion

In order to measure the innovation efficiency of listed companies in China's energy conservation and environmental protection industry and explore the main influencing factors of innovation efficiency, this article selects 45 listed companies in the energy conservation and environmental protection industry as the research objects, and selects indicator data from each listed company from 2016 to 2020. Firstly, the DEA-BCC model and Malmquist index model are used to measure the innovation efficiency of listed companies from static and dynamic aspects, respectively, Based on the measurement results of innovation efficiency using the DEA-BCC model, the Tobit regression method was used to study the main influencing factors of innovation efficiency of listed companies in the energy conservation and environmental protection industry. The main conclusions were as follows: firstly, from a static perspective, the overall innovation efficiency of listed companies in the energy conservation and environmental protection industry was relatively stable during the period from 2016 to 2019, and decreased due to the impact of the epidemic in 2020; Among them, 5 listed companies have a leading position in innovation efficiency in the industry; The innovation efficiency of listed companies in the western region is higher than that in the eastern and central regions, but the average innovation efficiency of listed companies in the three regions has not reached an effective state, and there is still significant room for improvement. Secondly, from a dynamic perspective, due to the decrease in scale efficiency and pure technological efficiency, the overall innovation efficiency of listed companies in the energy-saving and environmental protection industry decreased by 1% between 2016 and 2020; The progress in innovation efficiency of listed companies in the central region is significantly better than that of listed companies in the western and eastern regions, temporarily in a leading position. Finally, the main influencing factors on the innovation efficiency of listed companies in the energy conservation and environmental protection industry are regional public budget revenue, the number of universities in the region, and the number of employees with master's degrees or above in the company. Among them, there is a positive correlation between regional public budget revenue and innovation efficiency, while there is a negative correlation between the number of universities in the region and the number of employees with master's degrees or above and innovation efficiency.

5.2. Suggestions

5.2.1. Actively Adopting Epidemic Prevention and Control Measures

Listed companies in the energy conservation and environmental protection industry should establish an epidemic warning mechanism, actively obtain accurate information related to the epidemic, conduct effective analysis of the company's environment based on the collected information, identify potential risk points, and use the company's resources for risk management. When the epidemic occurs, all listed companies should immediately initiate emergency response measures, promptly distribute protective equipment to all employees, strengthen epidemic prevention and control publicity and education through various channels such as blackboard newspapers, bulletin boards, websites, WeChat, etc., guide employees to master prevention and control knowledge and skills, focus on strengthening mask wearing and hand hygiene education, and guide employees to consciously reduce social gatherings, card games, and other gathering activities. Once suspected symptoms are found in employees, they must immediately report to relevant departments and contact an ambulance to transport them to the nearest fever clinic for treatment, in order to prevent the spread of the epidemic in the factory area. At the same time, listed companies should take advantage of the advantages of mobile internet platforms and actively carry out new and effective work modes such as remote work and home work, in order to minimize the losses caused by the epidemic on enterprise shutdown and production. After the epidemic ended, all listed companies should timely summarize experience and lessons, comprehensively investigate the health status of employees, timely implement epidemic prevention disinfection and sterilization measures, strengthen health management, and resume work and production as soon as possible under the condition of ensuring safety.

5.2.2. Reasonably Selecting Investment Scale and Optimizing Resource Allocation

In response to the situation of low scale efficiency, listed companies in the energy conservation and environmental protection industry should choose a reasonable and effective investment scale based on their own actual situation. For situations where the return on scale is increasing, listed companies should appropriately increase their financing efforts and expand their investment scale. For situations where returns to scale are decreasing, listed companies should appropriately reduce their investment scale to avoid blindly expanding their investment scale. On the other hand, listed companies should enhance their awareness of resource allocation, improve their management system for resource allocation, gain insight into the changes in resource allocation concepts during social development, adjust their own resource allocation plans in a timely manner, and continuously update their allocation technologies. In the process of resource allocation, not only the work ability of employees should be considered, but also their psychological state should be considered, and employees should be arranged to suitable work positions to ensure their normal work efficiency. Finally, all listed companies should also make overall planning, conduct specific analysis of the actual situation of each project, invest funds in projects with higher output efficiency, maximize work efficiency, and improve innovation efficiency.

5.2.3. Improving the Innovation System

In response to the situation of low pure technological efficiency, listed companies in the energy conservation and environmental protection industry, as the main body of innovation activities, should strengthen the cultivation of independent innovation concepts, strengthen innovation training for employees, expand their innovative perspectives and ideas, provide employees with a fully free innovation environment and good innovation conditions, enable employees to actively unleash their innovation potential, and form a strong innovation culture atmosphere. At the same time, we will invest in the construction of independent innovation centers, improve basic research platforms, and create a group of interdisciplinary research teams with relatively concentrated research directions, strong complementarity, innovative capabilities, and research advantages. On the other hand, it is necessary to enhance the integrated thinking ability, horizontal expansion ability, and practical motivation of the research team, establish a management mechanism for sharing interests, risks, and common development, optimize the personnel and organizational structure of the research team, and improve the management mechanism of the research team. Each listed company should also actively establish open and stable industry university research cooperation relationships with higher education institutions and research institutes, and carry out various forms of industry university research alliances through achievement transfer, commissioned development, joint development, joint construction of technology development institutions, and technology-based enterprise entities, gradually forming an industry university research consortium with listed companies as the main body and active participation of higher education institutions and research institutes, Fully leverage the intellectual and talent advantages of universities and research institutes to quickly improve the research and development level of listed companies. Finally, each superior company should actively carry out the introduction and management of high-level talents, strengthen the cultivation and use of talents with innovative spirit and ability, create conditions to attract outstanding talents to participate in the company's innovation work, and establish classified and phased reward and punishment mechanisms based on the different positions of employees, to enhance the enthusiasm of the entire company for innovation.

5.2.4. Strengthen Regional Cooperation between Listed Companies

The innovation efficiency of listed companies in the energy conservation and environmental protection industry in the western region is higher than that of listed companies in the central and eastern regions. The progress in innovation efficiency of listed companies in the central region is higher than that of listed companies in the western and eastern regions. Listed companies in each region have their own advantages and disadvantages in innovation efficiency. Therefore, listed companies in the three regions should break the boundaries between regions, establish an industrial chain for regional innovation, formulate collaborative development strategies, clarify their respective functional positioning and development advantages, fully consider the accumulation of regional innovation factors, industrial development direction, and technological development stage, gradually improve the regional innovation division of labor and resource allocation framework, and promote the energy conservation and environmental protection industries in the three regions in information, technology Exchange of talents and other resources. At the same time, eliminate institutional barriers that restrict the cross regional flow of innovation factors, reduce the cost of innovation factor flow, gradually achieve complementary advantages and technology sharing, and improve the overall innovation efficiency of listed companies in the energy conservation and environmental protection industry.

5.3. Shortcomings and Prospects

The shortcomings of this study are mainly reflected in the following aspects: 1) In terms of indicator selection, there are still some indicators that can reflect input, output, and influencing factors that cannot be applied to the paper due to the lack of data, resulting in a lack of comprehensiveness in indicator selection, such as output indicators of social benefits and indicators of the degree of importance that enterprises attach to innovation. 2) In terms of selecting listed companies, due to the lack of data for some listed companies, only a portion of listed companies in the energy-saving and environmental protection industry can be selected during the research process on innovation efficiency and influencing factors of listed companies. 3) There are still shortcomings in the depth of research. This article only focuses on the analysis of the innovation efficiency and influencing factors of listed companies in the energy conservation and environmental protection industry, and the interpretation of the underlying reasons for the results is not deep enough, and further strengthening is needed.

Based on the limitations of the above research, future research on the innovation efficiency and influencing factors of listed companies in the energy conservation and environmental protection industry will select more listed companies as research objects, and select more indicator data that can reflect innovation efficiency and influencing factors based on corresponding theories to construct a scientific and complete evaluation system; Meanwhile, with the continuous updating of empirical methods, research methods on innovation efficiency and influencing factors of listed companies in the energy-saving and environmental protection industry will become more diverse, and the interpretation of empirical results will also be more in-depth and specific.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Ahmad, M., Ahmed, Z., Yang, X. Y., Hussain, N., & Sinha, A. (2022). Financial Development and Environmental Degradation: Do Human Capital and Institutional Quality Make a Difference? *Gondwana Research, 105,* 299-231. https://doi.org/10.1016/j.gr.2021.09.012

Aytekin, A., Ecer, F., Korucuk, S., & Karamaşa, Ç. (2022). Global Innovation Efficiency Assessment of Eu Member and Candidate Countries via Dea-Eatwios Multi-Criteria Methodology. *Technology in Society, 68,* Article 101896. https://doi.org/10.1016/j.techsoc.2022.101896

Fan, F., Lian, H., Liu, X. Y., & Wang, X. L. (2020). Can Environmental Regulation Promote Urban Green Innovation Efficiency? An Empirical Study Based on Chinese Cities. *Journal of Cleaner Production, 287,* Article 125060. https://doi.org/10.1016/j.jclepro.2020.125060

Geng, C. X., & Cui, Z. Y. (2020). Analysis of Spatial Heterogeneity and Driving Factors of Capital Allocation Efficiency in Energy Conservation and Environmental Protection Industry under Environmental Regulation. *Energy Policy, 137,* Article 111081. https://doi.org/10.1016/j.enpol.2019.111081

Huang, X. J. (2023). The Roles of Competition on Innovation Efficiency and Firm Performance: Evidence from the Chinese Manufacturing Industry. *European Research on Management and Business Economics, 29,* Article 100201. https://doi.org/10.1016/j.iedeen.2022.100201

Hui, N., Yu, Q., & Gu, Y. (2023). Does the Digital Economy Improve the Innovation Efficiency of the Manufacturing Industry? Evidence in Provincial Data from China. *Sustainability, 15,* Article 10615. https://doi.org/10.3390/su151310615

Ke, H. Q., Dai, S. Z., & Yu, H. C. (2021). Spatial Effect of Innovation Efficiency on Ecological Footprint: City-Level Empirical Evidence from China. *Environmental Technology & Innovation, 22,* Article 101536. https://doi.org/10.1016/j.eti.2021.101536

Li, C. M., Xu, Y., Zheng, H., Wang, Z. Y., Han, H. T., & Zeng, L. G. (2023). Artificial Intelligence, Resource Reallocation, and Corporate Innovation Efficiency: Evidence from China's Listed Companies. *Resources Policy, 81,* Article 103324. https://doi.org/10.1016/j.resourpol.2023.103324

Li, S. S., Wang, Y. J., Zheng, Y. N., Geng, J. C., & Zhu, J. Q. (2022). Research on Energy Saving and Environmental Protection Management Evaluation of Listed Companies in Energy Industry Based on Portfolio Weight Cloud Model. *Energies, 15,* Article 4311. https://doi.org/10.3390/en15124311

Liao, B., & Li, L. (2023). Urban Green Innovation Efficiency and Its Influential Factors: The Chinese Evidence. *Environment, Development and Sustainability, 25,* 6551-6573. https://doi.org/10.1007/s10668-022-02316-4

Mei, L. H., & Shao, W. (2016). The Effect of Firm Size on Regional Innovation Efficiency in China. *Modern Economy, 7,* 1035-1049. https://doi.org/10.4236/me.2016.710106

Qin, Y. D., Zhang, P., Deng, X. H., & Liao, G. B. (2023). Innovation Efficiency Evaluation of Industrial Technology Research Institute Based on Three-Stage DEA. *Expert Systems with Applications, 224,* Article 120004. https://doi.org/10.1016/j.eswa.2023.120004

Shi, J. H. (2019). Diversified Agglomeration, Specialized Agglomeration and Innovation Efficiency of Pharmaceutical Manufacturing. *Open Journal of Social Sciences, 7,* 147-158. https://doi.org/10.4236/jss.2019.77014

Song, W. F., & Han, X. F. (2022). The Bilateral Effects of Foreign Direct Investment on Green Innovation Efficiency: Evidence from 30 Chinese Provinces. *Energy, 261,* Article 125332. https://doi.org/10.1016/j.energy.2022.125332

Wan, Q. C., Yuan, L., Yao, Z., & Xu, Y. (2023). Impact of Intellectual Property Protection on the Innovation Efficiency in China's Hi-Tech Industry. *Technology Analysis & Strategic Management, 35,* 107-122. https://doi.org/10.1080/09537325.2021.1968372

Wang, K. L., Sun, T.-T., Xu, R.-Y., Miao, Z., & Cheng, Y.-H. (2022). How Does Internet Development Promote Urban Green Innovation Efficiency? Evidence from China. *Technological Forecasting and Social Change, 184,* Article 122017. https://doi.org/10.1016/j.techfore.2022.122017

Wang, M. L. (2023). Effects of the Green Finance Policy on the Green Innovation Efficiency of the Manufacturing Industry: a Difference-in-Difference Model. *Technological Forecasting and Social Change, 189,* Article 122333. https://doi.org/10.1016/j.techfore.2023.122333

Wang, Q., & Ren, S. M. (2022). Evaluation of Green Technology Innovation Efficiency in a Regional Context: A Dynamic Network Slacks-Based Measuring Approach. *Technological Forecasting and Social Change, 182,* Article 121836. https://doi.org/10.1016/j.techfore.2022.121836

Wang, Y., Pan, J.-F., Pei, R.-M., Yi, B.-W., & Yang, G.-L. (2020). Assessing the Technological Innovation Efficiency of China's High-Tech Industries with a Two-Stage Network DEA Approach. *Socio-Economic Planning Sciences, 71,* Article 100810. https://doi.org/10.1016/j.seps.2020.100810

Xi, X., Xi, B. X., Miao, C. L., Yu, R. J., Xie, J., Xiang, R., & Hu, F. (2022). Factors Influencing Technological Innovation Efficiency in the Chinese Video Game Industry: Applying the Meta-Frontier Approach. *Technological Forecasting and Social Change, 178,* Article 121574. https://doi.org/10.1016/j.techfore.2022.121574

Xie, L. Q., Zhou, J. Y., Zong, Q. Q., & Lu, Q. (2020). Gender Diversity in R&D Teams and Innovation Efficiency: Role of the Innovation Context. *Research Policy, 49,* Article 103885. https://doi.org/10.1016/j.respol.2019.103885

Xu, Y., Yuan, L., Lee, H., Baire, S., Nakonieczny, J., & Zhao, X. (2023). Fintech Development and Firm Technological Innovation Efficiency: Empirical Findings in China. *IEEE Transactions on Engineering Management*, 1-11. https://doi.org/10.1109/TEM.2023.3239499

Yang, X. H., Zhang, H. R., & Li, Y. (2022). High-Speed Railway, Factor Flow and Enterprise Innovation Efficiency: An Empirical Analysis on Micro Data. *Socio-Economic Planning Sciences, 82,* Article 101305. https://doi.org/10.1016/j.seps.2022.101305

Yu, H. C., Ke, H. Q., Ye, Y. L., & Fan, F. (2023). Agglomeration and Flow of Innovation Elements and the Impact on Regional Innovation Efficiency. *International Journal of Technology Management, 92,* 229-254. https://doi.org/10.1504/IJTM.2023.128840

Zhou, H. J., & Xu, G. Y. (2022). Research on the Impact of Green Finance on China's Regional Ecological Development Based on System GMM Model. *Resources Policy, 75,* Article 102454. https://doi.org/10.1016/j.resourpol.2021.102454

Zhou, H., Zhang, X., & Ruan, R. (2023). Firm's Perception of Economic Policy Uncertainty and Corporate Innovation Efficiency. *Journal of Innovation & Knowledge, 8,* Article 100371. https://doi.org/10.1016/j.jik.2023.100371