Efficiency Measurement and Influencing Factors Analysis of Green Technology Innovation in Industrial Enterprises Based on DEA-Tobit Model: A Case Study of Anhui Province

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Abstract. With the increasingly severe environmental situation, incorporating environmental effects into the research framework of enterprise technology innovation efficiency, a two-stage DEA model was used to measure the green technology innovation efficiency of industrial enterprises in 16 prefecture-level cities in Anhui Province from 2018 to 2020, and the influencing factors were analyzed in combination with the Tobit model. The results show that the innovation efficiency in the R&D stage is significantly higher than that in the technology transfer stage, and the efficiency performance in the Wanjiang region is significantly better than that in the non-Wanjiang region. Government support, innovation atmosphere, and regional economic development level all have a significant positive impact on the efficiency value of the R&D stage of enterprises. Applied research and government support have a significant negative impact on the innovation efficiency value of the green technology conversion stage, and talent factors have a significant positive impact on this stage. In order to further improve the green technology innovation efficiency of industrial enterprises in Anhui Province, environmental protection should be taken into consideration, an evaluation index system for green technology innovation efficiency of industrial enterprises should be established, and a green economic development model should be established.

Keywords: DEA; DEA-Tobit; Efficiency Measurement; Green Technology Efficiency.

1. Introduction

With the acceleration of industrialization, environmental pollution and resource shortages have become increasingly severe, and the contradiction between economic development and environmental protection has become increasingly prominent. Since the 18th National Congress of the Communist Party of China, China has continuously improved its scientific and technological innovation capabilities and placed technological innovation at the core of China's overall development. As a new model of technological innovation in the new era, green technology innovation not only maximizes the protection of the ecological environment, reduces pollution emissions, and alleviates the shortage of resources, but also drives sustainable economic development through innovation. "Green innovation" refers to innovative activities conducted on the basis of traditional technological innovation, taking into account environmental benefits and without causing harm to the external environment, aiming to achieve the coordination and unity of economic benefits, innovation activities, and environmental benefits, and ultimately achieve green sustainable development [1]. As an important subject in the process of economic development, the improvement of the technological efficiency of industrial enterprises can promote rapid economic development. Therefore, in the process of technological innovation, it is not only necessary to promote the improvement of the efficiency of innovation resource utilization by enterprises, but also to guide enterprises to vigorously carry out green technology innovation activities and transform to green production methods. The improvement of green technology innovation efficiency helps enterprises to integrate resources, seize the core of competition, promote sustainable development of enterprises, and improve their competitiveness in the international market. As the main industry of national

[1] Data from Anhui Statistical Yearbook

economic growth, industry is the cornerstone of economic development. In the era of rapid economic development, green technology innovation is particularly important.

The selected research area in this paper is Anhui Province. As an important industrial province in central China, in recent years, Anhui Province has actively responded to the implementation of the innovation-driven development strategy, and continuously increased investment in scientific and technological innovation. Anhui Province's R&D research funding has increased year by year, from 37.09224 billion yuan in 2016, to 63.94211 billion yuan in 2020, an increase of nearly twice [1]. However, the input of innovative elements is only a necessary condition for improving efficiency, and innovation resources are scarce resources. While increasing innovation investment, it is more necessary to focus on improving innovation efficiency. Green technology innovation, as a new model of technological innovation in the new era, pays more attention to the green innovation efficiency of enterprises. With the increasingly prominent resource and environmental issues, traditional enterprise technological innovation faces challenges. Therefore, this paper considers environmental effects in the research of technological innovation efficiency, measures and analyzes the green technology innovation efficiency of industrial enterprises in prefecture-level cities in Anhui Province using the DEA+Tobit model, discovers problems, and puts forward targeted suggestions. This research has important practical significance for fully utilizing innovative resources, achieving coordinated development of industrial economy and environment, etc.

From previous research, it can be found that the measurement of efficiency is mainly divided into two methods: parameter methods represented by SFA and non-parameter methods represented by DEA. Diao et al. (2011) [2]used the SFA model to measure the technical efficiency of 28 provinces in China. Yi et al. [3]used the stochastic frontier production function model to measure the innovation efficiency of China's high-tech industry from 2000 to 2015 and identified related influencing factors. In non-parametric research methods, Wang et al. [4] used the two-stage DEA method to measure the technological innovation efficiency of China's high-tech industry in the research and development stages, and Liu et al. [5] measured the technological innovation efficiency in the Guangdong-Hong Kong-Macao Greater Bay Area from 2006 to 2017 and conducted empirical analysis on the factors affecting technological innovation efficiency.

Through the above literature review, it can be seen that the relevant literature mainly focuses on the innovation efficiency of regions throughout China or on the innovation efficiency of high-tech zones, and there is relatively little research at the provincial level. Secondly, as an important pillar of China's national economic development, industry has been rarely studied. There is relatively little research on the impact of environmental factors on green technology innovation efficiency. Therefore, this paper uses the DEA+Tobit model to measure the green technology innovation efficiency of industrial enterprises in Anhui Province, analyzes the factors that affect their efficiency, realizes regional coordinated development, improves resource utilization, and provides a basis for transforming economic development.

2. Evaluation index system and model construction

2.1. Research Methodology

Combining with the value chain theory, from a two-stage perspective, the green technology innovation process is divided into two stages: green technology development and green technology achievement transformation, which are interrelated and shared with each other. In the first stage, the green technology development stage mainly involves the transformation of initial innovation inputs of the enterprise into technology outputs, such as patents and inventions. In this stage, the enterprise conducts research, development, and testing based on the guidance of green development ideas. In the second stage, the output achievements of the first stage are transformed into industrialization, market promotion, and operation, turning the output of the first stage into the input of the second stage, and finally obtaining expected economic outputs and some unexpected environmental outputs[8].

Assuming there are n DMUs, denoted as $DMU_j(j = 1,2,3,4\cdots n)$; each DMU has m types of innovation initial inputs, denoted as $x_i(i = 1,2,3,4\cdots m)$, q types of intermediate outputs, denoted as $z_p(T = 1,2,3,4\cdots q)$, and s types of final outputs, denoted as $y_r(r = 1,2,3,4\cdots s)$. Use x_{ij} to represent the input factor quantity of the i-th item of DMU_j, z_{pj} to represent the input factor quantity of the p-th item of DMU_j,, and y_{rj} to represent the input factor quantity of the r-th item of DMU_j. Assuming v_i is the weight of the i-th input, ω_p is the weight of the p-th output, and u_r represents the weight of the r-th output. Assuming the scale return is variable, the BCC model of the two stages is represented as follows:

The first stage is input-oriented BCC model:

$$\min\left[\theta - \varepsilon\left(e_m^T s^- + e_q^T s^-\right)\right]$$

$$\text{s.t}\begin{cases}\sum_{j=1}^{n} x_{ij}\lambda_j + s_j^- = \theta x_{ik}, i = 1,2,\cdots,m \\ \sum_{j=1}^{n} z_{pj}\lambda_j - s_p^+ = y_{pk}, p = 1,2,\cdots,q \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda \geq 0, s_j^- \geq 0 s_j^+ \geq 0, j = 1,2,\cdots n\end{cases}$$

The λ represents the linear combination coefficients of the DMU, and the optimal solution θ* of the model is the efficiency value, which ranges from $(0,1], s_i^-, s_i^+$ represent the slack variables of inputs and outputs, respectively. The above model measures inefficiency by the extent to which various inputs can be proportionally reduced under the condition of constant output. The additional constraint $\sum\lambda_i = 1(\lambda \geq 0)$ is added to the model, which ensures that the production scale of the projection point is at the same level as that of the evaluated DMU.

The second stage is the output-oriented BCC model.

$$\min\left[\theta - \varepsilon\left(e_q^T s^- + e_s^T s^-\right)\right]$$

$$\text{s.t}\begin{cases}\sum_{j=1}^{n} z_{pj}\lambda_j + s_p^- = z_{pk}, p = 1,2,\cdots,q \\ \sum_{j=1}^{n} y_{rj}\lambda_j - s_j^+ = \theta y_{rk}, r = 1,2,\cdots,s \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda \geq 0, s_j^- \geq 0 s_j^+ \geq 0, j = 1,2,\cdots n\end{cases}$$

2.2. Indicator Selection

Green technology innovation inputs. Green technology innovation inputs mainly include personnel inputs and financial inputs. The full-time equivalent of R&D personnel is used to measure personnel inputs in the green technology innovation process of industrial enterprises. Financial inputs are divided into two parts: internal R&D expenses and introduction, digestion, and absorption costs (equal to the sum of technology introduction expenses, digestion and absorption expenses, technology purchase expenses, and technology transformation expenses). The financial inputs are reduced using the R&D expenditure price index, with 2015 as the base year [9].

Intermediate output is measured from the perspective of patents to evaluate the intermediate output of industrial enterprises' green technology innovation activities. Patent applications are often used to measure the actual knowledge innovation output of industrial enterprises and are the most intuitive indicator of knowledge output. The number of patent applications and the number of invention patents granted are selected as the indicators to measure intermediate output.

Expected output is measured by two indicators: sales revenue of new products and industrial value added. Because this paper calculates the green technology innovation efficiency of industrial enterprises, the sales revenue of new products is more representative of the output value brought by innovation, and the industrial value added is reduced using the industrial value added index[9].

Non-expected output. Non-expected output mainly refers to environmental pollution output. It is mainly transformed into an environmental comprehensive index through the entropy method from five indicators: industrial waste gas, wastewater, solid waste, sulfur dioxide, and smoke (dust). The entropy method can summarize the influence of multiple variables and avoid the inaccuracy of single indicator evaluation[9].

The relevant variables are shown in the Table 1 below.

Table 1 Evaluation Index System for Green Technology Innovation Efficiency

Stage	Indicator	Classification	Indicator Name	Calculation
Green Technology Development Stage	Innovation Input	Funds input	R&D expenditure internal expenditure	R&D expenditure price index is reduced by multiplying the consumer price index by 54% and the fixed asset price index by 46%.
			Introduction, digestion and absorption costs	
		Human resources input	R&D personnel full-time equivalent	
	Mid term Input	Patent Invention	Number of patent applications	Directly from the Statistical Yearbook
			Number of effective inventions	
Green Technology Achievement Transformation Stage	Expected Output	Economic Output	New product sales revenue	Industrial producer price index is reduced by averaging.
			Industrial added value	Industrial added value index is reduced by averaging.
	Unexpected Output	Environmental Output	Industrial waste gas, wastewater, solid waste, sulfur dioxide, smoke (dust)	Negative treatment is carried out, and the comprehensive environmental index is calculated using the entropy method.

2.3. Data Source

In this paper, 16 prefecture-level cities in Anhui Province were selected as the evaluation objects, and the data of industrial enterprises above a certain scale from 2018 to 2020 were used to analyze the green innovation efficiency of industrial enterprises. All research data were obtained from the "Anhui Statistical Yearbook".

3. Analysis of Green Technology Innovation Efficiency of Industrial Enterprises in Prefecture-level Cities in Anhui Province

3.1. Efficiency Analysis of Research Stage

Using DEAP2.1 and DEA-SOLVER 5.0 to measure the green innovation technology efficiency of the research stage for 16 prefecture-level cities in Anhui Province from 2018 to 2020, the results are shown in Table 2, and the vertical time trend is shown in Figure 1. In order to make horizontal comparisons, Anhui Province was divided into two blocks: the Wanjiang Demonstration Zone (Hefei,

Wuhu, Ma'anshan, Tongling, Anqing, Chizhou, Chaohu, Chuzhou, Xuancheng) and the non-Wanjiang Demonstration Zone.

Table 2 Science and technology R&D efficiency value

City	2018	2019	2020	Average	City	2018	2019	2020	Average
	Score	Score	Score	Score		Score	Score	Score	score
He Fei	1	0.949	1	0.983	Huai Bei	0.279	0.157	0.567	0.334
Chu Zhou	0.781	0.781	0.781	0.781	Bo Zhou	1	1	1	1
Ma An Shan	0.655	0.393	0.369	0.472	Su Zhou	0.511	0.532	0.532	0.525
Wu Hu	0.962	1	1	0.987	Beng Bu	0.428	0.335	0.335	0.366
Xuan Cheng	0.655	0.512	0.512	0.56	Fu Yang	0.456	0.239	0.471	0.389
Tong Ling	0.547	0.287	0.287	0.373	Huai Nan	0.134	0.322	0.52	0.325
Chi Zhou	1	0.469	1	0.823	Lv An	1	0.793	1	0.931
An Qing	0.938	0.938	0.938	0.938	Non Wanjiang Region	0.544	0.483	0.632	0.553
WanJiang Region	0.817	0.666	0.736	0.74	Total	0.681	0.574	0.684	0.646

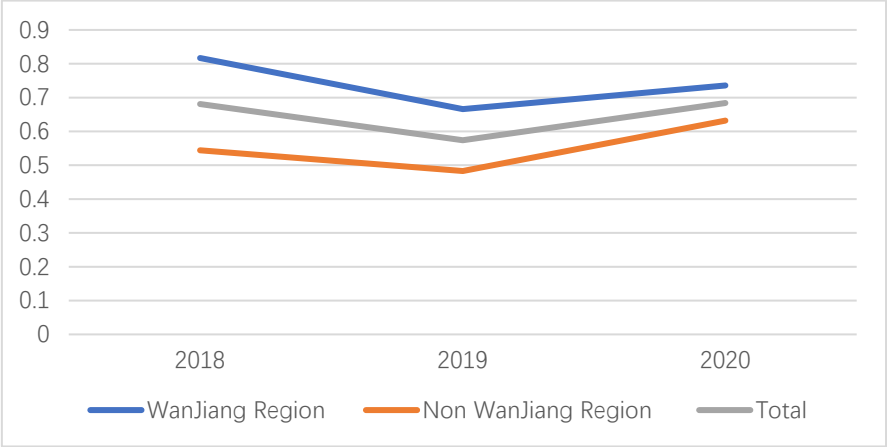


Figure 1 Trends in the efficiency of science and technology research and development

From the changes in Table 3 and Figure 1, it can be seen that from the vertical dimension of time development, the mean R&D efficiency was 0.681, 0.574, and 0.684 in 2018-2020, showing a inverted U-shaped trend, but overall showing a gradually increasing trend, which may be related to Anhui Province's increasing investment in R&D funds in recent years and emphasis on innovative development. In terms of horizontal comparison, there is a large difference in efficiency values between the Wanjiang region and non-Wanjiang regions, with a mean of 0.744 for the Wanjiang region and 0.544 for non-Wanjiang regions. The efficiency of green technology innovation in non-Wanjiang regions is clearly lower than the provincial average, indicating that there is great development potential in non-Wanjiang regions. Since the relevant policies of the Wanjiang City Economic Belt in the 2012 era, the Wanjiang demonstration zone has had a high degree of policy tilt and, with its good location advantages, has promoted the rapid development of science and technology and the continuous transformation and upgrading of industrial structure, as well as the increasingly benign development of the green ecological environment, making it a demonstration base for green development in the province. However, as an underdeveloped area in Anhui Province, non-Wanjiang regions have relatively lacking resource policies, and innovation resources have not been effectively utilized, resulting in lower technological innovation efficiency in the R&D stage. Within the Wanjiang region, it can be found that the R&D efficiency of industrial enterprises in Ma'anshan and Xuancheng needs to be improved, with the three-year average of the two cities consistently at the lowest level in the Wanjiang region. In non-Wanjiang demonstration zones, the R&D efficiency of Huainan and Huaibei is the lowest. Industrial areas in non-Wanjiang regions should learn from the more developed cities in the Wanjiang region and the eastern Yangtze River Delta, and continuously improve their technological innovation efficiency.

3.2. Efficiency analysis of conversion stage

Efficiency analysis in the conversion stage is as follows, with the changes in efficiency trends shown in Table 3 and Figure 2.

Table 3 Achievement transformation efficiency value

City	2018 Score	2019 Score	2020 Score	Average Score	City	2018 Score	2019 Score	2020 Score	Average score
He Fei	1	1	1	1	Huai Bei	1	1	1	1
Chu Zhou	1	1	1	1	Bo Zhou	0.619	1.000	0.732	0.784
Ma An Shan	1	0.787	0.832	0.873	Su Zhou	0.239	0.481	0.598	0.439
Wu Hu	0.965	1	1	0.988	Beng Bu	0.393	0.622	0.688	0.568
Xuan Cheng	0.67	0.747	0.701	0.706	Fu Yang	0.688	0.835	0.833	0.785
Tong Ling	1	1	0.856	0.952	Huai Nan	0.861	0.602	0.427	0.630
Chi Zhou	0.417	0.79	0.902	0.703	Lv An	0.613	0.928	0.618	0.720
An Qing	1	0.978	0.856	0.945	Non Wanjiang Region	0.630	0.781	0.699	0.704
WanJiang Region	0.882	0.913	0.893	0.896	Total	0.756	0.847	0.796	0.800

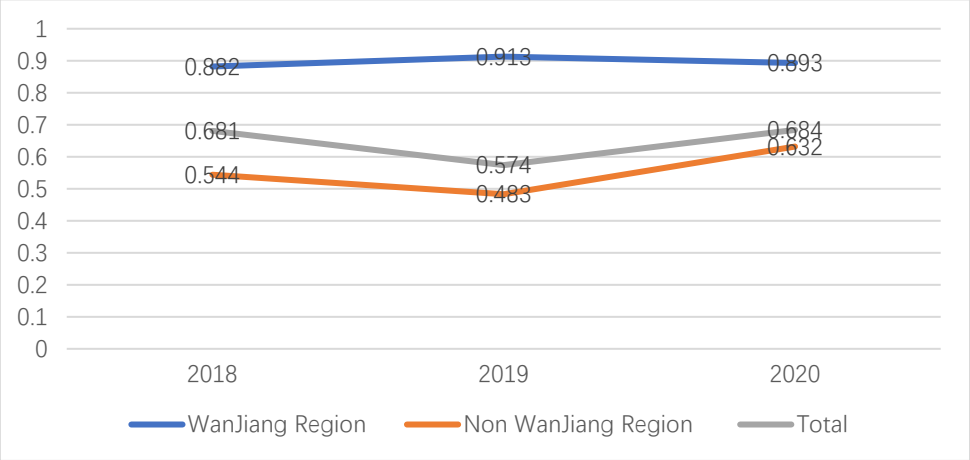


Figure 2 Trends in the efficiency of Achievement transformation efficiency value

Looking longitudinally, the conversion efficiency of scientific and technological achievements shows a trend of increasing year by year. The average value for the entire province is 0.8, indicating that Anhui Province's industrial enterprises have done relatively well in converting scientific and technological achievements into economic and environmental output. Horizontally, the efficiency of the cities in the Wanjian area is 0.896, while the efficiency value of the non-Wanjian area is 0.704, indicating that the efficiency in the Wanjian area is significantly higher than that in the non-Wanjian area. Within the Wanjian area, the cities of Xuancheng and Chizhou performed poorly, while in the non-Wanjian cities, the low innovation efficiency of the cities of Suzhou and Bengbu is an important reason for lowering the average efficiency of the region. Therefore, these two cities should focus on improving the platform for the transformation of scientific and technological achievements, establishing a good environmental awareness and promoting efficiency improvement.

In conclusion, comparing the green innovation efficiency of the two stages, it is found that the efficiency of the first stage is significantly lower than that of the second stage, with an average value of 0.646 for the entire province in the first stage and 0.8 for the entire province in the second stage. The efficiency of scientific and technological innovation and research and development in Anhui Province is the main factor restricting the development of green innovation efficiency in Anhui Province. The results by region show that the green innovation efficiency in the Wanjian area is always higher than that in the non-Wanjian area, whether in the research and development stage or in the conversion stage. The comparison of efficiency values in the two stages also shows a trend of gradual improvement over time. In terms of overall efficiency, Hefei has always been at the forefront

of efficiency, followed by Wuhu. Therefore, these two cities should be used as benchmarks to continuously improve green technology innovation efficiency. The difference in efficiency between the 16 prefecture-level cities in the province in the two stages is significant, but it shows a trend of gradually narrowing.

4. Analysis of Influencing Factors of Green Technology Innovation

4.1. Formation Mechanism of Green Technology Innovation Efficiency

The use of green technology is an important way to improve efficiency under resource constraints, and the use of green technology promotes the intensive use of resources. This is the result of the joint efforts of enterprises, markets, and governments.

Enterprises, as the main body of green innovation technology, are also the biggest beneficiaries of this technology. As "rational economic actors," enterprises pursue the maximization of their own profits, so the fundamental driving force for enterprises to innovate is to improve efficiency and obtain greater profits. Enterprises play an important role in the research and development of green technology and the transformation of results. The government plays a guiding role, mainly through the setting of various regulations and systems, subsidies from fiscal funds, and other means, to guide industrial enterprises to innovate in green technology, internalize the external environmental costs of enterprises, and force them to innovate. The market is the starting point and destination of green technology innovation, and the results of enterprise green innovation must be operated through market participation. Consumers' demand for green consumption is the market foundation of green technology innovation. Enterprises produce environmentally friendly products, and consumers purchase them on the market to give market value to green technology innovation.

4.2. Variable Selection

Firstly, at the enterprise level, three indicators of innovation atmosphere, enterprise scale, and applied research were selected. The innovation atmosphere is expressed by the participation rate of R&D enterprises in industrial enterprises. The more enterprises participate, the more frequent the competition and cooperation between enterprises. The enterprise scale is measured by the ratio of the total output value of industrial enterprises to the number of industrial enterprises. The impact of enterprise scale on the efficiency of green technology innovation is mainly in two directions. On the one hand, the larger the enterprise scale, the more usable funds the enterprise has, and the more obvious the spillover effects of various resource utilization, which is conducive to improving efficiency. On the other hand, as the scale of enterprises expands, organizational redundancy may occur, and enterprise management becomes more difficult, which is not conducive to improving the efficiency of enterprise innovation. Applied research is represented by the proportion of R&D expenses used for experimental development in enterprise R&D funds.

Secondly, at the market level, two indicators of regional economic development level and talent support were selected. The level of regional economic development is measured by the per capita GDP of the region. Regarding the impact of regional economic development level on the efficiency of green technology innovation, some scholars believe that there is a mutually promoting relationship, while others believe that due to the extensive growth of the economy, it may also lead to low efficiency. Talent support is measured by the proportion of the population with a college degree or above to the permanent population.

Finally, at the government level, two indicators of fiscal support and tax incentives were mainly selected to measure. Fiscal support is expressed by the proportion of government funds in internal R&D expenditures. The government promotes the development of enterprise innovation activities through financial support. Tax reduction and exemption policies are also used to encourage enterprises to carry out innovation activities. The tax relief received by enterprises is represented by the proportion of tax reduction and exemption for high-tech enterprises to their industrial added value. As Table 4 below.

Table 4 Variable indicators of influencing factors of green technology innovation efficiency

Level	Measurement Factors	Detail	Notation
Enterprise	Innovation atmosphere	The proportion of the number of R&D enterprises to the total number of enterprises.	CX
	Applied research	The proportion of applied research expenditure in the internal R&D expenditure of enterprises.	YYYJ
	Enterprise scale	Industrial output value divided by the total number of industrial enterprises.	SCALE
Market	Talent	The proportion of population with college education or above to the total population.	RC
	Regional economic development level	The ratio of GDP to the total population.	PGDP
Government	Tax incentive	The proportion of tax reduction and exemption for high-tech enterprises to their industrial added value	JMS
	Government spending	The proportion of government funding to internal R&D expenditure.	ZF

4.3. Model settings

The value range of industrial enterprise green technology innovation efficiency calculated by the DEA method is (0,1), which is prone to truncation. The Tobit model is a limited dependent variable model that can solve this problem well. The model is set as follows:

$$EFF_{it} = c + \beta_1 CX_{it} + \beta_2 ZF_{it} + \beta_3 YYYJ_{it} + \beta_4 JMS_{it} + \beta_5 RC_{it} + \beta_6 SCALE_{it} + \beta_7 PGDP_{it} + \varepsilon_{it}$$

EFF_{it} represents efficiency value, CX_{it} represents innovation atmosphere, ZF_{it} represents government expenditure, $YYYJ_{it}$ represents applied research, JMS_{it}represents tax reduction and exemption, RC_{it} represents talent, $SCALE_{it}$ represents enterprise scale, and $PGDP_{it}$ represents regional economic development level.

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4.4. Regression results and analysis

The regression results of the first phase are as follows Table 5.

Table 5 Regression results of influencing factors in the R&D stage

Variable	Coefficient	Z
Innovation scope	0.915**	-2.21
Government support	4.640*	-1.71
Applied research	0.614	-1.34
Tax incentives	8.946**	-2.17
talent	-2.05	-1.12
Economic development level	6.998*	-1.88
Enterprise scale	-3.966	-1.35
Constant	0.33	-1.19

The innovation scope represents the proportion of enterprises involved in R&D activities and shows a positive significance. As innovation activities among enterprises in the region become more frequent and the innovation atmosphere becomes stronger, the frequency of technological competition and cooperation between enterprises increases, which is conducive to improving innovation efficiency. Government support is significant and positively correlated with efficiency. In recent years, Anhui Province has continuously increased investment in scientific research funds, and the proportion of government funds in R&D expenditures has gradually increased. This provides financial support for industrial enterprises' R&D work, making enterprises more actively involved in R&D work and beneficial to improving efficiency. Tax incentives can increase the enthusiasm of

enterprises to participate in R&D activities by exempting taxes on relevant activities of high-tech industrial enterprises. Talent is not significant here, possibly because people with a college degree or above generally engage in production, marketing, and other activities related to the transformation of scientific and technological achievements, while scientific and technological R&D activities involve more professional R&D personnel. The higher the economic development level of the region, the better material basis it can provide for innovation, such as offering high salaries, which is conducive to promoting the development of R&D activities.

Regression results for the second stage. As follow Table 6.

Table 6 Regression results of influencing factors in the Conversion stage

Variable	Coefficient	Z
Innovation scope	0.128	(0.49)
Government support	-3.951**	(-2.15)
Applied research	-0.891***	(-2.76)
Tax incentives	0.754	(0.22)
talent	2.117**	(2.48)
Economic development level	-1.957	(-0.95)
Enterprise scale	0.740***	(4.98)
Constant	0.128	(0.49)

The government's support is significant, but negatively related to efficiency. As the main body of the market and technology innovation, enterprises may be crowded out by excessive government intervention during the transformation phase. The government should play a guiding role and focus its funds on small and medium-sized technology-based enterprises with good research results but difficult financing. The impact of applied research on enterprise technology research and development efficiency is not significant, but it has a significant negative effect on the efficiency of technology transformation in some regions. Tax incentives are not significant, and existing policies need to be further improved to provide real support to enterprises that are willing to engage in technological innovation activities. Talent has a significant positive impact, indicating that talent is highly involved in technology transfer and promotes efficiency. Enterprise size is not significant in either phase, indicating that enterprise size has little impact on green innovation technology efficiency.

5. Conclusion

There is still a lot of room for improvement in the green technology innovation efficiency of industrial enterprises in Anhui Province, especially in terms of the efficiency of research and development technology, with a provincial average of only 0.646. There is also a significant regional gap within Anhui Province. The performance of the Wanjiang Demonstration Zone is significantly better than that of non-Wanjiang Demonstration Zones. Among the 16 prefecture-level cities, Hefei and Wuhu are in the forefront of efficiency in both phases, with values above 0.8. In the two phases, the innovation efficiency in the research and development phase is significantly lower than that in the conversion phase. From the perspective of the influencing factors of green technology innovation efficiency, innovation atmosphere, government support, tax incentives, and economic development level all have a positive impact on the green innovation efficiency value of Anhui Province in the research and development phase. Government support, applied research, and talent have a significant impact on the efficiency of technology transformation, among which government support and applied research have a negative impact at this stage, while talent has a positive impact on efficiency.

6. Policy Recommendations

First, enterprises should improve their green technology innovation efficiency according to local conditions in the research and development and technology transformation phases. Industrial enterprises in the Wanjiang area, which are in a leading position in green innovation efficiency,

should continuously improve their own green technology innovation level, actively approach the Yangtze River Delta cities and international cutting-edge technologies, improve their independent research and development capabilities, strengthen the digestion and absorption of foreign technologies, and further improve the innovation intermediary service system and results transformation platform. While strengthening their own construction, they should fully leverage the spillover effect of technology, strengthen cooperation and exchanges with regions that lack economic development, and eliminate technological barriers between regional enterprises. In both phases, the emphasis should be on improving the efficiency of the research and development phase, establishing an evaluation index system for the green technology innovation efficiency of industrial enterprises, considering environmental factors in the evaluation system, attaching importance to the impact of environmental factors on technology innovation efficiency, and adopting a development strategy that emphasizes both economic and environmental benefits. Second, the government should fully play the role of a service-oriented government, strengthen guidance for industrial enterprises, provide a good external environment for innovation, and break the innovation path dependence and self-locking state in low-efficiency areas, reducing investment risks and uncertainties. The government's financial investment should encourage enterprises to actively engage in technological innovation, promote cooperation and exchanges among enterprises, and create a culture of innovation throughout society. The government should improve tax incentives for high-tech enterprises, strictly define innovative activities, and truly benefit enterprises that actively engage in green innovation. As the main body and leading role of green technology innovation, enterprises should actively play their role in technology innovation, give full play to the initiative of employees, improve the equity incentive methods of enterprise employees, and fully release the innovation potential of enterprises. The government should increase investment in education, provide a good environment for innovative education from both hardware facilities and software equipment, improve the quality of education and teaching, and cultivate high-quality innovative talents.

Acknowledgements

The authors gratefully acknowledge the financial support from Natural Science project funds.

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