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Inner Mongolia industrial development innovation ability evaluation

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Abstracts: *The innovation and development ability of industry mainly reflects in the industrial innovation activity and the innovation environment improvement. Therefore, this paper analyzes the development and innovation ability of industrial enterprises above designated size (IEADSs) in Inner Mongolia. Two-stage DEA method was used in the project evaluated the technological innovation efficiency in the stage of scientific and technological research and development and the technological innovation efficiency in the stage of achievement transformation of IEADSs in Inner Mongolia. In order to compare the related efficiency, we evaluated the innovation efficiency of IEADSs of 11 provinces and cities in western China. It shows that in the stage of scientific and technological research and development, Inner Mongolia has the lowest innovation efficiency.*

Keywords: *industrial development, innovation ability evaluation, two-stage DEA, Inner Mongolia*

1. Introduction

The innovation and development ability of industry mainly reflects in the industrial innovation activity and the innovation environment improvement. Therefore, this paper analyzes the development and innovation ability of industrial enterprises above designated size （IEADSs） in Inner Mongolia from three perspectives: Industrial innovation input capacity, industrial innovation output capacity and industrial innovation supporting environment.

Industrial enterprises above designated size (hereinafter referred to as IEADSs) are the subject of industrial departments in Inner Mongolia. At the same time, industrial enterprises are also the subject of industrial innovation because of their great technical foundation and abundant funds. Therefore, this topic takes IEADSs as the research object, then evaluates the industrial development and innovation ability in Inner Mongolia by analyzing and evaluating their innovation efficiency.

2. The Innovation and Development Ability of Industry

2.1 Innovation Input Capacity

The investment of science and technology covers a wide range. Through reviewing literature and combining with the reality of Inner Mongolia, this paper plans to analyze the technological innovation input of IEADSs in Inner Mongolia from three perspectives, including: R&D institutions, R&D activities and human capital.

2.1.1 Research and Development Institutions

During the "13th Five-Year Plan" period, the proportion of IEADSs in Inner Mongolia with R&D activities and R&D institutions changed little. From 2016 to 2019, the number of IEADSs with R&D activities and R&D institutions decreased, while the total number of IEADSs decreased increasingly from 4295 to 2964, hence the proportion of the former to the latter was basically unchanged, as shown in Fig.1.

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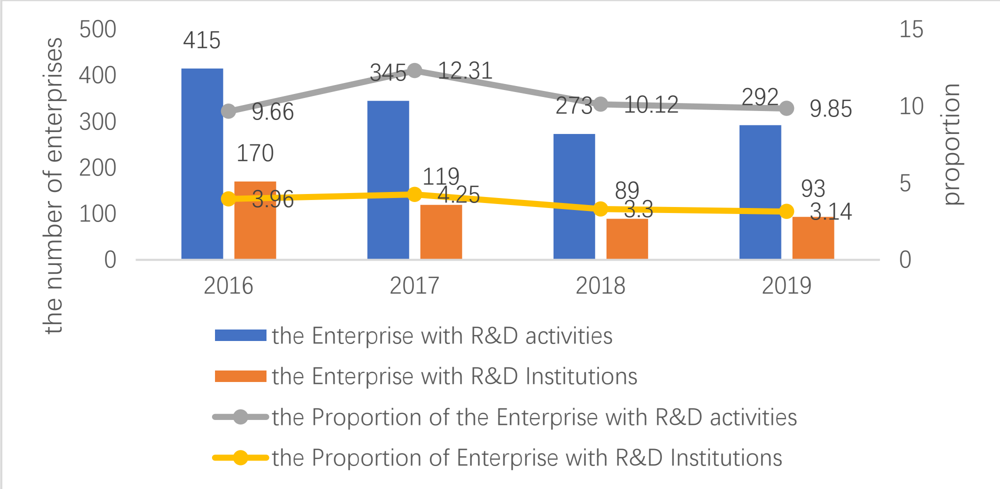

Fig.1 R&D Institutions of IEADSs in Inner Mongolia

Data source: China Science and Technology Statistics Yearbook

2.1.2 Research and Development Activities

(1) R&D project investment

During the “13th Five-Year Plan” period, the number of R&D projects and internal expenditure of R&D funds of IEADSs in Inner Mongolia increased little. However, the average internal expenditure of R&D funds, the number of new product development projects and expenditure for new product development increased significantly.

From 2016 to 2019, overall, the R&D funds of IEADSs in Inner Mongolia rise after the first drop, basically remaining the same. The number of new product development projects increased by 32.3%, while the expenditure for new product development projects increased by 40.8%. From the perspective of the average number of enterprises, with the total number of IEADSs decreasing by 31% and the average internal expenditure of R&D funds increasing by 43.7%, the number of new product development projects and the expenditure for new product development increased by 91.7% and 104.1% respectively, which indicated that the R&D density of IEADSs increased significantly in Inner Mongolia, as shown in figure 2.

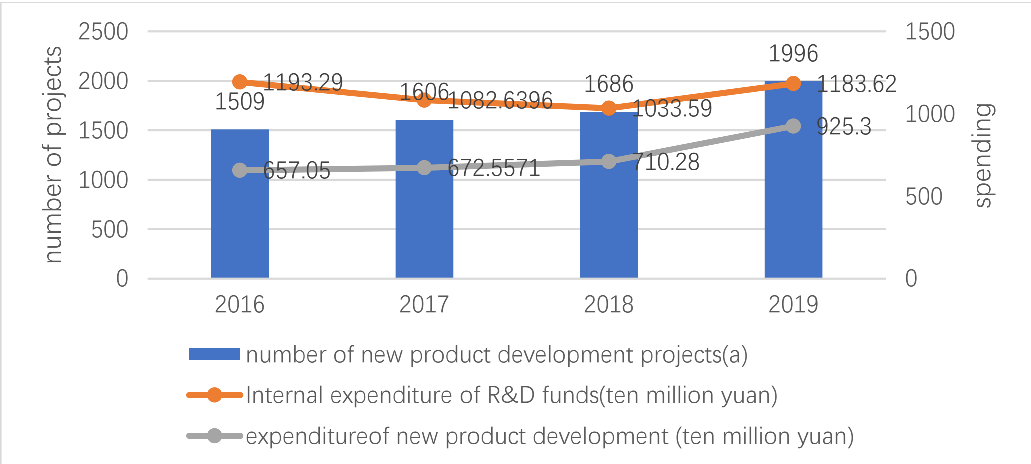

Fig.2 R&D Projects and Expenditure of IEADSs in Inner Mongolia

Data source: China Science and Technology Statistics Yearbook

(2) Spending on Technology Acquisition and Reform

During the "13th Five-Year Plan" period, the spending on technology acquisition and reform of IEADSs in Inner Mongolia decreased on the whole. Among them, the expenditure on technology introduction, digestion and absorption and domestic technology purchase decreased increasingly, then the expenditure on technology reform increased steadily. As shown in figure 3, from 2016 to 2019,

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IEADSs' technology related expenditures in Inner Mongolia decreased by 13.9%. Among them, the expenditure on importing foreign technology dropped by 49.4%; Expenditures on domestic technology purchases decreased after an initial increase, with an overall decrease of 46.8%, and expenditures on technology digestion and absorption decreased by 23.1%; Expenditures on technology reform rose by a modest 1.2%. Average corporate spending on technology acquisition and reform rose 24%.

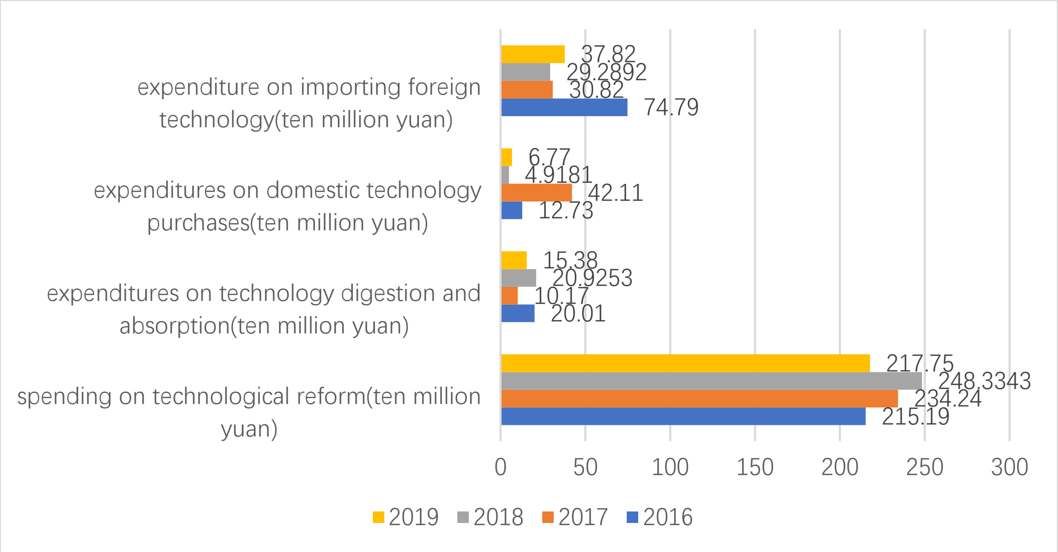

Fig.3 Spending on Technology Acquisition and Reform of IEADSs in Inner Mongolia

Data source: China Science and Technology Statistics Yearbook

2.1.3 Human Capital Investment

During the "13th Five-Year Plan" period, the total number of R&D personnel and the proportion of R&D personnel of IEADSs in Inner Mongolia decreased. From 2016 to 2019, the R&D personnel and their full time equivalent of IEADSs in Inner Mongolia decreased by 35.1% and 50.2% respectively, while the average R&D personnel of enterprises decreased by 6%, and the proportion of R&D personnel in enterprises decreased slightly. As shown in Figure 4.

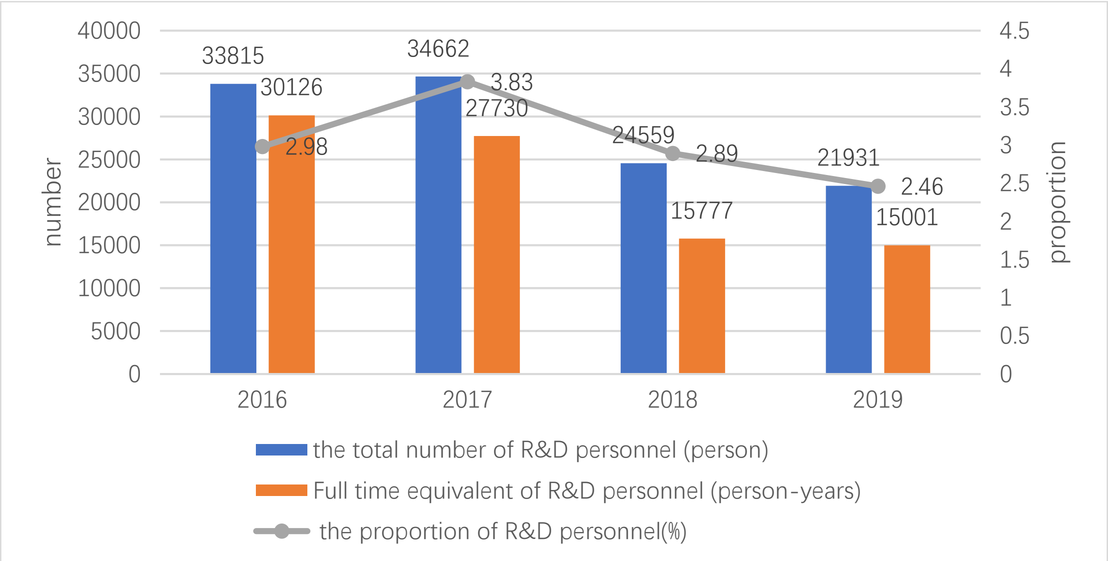

Fig.4 Total R&D Personnel of IEADSs in Inner Mongolia

Data source: China Science and Technology Statistics Yearbook

In summary, during the "13th Five-Year Plan" period, overall, in the innovation investment of IEADSs in Inner Mongolia, in addition to the number of new product development projects and expenditure increasing significantly, R&D funds, spending on technology acquisition and reform and R&D personnel investment decreased; However, in the average enterprise innovation investment, the

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R&D project and R&D funds, the spending on technology acquisition and reform all increased significantly, the new product development project and expenditure doubled, while the R&D personnel investment decreased.

2.2 Innovation output capacity

This paper intends to analyze the technological innovation output capacity of IEADSs in Inner Mongolia from three aspects: sales revenue of new products, new technology output and other innovation output (number of standard formation, number of registered trademarks and number of scientific and technological papers published).

2.2.1 New product output

During the 13th "Five-Year Plan" period, the new product sales revenue of IEADSs in Inner Mongolia increased significantly. From 2016 to 2019, the new product sales revenue of IEADSs increased by 57.4%, while the average enterprises' new product sales revenue increased by 1.28 times, as shown in Figure 5.

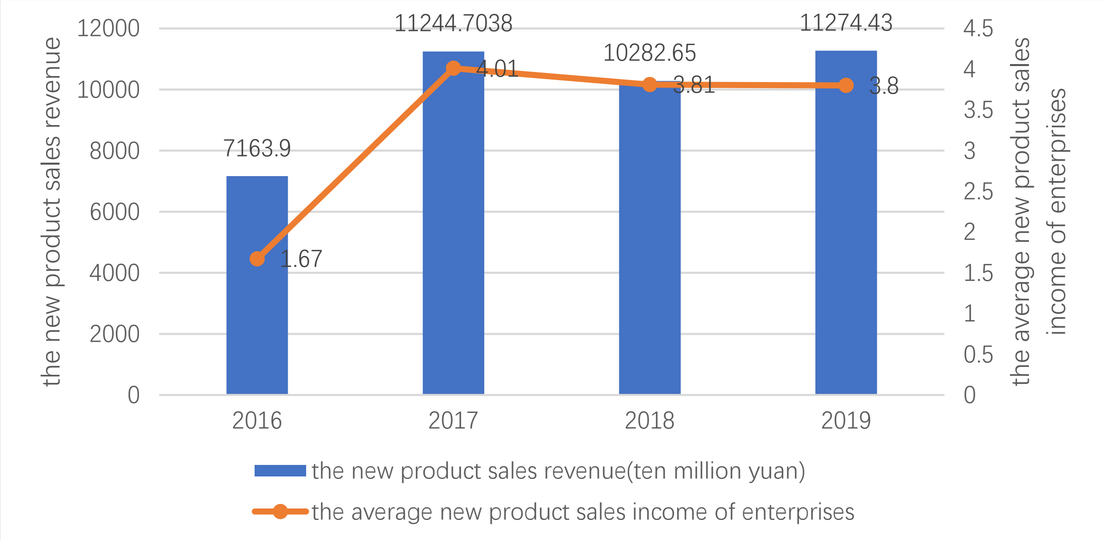

Fig. 5 New Product Sales Revenue of IEADSs in Inner Mongolia

Data source: China Science and Technology Statistics Yearbook

2.2.2 New Technology Output

During the "13th Five-Year Plan" period, the number of patent applications and effective invention patents of IEADSs in Inner Mongolia increased significantly, and the average number of patent applications and the average number of effective invention patents of enterprises doubled. From 2016 to 2019, as shown in Fig. 6, the number of patent applications and invention patent applications of IEADSs in Inner Mongolia increased by 97%, and the number of effective invention patents increased by 1.23 times; The average number of patent applications and the average number of invention patents applications of enterprises increased by 1.85 times, while the average number of effective invention patents increased by 2.24 times.

2.2.3 Other Innovative Outputs

During the "13th Five-Year Plan" period, other output of IEADSs in Inner Mongolia increased significantly. As shown in Figure 7, from 2016 to 2019, the number of technologies forming national or industrial standards of IEADSs in Inner Mongolia increased by 1.8 times, the number of registered trademarks increased by 42.5%, and the number of the formation of national or industrial standards increased by 34.7%.

To sum up, during the "13th Five-Year Plan" period, the innovation output of IEADSs in Inner Mongolia is remarkable. Among them, the new product sales revenue, the number of patent applications and the number of valid patents all increased significantly, while the formation of national or industrial standards increased by nearly two times.

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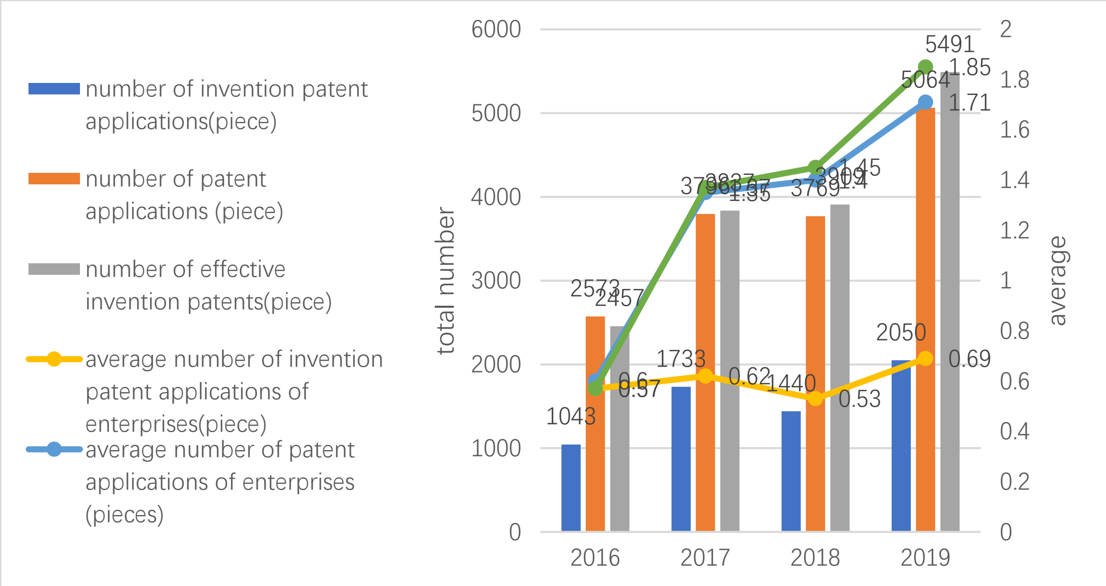

Fig. 6 Patent Application and Acquisition of IEADSs in Inner Mongolia

Data source: China Science and Technology Statistics Yearbook

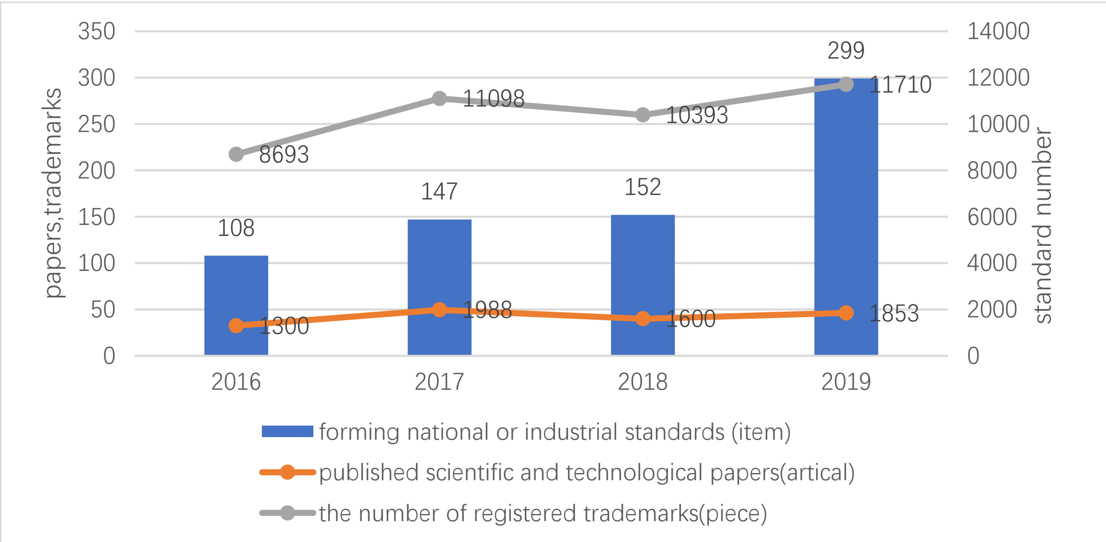

Fig.7 Other Innovation Output of IEADSs in Inner Mongolia

Data source: China Science and Technology Statistics Yearbook

2.3 Innovation Supporting Environment

This paper analyzes the technological innovation supporting environment of Inner Mongolia industry from the three indicators, including R&D funds from government departments, additional deductions and tax exemptions for R&D funds and tax exemption for high-tech enterprises.

During the "13th Five-Year Plan" period, the innovation supporting environment of IEADSs in Inner Mongolia has been increasingly improved. As shown in Fig. 8, from 2016 to 2019, the R&D funds from government departments of IEADSs in Inner Mongolia decreased by 3.2%, while additional deductions and tax exemptions for R&D funds and tax exemption for high-tech enterprises increased by 3.9 times and 3.6 times respectively.

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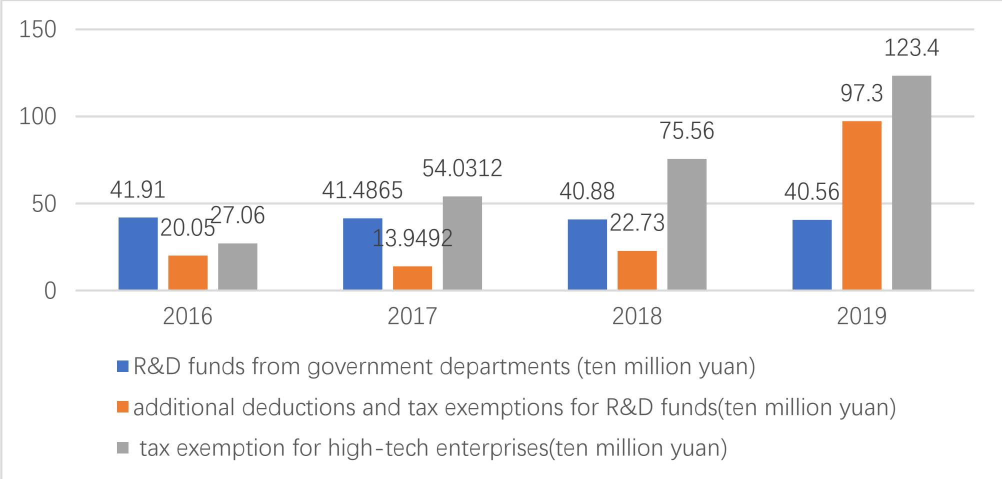

Fig.8 Innovation Supporting Environment of IEADSs in Inner Mongolia

Data source: China Science and Technology Statistics Yearbook

3. Comprehensive evaluation of innovation ability

3.1 Model building

This paper uses technological innovation efficiency to measure the innovation ability of IEADSs in Inner Mongolia. Technological innovation efficiency refers to the ratio of output to input of technological innovation activities.

At present, the research on innovation efficiency at home and abroad mainly uses stochastic frontier analysis (SFA) and data envelope analysis (DEA). Combined with the reality of the research object, DEA method is selected for evaluation.

From the perspective of value chain, according to the characteristics of R&D and innovation of IEADSs, the technological innovation activities can be divided into two stages: the stage of scientific and technological research and development and the stage of transformation of achievements. The stage of scientific and technological research and development shows input of R&D funds and R&D personnel, output of new technology and new product projects; On the one hand, the input of the stage of technological achievements transformation includes the output of the previous stage -- new technology and new product projects, on the other hand, the spending on technology acquisition and reform is reinvested, and the output is manifested as new technology and new product.

In line with the above innovation process, the two-stage DEA method used in the project evaluated the technological innovation efficiency in the stage of scientific and technological research and development and the technological innovation efficiency in the stage of achievement transformation of IEADSs in Inner Mongolia.

In terms of DEA model selection, Andersen et al. proposed super efficiency DEA model, which can avoid the problem that all efficiency values are 1 when efficiency is effective in traditional DEA models, and better distinguish the efficiency levels of decision making units on the DEA frontier.

The mathematical expression of the super efficiency DEA model is as follows:

$$\begin{cases} min\theta \\ \sum_{i=1,j\neq 1}^{n} x_j\lambda_j + s^- = \theta X_0 \\ \sum_{i=1,j\neq 1}^{n} y_j\lambda_j - s^+ = Y_0 \\ \lambda_j \geq 0, j = 1,2,\dots k-1, k, \dots n \\ s^- \geq 0, s^+ \geq 0 \end{cases} \quad (1)$$

Model (1): x_j, y_j are respectively the set of input and output variables of the J_{th} DMU; λ is the k_{th} weight of decision-making unit. θ is the efficiency value of DMU. s^+, s^- are slack variables.

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3.2 Variables and sample selection

referred to the existing literature and combined with the actual situation of innovation of IEADSs in Inner Mongolia, in the first stage -- the stage of scientific and technological research and development, the innovation input indexes are selected as per capita assets of employees, average asset size of enterprises, proportion of R&D personnel investment in employees and proportion of R&D internal funds in total assets. The innovation output indexes are selected as per capita effective invention patents of R&D personnel, per capita patent applications of R&D personnel and number of new product development projects. In the second stage, the stage of achievement transformation, the innovation input indexes are selected as per capita effective invention patents of R&D personnel, per capita patent applications of R&D personnel, per capita number of new product development projects of R&D personnel and proportion of technical reform funds in total assets. The innovation outputs indexes are selected as per capita profit of employees, per capita technology output of R&D personnel and per capita new product sales revenue of employees, as shown in Table 1.

Table 1 Evaluation Index of Innovation Efficiency of IEADSs in Inner Mongolia

Input in the stage of scientific and technological R&D	**intermediate output**	**Secondary input**	**Output in the stage of scientific and technological achievements transformation**
per capita assets of employees（100 million yuan/ten thousand people）, average asset size of enterprises（100 million yuan /enterprise, proportion of R&D personnel investment in employees(person /ten thousand), and proportion of R&D internal funds in total assets.	per capita effective invention patents of R&D personnel (piece/person), per capita patent applications of R&D personnel (piece/person), per capita number of new product development projects of R&D personnel (piece/person)	proportion of technical reform funds in total assets	per capita profit of employees (100 million yuan/ten thousand people), per capita technology output of R&D personnel (100 million yuan/ people), and per capita new product sales revenue of employees(100 million yuan/ten thousand people)

In order to make the evaluation results more comparable, 11 provinces and cities of the "Western Development" were selected as the reference frame (Xizang was not included due to lack of data).Since there is a certain time lag in the transformation of technological innovation resources from input to final output and the lag period of the project is 2 years, that is, the first-stage innovation input, intermediate output and secondary input, and the second-stage innovation output data are 2016, 2017 and 2018 respectively. All data is from China Statistical Yearbook of Science and Technology, China Statistical Yearbook.

Descriptive analysis of input-output data is shown in Table 2.

Table 2 Descriptive Statistical Analysis of Input-Output Data

Indicator	per capita assets of employees	average asset size of enterprises	proportion of R&D personnel investment in employees	proportion of R&D internal funds in total assets	R&D personnel's per capita effective invention patents	R&D personnel's per capita patent applications
Max	305.2047	10.3605	404.7312	0.0117	0.2635	0.271
Min	91.7619	2.7952	156.3338	0.0013	0.104	0.1197
Mean	196.5636	5.3651	286.534	0.0047	0.1839	0.1826
Std. Err	71.6326	2.3035	84.7869	0.0027	0.0483	0.0389

Indicator	new product development projects per capita of R&D personnel	proportion of technical reform funds in total assets	per capita profit of employees	per capita new product sales revenue of employees	R&D personnel's per capita technology output
Max	0.1288	0.0052	16.9603	272371.6408	685.8712
Min	0.0507	0.0007	3.6453	55247.6104	6.7542
Mean	0.0936	0.0026	9.7654	122924.3144	140.9636
Std. Err	0.0239	0.0014	4.0696	57688.7068	193.6053

3.3 The Evaluation Results

In order to Compare Inner Mongolia with western ten provinces and cities, we reused the Model (1)

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to evaluate the innovation efficiency of IEADSs of 11 provinces and cities in western China. It shows that in the stage of scientific and technological research and development, Inner Mongolia has the lowest innovation efficiency, which is reflected in the large input of R&D personnel and funds, while the output of patent and new product development projects are less. In the stage of scientific and technological achievements transformation, IEADSs in Inner Mongolia have absolute advantage, which are reflected in the large output of profits, new product sales revenue and technology output, as shown in Fig.9. The evaluation results show that compared with other western provinces and cities, the basic industrial research in Inner Mongolia is not that good, while it has a greater advantage in the technological application.

	province	efficiency value	per capita assets of employees s-(1)	average asset size of enterprises s-(2)	proportion of R&D personnel investment in employees s-(3)	proportion of R&D internal funds in total assets s-(4)	R&D personnel's per capita effective invention patents s+(1)	R&D personnel's per capita patent applications s+(2)
the stage of scientific and technological research and development	Xinjiang	1.414	0	0	0	0.0003	0.0964	0.1
	Guangxi	1.3689	24.5663	0	109.1512	0	0.0035	
	Qinghai	1.1673	0	0	0	0.0001	0	
	Yunnan	1.0593	0	0	0	0	0	
	Guizhou	1.0321	0	0	0	0	0.0195	
	Sichuan	1.0275	0	0.3303	0	0	0	
	Chongqing	1.0274	0	0.3272	0	0	0	
	Ningxia	0.7737	0	0.3273	72.7136	0	0.058	0.04
	Gansu	0.5102	103.059	2.7928	159.6084	0	0.0429	
	Shaanxi	0.4273	92.5842	2.5883	253.3503	0.0013	0	0.04
	Inner Mongolia	0.3294	182.3762	4.852	184.6531	0	0.0649	0.03

	province	efficiency value	R&D personnel's per capita effective invention patents s-(1)	R&D personnel's per capita patent applications s-(2)	new product development projects per capita of R&D personnel s-(3)	the proportion of technical reform funds in total assets s-(4)	the per capita profit of emplyees s+(1)	per capita sales revenue of new products of employees s+(2)
the achievement transformation stage	Inner Mongolia	1.3915	0.0262	0	0	0.0001	5.3798	27085.97
	Qinghai	1.29	0	0	0	0	0	
	Shaanxi	1.1356	0	0.0508	0.0109	0	0.0883	
	Chongqing	1.1202	0	0	0	0	0	116931.7
	Xinjiang	1.0733	0	0	0	0	0	
	Gansu	1.0072	0	0	0.002	0	0	
	Sichuan	0.4203	0.1225	0.019	0	0.0008	3.3368	
	Guizhou	0.3639	0.0507	0.0168	0	0.0021	0	14422.84
	Yunnan	0.2265	0.0014	0	0.0401	0.0004	2.6892	17065.85
	Ningxia	0.1623	0	0	0.009	0.0007	4.4482	
	Guangxi	0.1564	0.0334	0	0.0131	0.003	5.2044	

Fig.9 DEA Evaluation and Improvement of Technological Innovation Efficiency IEADSs of 11 Provinces and Cities in western China

4. Conclusion

Through the analysis of the innovation input, innovation output and innovation supporting environment of IEADSs in Inner Mongolia and the evaluation of the innovation efficiency of IEADSs, the following conclusions are drawn.

4.1 Innovation input.

The decrease of investment in industrial basic innovation in Inner Mongolia is reflected in the decrease of R&D funds and R&D personnel; the increase of investment in technology transformation is manifested as a substantial increase in new product development projects and expenditure. From the

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average index, except for the R&D personnel, the innovation investment of IEADSs has increased significantly.

4.2 Innovation output.

Industrial innovation output increased significantly in Inner Mongolia. Among them, the new product sales revenue, the number of patent applications and the number of valid patents all increased significantly, besides the formation of national or industrial standards increased by nearly two times.

4.3 Innovation supporting environment.

Overall, the innovation supporting environment of IEADSs in Inner Mongolia has been greatly improved. In addition to a small decrease in R&D funds of government departments, additional deductions and tax exemptions for R&D funds and tax exemptions for high-tech enterprises have doubled.

4.4 Innovation ability.

Compared with the other 10 western provinces, the innovation efficiency in the stage of scientific and technological research and development in Inner Mongolia is lower, while the technological achievements transformation efficiency is higher. It shows that Inner Mongolia has more advantages in the aspect of technological achievements transformation.

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