Evaluation of industry-university-research innovation efficiency in colleges and universities and its impact on provincial innovation——Based on the Malmquist index and grey management model

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Abstract. Taking science and engineering universities and humanities universities in 31 provinces as the main research subject, this paper uses the Malmquist index and gray management model to measure and evaluate the changes of industry-university-research innovation efficiency in colleges and universities in various provinces, and explores the impact of industry-university-research innovation efficiency on provincial innovation in the two types of universities. The results show that the innovation efficiency of industry-university-research in science and engineering universities is declining, and the innovation efficiency of industry-university-research in humanities universities is increasing, and the research area is divided into three types based on its efficiency changes, double increase provinces, single increase provinces and double decline provinces. The correlation between the innovation efficiency of industry, education and research and the innovation efficiency of provincial universities in China is significant, which is divided into science and engineering university-led and humanities university-led, and science and engineering universities have a more significant impact on provincial innovation and development. The changes in the innovation efficiency of production, education and research in colleges and universities and the impact on the innovation efficiency of provinces have not been consistent..

Keywords: universities; Industry-university-research innovation efficiency; provincial innovation; Malmquist index.

1 Introduction

This Industry-university-research collaborative innovation refers to enterprises, colleges and universities, research institutes on the basis of innovation resource sharing and innovation advantages complementarity, to cooperative research and development, benefit sharing, risk sharing as the principle, jointly carry out technological innovation activities of the collaborative mode, its essence is technology, talents, information and management and other innovation elements of the effective integration, domestic scholars believe that collaborative innovation activities is a systematic and complex mechanism interaction mode, the key to do a good job in knowledge innovation and technological innovation, government and financial institutions to assist. Effectively promote knowledge sharing and technology transfer, so as to carry out in-depth cooperation and achieve the utility of "1+1+1>3". From a macro

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perspective, collaborative innovation is to realize the synergy of various subsystems within the national innovation system, that is, the collaboration of knowledge innovation system, technological innovation system, knowledge dissemination system and 7 and knowledge application system. Think from a microscopic point of view. Collaborative innovation is the coordination, configuration and integration of multiple innovation resources and multi-party innovation subjects in the field.

Industry-university-research innovation is a multi-level, multi-subject comprehensive innovation model. In recent years, industry-university-research innovation has attracted more and more attention from scholars. Foreign scholars mainly conduct research on industry-university-research innovation from the perspectives of conceptual model, participation theme, efficiency evaluation and influencing factors, and the research methods are diverse[1-3]. Chinese scholars have also conducted rich research on the efficiency of industry-university-research innovation. Lu Minfeng[4], Zhuang Tao[5], Jiang Yan[6], etc., respectively, studied the innovation efficiency of the three main subjects of production, education and research from the financial industry, high-tech industry and medical manufacturing industry. Yang Qiuyue[7], Wang Bangjun[8], Yao Xiaoying[9], Zhu Jingyi[10], Chen Huaichao[11], etc. explored the influencing factors of industry-university-research innovation efficiency from different angles, and believed that the level of opening up, market demand, enterprise scale, government funding, and institutional guarantee all have different degrees of impact on the development of industry-university-research innovation efficiency. Zhang Xiufeng [12], Xiao Zhenhong [13], Duan Yunlong [14], Luo Xiaoxiao [15], Li Ying [16] and other negative binomial regression models, threshold regression model, coupled coordination degree model, Super-SBM model and network DEA model and other quantitative research methods to measure and evaluate the efficiency of industry-university-research innovation.

On the whole, most of the domestic and foreign research on industry-university-research innovation is based on the macro level of the overall empirical analysis of industry-university-research as a whole. Few scholars study the innovation efficiency of industry-university-research in universities, and there is a lack of systematic evaluation and research on the efficiency of industry-university-research innovation input-output in universities, and little attention is paid to the relationship between it and provincial innovation efficiency. Therefore, this paper takes universities across the country as the main body of research, constructs an evaluation index system for industry-university-research innovation efficiency, uses the malmquist index to measure the change value of industry-university-research innovation efficiency in science and engineering universities and humanities universities in various provinces, analyzes the change characteristics of industry-university-research innovation efficiency in colleges and universities in different provinces, and explores the relationship between it and provincial innovation with gray management model, discusses the countermeasures to the problem of industry-university-research innovation and development in universities, and hopes to provide reference experience for industry-university-research innovation and provincial innovation and development research in colleges and universities.

2 Research methods and index selection

2.1 Research Methods

Malmquist exponential model. The Malmquist productivity index was proposed by the Swedish economist Malmquist, and Fare and other scholars combined it with the DEA model to expand it into the total factor productivity index (TFPch), which is suitable for evaluating dynamic production efficiency across periods, and TFPch can be decomposed into Techch (Technological Progress Change Index) and Effch (Technological Efficiency Change Index); Effch can be further broken down into Pech (pure technical efficiency change index) and Sech (scale efficiency change index). TFPch= Techch*Pech*Sech. It can be used to measure the dynamic changes in the efficiency of industry-university-research innovation in colleges and universities in various provinces. The index expression formula is:

$$\mathrm{M}(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{d^{t+1}(x_{t+1}, y_{t+1})}{d^t(x_t, y_t)} \left[\frac{d^t(x_{t+1}, y_{t+1})}{d^{t+1}(x_{t+1}, y_{t+1})} \times \frac{d^t(x_t, y_t)}{d^{t+1}(x_t, y_t)} \right]^{\frac{1}{2}} \tag{1}$$

In the formula, $(x_t, y_t,)$ represents the input in the t period, (x_{t+1}, y_{t+1}) represents the output in the t+1 period, and $d^t(x_{t+1}, y_{t+1})$ represents the distance function of the t+1 period, that is, the efficiency of the t+1 period is measured by the distance of the production front in the t period, and the results can be divided into three situations: when M>1 indicates that the efficiency of tourism poverty alleviation is improved; M=1 indicates that the level of tourism poverty alleviation remains unchanged; M<1 indicates a decline in the level of tourism poverty alleviation follow the formatting instructions for headings given in Table 1.

Gray management model. Gray correlation model is a multi-factor analysis method, mainly used to analyze the strength of the relationship between related factors, with gray correlation degree to quantitatively characterize the degree of correlation between each factor, the greater the degree of grey correlation, the greater the degree of correlation between the two factors, and vice versa. The efficiency of industry-university-research innovation and the efficiency of provincial innovation in colleges and universities are related and interact, so the gray correlation model is adopted, and the specific calculation formula is as follows:

$$\gamma(x_0(k), x_i(k)) = \frac{\min\limits_i \min\limits_k |x_0(k) - x_i(k)| + \sigma \max\limits_i \max\limits_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \sigma \max\limits_i \max\limits_k |x_0(k) - x_i(k)|} \tag{2}$$

$$\gamma(X_0, X_i) = \frac{1}{n} \sum_{k=1}^{n} \gamma(x_0(k), x_i(k)) \tag{3}$$

Then$\gamma(x_0, x_1)$is the grey correlation betweenx_0 and x_1, where σ is the resolution coefficient, σ∈(0,1), usually σ=0.5. If the correlation degree is greater than 0.6, the correlation is significant.

2.2 Indicator selection

All When using the DEA method to study the innovation efficiency of production, education and research in universities, there are high requirements for the reasonable selection of input-output indicators. From 2013 to 2018, this paper takes science and engineering universities and humanities universities in various provinces as the decision-making unit of industry-

university-research innovation, and its industry-university-research innovation efficiency can be characterized as the output results under the input level of industry-university-research factors of a certain scale. At present, there is no clear standard industry-university-research innovation efficiency measurement index at home and abroad, according to the literature, the usual practice is to select calculable alternative indicators to characterize the industry-university-research input-output process and efficiency evaluation. Based on relevant research results, the evaluation index system of industry-university-research innovation efficiency was constructed from the two aspects of input and output, and the results are shown in Table 1.

Table 1. Evaluation index system of industry-university-research innovation efficiency

Evaluate the object	Input indicators	Output indicators
Science,engineering, agriculture, and medicine	Full-time equivalent of R&D personnel	Publication of scientific papers
	Funds internal expenditure on production, education and research	Publication of scientific and technical works
	Funding: External expenditure on production, education and research	Valid invention patents
Humanities and Social Sciences	Full-time equivalent of R&D personnel	Publication of scientific papers
	Funds internal expenditure on production, education and research	Publication of scientific and technical works
Provinces	Full-time equivalent of R&D personnel	Technology market turnover
	Funds internal expenditure on production, education and research	New product sales
	Funding: External expenditure on production, education and research	Number of patents granted
		Number of scientific papers

In terms of investment indicators, for the two types of university subjects, the investment in production, education and research mainly involves manpower and funds [17], and the full-time equivalent of R&D personnel can reflect the human resources invested by universities in industry-university-research innovation; The internal and external expenditure of industry-university-research can evaluate the financial support of universities in industry-university-research innovation, which is limited by the availability of data science, and the investment index of industry-university-research in humanities universities excludes the external expenditure on industry-university-research. In addition, provincial innovation input also selects these two indicators as human and capital investment indicators.

In terms of output indicators, scientific research achievements are the pursuit goal of industry-university-research innovation, science and engineering universities choose to publish scientific and technological papers, scientific and technological works and effective invention patents as output indicators, and humanities universities choose to publish scientific and technological papers and scientific and technological works as output indicators. In addition, provincial innovation includes three major subjects: enterprises, universities and scientific research institutions, drawing on existing research and selecting technology market turnover,

new product sales, patent authorizations and scientific and technological papers to characterize the industry-university-research innovation output of the three subjects.

2.3 Data Sources

The original data in this paper comes from the 2013-2019 "China Science and Technology Statistical Yearbook", usually, there is a certain lag in the input and output of universities, and this paper selects a lag of 1 year, such as the input data in 2013 corresponds to the output data in 2014. In order to ensure the comparability of data and eliminate the impact of price fluctuations, this paper treats the internal and external expenditures of industry, academia and research institutes at constant prices with the CPI (Consumer Price Index) in the statistical yearbook. Technology market turnover and new product sales are treated at constant prices using the PPI (Industrial Price Index) in the statistical yearbook.

3 Evaluation of innovation efficiency of industry-university-research in colleges and universities

3.1 Analysis of innovation efficiency of production, education and research in colleges and universities

Through DEAP 2.1 software, the Malmquist index of colleges and universities in 31 provinces from 2013 to 2018 was measured, and the changes in the efficiency of industry-university-research innovation were analyzed, and the results were shown in Table 2 and Figure 1. The average efficiency of industry-university-research innovation in science and engineering universities was 0.984, which showed a state of decline, and the efficiency changes in various provinces in the country fluctuated significantly. The average efficiency of industry-university-research innovation in humanities colleges and universities was 1.084, showing an increasing trend, except for Tianjin and Shanxi, which declined, and other provinces achieved growth. According to the growth and change of industry-university-research innovation efficiency of science and engineering universities and humanities universities in China, the research area can be divided into three types: (1) double-increase provinces, that is, the industry-university-research innovation efficiency of the two types of universities is increasing; (2) Single-growth provinces, that is, the innovation efficiency of industry, education and research of the two major types of universities is only one type of college, and the innovation efficiency of the colleges and universities is increasing; (3) The efficiency of production-university-research innovation in double-descending provinces, that is, the two types of universities, has shown a downward trend.

Table 2. Innovation efficiency of industry, education and research in science and engineering and humanities colleges and universities nationwide

region	province	Science and engineering universities					Humanities universities				
		techch	pech	sech	tfpch	Variability	techch	pech	sech	tfpch	Variability
	Beijing	1.014	1	1	1.014	increase	1.017	1	1.064	1.082	increase
eastern	Tianjin	1.019	1	1	1.019	increase	1.046	0.967	0.974	0.985	decline
	Hebei	0.919	0.986	1.071	0.97	decline	1.037	1.001	1.002	1.04	increase

	Shanghai	0.984	1	1.065	1.048	increase	1.014	1.036	1.053	1.106	increase
	Jiangsu	0.995	0.963	1.01	0.968	decline	1.111	1.012	0.988	1.11	increase
	Zhejiang	1.029	0.968	0.999	0.995	decline	1.023	1	1	1.023	increase
	Fujian	0.986	1.047	1.022	1.055	increase	1.142	1.04	0.956	1.136	increase
	Shandong	0.966	0.992	0.999	0.958	decline	1.025	1.023	1.03	1.081	increase
	Guangdong	0.999	1	1.075	1.074	increase	1.048	1	1.025	1.075	increase
	Hainan	0.933	1.067	1.026	1.022	increase	1.041	1.093	1.003	1.141	increase
	Shanxi	0.96	0.995	1.001	0.956	decline	0.998	0.897	1.001	0.921	decline
	Anhui	0.934	0.975	1.032	0.94	decline	1.113	0.979	0.966	1.053	increase
	Jiangxi	0.92	1.002	1.082	0.997	decline	1.063	0.998	0.98	1.041	increase
Central	Jiangxi	0.929	0.996	1.044	0.967	decline	1.04	1.033	1.056	1.134	increase
	Hubei	0.964	0.938	1.077	0.975	decline	1.03	0.992	1.05	1.072	increase
	Hunan	0.947	0.976	1.034	0.956	decline	1.053	0.961	1.005	1.018	increase
	Inner Mongolia	0.897	0.937	1.069	0.899	decline	1.039	1.065	1.006	1.114	increase
	Guangxi	0.964	1	1.043	1.006	increase	1.075	1.047	0.973	1.095	increase
	Chongqing	0.987	1.061	1.005	1.052	increase	1.046	1.037	1.023	1.11	increase
	Sichuan	0.938	0.964	0.981	0.886	decline	1.06	1.013	0.979	1.051	increase
	Guizhou	0.899	1.025	1.042	0.96	decline	1.108	1.009	0.985	1.101	increase
	Yunnan	0.951	1.041	1.025	1.016	increase	1.046	1.078	1.015	1.145	increase
westward	Tibet	0.74	1	1	0.74	decline	1.114	1.064	1.001	1.186	increase
	Shaanxi	1.018	0.974	1.02	1.012	increase	1.071	0.949	0.996	1.012	increase
	Gansu	0.921	1.108	1.015	1.036	increase	1.059	1.181	0.998	1.249	increase
	Qinghai	0.929	1	1	0.929	decline	1.017	1	1	1.017	increase
	Ningxia	0.988	1.016	1.189	1.194	increase	1.05	1.064	0.998	1.116	increase
	Xinjiang	0.854	1	1.085	0.926	decline	1.134	1	1.033	1.171	increase
	Liaoning	0.978	1	1.02	0.997	decline	1.055	1.032	1.011	1.1	increase
northeast	Jilin	0.921	1	1	0.921	decline	1.078	0.965	0.996	1.036	increase
	Heilongjiang	1.021	0.962	1.022	1.003	increase	1.014	1.057	1.018	1.091	increase
	mean	0.952	1.000	1.034	0.984	decline	1.057	1.019	1.006	1.084	increase

It can be seen from Table 2 that the types of changes in the efficiency of industry-university-research innovation in colleges and universities in China are mainly concentrated in double increase and single increase, with the lowest double decline provinces, and the overall growth trend is good. Among them, a total of 12 provinces belong to the double-increase type, a total of 18 belong to the single-increase province, and only 1 province in Shanxi Province belongs to the double-reduction type of change. From a sub-regional point of view, in the eastern region, the development trend of industry-university-research innovation efficiency of colleges and universities is better, all belong to double-increase and single-increase type, including Beijing, Shanghai, Fujian, Guangdong and Hainan, during the research period, the industry-university-research TFPCH of science and engineering universities and humanities universities has achieved growth, indicating that there is more personnel input and scientific research resource allocation, and input can bring effective output. In the remaining five single-

growth provinces, Tianjin belongs to science and engineering universities with an increasing trend in production, education and research TFPCH, and although humanities universities also attach importance to scientific research investment, PECH and SECH are in a state of decline, and they are slightly insufficient in scientific research output and scale efficiency. In the other four provinces, the industry-university-research TFPCH of humanities universities increased, while the industry-university-research TFPCH of science and engineering universities declined. Among them, the decline of industry-university-research TFPCH in science and engineering universities in Hebei and Jiangsu Province is affected by the decline of Techch and PECH, indicating that the efficiency and technological innovation ability of scientific research input and output in these two provinces need to be improved, Zhejiang Province is a science and engineering university PECH and SECH decline, failed to use scientific research investment to achieve scale effect, Shandong is science and engineering universities Techch, PECH, SECH have declined, should pay attention to the industry-university-research innovation and development of science and engineering universities.

In the western region, in recent years, the government has increased its support for scientific research, which has promoted the growth of the innovation efficiency of production, education and research in its universities, and a total of 6 provinces belong to the double-growth category. The remaining six provinces of Inner Mongolia, Sichuan, Guizhou, Tibet, Qinghai and Xinjiang are single-increment provinces of industry-university-research TFPCH in science and engineering universities, although they attach importance to the industry-university-research innovation of humanities universities, but due to the unreasonable input-output ratio and resource allocation, the efficiency of industry-university-research innovation in science and engineering universities has declined.

In the northeast region, Heilongjiang attaches importance to the innovative development of production, education and research in colleges and universities, science and engineering and humanities universities TFPCH are showing a growth trend, Liaoning and Jilin only humanities universities industry-university-research TFPCH has achieved growth, science and engineering universities Techch has declined, scientific research resources investment has failed to achieve effective allocation, resulting in the reduction of its production, education and research innovation efficiency.

In the central region, there are 5 single-growth provinces and 1 only double-descending province Shanxi, as far as Shanxi is concerned, although the management engineering and humanities universities Sech has increased slightly, resulting in certain economies of scale, but its Techch and pech show a downward trend, indicating that the overall efficiency of production-university-research innovation input-output transformation of Shanxi universities is limited. In Anhui, Jiangxi, Henan, Hubei and Hunan, humanities universities have achieved growth in industry-university-research TFPCH, but science and engineering universities Techch and PECH are in a downward trend, resulting in a decrease in their production-university-research TFPCH, and the innovation ability of industry-university-research in science and engineering universities should be strengthened, and a variety of incentive measures should be taken to improve the quality of output.

3.2 Analysis of the evolution characteristics of industry-university-research innovation efficiency in colleges and universities

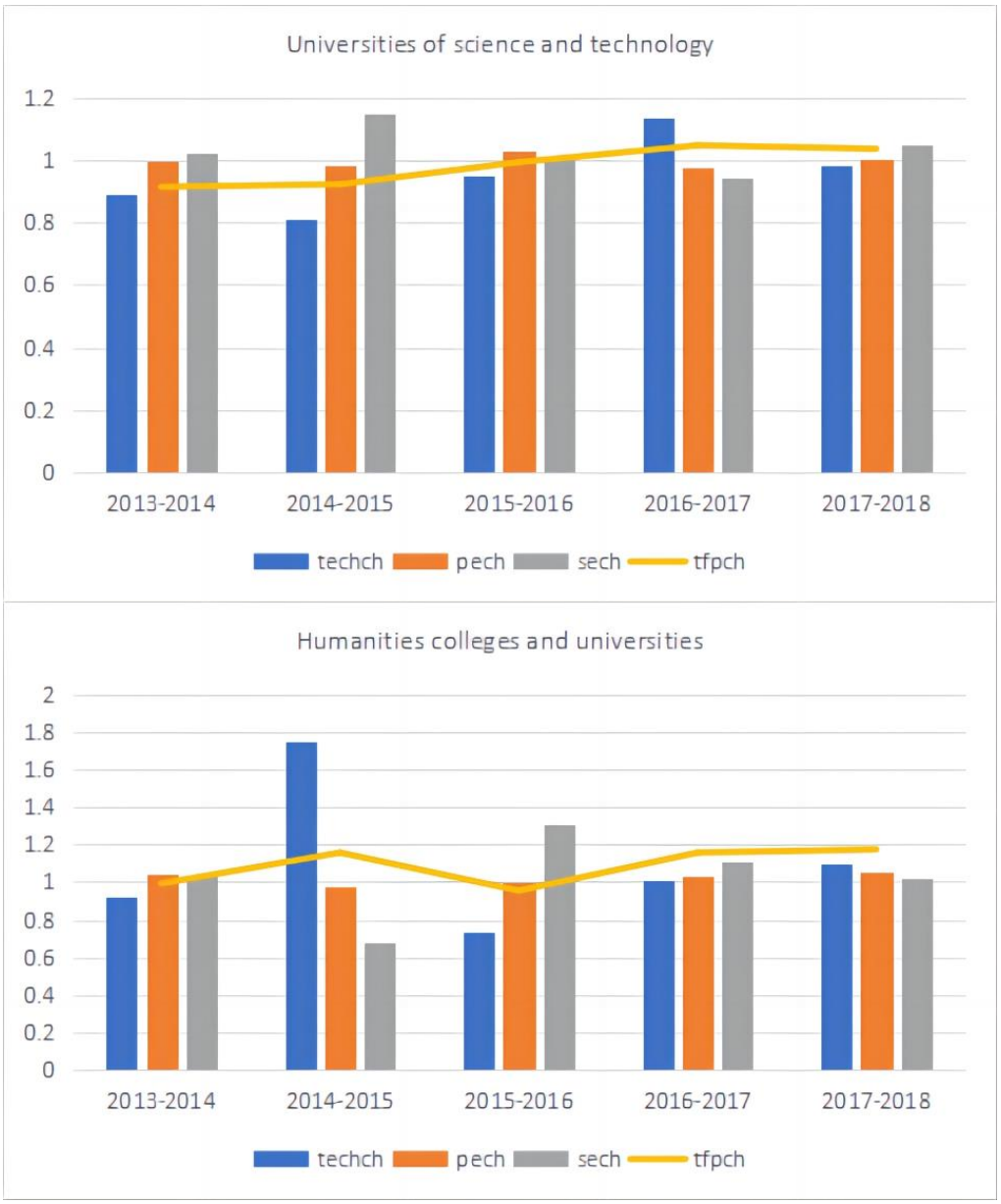

Fig. 1. Evolution characteristics of industry-university-research innovation efficiency in science and engineering and humanities universities in China

It can be seen from Figure 1 that the innovation efficiency of industry, education and research in science and engineering universities as a whole shows the evolution characteristics of first

decreasing and then increasing, showing a downward trend between 2013 and 2016, and only TFPCH is greater than 1 in 2016-2017 and 2017-2018, achieving growth. During the study period, TFPCH declined by an average of 1.6% per year, with both PECH and SECH showing upward increases of 0.3% and 3.3% per year, but Techch showed a downward trend, with an average annual decline of 5%. It shows that the investment in industry-university-research innovation and research and R&D in science and engineering universities is increasing, bringing a certain scale effect, but there is still a lot of room for development in technological progress.

The overall innovation efficiency of industry-university-research in humanities universities showed the evolution of fluctuations and increases, and TFPCH was greater than 1 in the three years of 2014-2015, 2016-2017 and 2017-2018, achieving growth, and showing a downward trend in the remaining years. During the research period, Techch, Pech and SECH all grew steadily, with an average annual growth rate of 5.7%, 1.8% and 0.6%, respectively, indicating that the technological progress of industry, education and research in humanities universities has improved rapidly, but the scale effect is still at a low level, and a collaborative system of industry-university-research innovation should be built to improve the efficiency of industry-university-research innovation in colleges and universities.

4 The impact of industry-university-research innovation efficiency on provincial innovation in colleges and universities

This paper measures the correlation between the innovation efficiency of industry-university-research and the provincial industry-university-research innovation efficiency of national science and engineering universities and humanities universities through the gray management model, and analyzes the impact of the industry-university-research innovation efficiency of the two types of universities on the provincial innovation and development, and the results are shown in Table 3. It can be seen that the correlation between the innovation efficiency of industry-university-research and provincial innovation in colleges and universities in China is greater than 0.6, and the correlation is significant, indicating that the industry-university-research innovation efficiency of science and engineering universities and humanities universities has a close impact on the development of provincial innovation efficiency. The average correlation degree of industry-university-research innovation efficiency in science and engineering universities was 0.891, and the average correlation degree of industry-university-research innovation efficiency in humanities universities was 0.840, indicating that from the perspective of the impact on provincial innovation and development, science and engineering universities have a more significant role than humanities universities. From a sub-regional point of view, the correlation degree of science and engineering universities and humanities universities in the eastern region is relatively close, 0.888 and 0.870 respectively, and the correlation degree between science and engineering universities and humanities universities in the central, western and northeastern regions is obviously different, indicating that the eastern region attaches importance to the balanced development of science and engineering and humanities industry-university-research innovation, and the central, western and northeastern regions of science and engineering universities have made greater contributions to industry-university-research innovation. Promote the coordinated development of industry, education

and research in science and engineering and humanities universities, and jointly promote the construction of regional innovation systems.

Table 3. Grey correlation analysis results of innovation efficiency between two types of universities and provinces in China

region	province	humanities	Polytechnic	type
eastern	Beijing	0.899	0.811	Humanities university-led
	Tianjin	0.910	0.927	Science and engineering universities are dominant
	Hebei	0.858	0.889	Science and engineering universities are dominant
	Shanghai	0.848	0.898	Science and engineering universities are dominant
	Jiangsu	0.918	0.938	Science and engineering universities are dominant
	Zhejiang	0.803	0.890	Science and engineering universities are dominant
	Fujian	0.834	0.908	Science and engineering universities are dominant
	Shandong	0.875	0.922	Science and engineering universities are dominant
	Guangdong	0.889	0.862	Humanities university-led
	Hainan	0.862	0.834	Humanities university-led
Central	Shanxi	0.909	0.921	Science and engineering universities are dominant
	Anhui	0.892	0.859	Humanities university-led
	Jiangxi	0.891	0.973	Science and engineering universities are dominant
	Henan	0.731	0.921	Science and engineering universities are dominant
	Hubei	0.936	0.967	Science and engineering universities are dominant
	Hunan	0.818	0.944	Science and engineering universities are dominant
westward	Inner Mongolia	0.705	0.914	Science and engineering universities are dominant
	Guangxi	0.826	0.865	Science and engineering universities are dominant
	Chongqing	0.866	0.953	Science and engineering universities are dominant
	Sichuan	0.850	0.886	Science and engineering universities are dominant
	Guizhou	0.838	0.952	Science and engineering universities are dominant
	Yunnan	0.814	0.839	Science and engineering universities are dominant
	Tibet	0.737	0.760	Science and engineering universities are dominant
	Shaanxi	0.881	0.903	Science and engineering universities are dominant
	Gansu	0.787	0.918	Science and engineering universities are dominant
	Qinghai	0.885	0.771	Humanities university-led
	Ningxia	0.830	0.849	Science and engineering universities are dominant
	Xinjiang	0.917	0.769	Humanities university-led
northeast	Liaoning	0.705	0.968	Science and engineering universities are dominant
	Jilin	0.825	0.865	Science and engineering universities are dominant
	Heilongjiang	0.899	0.952	Science and engineering universities are dominant

5 Conclusions and recommendations

5.1 Conclusion

This paper uses the Malmquist index to analyze the variation characteristics of industry-university-research innovation efficiency in colleges and universities in China from 2013 to 2018, and uses the gray management model to measure the correlation between the industry-university-research innovation efficiency of the two types of universities and the provincial industry-university-research innovation efficiency, and concludes the following:

(1) From 2013 to 2018, the innovation efficiency of production, education and research in science and engineering universities showed the evolution characteristics of first decreasing and then increasing, and the overall decline was in a state of decline, and the efficiency of various provinces in the country fluctuated significantly; The innovation efficiency of industry-university-research in humanities colleges and universities showed the evolution characteristics of fluctuations and increases, and achieved growth, and the efficiency changes in all provinces in the country were stable, and only Tianjin and Shanxi declined.

(2) Based on the growth and change of industry-university-research innovation efficiency of the two types of universities, the research area was divided into three types, double-increase provinces (12), single-growth provinces (18), and double-decline provinces (1), and the overall growth trend was good. In terms of sub-regions, in the eastern, western and northeastern regions, there are double-growth provinces with good development trend of industry-university-research innovation, and the central region is concentrated in single-growth provinces, and has the only double-descending province, Shanxi.

(3) The correlation between the innovation efficiency of production, education and research and the efficiency of provincial innovation in national colleges and universities is significant, and science and engineering universities have a more obvious impact on the innovation and development of provinces than humanities universities. From a regional perspective, the efficiency of industry-university-research innovation in science and engineering and humanities in the eastern region has developed in a coordinated and balanced manner, and the innovation of industry, education and research in science and engineering universities in the central, western and northeastern regions has made greater contributions.

(4) According to the relationship between the innovation efficiency of industry, education and research in the two types of universities and the efficiency of provincial innovation, the 31 provinces in the country are divided into two types, science and engineering universities (25) and humanities universities (6), the overall development of provincial innovation depends on the contribution of industry-university-research innovation in science and engineering universities, and the influence and scope of industry-university-research innovation in humanities universities are limited. Moreover, the changes in the innovation efficiency of production, education and research in colleges and universities and the impact on the innovation efficiency of provinces cannot be coordinated.

5.2 Recommendations

The research conclusion has certain practical significance for improving the efficiency of scientific and technological innovation in Chinese universities. The first is to give full play to

the role of graduate students' human capital, put the quality and quantity of postgraduate training in the first place, and expand the scale of training while improving the quality of training. Under the background of collaborative innovation of industry, education and research, strengthen the integration of science and education and the integration of industry and education, and build a higher level of talent training system. The integration of scientific research requires universities to strengthen the close integration of scientific research and teaching, support high-quality postgraduate training with high-level academic research, and promote the unity of talent training goals and enterprise development needs. Second, in the process of promoting school-enterprise collaborative innovation, it is necessary to maintain the moderate development of school-enterprise cooperative relations. On the one hand, we must actively open up integration channels to achieve cross-border integration and collaborative innovation with the government and industry; On the other hand, it is necessary to prevent the interference of school-enterprise excessive connection on high-level academic research, while improving the stability of school-enterprise cooperation and innovation, ensure that teachers' time and energy are mainly invested in academic research and education, and at the same time, encourage enterprises to participate in basic research projects, and increase enterprises' funding for basic research in universities, especially basic research for industrial core technologies.

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