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Research on the Influence of University Science and Technology Innovation on Enterprise Performance ---- *Taking Universities and Enterprises in the Yangtze River Basin as an Example*

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ABSTRACT
This paper establishes a two-stage DEA model for the output and transformation of scientific and technological(S&T) achievements, selects 19 provinces and cities in the Yangtze River Basin as the research objects and analyzes the impact of S&T innovation efficiency of Universities on enterprise performance and its influencing factors. The purpose of this research is to raise attention of the industry-university-research cooperation platform and improve the quality of S&T output and the level of achievement transformation. The results show that: (1)In the stage of achievement output, Jiangsu has achieved strongly DEA efficient from 2014 to 2018, while in the stage of achievement transformation, Guangdong, Guizhou and Qinghai have achieved strongly DEA efficient from 2015 to 2019; (2) By comparing the average efficiency of the two stages, it is found that both efficiency are relatively stable during five years, but there is a big difference between them; (3) The reasons for the inefficiency of DEA in the two stages lie in the input redundancy of universities and the insufficient output of enterprises. It is necessary for universities, enterprises, and the government to cooperate to improve the innovation efficiency of universities and the innovation performance of enterprises.

Keywords: *DEA, innovation efficiency of university science and technology, performance of enterprise, output and transformation of achievements.*

1. INTRODUCTION

Great unseen changes are in the progress in China. Capturing the development opportunity, speeding up the pace of S&T innovation and realizing the domestic and international double cycle development are the fundamental road to realize from "quantity- growth" to "quality-growth". From the perspective of domestic productivity, the high-quality development owns many favourable factors:(1) the per capita GDP is more than 10000 dollars and the rate of urbanization is more than 60%; (2) with over 400 million middle class, it has become the second largest economy in the world. Meanwhile, various contradictions still exist. From the perspective of international environment, China faces a severe international situation: Occident, led by the United States, have implemented "science and technology blockade" against China, curbed S&T progress and cut off technological cooperation, which has enhanced our confidence in building capacity in science and technology [1].

As early as the 18th National Congress of the Communist Party of China, it has been proposed that China will enter the ranks of innovative countries in the world in 2020. At the end of 2020, the State Council issued the *"Suggestions of The CPC Central Committee on Formulating The 14th-five-year plan For National Economic and Social Development and The Long-Term Goals For The Year 2035"*, which clearly puts forward that enterprises should strengthen the dominant position of innovation and improve their technological innovation ability. As the main body of S&T innovation and the main delivery place of innovative talents, universities have complete disciplines and advanced facilities. Therefore, it is of theoretical and practical significance to evaluate the impact of S&T innovation on enterprise innovation performance, analyse influencing factors for further rational allocation of innovation resources in universities and deepen technology integration between universities and enterprises

2. LITERATURE REVIEW

Many researchers have been done on the evaluation of the efficiency of S&T innovation in universities by domestic scholars and the achievements are remarkable. The methods of research can be divided into parameter and non-parametric method, among which DEA data envelopment model is the main method. Fan Bonai used DEA method to measure the efficiency of technology transfer in 31 provinces and cities in China from 2005 to 2011. The panel Tobit model was used to analyse the influence of main factors, main relationship, and environmental factors on the efficiency of technological transformation of universities [2]. Zhu et. combined the parameter and nonparametric method, constructed PCA and SFA model and studied the construction efficiency of Jiangsu collaborative innovation center [3]. Scholars had different perspectives, but they focused on the innovation dimension of universities. Fang Yanling analysed the development mode, input-output ratio and collaborative innovation ability of the university in the development period of R & D from the perspective of regional innovation[4]; Gong Hong explored the influence of scientific research on the transformation of achievements from the dual innovate on perspective, and further analysed the adjustment of the prestige, the intensity of production and the external competition degree of universities [5];Chu Xuxin divided the S&T innovation into three stages based on the innovation value chain: knowledge innovation, scientific research innovation and innovation income. The efficiency of S&T innovation in Chinese universities is evaluated from the perspective of innovation value chain [6]. The above research focuses on the internal of universities and analyses the efficiency of input-output innovation in a certain region, which has not been implemented to the enterprise level. The value brought by S&T innovation should be measured by the improvement of enterprise products or the birth of new products.

Above all, this paper constructs two-stage DEA model, and selects universities and enterprises in 19 provinces and cities in the Yangtze River Basin as the research object. Taking into account the time lag of the transformation of S&T innovation achievements, the input and output data of universities from 2014 to 2018 and the output data of new products of enterprises from 2015-2019 are selected. The innovation of this paper lies in (1) horizontal comparison of the efficiency of S&T innovation between different regions and vertical comparison of the fluctuation of the efficiency of S&T innovation in the same region; (2) this paper classifies the output of S&T into theoretical output of universities and practical output of enterprises, explains the impact of S&T innovation of universities on enterprises in the region and analyses the causes of the differences between the efficiency of S&T innovation output and transformation efficiency, including its influencing factors.

3. RESEARCH METHODS AND INDEX SELECTION

3.1 Research Methods

DEA is a mathematical analysis tool used to analyse the relative efficiency of decision-making units with the characteristics of multi-input and multi-output. In 1978, operational researchers Charnes, Cooper and Rhodes first proposed the concept of DEA [6]. The advantage of DEA data envelopment model is that it can deal with multi-input and multi-output data and meet the requirements of no need to build functions. However, a single-stage DEA model cannot reveal the complex relationship between universities and enterprises. Therefore, considering the internal complexity, the Two-stage DEA model is introduced. The first stage is the output of S&T achievements, and the funds allocated by the state to universities become the financial and human resources universities; the second stage considers the theoretical results of the first stage of universities as input, and the new products of enterprises as output. Considering that there are differences in university resources and their utilization and enterprise competition among regions, which make it impossible to achieve the optimal scale within the region, this paper adopts the classic DEA-BCC model, which is variable returns to scale, for the evaluation of the impact of S&T innovation of universities in the Yangtze River Basin on the performance of local enterprises. Then the DEA-BCC model can be expressed as:

$$\min \left(\theta - \left(\sum_{p=1}^{P} s^{-} + \sum_{q=1}^{Q} s^{+}\right)\right) \tag{1}$$

$$\begin{cases} \sum_{n=1}^{N} X_{np}\lambda_p + S^{-} = \theta X_P^n, \ p = 1, 2, \ldots, P & (2) \\ \sum_{n=1}^{N} Y_{nq}\lambda_q - S^{+} = \theta Y_q^n, \ q = 1, 2, \ldots, q & (3) \\ \sum_{n=1}^{N} \lambda_n = 1, \ \lambda \geq 0, \ S^{-} \geq 0, \ S^{+} \geq 0, & \\ n = 1, 2, \ldots, N & (4) \end{cases}$$

When $S^{-}=S^{+}=0$, $\theta=1$, DEA is strongly efficient, both scale and technical efficiency are the best; when $\theta=1$, $S^{-} > 0$ or $S^{+} > 0$, DEA is weakly efficient, the scale efficiency and technical efficiency are either efficient; when $\theta< 1$, DEA is inefficient, both are not the best.

3.2 Index Selection

The first stage selects the relevant data of universities from 2014 to 2018. The input includes human and financial resources, as shown in Table1.The second stage is the process of achievement practice based on the relevant data of enterprises from 2015 to 2019.The output of first stage is used as input and technology transfer is introduced, also as shown in Table 1.

Table 1 Input and output indicators of two stages

	Level 1 indicators	Level 2 indicators	Level 3 indicators
The first stage	input	Human resources	Teaching and research personnel
			Research and development personnel
			Achievements application and technology service personnel
		Financial resources	Science and technology funds
			Research and development funds
			Achievements application and technology service funds
	Output	Scientific and technological achievements	Scientific and technological works
			Academic papers
			Number of patents
The second stage	input	Scientific and technological achievements	Scientific and technological works
			Academic papers
			Number of patents
		technical transformation	Number of contracts
			Contract amount
	output	New Enterprise Products	Number of new product projects
			New product sales revenue

4. EMPIRICAL ANALYSIS

4.1Analysis of the First Stage Efficiency

The efficiency of S&T output in 19 regions guided by Input-Oriented is calculated by using MAXDEA software and VBS method. The results are shown in Figure1. We can draw the following conclusions: (1) According to the average efficiency, it can be divided into 3 categories: the first, where DEA is strongly efficient, only the efficiency of Jiangsu is 1, which indicates that pure technical efficiency (PTE) and scale efficiency (SE) are both optimal; the second: the efficiency is at (0.81, 1), higher than the average level, including Gansu, Guangxi, Guizhou etc. The third is the others whose efficiency is lower than the average within the range of (0.53, 0.81). (2) During the five years, the overall comprehensive efficiency had small fluctuation, maintained between 0.799 and 0.852 and there was little space for improvement, but the overall level showed a downward trend. (3) The efficiency of most regions remained stable and did not change significantly in the past five years, only Guangxi and Henan changed greatly.

Technological efficiency (TE) was further divided into PTE and SE, and the causes for low TE were analyzed. Excluding the four provinces Gansu, Guizhou, Jiangsu and Tibet, whose DEA efficiency is strongly efficient, the PTE and SE of the remaining 15 provinces were shown in Figure2.It can be found that :(1) The reason why DEA is not efficient in Tibet is that the SE is not effective for five consecutive years and scale economy can be realized by adjusting the scale;(2) Anhui, Guangdong, Zhejiang and Hubei all face the situation that SE is efficient but PTE is inefficient, which leads to the weak DEA efficiency and through improving the internal management system of universities could achieve optimization.(3) Similar to Tibet, Gansu, Guangxi, Henan, Jiangxi, Qinghai, in different years, the PTE was efficient but the SE was inefficient;(4) The above two points indicate that the output efficiency of S&T achievements in universities is affected by both technical factors and scale factors.

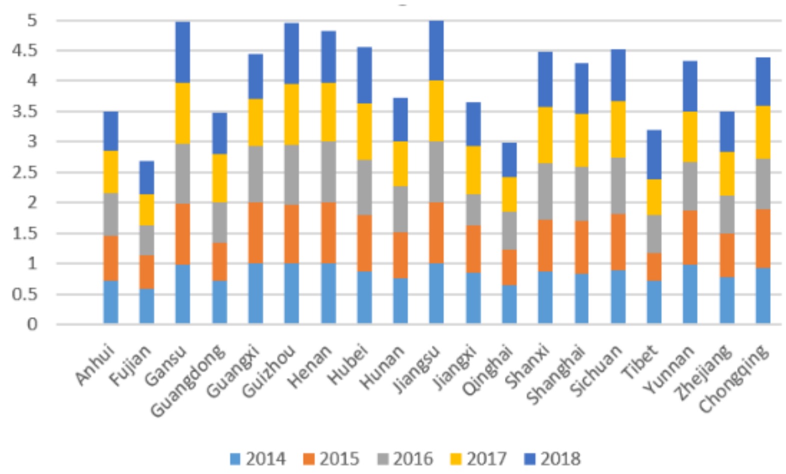

Figure 1 The efficiency of the first stage

Time	2014		2015		2016		2017		2018	
DMUS	PTE	SE	PTE	SE	PTE	SE	PTE	SE	PTE	SE
Anhui	0.722	0.996	0.741	1	0.69	0.997	0.803	0.874	0.7	0.93
Fujian	0.6	0.97	0.571	0.983	0.487	0.98	0.523	0.999	0.562	0.951
Gansu	1	0.992	1	1	1	0.977	1	1	1	1
Guangdong	0.845	0.843	0.718	0.887	0.657	1	0.8	0.997	0.684	1
Guangxi	1	1	1	1	0.963	0.96	1	0.779	0.782	0.947
Henan	1	1	1	1	1	1	0.987	0.99	1	0.848
Hubei	0.873	1	0.936	0.982	0.919	0.999	0.954	0.961	0.981	0.944
Hunan	0.786	0.969	0.76	1	0.782	0.964	1	0.725	1	0.731
Jiangxi	0.867	0.986	0.789	0.979	0.534	0.968	1	0.795	0.752	0.936
Qinghai	0.732	0.885	1	0.583	0.763	0.828	0.657	0.837	0.629	0.924
Shaanxi	0.88	0.993	0.857	0.995	0.929	0.996	0.927	0.999	0.907	0.996
Shanghai	0.844	0.995	0.873	0.995	0.897	0.997	0.857	0.997	0.844	0.998
Sichuan	0.888	0.997	0.925	1	0.985	0.955	1	0.912	1	0.854
Tibet	1	0.729	1	0.442	1	0.623	1	0.583	1	0.822
Yunnan	0.995	0.996	0.89	0.994	0.804	0.993	0.982	0.849	0.831	0.997
Zhejiang	0.791	0.995	0.7	1	0.641	0.993	0.735	0.976	0.713	0.925
Chongqing	0.948	0.987	0.966	0.999	0.824	0.989	0.872	0.999	0.832	0.963

Figure 2 PTE and TE of the first stage

Time	2015		2016		2017		2018		2019	
DMUS	PTE	SE	PTE	SE	PTE	SE	PTE	SE	PTE	SE
Anhui	0.291	0.94	0.228	0.924	0.22	0.914	0.304	0.97	0.271	0.996
Fujian	0.582	0.93	0.431	0.905	0.409	0.901	0.698	0.985	0.411	0.905
Gansu	0.39	0.889	0.439	0.715	0.57	0.732	0.331	0.953	0.241	0.95
Guangxi	0.194	0.941	0.195	0.946	0.266	0.99	0.216	0.996	0.216	0.926
Henan	0.389	0.959	0.323	0.995	0.547	0.981	0.368	0.991	0.253	0.9
Hubei	0.214	0.997	0.299	0.852	0.137	0.994	0.162	0.999	0.173	0.972
Hunan	0.153	0.942	0.125	0.883	0.303	0.962	0.254	0.993	0.42	0.947
Jiangsu	0.453	0.998	0.313	0.992	0.277	0.988	0.308	0.989	0.283	0.984
Jiangxi	0.47	0.992	0.576	0.987	0.365	0.972	0.794	0.998	1	0.951
Shaanxi	0.101	0.873	0.072	0.867	0.062	0.782	0.069	0.824	0.077	0.803
Shanghai	0.2	0.961	0.153	0.993	0.154	0.998	0.117	0.921	0.16	0.979
Sichuan	0.176	0.934	0.135	1	0.167	0.996	0.164	0.937	0.176	0.924
Tibet	1	0.981	1	0.857	1	1	1	1	1	0.92
Yunnan	0.489	0.965	1	0.843	1	1	0.321	0.968	0.759	0.874
Zhejiang	0.783	0.999	0.62	0.998	0.561	0.978	1	1	0.564	0.978
Chongqing	0.271	0.901	0.257	0.985	0.268	0.889	0.228	0.888	0.238	0.861

Figure 3 PTE and TE of the second stage

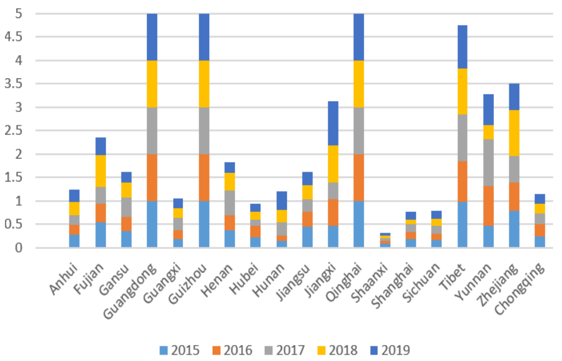

Figure 4 The efficiency of the second stage

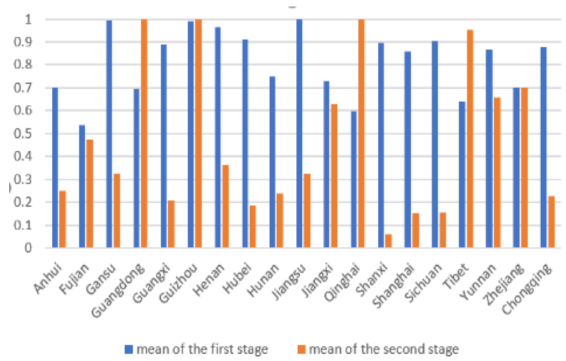

Figure 5 Comparison of efficiency in two stages

4.2 Analysis of the Second Stage Efficiency

The output-oriented DEA-BCC model was selected to calculate the efficiency of transformation under the condition of VRS. The results are shown in Figure3:(1) During the second stage, efficiency of transformation in most provinces is inefficient or weakly efficient. Only Guangdong, Guizhou and Qinghai maintained strongly efficient in five years, indicating that both PTE and SE were efficient. (2) It is worth noting that the provinces and cities with strongly DEA efficient are concentrated in the west, including Qinghai and Guizhou. In contrast, more than half have relatively low efficiency at (0.1, 0.4). (3) The comprehensive efficiency performance of different regions showed great differences, but the overall fluctuation was not large. Also, the provinces and cities with low efficiency did not make significant efficiency progress in the past five years. (4) The overall comprehensive efficiency is maintained at (0.46, 0.49), which is relatively stable, and the improvement space is more than 50%.

Also, the TE of the second stage has been divided into PTE and SE, as shown in Figure4. It is easy to find, in addition to Tibet, Yunnan, and Jiangxi, the main reason why the efficiency of the rest of the provinces and cities is low lies in the low PTE, and even the PTE of individual provinces and cities far below the SE. The direct cause of low PTE lies in the poor management system and technical means of the enterprise, which leads to low production efficiency of the enterprise, and this phenomenon is common.

Compare the mean efficiency of the first stage with that of the second stage, as shown in Fig. 5:It is most easily observed that the TE in the second stage is significantly lower than that in the first stage, indicating that there is a serious "island effect" between universities and enterprises, in which S&T achievements are isolated from economic and social development and dissociated from market demand, resulting in failure to be translated into real productivity [7].In other words, the S&T achievements of universities are not well applied to the process of developing and selling new products, and the integration of science and technology between the two sides is not sufficient.

From the above analysis, it can be concluded that the 19 provinces and cities of the Yangtze River Basin in China have obvious differences. According to the research method of scholar Zhao, this paper divides the 19 provinces and cities into five categories according to the average comprehensive efficiency of the two stages [9]. As can be seen from Figure 2, only Jiangsu is in the first class of the first stage. Different from the first stage, in the transformation stage of S&T achievements, the provinces of first class include Guangdong, Guizhou and Qinghai. Obviously, the comprehensive efficiency of the first stage and the second stage are obviously different, so why are the S&T output and S&T transformation efficiency in the same region so different? Based on the triple helix theory, this paper continues to explore the influence of the main factors of universities and enterprises, the relationship factors of both parties and the objective environmental factors on the output of universities and the transformation of university-enterprise achievements.

5. ANALYSIS OF THE INFLUENCING FACTORS

5.1 Analysis on Influencing Factors of The First Stage

The Triple Helix Theory was firstly proposed by American sociologists Etzkowitz and Leydesdorff aiming at the knowledge social environment [10]. According to this theory, the key to construction of the relationship lies in whether the universities, enterprises and the government can break through the traditional roles and assume other functions [11]. Therefore, the following factors can be concluded.

Firstly, the university level: One of the main reasons for the difference is the innovation ability of universities themselves. In terms of university infrastructure, Wang et al. found that the regression coefficient between financial expenditure of education and the volume of books in libraries was relatively large. Both were positively correlated with the innovation ability, which play a fundamental role in the output of S&T achievements[12].In terms of researchers, based on the panel data analysis of more than 60 universities from 2002 to 2016, Gao et al. concluded that postgraduate training has a significant relationship with the efficiency of innovation: human resources of graduate students improves the learning ability and creativity of universities by promoting the flow, integration and creation of knowledge, thus improving innovation efficiency [13].Therefore, the construction of research team is also critical in universities. Secondly, the level of enterprises and government: Both are regarded as the external environmental factors of innovation in universities and the indispensable subjects of innovation in universities. Two sides mainly provide guarantee for university science and technology innovation in the form of policy and enterprise support.

5.2 Analysis on Influencing Factors of The Second Stage

Firstly, the university level: As the supplier of technology, the quality of S&T output has a serious impact on the quality of achievements. Based on the empirical analysis of patent quality, Deng et al. found that: first, many universities fail to have specialized institutions and these personnel are regarded as administrative personnel rather than experts in the field; next, related data shows that number of patent application is five times bigger than European and American universities generally, but obviously not confirm to the actual level; finally, most universities lack the conditions for the implementation and practice of achievements. These obstacles cause that "high-quality" patent protection cannot be formed, which ultimately affects the transformation process [14]. Secondly, the enterprise level: From the inside, when universities provide S&T achievements in the form of patents, enterprises rely on their ability to transform them into products, which largely depends on themselves to absorb. From the outside, with increasingly fierce market competition, if enterprises cannot keep up with the trend of S&T innovation, they will lack their competitive advantages [15]. Therefore, the low efficiency of the transformation not only affects universities, but also curbs the growth of enterprise. Thirdly, the government level: Taking Qinghai as an example, it can be observed that the efficiency of second stage is 1. On the one hand, Qinghai established the technological alliance with several western provinces and cities in 2016.Local government attaches more importance to the rational allocation of resources and the construction of industrial platform. On the other hand, Qinghai, located in the middle zone of the new "Silk Road" economic belt, has unique regional advantages and the commercialization of S&T achievements is also strongly supported [16]. It can be predicted that the government has a great guiding force for the integration of innovation.

6. ANALYSIS ON TWO-STAGE EFFICIENCY OPTIMIZATION

The output of S&T achievements in 2018 and the transformation of S&T achievements in 2019 were selected as samples to analyze the input redundancy and output deficiency. In this paper, the number of personnel and scientific research funds are summarized and calculated in order to find out whether universities are in the situation of redundant or insufficient input. Through calculation, the remaining provinces and cities in the first stage all have different degrees of input redundancy as shown in Figure6. This indicates that the structure of resource allocation is quite unreasonable. First, the use of research funds is wasteful and not reasonably allocated within the university. Second, researchers are partially redundant, which indicates the phenomenon of over-staffing in universities. Therefore, it is necessary to readjust human resources for scientific research to stimulate their enthusiasm and achieve reasonable output. In the second stage, this paper calculates the output deficit when the input is certain and compare it with the current situation, as shown in Figure7: First, only in Henan, the number of new product development projects is insufficient; Second, only Gansu, Guangdong, Guizhou and Qinghai provinces achieved the target volume of new product sales revenue. The phenomenon is common that most provinces and cities have different degrees of output shortage.

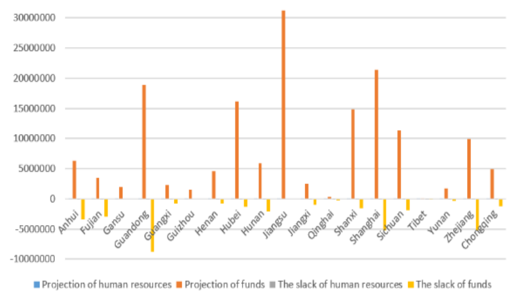

Figure 6 Analysis of redundancy of the first stage

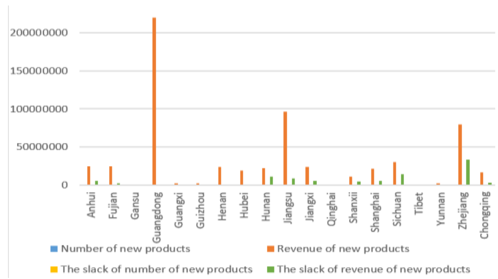

Figure7 Analysis of insufficiency of second stage

7. CONCLUSIONS AND SUGGESTIONS

This paper studies the impact of university S&T innovation on enterprise innovation performance in the Yangtze River Basin. And the following conclusions are drawn: (1) In the first stage, only Jiangsu strongly got DEA efficient from 2014 to 2018. While The efficiency of other provinces and cities were not efficient in PTE and SE with some input redundancy. (2) In the second stage, only Guangdong, Guizhou and Qinghai achieved strong DEA effectiveness. Low PTE was the main reason for the ineffectiveness of comprehensive efficiency. (3) By comparing the efficiency of the two stages, it is not difficult to find that there is a large gap between them, indicating that the cooperation is not close, and the output of S&T has not been effectively transformed. (4) Input redundancy and output deficiency generally occur in each province and cities, which directly lead to the weak effectiveness or ineffectiveness of DEA in these regions. The above conclusions are of enlightening significance to explore the path of efficient achievement transformation:

In the first place, through innovating the scientific research evaluation system and realizing the reasonable allocation of resources, universities could reduce the redundancy of scientific research investment accordingly. On the one hand, the funding resources can be reviewed and approved according to the applications of various departments and avoid abuse. On the other hand, to strengthen the construction of the team of scientific research personnel in universities can appropriately refer to the performance appraisal system of enterprises and raise the quality of papers, S&T works and patents into the appraisal scope. In the second, building a university-enterprise cooperation platform could ensure the flow and sharing of innovation resources and improve the efficiency of transformation. Chen takes 71 universities as the study sample and finds that cooperation between school-enterprise is positively affecting the scientific research output of universities and joint application for patent has a stronger positive effect than the transformation of S&T achievements [17]. In the third, the government can issue relevant policies to narrow regional differences. These provide the guarantee for the industry-university-research platform and guide the cooperation between them to realize the flow of high-quality S&T achievements to the enterprises, which is able to allocate S&T funds in various regions from the macro perspective and enhance cost and benefit analysis in the process of project approval to rationalize resources. Financial support can be appropriately provided to underdeveloped areas to balance the development of different regions and narrow the regional gap. Finally, policies can encourage university researchers to implement innovative activities and regional development.

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