ISSN 1749-3889 (print), 1749-3897 (online)
International Journal of Nonlinear Science
Vol.28(2019) No.1,pp.3-9

Research on Improving The Conversion Efficiency of Scientific and Technological Achievements in Jiangsu Provincial Universities

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(Received 19 February 2019, accepted 24 May 2019)

Abstract: Based on the total factor productivity theory, this paper estimates the technical efficiency and scale efficiency of the transformation from patent to actual productivity of universities, by using the statistics of transformation achieved by 12 provincial universities in Jiangsu as well as the method of data envelopment analysis. It is found that the conversion efficiency of patent productivity in colleges and universities in 2016 and 2017 are both 58.33% in pure technical efficiency. However, looking closer at the nuclear density map of technical efficiency scores of these two years, the distribution of pure technical efficiency is obviously shows that the situation in 2017 has been greatly improved compared with 2016's. In addition, in terms of the scale efficiency of the conversion, the average scale efficiency in 2016 and 2017 were 1.129 and 0.897 respectively, with a slight decrease. This because that the scale efficiency of Huaiyin Normal University in 2016 was 5.261109, making the average value exceed 1. However, the overall sample showed a state of constant scale compensation and declining scale compensation. Half of the samples in 2016 and 2017 had a scale efficiency value of 1 and were in the stage of constant scale compensation. On this basis, we put forward countermeasures to improve the efficiency of patent productivity conversion in colleges and universities.

Keywords: Jiangsu universities; Patents; Actual productivity; Conversion efficiency; DEA

1 Introduction

The report of the 19th National Congress clearly pointed out that innovation was the first driving force of development and the strategic support for the construction of a modern economic system. Institutions of higher education, undertaking a considerable number of scientific and technological research projects, are important places for scientific and technological innovation and "boosters" of economic and social development. Jiangsu province currently has 167 institutions of higher education, ranking first in the country, with more than 1.9 million university students and 103 academicians of the Chinese Academy of Sciences and Chinese Academy of Engineering. It is rich in scientific and educational resources and strong in scientific research. However, there are still some outstanding "shortcomings" in scientific and technological innovation of Jiangsu's universities: the scientific and technological innovation of universities is not closely related to the development of regional economy; the efficiency of converting intellectual property rights into actual productivity is not high; there are not many innovative achievements that can directly serve the economy and society. Patent plays an irreplaceable role in measuring scientific and technological innovation. Colleges and universities are one of the main sources of producing high-quality patents. Researches on the conversion efficiency of scientific and technological achievements in Jiangsu's colleges and universities as well as the release of the potential of scientific and educational resources have naturally become the focus of relevant functional departments and scientific research institutes by now.

Due to the increasing attention paid by the government to scientific and technological innovation, domestic literature on scientific and technological achievements in colleges and universities has been increasing in recent years, mainly from the aspects of evaluation system, innovation efficiency, personnel training, policy system, regional contribution and so on. Wang et al. [1] divided the scientific and technological innovation capability into basic ability, input ability and output ability, and gave them different weights. Based on strategic map theory, Chen [2] constructed four first-level, eight

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IJNS.2019.08.15/1045

second-level and 21 third-level evaluation indexes, and made a comprehensive evaluation of scientific and technological innovation in colleges and universities as a standard for evaluating scientific research contributions. Li [3] evaluated and calculated the efficiency of scientific and technological innovation in colleges and universities from knowledge innovation output and transformation of technological innovation achievements. Song et al. [4] do the same analysis from four dimensions of two inputs of human and financial resources and two outputs of new products, and scientific and technological achievements. Some scholars believed that the root of scientific and technological innovation lies in human beings so the nation should pay more attention to the cultivation of innovative talents. Xu [5] proposed to increase investment in scientific research in colleges and universities. Dong [6] put forward a training system that combines resources guarantee, institutional incentives and academic atmosphere to attract young talents according to different characteristics of different growth stages. Li et al. [7] borrowed the experience of research universities in the United States in strengthening institutional innovation, training approaches, characteristic modes, educational environment and other aspects to speed up the cultivation of scientific and technological innovative talents in colleges and universities. Some scholars believed that institutional and policy factors were important factors that affected the transformation of scientific research achievements in colleges and universities. Lu [8] believed that the main reason for the large performance gap between the output and transformation of scientific research achievements in colleges and universities lies in the reward system and policy for the transformation of scientific research achievements. Wen [9] proposed that the old institutional arrangements result in the utilitarianism of scientific research goals, the superficial evaluation of scientific research achievements, the blurring of transformation incentives and other path-dependent problems. Zhang et al. [10] based on panel data model research showed that R&D personnel, financial input and patent technology output in universities had different influence on technological progress in different regions of our country. Li et al. [11] found that the supporting role of scientific and technological innovation in provincial universities in regional economic development was generally low through empirical analysis, which contradicts with our expectations. How to efficiently convert scientific and technological achievements (especially patents) of colleges and universities into real productivity has naturally become the most concerned issue of academia and the industry. However, we should also clearly realize that the current research is relatively inadequate, especially empirical studies. How to measure and compare the conversion efficiency is not only an economic theory problem, but also an important policy choice problem. This paper systematically studies this issue through data envelopment analysis (DEA) method based on the panel data on the implementation of three types of patent applications, authorizations, and conversions in 12 representative colleges and universities in Jiangsu province.

2 Theoretical framework and research methods

2.1 Theoretical framework

Joseph Schumpeter first proposed the concept of “innovation” in his book Economic Development Theory in 1912 and linked it with economic development. He believed that technological innovation was a process of promoting economy by technology and of the commercialization of knowledge achievements. The model of transforming efficiency from innovation to actual productivity in colleges and universities can be described in Fig. 1: the purpose of scientific and technological research and development investment in colleges and universities is to realize expected output results and then to transform them into actual productivity. In the research and development stage after investment, patent authorization is a key node for transforming actual productivity. After the patent is authorized, it can realize the industrialization of achievements either through direct industrialization or through the implementation and transfer of foreign licenses, so as to achieve the aim of producing actual productive forces with economic benefits, social benefits and other benefits. However, due to the influence of the quality of patents themselves, as well as the maturity, service perfection and system and mechanism of the carriers of achievements transformation and innovation platforms, the progress and results of patent transformation implementation are difficult to guarantee, thus affecting the efficiency of transformation into actual productivity.

2.2 Research methods

The main purpose of this section is to measure the conversion efficiency of patent authorization to actual productivity in colleges and universities, and to conduct an empirical study on the influencing factors. First of all, the measurable indicators representing actual productivity are sorted out from the statistical table data of patent achievements transformation in colleges and universities. Secondly, the data envelopment analysis (DEA) is used to explore the conversion efficiency of university patent authorization to actual productivity. DEA method is a non-parametric input-output model, which can measure the efficiency of the decision-making unit on the current technical level. The technical efficiency is measured by maximizing the output under the given input or minimizing the input under the given output. Taking the university code in the sample as the decision-making unit, three patent authorization quantities (invention, utility model and appearance design) as inputs, and the achievement conversion amount and technology transfer income as outputs, this paper analyzes the conversion efficiency of university patent authorization quantities to actual productivity. Then, based on the score of DEA model of the conversion efficiency of university patent authorization to actual productivity, this paper discusses the conversion efficiency of university patent authorization to actual productivity in different years' samples, and analyzes the changing trend. Furthermore, through the regression of panel data, the factors affecting the conversion efficiency of university patent authorization to actual productivity are analyzed by taking the scores of the conversion efficiency of university patent authorization to actual productivity as dependent variables.

3 Data acquisition, variable processing, and descriptive statistics

3.1 Data acquisition

The statistical tables contain information about achievements transformation of 12 provincial science and engineering and comprehensive colleges and universities in Jiangsu province, which represents the strength of Jiangsu colleges and universities as a whole. This paper studies the data of Jiangsu provincial universities in 2017 and 2018.

Invest patents, utility model patents, design patents, total amount of patents, and patent transformation implementation are used as input variables for scientific and technological innovation in colleges and universities.

A complete and relatively independent set of indicators representing actual productivity is selected to form an output set, which is used as the output of actual productivity, including the following two variables: the amount of achievement conversion and the actual income of the year of technology transfer.

3.2 Descriptive statistical analysis

Table 1 illustrates the descriptive statistical analysis of the main variables. All the statistics are carried out according to the samples in 2017 and 2018 respectively, so as to compare the dynamic changes of the variables.

Table 1: Descriptive statistical analysis of major variables.

	2017				2018			
Variable name	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum
invention patent authorization amount (piece)	193.8333	237.6035	18	807	205.1667	245.1756	22	880
utility model patent authorization amount (piece)	109.75	85.72485	6	314	137.6667	106.6237	5	383
design patent authorization amount(piece)	19.33333	21.08568	0	59	70.33333	206.4661	0	725
total amount of patent authorization (piece)	322.9167	264.9101	38	946	413	370.1582	32	1187
the amount of patent conversion implementation (piece)	48.66667	72.061	1	247	77.83333	115.3223	2	395
the amount of achievement conversion (10^8 yuan)	201.9308	299.2891	20.3	1069.65	299.892	478.8626	32.48	1711.44
the actual income of the year of technology transfer (10^8 yuan)	940.3333	2744.718	0	9620.6	1504.533	4391.549	0	15392.96

Source: The statistical table data of achievements transformation of 12 provincial colleges and universities in Jiangsu province.

First, look at the status of the main indicators of the output set representing actual productivity. The actual income of the year of technology transfer increased greatly, indicating that the overall strength of scientific and technological innovation is improved.

Secondly, this section analyzes the main indicators of the input set representing scientific and technological innovation capability. This shows that the largest increase in the number of patent conversion implementations occurred in Jiangsu province.

4 Empirical analysis

4.1 Determining input-output indicators

In the existing research, the output index representing actual productivity is mainly determined through theoretical analysis. Based on the existing total factor productivity theory and related literature, two variables representing actual productivity, namely, the amount of achievements conversion and the actual income of the year of technology transfer (10,000 yuan), are compiled from the statistical data of achievements conversion in 12 provincial science and technology and comprehensive universities in Jiangsu province. Similarly, input variables also sort out five representative variables from the data: the amount of invention patent authorization, the amount of utility model patent authorization, the amount of appearance design patent authorization, the total amount of patents, and the amount of patent conversion implementation.

4.2 DEA analysis

A non-parametric input-output efficiency analysis method, data envelopment analysis (DEA) is used to study the conversion efficiency. The method does not need to set the functional relationship between input and output, nor does it need to manually set the weights of different input or output indicators. Therefore, it is a very widely used efficiency analysis tool. At present, the commonly used DEA models include CCR model and BCC model. Therefore, the pure technical efficiency is obtained. Both models can be analyzed according to input orientation and output orientation. In this paper, the input-oriented DEA analysis is applied. In addition, it is not possible to theoretically determine the scale compensation of universities from scientific and technological innovation to actual productivity, so it is more reasonable to adopt the BCC model. Considering all these factors, we analyze the pure technical efficiency of welfare conversion based on the output-oriented BCC model. CCR model with output orientation is used to calculate the scale efficiency of income to welfare conversion. The software used is max DEA 6.6.

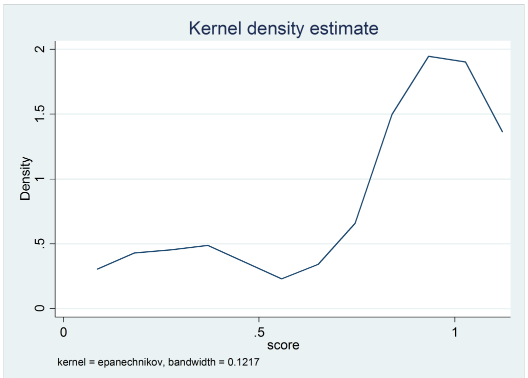
Analysis of the technical efficiency of the transformation from scientific and technological innovation to actual productivity in colleges and universities using the output-oriented BCC model, we calculated the technical efficiency in 2017 and 2018 respectively, as shown in the following Table 2. According to the efficiency value, it is found that the number of effective individuals is 12, and the effective ratio is the 58.33% and 66.67%. It can be seen that more than half of the effective individuals in these 12 Jiangsu colleges and universities have switched from scientific and technological innovation to actual productivity.

Table 2: Pure technical efficiency from scientific and technological innovation to actual productivity.

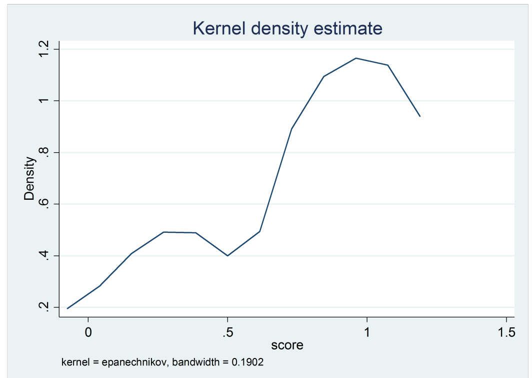
Decision making unit (DMU)	2017 Pure technical efficiency	2018 Pure technical efficiency
Jiangsu University	1	1
Nanjing Forestry University	0.857442	1
Soochow University	0.892037	0.438054
Yangzhou University	0.274884	1
Nanjing Medical University	1	1
Nanjing University of Traditional Chinese Medicine	1	1
Jiangsu University of Science and Technology	1	1
Nanjing Normal University	0.209082	1
Huaiyin Institute of Techology	1	0.115404
Suzhou University of Science and Technology	0.542717	0.21841
Huaiyin Normal University	1	1
Changshu Institute of Technology	1	0.522896

Comparing the distribution of technological efficiency from scientific and technological innovation to actual productivity transformation in 2017 and 2018, the average technical efficiency in 2017 is 0.815 and that in 2018 is 0.775, which shows a slight decrease in the efficiency. Fig. 1 demonstrates the nuclear density map of the technical efficiency scores over the past two years. We found that compared with 2017, the distribution of pure technical efficiency in 2018 was similar, which showed that the situation in 2018 had not been improved, the overall distribution was closer to the normal distribution, and the peak value of the distribution was also obviously shifted to the right, indicating that the pure technical efficiency of a large number of samples from scientific and technological innovation to actual productivity conversion had not been obviously improved.

In short, the effective ratio of transformation from scientific and technological innovation to actual productivity is not high in China's colleges and universities. Most colleges and universities have not fully utilized their scientific and technological innovation capabilities or played a greater role in promoting the improvement of actual productivity. The reason may be various constraining factors, including the subjective wishes of colleges and universities, government policies, their environment and so on. However, we see that from the perspective of the dynamic trend, the technical efficiency



(a) 2017



(b) 2018

Figure 1: Nuclear density diagram of conversion technology efficiency in 2017 and 2018.

of the transformation from scientific and technological innovation to actual productivity in colleges and universities is rapidly improving. As long as this trend continues, colleges and universities may achieve higher efficiency in the future.

5 Conclusions and policy recommendations

Statistical analysis shows that from 2016 to 2017, the number of implementation of patent conversion in 12 representative provincial universities in Jiangsu was 754, the effective patent amount was 7394, and the patent conversion rate was only 10.2%, which was basically the same as the national average. Jiangsu's advantages in science and education resources could not be brought into full play effectively. There are still such problems as weak awareness of intellectual property rights, low quality of patents, asymmetric information on patent transformation, lack of financial support, and unsmooth transformation channels. A large number of scientific and technological achievements have been shelved, which have not played an obvious supporting role in Jiangsu's regional economic development and are extremely incompatible with the status of Jiangsu's major province of higher education. This also shows that "40 articles of scientific and technological innovation" and other good policies have not been implemented. The results are not obvious enough. The main contradiction between the need for innovative incentive policies and the insufficient support for innovation of university faculty and researchers is still prominent.

5.1 Causal analysis

The main reasons for the low conversion efficient rate of scientific and technological achievements in colleges and universities are as follows:

(1) The mind should be further emancipated and the degree of emphasis is not high. In the implementation of science and technology policies, universities have not emancipated their minds. They have not really put science and technology innovation work into the political height of modern universities' connotative development to plan and put universities into practice as the source of science and technology innovation. The enthusiasm, initiative and creativity to promote transformation have not been fully stimulated. School leaders worry that grasping the policy is not comprehensive and accurate, shouldering the name of the loss of state-owned assets or affecting the dynamic stability of the teaching staff in colleges and universities, and are being held accountable by the discipline inspection department of the audit patrol. Scientific and technological personnel are even more concerned about the situation. In the process of implementation, most of the science and technology departments are singing "monologues". Training is limited to management and administrative personnel. Front-line researchers know little about science and technology policies. The coordination and linkage of scientific research, personnel, finance, assets and other departments have not yet taken shape. Among the 23 policy points involved in the implementation of colleges and universities, "scientific research project funding management" and "decentralization of professional title evaluation" have a high rate of introduction of normal policy supporting measures, "equity and bonus incentive" and other market-oriented policies have a low rate of landing. Researchers are also reluctant to influence their future fate due to market factors unknown to individuals such as equity. Only one of the 12 sample colleges and universities collected has used equity incentive methods.

(2) Lack overall planning and many contradictions exist between supply and demand in supporting policies. The ecology conducive to the implementation of scientific and technological innovation policies in colleges and universities is not optimized enough. Key departments such as development and reform, education, science and technology, economics and information, finance, people's organizations, auditing, and organization are focusing on the essential attribute of "scientific and technological innovation" and the core meaning of "letting go of management service". The functions and processes of multi-dimensional and one-game chess-playing are not enough, and the macro-control and micro-design are both short of heat, resulting in the lack of convergence of supporting policies between departments, numerous mess and frequent blocking points. Taking the purchase of scientific research equipment as an example, education, finance, science and technology and other departments have different standards and are difficult to operate. In the implementation of the policy, they still need to apply, declare, report and file with several mothers-in-law. As a result, some colleges and universities are only willing to copy the main policies, while others simply rely on them. In the formation and detailed implementation of the policy, the pertinence is not strong. The thinking angle is more the "hourglass release" of government power than the "support guarantee". The depth in studying the major institutional obstacles and basic contradictions in Jiangsu's universities is not enough. The government's "supply" does not satisfy the "demand" appetite of universities, which makes it difficult to implement good policies and to do things with good intentions.

(3) The support of innovative resources is insufficient, and the inertia of traditional evaluation guidance is relatively large. The integration of scientific and technological innovation resources is not in place. There is a lack of a unified scientific and technological big data operation and management mechanism and a pilot-scale aging base across the province. All kinds of existing innovation platforms and technology transfer centers in colleges and universities are in urgent need of interconnection and interpretability, thus becoming the accelerator of policy effectiveness. Due to the policy orientation of Double First-rate University evaluation, coupled with the "total performance salary" and "management of state-owned intangible assets", most of the scientific and technological innovations in universities still aim at publishing high-level SCI papers. There is a phenomenon of emphasizing basic research but neglecting the transformation of achievements. The three major elements of scientific and technological achievements, outstanding talents and transformation expectations generated are not clear enough. The flow between universities and colleges is not active, and the contribution of original innovative resources as important production elements to the overall scientific and technological contribution of Jiangsu economy needs to be improved.

5.2 Policy recommendations

(1) Increase top-level design to improve the system and accuracy of policies. To push forward the structural reform on the supply side of scientific and technological innovation in Jiangsu provincial universities, it is of great importance to stick to re-innovation and pain points, integrate university scientific and technological innovation into the overall framework of Jiangsu's scientific and technological innovation supply-side reform, put it into a layout to promote the high-quality development of "Jiangsu 1+3 Key Functional Areas" and "Innovation Demonstration Zone in south of Jiangsu", systematically integrate various innovation platforms, and study the re-innovation of scientific and technological system and mechanism. Besides, as soon as possible, the reform of the "personnel system in colleges and universities" will be taken as the design of the placement system, and a work plan will be drawn up to comprehensively push forward the deepening reform of colleges and universities in Jiangsu province. Around the goal of "deadministration", the overall and fundamental blocking points such as the establishment of posts, the total compensation limit, and the cadre management authority will be completely eliminated, and the colleges and universities will be freed from the restrictions so that they can travel lightly and solve the "fear" problem.

(2) Establish scientific guidance and establish a coordinated and balanced mechanism for policy implementation. First, the party and government departments in the whole province have established the concept of "full decentralization and respect for the dominant position of colleges and universities", made in-depth study of the advantages of scientific and technological innovation in colleges and universities, and changed the "project evaluation" to "asking the needs of the applicants". It not only provides sufficient funds for training socialist successors and outstanding teachers, but also speeds up the development of concise incentive and safeguard measures on "putting scores" and "managing science", and promotes the pilot work of colleges and universities in the whole province in a hierarchical and classified manner, thus kicking the finishing touches. The second is to establish a system of on-the-ground assessment and fault-tolerant and error-correcting of scientific and technological policies in colleges and universities, to strengthen the main responsibility of university leaders, and to require effective political Excellence and high skills, to set up a dynamic scientific and technological innovation work system and operation mechanism in colleges and universities according to local conditions, so as to cultivate innovation and entrepreneurship between teachers and students, to ensure the vigorous development of

educational undertakings, and to speed up the pace of "doing".

(3) Optimize the allocation of resources and speed up the integration of scientific and technological innovation resources across the province. Relying on big data to carry out refined services, one is to take the construction of "Jiangsu smart science and technology innovation big data cloud center" as a leader and build a strong science and technology resources sharing and opening platform in Jiangsu from the two dimensions of innovation subjects such as university enterprisers, high-tech zones of research institutes, property right trading markets, and production factors such as intellectual property rights of scientific and technological achievements and scientific research talents, laying the Broad Road for the development of science and technology policies. The second is to build a "government supervision service center" with multi-departments linked online to simplify and highlight the key issues. Jiangsu's innovation policy will be streamlined and informativeness, and big data will be used to realize online interaction between universities and the government. The two major functions of effective supervision and full support will be realized, and the key to "protection" will be implemented.

Acknowledgments

The research is supported by the National Natural Science Foundation of China (No. 71603113), Ministry of Education Humanities and Social Sciences Research Youth Fund Project (18YJC790141), the Key Project of Philosophy and Social Science Research in Universities of Jiangsu Province (No. 2018SJZDI095).

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