Evaluation of University Scientific Research and Technology Transfer Efficiency Based on Dynamic DEA Model

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Abstract. This paper analyzes the efficiency of scientific research transfermation. We clarifies the relationship and difference between the efficiency of scientific research output and the efficiency of technology transfer, constructs the evaluation index system, organically combines the two factors, and takes Sichuan province as an example. We analyzes the relationship between the efficiency of scientific research and the efficiency of technology transfer, and makes a dynamic trend analysis with DEA-Malmquist model. The results of empirical analysis show that: for one university, there may be differences between the efficiency of scientific research and the efficiency of technology transfer. Personnel, funds, management mechanism and organization mode are the key factors that affect the efficiency of scientific research transfer. Based on this, some suggestions are put forward.

1. Introduction

Technological innovation has gradually become a main driving force for social and economic development. Universities, as an important part in science and technology innovation system, are mainstay in technological innovation, scientific research achievements transfer[1]. Although the annual scientific and technological research achievements in China's colleges and universities are fruitful, the ratio of ultimately turning into social productivity is not high. This largely affects the level of technology transfer of our country. Therefore, there is an imperative to improve technology transfer efficiency in colleges and universities, and it has become a concern by the whole nation.

In fact, the efficiency of technology transfer in universities is closely related to the efficiency of scientific research. The efficiency of technology transfer mainly measures the marketization of scientific research results, while the efficiency of scientific research mainly measures the output of scientific and technological input. The efficiency of scientific research output and technology transfer are closely related. In recent years, scholars focus their researches on three aspects: scientific research input[2], university type[3]and region[4,5]. Researches about technology transfer efficiency evaluation mainly include two aspects: on one hand, constructing university technology transfer evaluation system, for example, Chai et al. proposed a comprehensive evaluation system with both “functionality” and “coordination”. Based on catastrophe theory[6], Yu et al. put forward a complete evaluation system for the whole process of technology transform in colleges and universities[7]. On the other hand, university technology transfer evaluation methods. Commonly used methods are hierarchy analysis, blur comprehensive evaluation, mathematical statistics method, and DEA methods, etc.[8]. There is a lack of researches on the distinction between scientific research efficiency and technological transfer efficiency. A situation where technology transfer efficiency mixes up scientific research has existed, which does not reflect the periodicity of scientific research transfer. Thus, existing studies concern about singular index evaluation of the economic and social benefits of the technology transfer results, and lack the relevance evaluation of the research efficiency-technology transfer efficiency in the transfer process.

This paper begins with two dimensions: efficiency of scientific research and efficiency of technological transfer. By constructing a dynamic DEA model, we have a deep analysis of status of

scientific research efficiency and technological transfer efficiency in colleges and universities, which offers suggestion to promote the technology transfer efficiency.

2. Model and Indicator System Construction

2.1. Model Construction

Scientific research efficiency and technology transfer efficiency are typical more input--more output problems. DEA, because of its objectivity and efficiency, has been widely applied in input-output comprehensive evaluation [8-10].

2.1.1. DEA Model

DEA model includes two basic models, CCR and BCC. The CCR model measures total efficiency (TE) of the evaluation object, it can judge the technical effectiveness and scale effectiveness based on optimal solution. The BCC model measures the pure technical efficiency (PTE) to judge whether the input production potential is fully exerted. The relationship between the two is

$$\text{Total Efficiency (TE)} = \text{Technical Efficiency (PTE)} \times \text{Scale Efficiency (SE)} . \tag{1}$$

Suppose that university technological transfer efficiency system has N decision units (DMU) , each decision unit contains *M* input indicators and *S* output indicators, to set x_{mj} as the No. *m* input of DMU_j, to set y_{sj} as the No. s output of DMU_j. Then, the BBC model is as follow[10]:

$$\begin{cases} \min \theta \\ s.t. \sum_{j=1}^{n} x_i \lambda_j \le \theta x_0 \\ \sum y_j \lambda_j \ge y_0 \\ \sum \lambda_j = 1, \lambda_j = 0, \quad j = 1,2,\cdots,n \end{cases} , \tag{2}$$

where θ as efficiency evaluation indicator, λ_j as input and output weight vector, results of this formula is pure technological efficiency value of each decision unit (PTE), to subtract convexity hypothesis ($\sum \lambda_j = 1$), we get comprehensive efficiency (TE, optimal solution of CCR model).

2.1.2. DEA-Malmquist Model

Malmquist indicator has been mainly used to evaluate dynamic productivity across time. Assume that scale return is fixed (CRS), formula for the production productivity indicator from period *t* to period *t+1* is [8]:

$$M(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{d^t(x_{t+1}, y_{t+1})}{d^t(x_t, y_t)} \times \frac{d^{t+1}(x_{t+1}, y_{t+1})}{d^{t+1}(x_t, y_t)} \right] . \tag{3}$$

where the first part of the right side is the technical efficiency transfer rate (EC), another part is the technological progress rate(TC). Technological efficiency change rate (EC) can be decomposed into pure technological efficiency change rate (PEC) and scale efficiency change rate (SEC).

When M>1, the productivity level is increased; when M=1, the productivity level is unchanged; when M<1, the productivity level is decreased.

2.2. Evaluation Indicator

Evaluation indicators for technology transfer efficiency in colleges and universities use the same indicators for scientific research efficiency evaluation. However, it still need a further discussion on

the scientificalness of using scientific research input to evaluate technological transfer efficiency. In fact, technology transfer efficiency is closely related to the quantity, quality, innovation and market acceptance of scientific research results. Factors, such as science and technology investment, regional development environment, degree of foreign exchange, and disciplinary differences can impact on technology transfer efficiency through influencing scientific research efficiency, that is technology investment →scientific research efficiency→technological transfer efficiency. Therefore, it is necessary to apply a whole new perspective to comprehensively evaluate scientific transfer efficiency with two dimensions.

In fact, technological transfer efficiency is the evaluation for scientific research results efficiency, therefore, scientific research results as input indicators to evaluate technological transfer efficiency is necessary. The proposed indicators are shown in Table 1.

Table 1. Evaluation indicators for the efficiency of scientific research and technology transfer

		project	index	unit		
Scientific research efficiency evaluation	Input	researcher	Research staff	people		
		research funding	science and technology funds, Science and technology expenditure	thousand yuan		
	Output	Science and technology projects	Science and technology projects number	item	Input	Technology transfer evaluation
		Technology monograph	Monograph quantity	unit		
		Academic paper	papers number	article		
		Identification result	Identification number	item		
		Achievement awards	Achievement awards	item		
		transfer number	contracts signed	item	Output	
		transfer income	Actual transfer income	thousand yuan		

3. Empirical Analysis

3.1. Analysis of the Efficiency of Scientific Research and Technology Transfer

Sichuan province, as one of the major educational provinces in China, its government always attaches a great importance in technology investment and vigorously promotes the transformation innovation, and transformation of technological achievements. In order to deeply understand the differences of scientific research and technology transfer efficiency among different universities, this paper chooses eight representative universities for comparative analysis.

According to the 2013-2017 Compilation of Science and Technology Statistics in institutions of higher Education, we analysis the efficiency of scientific research and technology transfer.

3.1.1. Scientific Research Efficiency

As can be seen from Table 2, the overall scientific research efficiency has a slight decrease from 2012 to 2016, it is in line with a phenomenon that scientific investment in Sichuan is growing rapidly while research outcomes are increasing slowly. Between 2012 and 2016, overall scientific research efficiency of the two 985 college university were below overall efficiency level of Sichuan Province. Sichuan University as the one of the 985 university, its scientific research investment always ranks top. However, from DEA efficiency analysis results, under existing scientific research investment scale, this university does not reach optima scientific outcome level, there is still a room

for improvement. The same with the Electronic Science and Technology University. Compared with the two 985 university, other 6 universities hit the optimal level during the 5 years.

Based on the analysis results of Table 2, we get a conclusion that non-985 colleges and universities overall scientific efficiency are better than 985 universities. Generally, people tend to believe that scientific research level of 985 universities are higher than that of non-985 universities.

Table 2. 2012-- 2016 scientific research efficiency of universities in Sichuan

School name \ year	2012			2013			2014			2015			2016			Mean
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE
Total	0.901	1	Dec.	0.832	1	Dec.	0.816	1	Dec.	0.751	1	Dec.	0.815	1	Dec.	0.823
Scu	0.904	1	Dec.	0.748	1	Dec.	0.782	1	Dec.	0.677	1	Dec.	0.843	1	Dec.	0.791
Estu	0.691	0.805	Dec.	0.703	1	Dec.	0.542	0.929	Dec.	0.356	0.595	Dec.	0.426	0.572	Dec.	0.543
Sjtu	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1
Scau	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1
Cdtu	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1
Cditu	1	1	con.	0.728	1	Incre.	1	1	con.	1	1	con.	0.845	1	Dec.	0.969
Xhu	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1
Cdcmu	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1

*Total: General Data of Sichuan, Scu: Sichuan University, Estu: Electronic Science and Technology University, Sjtu: Southwest Jiao Tong University, Scau: Sichuan Agricultural University, Cdtu: Chengdu Technology University, Cditu: Chengdu Information Technology University, Xhu: Xihua University, Cdcmu: Chengdu Chinese Medicine University

3.1.2. Technology Transfer Efficiency

From Table 3, overall technological transfer efficiency of universities in Sichuan Province has climbed steadily, and reached the DEA validity in 2016. Technological transfer efficiency of the two 985 universities in Sichuan witness an increasing trend. In 2014, technology transfer integrated efficiency reached DEA validity, which means the market has gradually accepted the research achievements from Sichuan University, the scientific achievements transformation and the market acceptance has been optimized year by year. Technological transfer efficiency of Electronic Science and Technology University met the optimization in 2015, but with a decline in 2016. That means its technological transfer efficiency is not stable, there still has a huge improved room.

Table 3. Technology transfer efficiency of universities in Sichuan, 2012-2016

School name \ year	2012			2013			2014			2015			2016			Mean
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE	TE
Total	0.217	1	Dec.	0.565	1	Dec.	0.569	1	Dec.	0.768	1	Dec.	1	1	con.	0.624
Scu	0.132	1	Dec.	0.922	1	Dec.	1	1	con.	1	1	con.	1	1	con.	0. 11
Estu	0.111	0.435	Incre.	0.363	0.440	Incre.	0.739	0.745	Incre.	1	1	con.	0.499	0.589	Dec.	0.542
Sjtu	0.018	0.418	Incre.	0.020	0.171	Incre.	0.077	0.367	Incre.	0.131	1	Incre.	0.064	0.437	Dec.	0.062
Scau	0.477	0.681	Incre.	0.603	0.767	Incre.	1	1	con.	0.886	1	Incre.	0.527	0.617	Dec.	0.699
Cdtu	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1
Cditu	0.052	1	con.	1	1	con.	1	1	con.	1	1	con.	0.163	1	Dec.	0.643
Xhu	1	1	con.	1	1	con.	0.063	1	Incre.	0	1	--	0.077	1	Dec.	0.428
Cdcmu	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1	1	con.	1

The overall technology transfer efficiency of Southwest Jiao Tong University is low, only 0.062, which indicates that although its research efficiency is relatively high, its transfer efficiency is low, and the scientific research results are not effectively converted into economic benefits. There is an urgent need to vigorously promote the transformation of scientific research results.

3.2. Dynamic Analysis of Scientific Research and Technology Transfer Efficiency

We apply DEA-Malmquist index to have a further analysis of 8 universities' scientific research input and output panel data in Sichuan, results of Technology Efficiency Change (EC), Technology Change (TC) and Total Factors Productivity Change Index (MI) are shown in Table 4 and Table 5.

As shown in Table 4, from the perspective of MI, in 2012-2016 the overall scientific efficiency average value of universities in Sichuan Province is 0.999, the scientific productivity level is stable. It means, though total factors productivity is stable, overall scientific research efficiency level of universities in Sichuan decreased, the results meet the previous analysis. From 2012 to 2015, scientific research technology efficiency had a negative growth, indicating that scientific research management level and organization management system of universities in Sichuan both declined.

Table 4. Malmquist index of scientific research efficiency of universities in Sichuan, 2012-2016

School name \ year	2012-2013			2013-2014			2014-2015			2015-2016			Mean		
	EC	TC	MI	EC	TC	MI	EC	TC	MI	EC	TC	MI	EC	TC	MI
Total	0.923	0.914	0.844	0.981	1.099	1.078	0.921	1.159	1.067	1.085	0.928	1.007	0.978	1.025	0.999
Scu	0.828	0.904	0.749	1.045	1.077	1.126	0.865	1.219	1.055	1.245	0.891	1.109	0.996	1.023	1.009
Estu	1.017	0.918	0.934	0.769	1.222	0.941	0.656	1.490	0.978	1.198	0.889	1.065	0.91	1.129	0.979
Sjtu	1	0.770	0.770	1	0.999	0.999	1	1.036	1.036	1	0.857	0.857	1	0.916	0.916
Scau	1	1.238	1.238	1	1.14 1	1.14 1	1	1.475	1.475	1	0.994	0.994	1	1.212	1.212
Cdtu	1	0.810	0.81	1	1.249	1.249	0.966	1.441	1.392	1.035	1.048	1.084	1	1.137	1.134
Cditu	0.728	0.995	0.724	1.374	1.166	1.602	1	3.173	3.173	0.845	0.302	0.255	0.98 7	1.409	1.439
Xhu	1	1.259	1.259	1	0.940	0.94	1	0.720	0.720	1	1.063	1.063	1	0.996	0.996
Cdcmu	1	1.459	1.459	1	0.953	0.953	1	0.604	0.604	1	0.628	0.628	1	0.911	0.911

Table 5. Malmquist index of technology transfer of universities in Sichuan, 2012-2016

School name \ year	2012-2013			2013-2014			2014-2015			2015 -2016			Mean		
	EC	TC	MI	EC	TC	MI	EC	TC	MI	EC	TC	MI	EC	TC	MI
Total	2.60	0.462	1.202	1.008	0.912	0.919	1.088	0.965	1.050	1.614	1.279	2.064	1.578	0.905	1.309
Scu	6.977	0.588	4.105	1.084	0.739	0.802	1	1.148	1.148	1	1.170	1.170	2.515	0.911	1.806
Estu	3.285	0.543	1.783	2.032	0.827	1.679	1.351	0.822	1.111	0.501	1.238	0.620	1.792	0.858	1.298
Sjtu	1.162	1.014	1.178	3.757	0.475	1.786	1.253	0.660	0.827	0.669	2.284	1.527	1.71	1.108	1.329
Scau	1.266	0.909	1.150	1.658	0.694	1.150	0.622	0.786	0.489	0.848	1.108	0.939	1.098	0.874	0.932
Cdtu	1	1.115	1.115	1	0.729	0.729	1	0.607	0.607	1	1.072	1.072	1	0.881	0.881
Cditu	19.3	0.969	18.7	1	0.427	0.427	1	0.413	0.413	0.163	2.408	0.393	5.366	1.054	4.983
Xhu	1	0.826	0.826	0.063	0.863	0.054	0	0	0	0	0	0	0.266	0.845	0.44
Cdcmu	1	0.610	0.610	1	1.159	1.159	1	0.615	0.615	1	13.27	13.27	1	3.913	3.913

In the perspective of technology transfer efficiency, as shown in Table 5, Malmquist index of universities in Sichuan and its decomposition value are on the contrary of scientific research efficiency. It tells that the organization management level of technology transfer efficiency of universities in Sichuan shows an upward trend, however, the overall progress level is in a downward trend, management growth level is decreasing year after year. Besides, overall technology transfer efficiency in Sichuan province has been promoted hugely, with a growth rate at 106.4%, Chengdu Traditional Chinese Medicine University has the most outstanding growth, 1226.6%, which becomes the main factor promoting the technological transfer efficiency.

4. Summary

This paper analyzes the efficiency of scientific research transfermation. The analysis results of DEA-Malmquist index shows that scientific research efficiency growth of universities in Sichuan is

slowing down, while technology transfer efficiency is in a stage of climbing up. The improvement of technological efficiency is the key factor to push the technology transfer efficiency. And the input and output structure, irrational scale, organization management level are the main reasons affecting scientific research efficiency and technology transfer efficiency. Funds and talents invested in science and technology directly affect scientific research efficiency. It has to be controlled in a rational scale, and properly balances scientific investment in different types of universities. Besides, management mechanism also affects enthusiasm of scientific researchers. In addition, scientific research transfer efficiency in universities can be promoted by optimizing personnel and funds investment, mechanism and organization management.

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