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Research on the Evaluation of Enterprise-University-Research Cooperation Ability in Hubei Province

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***Abstract*—**The measurement of enterprise-university-research cooperative efficiency has important meanings in improving the cooperative efficiency, strengthening the effective integration of regional resource, enhancing the ability of regional innovation and promoting the development of regional economy. The paper constructs the DEA method and DEA-Malmquist productivity index method to research the cooperation efficiency of Hubei by making comparisons with other provinces in China. The study found out the index of technology efficiency is 0.52 and the enterprise-university-research cooperative efficiency is Non-DEA efficient. To realize the DEA efficiency of Hubei province, the amount of 1652.596 R&D employees and 638.368 R&D employees' full time equivalence should be reduced or 137.89 billion yuan of new products' sales income be increased. Finally, it puts forward policy recommendations on existing problems to strengthen the standings of the cooperation, realize the effective application of the research results, and improve the level of management of enterprise-university-research cooperation efficiency.

***Keywords*—**Cooperation Ability, DEA Method, Enterprise-university-research Cooperation, Malmquist Efficiency Index.

I. Research Background

THE enterprise-university-research cooperation is playing an increasingly important role in enhancing the independent innovation ability of enterprise, speeding up the industrialization of technological production and promoting the adjustment of industrial structure. It has an important strategic position in the development of economic growth [1]. In China, as an important constituent part of state innovation system, enterprise-university-research cooperation is promoted to the height of national strategy. As the practical enterprise-university-research cooperation goes deeper, the research of its efficiency and performance becomes more and more important. The overseas researchers such as Bonaccorsi, believed that the cooperation performance of enterprise-university-research includes three parts: Generation, Transmission, and Derivative. The measurement of performance includes subjective measurement and objective measurement. The objective measurement is about the quantity of new products, researchers, publications and patents etc. [2]; Mora Valentin used the degree of cooperation's satisfaction and the continuity of the cooperation to do the measurement. He also designed a corresponding measurement scale [3]; Maria Theresa Larsen found out that the professors who cooperate with enterprises usually have more publications. The productivity and the degree of cooperation form an inverted "U" distribution [4]; Antonio pointed out that the innovation of enterprise-university-research should be based on the technology complementation and alliance [5].

The research achievements inland is as follows: Jin and Luo established a performance evaluation index system for the enterprise-university-research cooperation by using a combining method [6]. Liu researched the cooperation efficiency of ten main manufacturing industries in Shaanxi province by using the DEA method [7]. Xin analyzed decision making unit's feature of distribution and projection property. He proposed improved methods for DEA unefficient parts and also raised the typical method and evaluation procedure for the measurement of cooperation parts' overall efficiency [8]. Li designed the performance evaluation index from two aspects: input and output. And he used the method of set pair analysis to establish the performance evaluation model of enterprise-university-research projects [9]; Xiao evaluated the innovation efficiency of 260 cooperation enterprises by using beyond logarithm stochastic frontier model [10]; Li analyzed the innovation performance of enterprise-university-research cooperation from the micro angle of coupling interaction [11].

Hubei province is a major province of science and education. It has solid foundation of scientific research and it has huge potential of technological innovation. The amount of colleges and universities in Hubei province ranks front row in the country. Its research in the fields such as optical fiber communication, laser, plant function genomics are ahead of other regions of the country. In recent years, considering the practical situation, the provincial Party committee and provincial government of Hubei province strongly promoted the enterprise-university-research cooperation. Enterprises, universities and scientific research institutions take the enterprise-university-research cooperation as the inner demand of self-development. They explored and practiced all kinds of valid formation. It makes the enterprise-university-research cooperation has a good development trend. However, in general, the technology innovation system which makes enterprise as the main body and market as the guidance has not formed. The function of enterprise which is as the main body of technology innovation is obviously insufficient. The level of the enterprise-university-research cooperation is low and the

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valid connection and interaction between enterprise and university is insufficient.

This paper uses the DEA-Malmquist index method to investigate the enterprise-university-research cooperative efficiency and sustainability according to the panel data of 30 provinces in China. It offers guidance and reference to the assessment of the enterprise-university-research cooperative ability. At the same time, it puts forward policy recommendations on existing problems to strengthen the standings of the enterprise-university-research, realizes the technology transfer and the effective application of the research results, and improves the level of management of enterprise-university-research cooperative efficiency.

II. DEA Method and Malmquist Index Method

A. DEA Model and the Measurement

Data envelopment analysis (DEA) is a nonparametric analysis of evaluating multiple input and multiple output. It is put forward by the famous American operational research expert Charnes in 1978. It is method which uses mathematical programming model to evaluate whether a "part" or a "unit"(it is named as "decision-making unit", DMU) which has multiple input and output is relative efficient(it is named as DEA efficiency) [12]. DEA confirms the leading surface of the manufacturing system using lining programming technology. Then it can get the information about relative efficiency of each decision-making unit and economies of scale. According to the observation data of each DMU, it can be judged that whether each DMU is DEA efficient. Essentially, it is judged that whether DMU is on the leading surface of production possibility. In economics, production leading surface is a kind of generalization from production function to multiple output. Using DEA method and model can ensure the structure of the production leading surface. Therefore, DEA is a nonparametric statistical estimation method [13].

The representative model of DEA is CCR, BCC etc. The premised hypothesis of CCR is the returns to scale not changed. It means the output is of the same proportion as the increase of the input. The scale does not affect its technical efficiency. This kind of condition does not confirm to the reality. This paper aims to investigate the enterprise-university-research cooperative efficiency. However, the enterprise-university-research is usually in the condition of variable return to scale. Therefore, BCC model which considers the scale reward is used here. The model assumes there are n decision-making units, and each DMU has m types of "input" and s types of "output" which presents "the cost resource" and "the work efficiency" respectively. It uses x_{ij} ($x_{ij}>0$, i=1, 2, …, m) to represent the number i targeted input value of the number j DMU. Yrj ($y_{rj}>0$, r=1, 2, …, s) means the number r targeted output value of number j DMU. It is recorded as $X_j=(x_{1j}, x_{2j}, \ldots, x_{mj})$ T, $Y_j=(y_{1j}, y_{2j}, \ldots, y_{sj})$ T, j=1, 2, …, n.

In order to avoid the condition that the return of scale is constant, a convexity postulated condition should be added: $\sum_{j=1}^{n}\lambda_j=1$ .After Archimedes dimensionless ε, slack variable of input s^- and slack variable of output s^+ are imported in, the number j_0 DMU's BCC model is :

$$\begin{cases} M \text{ in}\,\theta \\ S.T.\sum_{j=1}^{n} X_j\lambda_j + s^- = \theta X_0 \\ \sum_{j=1}^{n} Y_j\lambda_j - s^+ = Y_0 \\ \sum_{j=1}^{n}\lambda_j = 1 \\ \lambda_j \geq 0,\ j=1,2,\cdots,n \\ s^+ \geq 0, s^- \geq 0 \end{cases} \quad (1)$$

θ is overall efficiency which means technical efficiency. It represents the correlation between input and output in operation. It reflects that whether the resource allocation and the proportion of input and output are appropriate. θ=1, it means the representative DMU is DEA efficient. Its proportion of input and output is appropriate and the production scale is suitable. Considering scale efficiency, technical efficiency can be broken up into pure technical efficiency and scale efficiency. Pure technical efficiency merely reflects whether the proportion of input and output is appropriate, meaning the rationality of technological level. Scale efficiency reflects whether the operation is conducted under suitable scale, meaning "Technical Efficiency= Pure Technical Efficiency×Scale Efficiency". The economic meaning of theoretical equation is as follows: if the value of pure technical efficiency and scale efficiency are both 1, it means DEA efficiency. If only one of these two is 1, it means weak DEA efficiency. If neither of these two is 1, it means non DEA efficiency. $s^-$and s^+ are non-zero. They mean the redundancy of input and deficiency of output respectively.

DEA method is widely used in the areas such as progression of technology and productivity, the creation of technology and financial investment. It is used to do the efficiency analysis, assessment and determination. Its superiority in tackling with the problem of multiple input and output is shown in:

1) DEA method is invariable in each unit. The variation of input and output would not affect the value of efficiency. The weight of index is generated by mathematical programming according to the data of samples. It excluded lots of subjective factors effectively and it is strongly objective.
2) DEA method has no need to ensure the explicit relationship between input and output and there is no need to define the concrete form of production function. There is no strict demand of the price information of input and output. It made the investigation of complex productive process easier [14].

B. Malmquist Index Method of Total Factor Productivity

The achievement of theory and application of DEA is increasingly abundant. The dynamic DEA method is one of it. Dynamic DEA method means importing time space on the basis of decision space and target space. The research is about how input (or output) of DMU can affect the progress of

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productivity. The basis of dynamic DEA is Malmquist index method of total factor productivity.

Malmquist index method of total factor productivity is come up with Malmquist at first. It is used to present the index of total factor productivity of each unit. Another researcher Fare has improved it. The DEA—Malmquist index constructed by him is total factor productivity index on base of using panel data:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = [\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}]^{1/2} \quad (2)$$

$M(x^{t+1}, y^{t+1}, x^t, y^t)$ presents the variation condition of total factor productivity; (x^{t+1}, y^{t+1}) and (x^t, y^t) presents vector quantity of input and output in t+1 and t; D^t and D^{t+1} presents that when taking the technical parameters as reference, the distance function of decision-making unit in t and t+1 respectively.

Fare also pointed out that: If total factor productivity index is greater than 1, it means the growth rate is positive from period t to period t+1. Total factor productivity index can be decomposed into technical efficiency change (effch) and technical change (techch)[15]:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times [\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}]^{1/2} = \text{effch} \times \text{techch} \quad (3)$$

when returns to scale changes, the index of technical efficiency change can be decomposed into pure technical efficiency change (pech) and scale efficiency change (sech). Therefore, the function can be adjusted as follows:

$$\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} = \frac{D^{t+1}(x^{t+1}, y^{t+1}/V)}{D^t(x^t, y^t/V)} \times \frac{S^{t+1}(x^{t+1}, y^{t+1})}{S^t(x^t, y^t)} = pcch \times sech \quad (4)$$

In this function, $\frac{D^{t+1}(x^{t+1}, y^{t+1}/V)}{D^t(x^t, y^t/V)}$ presents pure technical efficiency change (pech); $\frac{S^{t+1}(x^{t+1}, y^{t+1})}{S^t(x^t, y^t)}$ presents scale efficiency change (sech).

Therefore:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \text{tfp} = \text{effch} \times \text{techch} = \text{pech} \times \text{sech} \times \text{techch} \quad (5)$$

In the function above: tfp>1 means that total factor productivity improves, otherwise it declines. Techch means index of technical progress from period t to t+1. It is called "leading surface movement effect". If techch>1, it means that the technology has been improved or innovated. The best state of production has been improved, otherwise, the technology recessed. effch presents the realization degree of best production state. It is also called "chase effect". If effch>1, it means the production of DMU is close to the best production state, and the relative technical efficiency is improved, otherwise, the efficiency reduces. sech presents the change of the degree that DMU close to the best scale. If sech is greater than 1, it means DMU is closer to the best scale, otherwise, it is deviate from the scale.

III. Empirical Analysis

A. The Assessment Indicator System of Enterprise-University-Research Cooperative Efficiency Based on the DEA-Malmquist Index Method

When using DEA model and Malmquist index method to do the assessment of enterprise-university-research cooperative efficiency and sustainability, the key is to select the input and output index. The index should not be too much. The selection should confirm to the principle of systematicness, applicability and availability. At the same time, it should be noticed that the strong correlation of each index will affect the evaluating effectiveness. Therefore, the index should not be correlated with each other. This paper constructs the assessment indicator system mainly from two parts of the provincial enterprise-university-research cooperation: input and output.

The fundamental core resources of enterprise- university-research activity are human capital and material capital. Human capital is the primary core factor among all the factors, and material capital is the premise and basis for human capital to undertake enterprise-university-research activity. This paper adopts internal R&D expense as an index to measure material capital input in enterprise-university-research cooperation. This paper adopts R&D internal expense as an index to measure material capital input in enterprise-university-research cooperation. R&D expense represents the support and range of the innovation. It can be divided into several parts according to the financial resources: government funds, business capital, foreign capital and other capitals. The R&D expense is used in 3 aspects; fundamental research, applied research and experimental development. The amount of R&D employees and R&D employees' full time equivalence are taken to measure the input of human capital. The R&D employees include enterprise internal research personnel, and the technicians from universities or scientific research institutions. R&D employees' full time equivalence is the amount of full time employees (part time employees should be converted to full time employees according to workload).

As for the subject of enterprise-university-research the output of enterprise-university-research activity is the innovative product achieved by valid exploitation and configuration of all kinds of resources. The measurement index of enterprise-university-research cooperation's innovative achievements should embody 3 parts: knowledge production, achievement transformation and products production and marketing. As the scientific achievements of enterprise-university-research cooperation, patent is one of the main manifestation pattern of knowledge production. Patents include invention, utility model and appearance design. The quantity of granted patents can better reflect innovative achievements and effective output than applied patents. Therefore, this paper takes the quantity of granted patents as the index to measure scientific and technological achievements. At the same time, the fundamental objective of enterprise-university-research

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cooperation is the economically realization of scientific and technological achievements. It means acquiring economic benefit through successful commercialization of scientific achievements is the most fundamental objective. The volume of transaction on technology market can reflect achievements in the process of cooperation. It also represents the degree of efforts and activeness of scientific research and technical exchange in a region. The sales revenue of new products can represent the degree that cooperation achievements accepted by the market and customers. It can also reflect the effective utilization of the enterprise-university-research cooperation. Therefore, it selects the volume of settled technical contracts and sales revenue of new products as the indexes of reflecting enterprise-university-research cooperation's output.

B. Date Resource and the Procession

This paper uses DEA-Malmquist index method to investigate the enterprise-university-research cooperation's efficiency and sustainability of 30 provinces (autonomous region, direct-controlled municipality). The 30 provinces are as decision-making units. If sample size (30) is greater than two times of input and output index' product, it can be believed than the results of DEA assessment has reasonable discrimination. The decision-making unit is each province in China. Therefore, they are congeneric decision-making units which can meet the demand of DEA analysis.

The data of input and output of enterprise-university-research cooperation such as the internal expense of R&D, the R&D employees, the R&D employees' full time equivalence, the quantity of granted patents (3 types of patents), the sales revenue of new products, the volume of settled technical contract are all came from Science and Technology of China Statistical Yearbook in the year 2007-2012(the input and output data of enterprise-university-research cooperation in each province 2006-2011). "The large and medium-sized industrial enterprise" is adopted as the statistical caliber of sales revenue before the year 2011. In 2011, "industrial enterprises above designated size" is adopted as the statistical caliber. The reason of the change is because the statistical caliber of "industrial enterprises above designated size" improved to "the main business income each year is above 20 million" from "5 million" from 2011, which is basically equal to " the large and medium-sized industrial enterprise" before 2011. Therefore, the statistical caliber is consistent actually. It is generally acknowledged that the output of enterprise-university-research cooperation has hysteretic nature. The paper takes 1 year as lag phase. When assessing the cooperation efficiency, the output of t years is in correspondence with t-1 year. For example, the efficiency evaluation data in2007 is from the input data in 2006 and the output data in 2007. By parity of reasoning, the evaluation data in 2011 is from the input data in 2010 and the output data in 2011.

C. Analysis of Enterprise-University-Research Cooperation Efficiency in Hubei Province

1) Overall Efficiency Analysis of Enterprise-University-Research Cooperation in Hubei Province

The software Deap2.1 is used to process the data of cooperation's input and output index from the year 2007-2011. The data processing covers 30 provinces including Hubei province. The resolved results of overall technical efficiency, pure technical efficiency and scale efficiency in each province is got. As shown in Table I, the overall efficiency of the enterprise-university-research cooperation in the year 2007-2011 is 0.520, less than 1. After decomposing it, the value of pure technical efficiency and scale efficiency is 0.526 and 0.989 respectively. They are Non-DEA efficient. The average overall efficiency nationwide is 0.712, less than 1, the pure technical efficiency is 0.749 and scale efficiency is 0.953. It means that as for the overall efficiency (both pure technical efficiency and scale efficiency) of enterprise-university-research cooperation in Hubei province, there is large rising space.

TABLE I
THE DECOMPOSED DEA VALUE OF EACH PROVINCES' ENTERPRISE-UNIVERSITY-RESEARCH EFFICIENCY IN 2007-2011

Provinces	Technical Efficiency (crste)	PureTechnical Efficiency (vrste)	Scale Efficiency (scale)	Returns to Scale (type)
Beijing	1	1	1	-
Tianjin	1	1	1	-
Hebei	0.440	0.443	0.993	irs
Shanxi	0.409	0.467	0.875	drs
Inner Mongolia	0.597	0.613	0.974	irs
Liaoning	0.586	0.593	0.989	drs
Jilin	0.698	0.714	0.978	drs
Heilongjiang	0.556	0.565	0.984	drs
Shanghai	1	1	1	-
Jiangsu	0.748	1	0.748	drs
Zhejiang	1	1	1	-
Anhui	0.478	0.487	0.980	drs
Fujian	0.857	0.86	0.997	irs
Jiangxi	0.451	0.467	0.965	irs
Shandong	0.866	1	0.866	drs
Henan	0.548	0.557	0.985	drs
Hubei	0.520	0.526	0.989	drs
Hunan	0.767	0.799	0.961	drs
Guangdong	1	1	1	-
Guangxi	0.797	0.897	0.889	drs
Hainan	1	1	1	-
Chongqing	1	1	1	-
Sichuan	0.531	0.534	0.995	drs
Guizhou	0.647	0.665	0.974	irs
Yunnan	0.649	0.650	0.999	irs
Shanxi	0.268	0.270	0.992	irs
Gansu	0.651	0.662	0.983	irs
Qinghai	0.933	1	0.933	irs
Ningxia	0.361	0.693	0.521	irs
Xinjiang	1	1	1	-
Mean	0.712	0.749	0.953	

Annotations: "irs" means DMU is at the stage of increasing returns to scale,"-" means DMU is at the stage of constant returns to scale, "drs" means DMU is at the stage of decreasing returns to scale.

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2) Evaluation of Enterprise-university-research Cooperative Technical Efficiency in Hubei Province

From the results in Table I, it can be concluded that:

Firstly, in the aspect of technical efficiency, the technical efficiency in Hubei province is 0.52 which is Weak-DEA efficient and is lower than the national average value 0.712. Among 30 provinces in China, 8 provinces(autonomous regions, direct-controlled municipality) including Beijing, Tianjin, Shanghai, Zhejiang, Guangdong, Hainan, Chongqing and Xinjiang which are DEA Efficient account for 26.7% of the 30 provinces nationwide. Jiangsu, Shandong, Qinghai provinces which are Weak-DEA Efficient account for 10% of the 30 provinces. 19 provinces (such as Shanxi, Hebei and Shanxi) which are Non-DEA efficient account for 53.3% out of 30 provinces. The cooperation technical efficiency of Hubei Province ranks 24th out of 30 provinces. It is relatively backward in China. There is a large gap between Hubei and the best provinces or municipalities (Beijing, Tianjin etc.) which cooperation technical efficiency's DEA is 1.

Secondly, from the perspective of pure technical efficiency, the pure technical efficiency of Hubei province is 0.526 which is below the national average value 0.749. The pure technical efficiency of 11 provinces (autonomous regions, direct-controlled municipality) is DEA efficient. These provinces account for 26.7% out of the 30 provinces nationwide. The pure technical efficiency values of other 19 provinces are less than 1. The cooperation pure technical efficiency of Hubei Province ranks 25th out of 30 provinces. It is relatively backward in China. There is a large gap between Hubei and the best provinces. Pure technical efficiency reflects the production efficiency affected by management and technology. Therefore, to a certain degree, it can represent the level of the enterprise-university-research cooperation's management and technology and examine whether it is of the best production pattern in each province. It can be concluded that: In the respect of management and technology, the enterprise-university-research cooperation in Hubei province falls behind. Compared with the best production pattern, there is large room for growth. Its management and technology should be improved continually.

Thirdly, from the perspective of scale efficiency, the DEA value of scale efficiency in Hubei is 0.989, exceeding the national average value 0.953. Only 8 provinces' DEA is equal to 1. And the returns to scale are consistent. 22 provinces which scale efficiency's values are less than 1 account for 73.3% out of 30 provinces in China. The cooperation pure technical efficiency of Hubei Province ranks 17th out of 30 provinces. It is relatively backward in China. There is a large gap between the scale efficiency value of Hubei and that of the best provinces. At the same time, in Hubei, there is decreasing return to scale of the enterprise-university-research cooperation. The utilization rate of cooperation input factors is low .It have not reach the optimal scale of production which leads the diseconomies of scale. Therefore, as for Hubei, the investment of enterprise-university-research cooperation should not be emphasized too much. In order to effectively improve the enterprise-university-research cooperation efficiency of Non-DEA efficient decision-making unit, we should integrate the resource input structure and pay attention to the achievement transformation.

Fourthly, the input redundancy and output insufficiency (shown in Tables II and III) of enterprise-university-research cooperation in Non –DEA efficient provinces can be calculated according to the data of 30 provinces(autonomous regions, direct-controlled municipality) in 2007-2011 by using the software Deap2.1. It means transferring Non-DEA efficient to DEA efficient, the needed increased output and reduced input can be calculated. From the table below, it can be concluded that the technical efficiency of Hubei is 0.52 and is Non-DEA efficient. To realize DEA efficiency, the amount of 1652.596 R&D employees and 638.368 R&D employees' full time equivalence should be reduced or 137.89 billion Yuan of new products' sales income be increased. The input redundancy is mainly embodied in R&D employees and R&D employees' full time equivalence. Other provinces nationwide except Ningxia are in the same situation. The output deficiency of Hubei is mainly embodied in the sales revenue of new products. It is not reflected by the quantity of granted patents and the volume of technical contracts transaction. In other provinces nationwide, the output deficiency is embodied in all the three indexes. The volume of technical transaction contracts embodied in major provinces comparatively. Therefore, it can be seen that though the output is sufficient in Hubei concerning the two indexes: the quantity of granted patents and the volume of technical transaction contracts, the utilization rate is low. It does not transform to the selling of new products. The practical contribution to economic growth is insufficient. Therefore, what Tables II and III list has practical and guiding significance on the technical efficiency of enterprise-university-research cooperation of Hubei province.

TABLE II
THE INPUT REDUNDANCY OF NON-DEA EFFICIENT PROVINCES

Provinces	R&D Internal Expense (10^4 Yuan)	R&D Employees (persons)	R&D Employees' Full Time Equivalence (persons/year)
Hebei	0	0	412.367
Shanxi	0	19392.910	5957.400
Inner Mongolia	0	0	1745.806
Liaoning	0	1590.447	0
Jilin	0	0	23.1050
Heilongjiang	0	0	4284.803
Anhui	0	3220.305	0
Fujian	0	0	3878.505
Jiangxi	0	0	1388.704
Henan	0	18912.27	6011.513
Hubei	0	1652.596	638.368
Hunan	0	22837.20	2543.158
Guangxi	0	16266.00	5286.537
Sichuan	0	11607.71	4707.806
Guizhou	0	1684.812	1586.712
Yunnan	0	4401.030	1558.478
Shanxi	0	0	3620.917
Gansu	0	12176.730	2089.596
Ningxia	13414.89	0	1846.994
Mean	447.163	3791.400	1586.026

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TABLE III
THE OUTPUT DEFICIENCY OF NON-DEA EFFICIENT PROVINCES

Provinces	The Quantity of Granted Patents (patents)	Sales Revenue of New Products (10^4 Yuan)	The Volume of Technical Transaction Contracts (10^4 Yuan)
Hebei	0	0	56298.250
Shanxi	311.242	0	90566.320
Liaoning	0	2370179.000	0
Jilin	905.243	0	126256.800
Heilongjiang	0	3788594.000	0
Fujian	0	0	416564.700
Jiangxi	0	0	76383.550
Henan	0	0	48645.950
Hubei	0	1378934.000	0
Hunan	0	3582102.000	0
Guangxi	312.490	0	156351.000
Guizhou	0	0	29950.880
Gansu	115.253	0	0
Ningxia	0	339136.200	686.562
Mean	54.808	381964.800	33390.130

D.Sustainability Analysis of the Enterprise-University-Research Cooperation Efficiency

The sustainability of enterprise-university-research cooperation's total factor productivity can be further studied by using DEA-Malmquist index method. The Malmquist index which reflects the increasing or decreasing degree of total factor productivity is the result got from comparing the efficiency this year with last year. If the index is greater than 1, it means the efficiency has been improved. On the contrary, if the index is less than 1, it means the efficiency has been reduced. If the index is equal to 1, it means the efficiency has not been changed. According to the research of Fare, each index minus 1 is the growth rate of each year. The annual average value, annual average index and its constitution technical efficiency change (effch), technical progress change (techch), pure technical efficiency change (pech), scale efficiency change (sech) and total factor productivity change (tfpch) is shown in Table IV.

The growth of the productivity is the result of the technical progress and the improvement of technical efficiency. The technical progress represents the outward movement of the optimal production possibility curve of an economic entity. The technical efficiency represents the relative distance from the practical production possibility curve to the optimal production possibility curve of an economic entity. From Table IV, it can be concluded that:

Firstly, in general, the total factor productivity of enterprise-university-research cooperation is improved a little in the year 2007-2011, and the growing rate is 8.1%. In the same period, the total factor productivity of most other provinces nationwide is all improved to some degree, excepting 5 provinces (Xinjiang, Hainan, Inner Mongolia, Yunnan and Guangxi). The total factors growth rate of Hubei Province ranks 21th out of 30 provinces.

Secondly, from the perspective of the constitution of total factor productivity, as for Hubei province, the technical efficiency is declined a little and the descend rate is 1.2%. The technical progress is improved by 9.3%. It means as for Hubei province, the production technical progress is the main source of total factor productivity growth. The average nationwide technical efficiency is declined by 1.2%. The technical efficiency of Hubei Province is declined by 1.2%, ranking the 17th out of 30 provinces, which is the same as the average value. The average nationwide technical progress is increased by 10.9%. It is 9.3% in Hubei province which is lower than the average value by 1.7%, ranking 19th out of 30 provinces. To compare Hubei province with other leading provinces, it can be found out that Anhui and Shaanxi are in the leading place nationwide. The annual technical progress growth rate is 12.8% and 9.7% respectively and the technical efficiency growth rate is 17.7% and 19.5% respectively. On one side, the growth of total factor productivity in Anhui and Shaanxi arises from the growth of technical efficiency. On the other hand, it arises from the improvement of technical progress. More of it is from the improvement of technical efficiency comparatively. As for Hubei province, its enterprise-university-research cooperation depends mainly on technical progress. However, its technical progress does not reach the national average value. It is the main reason why its total factor productivity is low.

TABLE IV
THE MALMQUIST PRODUCTIVITY INDEX AND ITS DECOMPOSITION OF REGIONAL ENTERPRISE-UNIVERSITY-RESEARCH COOPERATION IN 2007-2011

Province	Effch	Techch	Pech	Sech	Tfpch	Tfpch rank
Beijing	1	1.182	1	1	1.182	6
Tianjin	0.989	1.139	0.989	1	1.126	11
Hebei	0.99	1.170	0.997	0.993	1.158	9
Shanxi	0.960	1.045	0.940	1.021	1.003	24
Inner mongolia	0.871	1.080	0.932	0.934	0.941	28
Liaoning	0.987	1.113	0.987	1	1.099	17
Jilin	1.088	1.124	1.088	1	1.223	4
Hei longjiang	0.992	1.070	0.994	0.997	1.061	22
Shanghai	1	1.101	1	1	1.101	16
Jiangsu	1.075	1.186	1	1.075	1.276	3
Zhejiang	1	1.194	1	1	1.194	5
Anhui	1.177	1.128	1.174	1.002	1.327	1
Fujian	0.942	1.181	0.942	1	1.112	12
Jiangxi	0.990	1.143	0.992	0.998	1.132	10
Shandong	0.979	1.187	1	0.979	1.162	8
Henan	0.957	1.090	0.955	1.002	1.043	23
Hubei	0.988	1.093	0.986	1.002	1.081	21
Hunan	0.966	1.145	0.990	0.976	1.105	14
Guangdong	0.934	1.182	1	0.934	1.103	15
Guangxi	0.943	1.017	0.924	1.021	0.959	26
Hainan	0.910	1.021	1	0.910	0.929	29
Chongqing	1	1.107	1	1	1.107	13
Sichuan	1.010	1.160	1.023	0.988	1.172	7
Guizhou	0.995	1.090	1.014	0.982	1.085	19
Yunnan	0.913	1.041	0.936	0.975	0.950	27
Shanxi	1.195	1.097	1.198	0.998	1.312	2
Gansu	1.047	1.035	1.059	0.989	1.083	20
Qinghai	0.962	1.043	1	0.962	1.003	25
Ningxia	1.043	1.054	1.030	1.013	1.099	18
Xinjiang	0.813	1.086	0.861	0.944	0.883	30
Mean	0.988	1.109	0.998	0.989	1.095	

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IV. Conclusions and Suggestions

This paper uses DEA-Malmquis index method and the panel data of the enterprise-study-research cooperation's input and output of 30 provinces (autonomous regions, direct-controlled municipality) including Hubei province to do the investigation. It analyzes the enterprise-study-research cooperation ability of Hubei from the perspective of cooperation efficiency and total factor productivity sustainability. The conclusions are as follows:

Firstly, the technical efficiency of Hubei province is 0.52 which is Weak-DEA efficient. It is lower than the national average value which is 0.712. It has the problems of input redundancy and output deficiency. From the perspective of pure technical efficiency, the pure technical efficiency value of Hubei is 0.526 and it is lower than the national value which is 0.749. It indicates that its level of management and technology is below average. There is large room for growth. From the perspective of scale efficiency, the DEA value is 0.989. It is higher than the national average value which is 0.953.

Secondly, from the perspective of total factor productivity, the overall annual growth rate is 8.1% in Hubei. Thereinto, the average growth rate of technical progress is 9.3% while the decline rate of its technical efficiency is 1.2%. It indicates that the production technical progress is the main source of total factor productivity growth. However, the growth rate of its technical progress is still very low and it has not reached the national average level yet.

Therefore, in order to improve the enterprise-university-research cooperation ability of Hubei, policy suggestions can be put forward as follows:

Firstly, the utilization efficiency of resources should be raised. There should be a demand-oriented reform in aspects of organizational management, personnel system, talent cultivation and Personnel assessment. In order to make the most use of resources and improve its efficiency of enterprise-university-research cooperation, the reform should aim to simplify the R&D employees, cut down the work time of employees, raise the professional quality and work efficiency of R&D employees, enhance the level of management, optimize allocation of resources, and pay equal attention to the improvement of technical progress and technical efficiency.

Secondly, the transformation efficiency of scientific and technological achievements should be improved. The cooperation achievements, technology transformation and effective utilization are severely insufficient. Its productivity transformation efficiency is low. They should put emphasis on promoting the transformation of research achievements and make increasing economic income as the main target in order to realize the technology transformation and effective application

Thirdly, from the perspective of universities and scientific research institutions, they should depart from the strategic problems of the development, the prospective problems of science frontier and the major nonprofit problems of national economy and the people's livelihood to assemble the first-class innovation group, create first-class innovation atmosphere, gain first-class innovation achievements and cultivate first-class innovation talents. They can improve their research ability when trying to meet the national significant demands.

Fourthly, from the perspective of enterprises, in order to promote the technology level substantially, the enterprises should accelerate the development of frontier technology. The enterprises in Hubei province should meet Hubei's strategic demands, put emphasis on improving the capability of independent innovation, support the subdivision of mainstay industry, build the service platform of technology research and development and construct industrial technology innovation alliances through mutual cooperation with other superior fields.

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