Research on Development Efficiency of Chinese Science Popularization Industry Based on DEA Model

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Abstract- **The development of science popularization industry in China has been elevated to a strategic height. It plays an irreplaceable role in the improvement of national scientific literacy and the construction of innovation-oriented country. However, the current Chinese science popularization industry is still "scattered, small, slow and weak" and has a great gap compared with that of developed countries. This paper conducts empirical research on the input and output efficiency of science popularization industry in 11 provinces in east China from 2006 to 2011 with DEA evaluation method according to statistical data of science popularization in China. The research result shows that Chinese science popularization industry has a strong development momentum and is during the rising stage.**

I. INTRODUCTION

Science popularization refers to "activities for popularizing the knowledge of science and technology, advocating scientific methods, spreading scientific thoughts and promoting scientific spirits with a method the public."[1] China always attaches great importance to science popularization work. In March 2006, the government issued Outline of the National Scheme for Scientific Literacy (2006-2010-2020). One of the important measures put forward therein is "establishing preferential policies and relevant specifications, effectively cultivating market and promoting the development of science popularization culture industry" so as to improve scientific literacy of citizens more effectively.[2] Since then, promoting the development of science popularization industry has been included into relevant national development outline and become a nationwide action promoted by the state.

Science popularization industry refers to activities providing science popularization products and services for the nation, society and public based on market mechanism and under the premise of meeting demands of the nation, society and public in science popularization market and the collection of activities related to these activities [3]. Science popularization industry is an economic form of science popularization, existence form of science popularization economy, product of detailed division of labor in science popularization production, increase of science popularization production mode, transition of circulation and sale carrier of science popularization and increasing consumer demands of science popularization, as well as an industry with research and development, production and operation, distribution and circulation and consumption [4]. With the in-depth development of science popularization activities towards the trend of externalization and marketization, science popularization activities increasingly present the characteristic of industrialization and more and more importance is attached to the industrialization trend of science popularization. The coming era of knowledge-based economy strongly penetrates various aspects of social and economic activities.

Currently, the development of science popularization industry has become increasingly mature in basic conditions such as human and materials and a strong support force of market space. At this time, appropriately supporting science popularization industry, strongly supporting the research and development of science popularization, promoting the innovation of content, service and type of science popularization industry and building a supporting system of healthy development of science popularization industry will not only play a significant role in promoting the sustainable and healthy development of science popularization industry and strengthening soft power of the nation, but also is feasible and has important practical significance for promoting the construction of innovation-oriented country. However, though the development of Chinese science popularization industry has begun to take shape currently, its overall strength is weak and there are such problems as unbalanced regional development, low degree of intensification and weak international competitiveness. In particular, its operating efficiency has a great gap lagging far behind developed countries. Chinese science popularization industry is being faced with good development opportunities as well as many challenges. Therefore, this paper intends to conduct empirical research on the efficiency of Chinese science popularization industry with Chinese science popularization statistical data from 2006 to 2011 with DEA method from the perspective of input and output so as to have an objective understanding of the development level and competitiveness of Chinese science popularization industry.

II. DEVELOPMENT STATUS OF CHINESE SCIENCE POPULARIZATION INDUSTRY

In China, with the deepening of construction of citizens' scientific literacy and the increase of demand of the society and public for science popularization, science popularization has achieved certain development and made some achievements. Main achievements are as follows: (1) the resource foundation of the industry has been preliminarily laid. Over the years, China has strengthened the construction of infrastructure of science popularization and preliminarily established a diversified and multi-class infrastructure

network of science popularization with comprehensive science and technology museum as guide, a batch of special science and technology venues as backbone and numerous basic science popularization education bases and science popularization stations as support. (2) The project foundation of the industry has been cultivated preliminarily. Science popularization project benefiting peasants, community science popularization plan benefiting people, construction of demonstration science Popularization County, science popularization caravan and science popularization engineering in central and western regions etc. have been implemented widely. (3) The platform of industrial development starts to be built. Wuhu Science Fair has been held successfully for five consecutive times and Wuhu Science Popularization Industrial Park has been constructed and put into operation under the strong support of Anhui and China Science Association. (4) Under the background of great prosperity and development of national culture, new forms of science popularization industry have developed rapidly. Emerging new science popularization forms such as science popularization cartoon, digital science popularization and science popularization originality have a strong development momentum.

However, the development situation of science popularization industry is less than satisfactory, mainly manifested in the following aspects: (1) scattered. Production and processing of science popularization products and services are scattered and the industry has a low degree of concentration. Except Wuhu Science Popularization Park, there is no standard construction of science popularization industrial park and science popularization industrial cluster zone up to now. (2) Slow. Science popularization industry has lagged behind in development and was growing at a too slow pace. This is manifested by the product scale and trading volume in Wuhu Science Fair. As the only national science popularization product fair in China currently, Wuhu Science Popularization Fair has been held successfully for five times. Over 1400 domestic and foreign colleges, research and development institutions and enterprises have participated in the fair. However, there were only over 20,000 science popularization products in the fair. The trading volume was only less than 1.5 billion Yuan and only over 1.1 million people participated in the fair. (3) Small. The overall industry scale and the production and service scale of single enterprise are small. There is no influential science popularization industrial group or listed science popularization enterprise up to now. (4) Weak. The overall development of the industry is in a weak position in market competition. It belongs to weak industry in the overall culture industry system and national industrial system. Compared to the great market demand of science popularization industry, the cumulative trading volume of the previous 5 Wuhu Science Fairs is less than 1.5 billion Yuan. It serves to show its weak situation.[5-7]

III. EFFICIENCY EVALUATION OF CHINESE SCIENCE POPULARIZATION INDUSTRY

A. Methodology—DEA

DEA model has many types. The most basic one is C2R model for evaluating effectiveness and technological efficiency. This model is a method for measuring multi-input and output efficiency put forward by Charnes et al. who introduced Farrll's concept of input and output efficiency measurement and used duality theory.[8-11]

Charnes and Cooper introduced the concept of non-Archimedean infinitesimal and built C^2R model with non-Archimedean infinitesimal to judge DEA effectiveness of the decision-making unit.

In the field of real numbers in the broad sense, non-Archimedean infinitesimal ε is an abstract number less than any positive number and greater than zero. C^2R model (P_ε) with non-Archimedean infinitesimal ε is considered:

$$\begin{cases} \max \mu^T Y_0 = V_P \\ s.t. \omega^T x_j - \mu^T y_j \geq 0 \\ \omega^T x_0 = 1 \\ \omega \geq \varepsilon e^{-T}, \mu \geq \varepsilon e^{+T} \end{cases}$$

Where, $e^{-T} = (1,1,\cdots 1) \in E_m$; $e^{+T} = (1,1,\cdots,1) \in E_j$.

Dual program problem of (P_ε) is (D_ε):

$$\begin{cases} \min\left[\theta - \varepsilon\left(e^{-T}s^- + e^{+T}s^+\right)\right] = V_D \\ s.t. \sum_{j=1}^{n} \lambda^T x_j + S^- = \theta x_{j0} \\ \sum_{j=1}^{n} \lambda_j y_j - S^+ = y_{j0} \\ \lambda_j \geq 0, j = 1,2,\cdots,n \\ S^+ \geq 0, S^- \geq 0 \end{cases}$$

This model can judge whether the j0th decision-making unit has DEA effectiveness or only weak DEA effectiveness at a time.

Theorem: assuming that ε is non-Archimedean infinitesimal and the optimal solution of program problem (D_ε) is $\lambda^*, S^{*-}, S^{*+}, \theta^*$,

(1) If $\theta^0 = 1$, it has weak DEA effectiveness, i.e. input x can decreased by S^{-0} and the original output remains unchanged, or output increases by S^{+0} while input x remains unchanged.

(2) If $\theta^0 = 1$ and $S^{-0} = 0, S^{+0} = 0$, it has DEA effectiveness, i.e. output y obtained based on the original input x is optimal.

(3) If $\theta^0 \prec 1$, DEA is ineffective, i.e. input can be

reduced to θ^0 proportion of the original input x through combination and the original output remains unchanged.

(4) $K^* = \sum \lambda^*$ and K^* is scale efficiency of DUM. When $K^* = 1$, the scale efficiency of this DUM remains unchanged, i.e. the scale when marginal output is equal to marginal input; when $K^* \prec 1$, the scale efficiency of this DUM increases progressively, i.e. the appropriate increase of input can produce a higher proportion of increase of output on the basis of the original input; when $K^* \succ 1$, the scale efficiency of this DUM decreases progressively, i.e. the increase of input might make the output increase, but its increase amount will be less than that of input.

In practical problems, as long as ε is small enough, (if $\varepsilon = 10^{-6}$), simplex method can be used to solve program problem (D_ε).

B. Selection and description of evaluation indicators

According to such principles as comparability, availability and scientificity in the selection of indicators, input indicators mainly refer to the input of funds, manpower and infrastructure etc. and output indicators mainly refer to output value, taxation of profit and added value etc. in the evaluation process of input and output efficiency. However, based on the reality of Chinese statistical system, science popularization statistics has not been included into the statistical series of State Statistics Bureau yet. It is very difficult to obtain individual value quantity indicators of science popularization industry. Moreover, for an emerging industry like science popularization industry, such accounting is not the optimal choice. Value quantity data reflect the state of operation of enterprises and are used to measure the value created by enterprises. Physical quantity data are objective descriptions of the production and operation process and reflect the original appearance of production and operation process of enterprises. Pure selection of indicators such as added value cannot reflect the development status of science popularization industry most intuitively and is not suitable for emerging industries. To guarantee the overall effectiveness evaluation, the author puts forward the following indicators to form a corresponding evaluation indicator system according to the practical situation of the development of Chinese science popularization industry. Input indicators include the input of science popularization personnel, funds and goods and materials; corresponding output indicators include the output of science popularization media and activities.

Data used by the research institute come from Chinese Science Popularization Statistics from 2006 to 2012. As data over five years are involved, comparable data are selected in the selection of indicators. The system including 5 input and output indicators is finally established based on repeated test with DEA software and consultation with experts. Input indicators include full-time science popularization personnel and input of science popularization funds; output indicators include the quantity of publication of science popularization books and periodicals and quantity of major science popularization activities.

C. Establishment of evaluation model

To analyze the overall effectiveness of input and output of Chinese science popularization industry, this paper selects data of Chinese science popularization statistics from 2006 to 2011 as decision-making units and uses C^2R model to evaluate the efficiency of science popularization industry. As the economic development in central and western regions of China lags behind that of eastern regions and the input and output of science popularization are also lagging, this paper selects 11 representative provinces in the east as research samples.

According to the research aims and indicator selection requirements of DEA method, only 5 most typical indicators are selected for tentative research. Input indicators are full-time science popularization personnel X1 and science popularization fund input X2; output indicators include the quantity of publication of science popularization books Y1, the quantity of publication of science popularization periodicals Y2 and the number of major science popularization activities Y3.

C^2R model is established as follows:

$$\begin{cases} \text{Min}\theta - 10^{-6}(s_1^- + s_2^- + s_1^+ + s_2^+ + s_3^+) \\ \text{s.t.}\sum_{j=1}^{5} \lambda_j x_{1j} + s_1^- = \theta x_{10} \\ \sum_{j=1}^{5} \lambda_j x_{2j} + s_2^- = \theta x_{20} \\ \sum_{j=1}^{5} \lambda_j y_{1j} - s_1^+ = y_{10} \\ \sum_{j=1}^{5} \lambda_j y_{2j} - s_2^+ = y_{20} \\ \sum_{j=1}^{5} \lambda_j y_{3j} - s_3^+ = y_{30} \\ \lambda_j \geq 0; \\ s^+ \geq 0, s^- \geq 0 \end{cases}$$

D. Efficiency evaluation process of Chinese science popularization industry based on DEA and result analysis

According to Chinese science popularization statistical data from 2006 to 2011, as science popularization statistics was implemented once every two years before 2008, this paper does not study the efficiency of science popularization industry in 2007[12][13]. The evaluation value of relative efficiency of input and output can be calculated with lingo software. Table 1 shows the integrated evaluation value (DEA effectiveness coefficient) and average score of various provinces in east China from 2006 to 2011.

TABLE 1 EFFICIENCY VALUES OF SCIENCE POPULARIZATION INDUSTRY IN EACH PROVINCE IN EAST CHINA

Provinces / Year	Beijing			Tianjin			Hebei		
	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency
2006	1	1	1	1	1	1	1	1	1
2008	0.805	0.9	0.895	0.963	0.971	0.991	1	1	1
2009	0.891	0.916	0.972	1	1	1	1	1	1
2010	0.881	1	0.881	1	1	1	0.799	0.929	0.86
2011	1	1	1	0.969	1	0.969	1	1	1
Average value	0.915	0.963	0.950	0.986	0.994	0.992	0.960	0.986	0.972

TABLE 1 EFFICIENCY VALUES OF SCIENCE POPULARIZATION INDUSTRY IN EACH PROVINCE IN EAST CHINA (CONTINUED 1)

Provinces / Year	Liaoning			Shanghai			Jiangsu		
	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency
2006	1	1	1	0.967	1	0.967	1	1	1
2008	0.997	1	0.997	1	1	1	0.906	0.991	0.914
2009	0.791	1	0.791	1	1	1	1	1	1
2010	0.849	1	0.849	0.929	1	0.929	0.969	1	0.969
2011	0.668	1	0.668	0.948	1	0.948	0.862	1	0.862
Average value	0.861	1	0.861	0.969	1	0.969	0.947	0.998	0.949

TABLE 1 EFFICIENCY VALUES OF SCIENCE POPULARIZATION INDUSTRY IN EACH PROVINCE IN EAST CHINA (CONTINUED 2)

Provinces / Year	Zhejiang			Fujian			Shandong		
	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency
2006	1	1	1	1	1	1	1	1	1
2008	0.891	1	0.891	0.66	0.706	0.935	0.928	0.957	0.97
2009	0.705	0.853	0.826	1	1	1	1	1	1
2010	0.834	0.891	0.936	0.926	1	0.926	0.754	0.774	0.974
2011	1	1	1	1	1	1	1	1	1
Average value	0.886	0.949	0.931	0.917	0.941	0.972	0.936	0.946	0.989

TABLE 1 EFFICIENCY VALUES OF SCIENCE POPULARIZATION INDUSTRY IN EACH PROVINCE IN EAST CHINA (CONTINUED 3)

Provinces / Year	Guangdong			Hainan		
	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency	Comprehensive technical efficiency	Pure technical efficiency	Scale efficiency
2006	1	1	1	0.511	1	0.511
2008	1	1	1	1	1	1
2009	1	1	1	0.803	0.856	0.938
2010	0.967	0.975	0.992	1	1	1
2011	1	1	1	1	1	1
Average value	0.993	0.995	0.998	0.863	0.971	0.890

According to the result of empirical research, there are several discoveries as follows:

First, in terms of comprehensive technical efficiency and pure technical efficiency, input and output efficiencies of science popularization industry in each province in east China present a rising trend and all average values are greater than 0.9 and close to DEA effective value 1. This conforms to the development law of Chinese science popularization industry. This indicates that science popularization industry in each province in east China has a strong development momentum and good development trend and is during the rising stage. Compared to other regions, the development of science popularization industry in these 11 provinces is in a leading position.

Second, according to the average value of comprehensive technical efficiency and pure technical efficiency of Chinese science popularization industry from 2006 to 2011 in table 1, only the pure technical efficiency value of Shanghai is 1. It is the only province with technical effectiveness among all research objects. Other provinces have DEA ineffectiveness. Their common problems are relative surplus of some input and relative shortage of some output, which makes the efficiency of science popularization industry in these provinces fail to achieve DEA effectiveness.

Third, among 11 provinces in the east under research, no region has an effective average scale efficiency and their evaluation results are less than 1, indicating that Chinese science popularization industry is generally in the stage of progressively increasing scale efficiency and the output of science popularization industry will have a higher proportion of increase if the input of science popularization industry increases according to the existing input structure. Though China has been constantly increasing the input of science popularization personnel and funds in recent years, compared to developed countries and actual demand in China, science popularization input is relatively insufficient. Continuing to increase the input of science popularization industry and supporting the development of science popularization industry is still a key emphasis in work for a period of time in the future. Meanwhile, the evaluation result also reflects the problem of irrational resource allocation. For example, the science popularization input of Beijing, as the political and cultural center of China ,has unique advantages in China. However, according to our tracking of data from 2006 to 2011, it is found that Beijing has excessive science popularization input and relatively insufficient science popularization output. According to the selected input and output indicators, Beijing has a great gap in both the quantity of publication of science popularization periodicals and the quantity of major science popularization activities over these 5 years. Relatively, excessive input of science popularization personnel and funds directly causes the relatively lower efficiency of science popularization industry in Beijing under the favorable situation of heavy input.

Conclusions above provide important scientific basis for promoting the improvement of efficiency of Chinese science popularization industry and the reform of science popularization system. This paper makes the following policy suggestions based on empirical research:

Firstly, break through system constraints and further promote the reform of science popularization system. In the development of science popularization industry in China, we must change the concept, strengthen the service awareness of science popularization industry, turn the development of science popularization industry fundamentally to the trail of serving science popularization demands of the public and the construction of citizens' scientific literacy. On the one hand, the development of science popularization industry should make full use of the power of market mechanism to optimize the allocation of science popularization resources, subdivide and prosper science popularization service market, enrich science popularization products and services, improve the efficiency and quality of science popularization products and services, make up for the deficiency of public science popularization products and services, promote the development of science popularization career and actually meet multi-level, multi-aspect and diversified demands of the masses for science popularization. On the other hand, the development of science popularization industry should follow the general rule of industry development, create and build its own industrial chain, cultivate a batch of science popularization enterprises and enterprise groups with independent innovation ability of science popularization, famous brand and proprietary intellectual property rights, be good at making use of the driving force and radiation force of development of relevant industries, build a solid development platform for science popularization industry and meanwhile enrich the connotation of development of science popularization industry and extend its depth and breadth with the development space of service industry.

Secondly, allocate science popularization opinions rationally, vitalize invisible resources of science popularization and cultivate a new industry growth point. In China, science popularization resources widely exist in various fields and departments. The system of China Association for Science and Technology has a lot of science popularization resources of various types and rich contents such as science popularization infrastructure, education base and base benefiting peasants. Meanwhile, such departments and fields as agriculture and forestry, science and technology, weather, earthquake, sanitation, land, tourism, publishing and ocean also have a lot of science popularization resources. The cultivation of growth point of science popularization industry development inevitably requires to integrate and vitalize these science popularization resources, exploit science popularization resources with operation value and promote the integration of these science popularization resources into the trail of industrialization development in relevant fields and the innovation and development of relevant science popularization forms.

Thirdly, cultivate talents of science popularization industry and establish and improve education and training system for talents of science popularization industry. It is required to give full play to the important role of

institutions of higher learning in the cultivation of science popularization talents; actively create conditions and train a batch of talents of science popularization industry in a planned way; learn successful experience of developed countries, create a talent recognition and use mechanism for the entry, retaining and use of excellent talents and establish a vigorous use and motivation mechanism of excellent and special talents in science popularization industry. The government, colleges and society should establish a corresponding talent training institution of science popularization industry and vigorously implement the training of talents in science popularization industry through division of labor and cooperation to improve the overall quality and management level of employees.

IV. CONCLUSION

A. Research conclusions

(1) The necessity of analysis on input and output efficiency of Chinese science popularization industry is put forward.

(2) Preliminary framework of input and output efficiency evaluation indicators of Chinese science popularization industry is established.

(3) The basic situation of development of Chinese science popularization industry is described. With 11 provinces in east China as research objects, this paper selects science popularization statistical data from 2006 to 2011 for tentative research on input and output efficiency of Chinese science popularization industry and reveals input and output efficiency of science popularization industry in different provinces in different years.

(4) According to the empirical research, Chinese science popularization input and output increase year by year. On the whole, the overall efficiency of input and output of Chinese science popularization industry basically maintains a growing trend. However, a relative shortage of output still exists and the utilization efficiency of science popularization funds is to be improved.

B. Discussion

Firstly, for the comparison of input and output of science popularization industry in each province in east China each year, only tentative research is conducted. Considering the short time of science popularization statistics implemented in China, less data available and less indicators selected according to the requirement of DEA method, e.g. output indicators of science popularization industry are not limited to science popularization books, periodicals and major science popularization activities, and also include science popularization film and television, toys and exhibits, the evaluation result has certain one-sidedness and only the research train of thought is provided.

Secondly, the evaluation result obtained in this paper with DEA method is relative efficiency. That is to say, there must be an effective decision-making unit among decision-making units. Though input and output efficiency of science popularization industry in individual provinces over some years has DEA effectiveness, it does not mean that it's unnecessary for these provinces to improve the absolute amount of science popularization input in the year. Compared to developed countries, both the absolute amount and relative amount of Chinese science popularization input are still remaining lower. Therefore, China should greatly improve the input of science popularization.

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