

# An Empirical Study on the Measurement of Operational Efficiency of Science and Technology Business Incubators in China

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## ABSTRACT

Based on DEA-BCC model and DEA Malmquist index, 4848 science and technology business incubators in 30 provinces of China are selected and their operation efficiency is analyzed in this paper. The results show that the management and technology of science and technology business incubators in most provinces of China have reached a high level, but there are problems of input redundancy and output insufficiency. At the same time, it is found that technological progress contributes the most to the total factor productivity of incubators. According to the analysis results, this paper puts forward some policy suggestions to optimize the allocation of incubation resources, improve the selection mechanism of incubation projects, and establish an integrated incubating service system, so as to improve the operational efficiency of technology business incubators.

**Keywords:** Innovation incubation, Operational efficiency, Science and technology business, DEA

## 1. INTRODUCTION

Science and technology enterprises have become an important part of promoting regional and national economic development, promoting employment and innovation and entrepreneurship [1-2]. Science and technology business incubator is a service organization to cultivate and support high-tech small and medium-sized enterprises. It is an important carrier to promote the transformation of scientific and technological achievements, cultivate science and technology-based small and medium-sized enterprises and develop new economic momentum. It provides a series of resource support for science and technology-based enterprises in the process of entrepreneurship, reduces the risk and cost of entrepreneurship, and improves the success rate of enterprises [3]. China attaches great importance to the construction and development of incubators, which has issued policies including financial consultation, tax preference, infrastructure support, science and technology finance, etc. The development of incubator shows a high-speed growth trend, from the single investor in the early stage of development to the current development pattern of diversified investors, public welfare type and profit-making type.

The value of incubator lies in that it allocates resources for start-ups by establishing various external social resource networks. The operational efficiency of incubator reflects its ability to allocate resources. Resources are limited, and the number of start-ups that need resources is increasing, so it is particularly important to study the operational efficiency of incubators. In recent years, the research on

science and technology business incubators by domestic scholars has been increasing. Song Qing (2013) studied the resource allocation of state-level science and technology business incubators in 23 provinces in China, and put forward suggestions on building a resource regulation system combining government guidance and market driving [4]. Lin Quanlu et al. (2019) studied the development status of science and technology business incubators in China [5]. Xu Yanan et al. (2020) studied the evaluation and influencing factors of China's maker space operation efficiency, and proposed two types of antecedent configurations that triggered the high and low efficiency of maker space [6]. Zhao Tianyan et al. (2018) used network SBM model to evaluate the operation efficiency of science and technology business incubator in Jiangsu Province [7]. Sun Qixin et al. (2020) studied the impact of preferential tax policies on the technological innovation of incubating enterprises [8].

To sum up, scholars have researched science and technology business incubators from multiple perspectives. However, there is no empirical research on the measurement and in-depth analysis of the operational efficiency of science and technology business incubators in more provinces (including autonomous regions and municipalities directly under the central government) of China. This study intends to use data envelopment analysis( DEA) to measure the operating efficiency of 4848 incubators of science and technology enterprises in 30 provinces (including autonomous regions, municipalities directly under the central government) in China, and put forward corresponding suggestions, which have reference value for improving the efficiency of incubation resource allocation, reasonably investing incubation resources, and

efficiently cultivating more and better science and technology enterprises.

## 2. RESEARCH DESIGN

### 2.1. Research Method

The main methods of efficiency evaluation are analytic hierarchy process (AHP), fuzzy comprehensive evaluation and DEA. AHP and fuzzy comprehensive evaluation depend on experts' knowledge and scores, so they are subjective. Because the science and technology business incubator is a complex system with multiple inputs and outputs, and it is difficult for experts to fully understand the operation of each incubator if they want to measure the technology business incubators of 30 provinces in China. DEA has special advantages in dealing with the efficiency of multi input and multi output complex systems [9]. DEA method does not need to assume the specific functional relationship between input and output, and can reflect the input-output efficiency of the object under investigation objectively. Therefore, DEA-BCC model and DEA Malmquist index are selected as the main research methods in this study.

### 2.2. Sample Selection

In this study, 4848 science and technology business incubators from 30 provinces in 2018 were selected as research samples. The data comes from 'China Torch statistical yearbook 2019' issued by the Ministry of science and technology. Due to the small scale of science and technology business incubators in Tibet Autonomous Region, there is only one incubator in 2018, and the input and output are quite different from other provinces.

Therefore, Tibet Autonomous Region is rejected from the sample. The operation modes of incubators in Hong Kong, Macao and Taiwan are quite different from those in other regions, which are also excluded from the sample.

## 3. MEASURE INDEX CONSTRUCTION

Science and technology business incubator is a resource allocation platform, which invests in various incubation resources such as people, finance and materials. The final output includes the number of incubation enterprises, the income, scale and technological achievements of enterprises etc. When Song Qing (2013) studied 204 The allocation efficiency of incubation resources of national science and technology business incubators, used number of employees of incubators, total incubation fund, investment into the public service platform and total space area of incubators as input index; accumulated number of graduated enterprises, number of incubating enterprises, total income of incubating enterprises and the average income of graduation enterprises as output index. When Zhao Tianyan et al. (2018) studied the operation efficiency of science and technology business incubator of Jiangsu province, used the employees of incubator, total space area of incubator and total incubation fund as input index; accumulated number of graduated enterprise, total income of incubating enterprise, employees of incubating enterprises as output index. When Zhu Jing et al. (2020) measured the technical efficiency of science and technology business incubator in province, used number of management personnel, number of innovation mentors, total incubation fund, investment into the public service platform, total space area of incubator as input index; accumulated number of graduated enterprise, number of intellectual property applications, total income of incubator, employees of incubating enterprises as output index [10].

**Table 1.** Efficiency measurement index of science and technology business incubator

Category	First level index	Secondary index
Input	Human resources	Number of innovation mentors, $X_1$
	Material resources	Total space area of incubator, $X_2$
	Financial	Total incubation fund, $X_3$
		Accumulated investment into the public service platform, $X_4$
Output	Incubation ability	Accumulated number of graduated enterprise, $Y_1$
	technological achievements	Output technology turnover, $Y_2$
	Economic performance	Total income of incubating enterprise, $Y_3$
		Number of enterprises with income more than 50 million yuan, $Y_4$
	Social benefit	Number of employees in incubating enterprises, $Y_5$

To sum up, in terms of input, it mainly focuses on the input of human, material and financial resources of the incubator, and in terms of output, it considers the incubator's incubation capacity, the economic benefits, technical achievements and social benefits, etc. Based on the research of related scholars and the new characteristics of incubation technology and resource allocation, this study

optimizes the input and output index. First of all, in terms of the investment personnel of the science and technology business incubator, the innovation mentor plays an important role. With the development of Internet technology, the resource allocation of the incubation network is more dependent on the network technology and data computing ability, so other employees of the

incubator are not the most important investment resources. Secondly, in terms of the output of science and technology business incubators, in addition to the total income of incubating enterprises, we should also consider the number of enterprises with income more than 50 million yuan. At the same time, the output technology turnover can better reflect the actual results of technological innovation than the number of intellectual property applications. As a result, the measurement indicators of the efficiency of science and technology business incubators in this study are formed, as shown in Table 1.

**4. EMPIRICAL RESULT AND ANALYSIS**

**4.1. BCC model Evaluation**

Use deap2.1 software to calculate the data of 30 provinces, and the results are shown in Table 2. Among them, 13 provinces have achieved DEA effectiveness, while the rest provinces have not achieved DEA effectiveness. The mean value of overall efficiency is 0.869, and only 13 regions that have reached 1. This indicates that the resource allocation efficiency of China's science and technology business incubators needs to be further improved. The mean value of pure technical efficiency in the statistical sample is 0.927, and 19 provinces are reaching 1,

indicating that the management level and technology of science and technology business incubators in most provinces of China have reached a high level. In the sample, there are 10 provinces with increasing scale efficiency, 6 provinces with decreasing scale efficiency, and the rest are the constant scale efficiency. As shown in Table 2.

**4.2. Input and Output Analysis**

By analyzing the differences of technical efficiency between CRS and VRS models, 9 out of 17 provinces failed to reach DEA efficiency are scale inefficiency. In terms of input, the number of innovation mentors, the total space area of incubator, the total incubation fund and the accumulated investment into the public service platform in these provinces all have investment redundancy, which failed to work effectively. In terms of output, Accumulated number of graduated enterprise, Output technology turnover, the total income of incubating enterprises, the number of enterprises with income more than 50 million yuan and the number of employees in the incubating enterprises in these provinces failed to reach the maximum output, which can be increased to different degrees. As shown in Table 3.

**Table 2.** Evaluation results of operational efficiency of science and technology business incubators based BCC model

<b>Regions</b>	<b>Overall efficiency</b>	<b>Pure technical efficiency</b>	<b>Scale efficiency</b>	
Beijing	1.000	1.000	1.000	-
Tianjin	1.000	1.000	1.000	-
Hebei	0.945	0.996	0.949	drs
Shanxi	0.876	0.947	0.925	irs
Neimenggu	1.000	1.000	1.000	-
Liaoning	1.000	1.000	1.000	-
Jilin	0.560	0.575	0.973	drs
Heilongjiang	0.789	0.796	0.991	irs
Shanghai	1.000	1.000	1.000	-
Jiangsu	1.000	1.000	1.000	-
Zhejiang	0.714	0.864	0.827	drs
Anhui	0.788	0.801	0.983	irs
Fujian	0.972	0.973	1.000	-
Jiangxi	0.877	0.897	0.977	irs
Shandong	0.636	1.000	0.636	drs
Henan	1.000	1.000	1.000	-
Hubei	0.825	1.000	0.825	drs
Hunan	1.000	1.000	1.000	-
Guangdong	0.637	1.000	0.637	drs
Guangxi	1.000	1.000	1.000	-
Hainan	1.000	1.000	1.000	-
Chongqing	0.996	1.000	0.996	irs
Sichuan	1.000	1.000	1.000	-
Guizhou	1.000	1.000	1.000	-
Yunnan	0.859	0.913	0.941	irs

<b>Cont. to Table 2.</b>				
Shanxi	1.000	1.000	1.000	-
Gansu	0.526	0.529	0.994	irs
Qinghai	0.307	0.515	0.596	irs
Ningxia	0.789	1.000	0.789	irs
Xinjiang	0.959	1.000	0.959	irs
Mean	0.869	0.927	0.933	

**Table 3.** Percentage of input redundancies and output insufficient of nine provinces in 2018

Unit: %

Regions	Input redundancy				Output insufficient				
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	Y <sub>1</sub>	Y <sub>2</sub>	Y <sub>3</sub>	Y <sub>4</sub>	Y <sub>5</sub>
Shanxi	-5.00	-39.00	-14.00	-5.00	20.00	10.00	0	0	58.00
Jilin	-42.00	-42.00	-60.00	-42.00	23.00	76.00	0	0	0
Heilongjiang	-57.00	-59.00	-20.00	-40.00	13.00	30.00	0	6.00	137.00
Zhejiang	-14.00	-14.00	-14.00	-14.00	0	23.00	15.00	155.00	147.00
Anhui	-20.00	-20.00	-20.00	-37.00	0	0	6.00	0	0
Fujian	-3.00	-21.00	-03.00	-26.00	0	0	90.00	77.00	93.00
Jiangxi	-10.00	-33.00	-44.00	-10.00	0	0	11.00	0	126.00
Yunnan	-9.00	-55.00	-16.00	-9.00	0	0	4.00	162.00	32.00
Qinghai	-63.00	-48.00	-49.00	-63.00	0	152.00	32.00	28.00	0

### 4.3. Malmquist Index Model Evaluation

In order to further study the changes in the operational efficiency of science and technology business incubators, DEA Malmquist index model is used to analyze the changes in technical efficiency, technical progress, pure technical efficiency, scale efficiency and total factor productivity of science and technology business incubators. It shows that the mean value of total factor productivity of science and technology business incubators in 2017-2018 is 1.045, its average growth rate is 4.50%, the mean value of technical progress change index is 1.058, its average growth rate is 5.80%, the mean value of technical efficiency index is 0.989, its average decline rate is 1.10%, the pure technical efficiency change index is 0.997, its average decline rate is 0.30%, and the scale efficiency changes index is 0.991, its average decline rate is 0.90%. As shown in Table 4. In the table, effch is technical efficiency change index, techch is technical progress change index, pech is pure technical progress efficiency change index, sech is scale efficiency change index, tfpch is total factor productivity index.

Through table 4, we can further analyze the main problems in the operation of science and technology business incubators. For example, the TFP index of Hebei Province is 1.019, but the technical efficiency change index, the pure technical progress efficiency change index, and the scale efficiency change index all show a downward trend, so the improvement of TFP in Hebei mainly comes from the contribution of technological progress. For example, the TFP index of Hubei Province is 1.220, and the technical efficiency change index, pure technical progress efficiency change index and scale efficiency change index

are an upward trend, but only the Technical progress change index declined, which shows that the science and technology business incubators of Hubei Province should make more efforts to improve the technical progress.

## 5. CONCLUSIONS AND SUGGESTIONS

**Table 4.** Analysis results of DEA Malmquist index of operational efficiency of science and technology business incubators in 2017-2018

Regions	Effch	Techch	Pech	Sech	Tfpch
Beijing	1.000	0.787	1.000	1.000	0.787
Tianjin	1.000	1.077	1.000	1.000	1.077
Hebei	0.945	1.078	0.996	0.949	1.019
Shanxi	0.876	1.049	0.947	0.925	0.920
Neimenggu	1.000	1.448	1.000	1.000	1.448
Liaoning	1.000	1.038	1.000	1.000	1.038
Jilin	0.978	1.012	0.984	0.994	0.989
Heilongjiang	1.227	1.173	1.203	1.020	1.439
Shanghai	1.044	1.154	1.041	1.003	1.204
Jiangsu	1.000	0.959	1.000	1.000	0.959
Zhejiang	1.004	0.886	0.898	1.118	0.890
Anhui	0.993	1.085	0.976	1.017	1.077
Fujian	0.972	0.987	0.973	1.000	0.959
Jiangxi	0.877	1.007	0.897	0.977	0.883
Shandong	1.015	0.897	1.000	1.014	0.911
Henan	1.000	1.633	1.000	1.000	1.633
Hubei	1.277	0.955	1.000	1.277	1.220
Hunan	1.000	0.945	1.000	1.000	0.945
Guangdong	0.762	1.210	1.000	0.762	0.922
Guangxi	1.000	0.990	1.000	1.000	0.990

<b>Cont. to Table 4.</b>					
Hainan	1.000	1.084	1.000	1.000	1.084
Chongqing	0.996	1.098	1.000	0.996	1.094
Sichuan	1.201	1.122	1.134	1.059	1.348
Guizhou	1.000	1.220	1.000	1.000	1.220
Yunnan	1.031	1.077	0.955	1.080	1.110
Shanxi	1.118	0.845	1.095	1.021	0.945
Gansu	1.022	0.961	0.991	1.031	0.981
Qinghai	0.660	1.274	0.882	0.749	0.841
Ningxia	0.911	1.277	1.000	0.911	1.163
Xinjiang	0.959	0.809	1.000	0.959	0.776
Mean	0.989	1.058	0.997	0.991	1.045

### 5.1. Conclusions

First of all, this paper puts forward nine indicators to measure the science and technology business Incubator by combing the relevant research of previous scholars, including four indicators of input from the aspects of human, material and financial resources, and five indicators of output from the aspects of incubation capacity, technological achievements, economic performance and social benefits.

Secondly, the input and output efficiency of science and technology business incubators in 30 provinces of China are calculated by using DEA-BCC model. In terms of pure technical efficiency, the management level and technology of science and technology business incubators in most provinces of China have reached a high level. However, 17 provinces fail to reach the DEA efficiency, and there are input redundancy and output insufficient, among which 9 provinces have scale inefficiency, which indicates that the resource utilization efficiency of science and technology business incubators is not ideal, there are problems of resource waste or unreasonable structure, and there is still a large space for improvement in the operation of incubators.

Finally, using DEA Malmquist index model to analyze the change of TFP of science and technology business incubators, it is found that the mean value of technical progress change index is the highest, and the mean value of scale efficiency change index is the lowest, which indicate that science and technology business incubators promote technology progress. However, due to the differences in policies, management capabilities, resource integration capabilities and the actual situation of regional economic development, the technical efficiency change index, pure technical progress efficiency change index and scale efficiency change index of each region are quite different in terms of promotion and decline.

### 5.2. Suggestions

#### 5.2.1. Optimizing the allocation of incubation resources

The empirical study found that there are 9 provinces with scale inefficiency, among which the investment redundancy of total space area of incubator and the total incubation fund relatively serious. This is related to the country's strong support for innovation and entrepreneurship development in recent years. Local governments have invested heavily in establishing incubation sites and increasing incubation funds. However, these resources have not been effectively utilized. Therefore, for provinces with decreasing returns to scale, without affecting their overall development, they can reduce the investment of material and financial resources and innovate the way of resource allocation, such as resource sharing and information sharing. Increase the input of human resources, promote the effective transformation of input resources into output, and optimize the allocation of incubation resources from the structure.

#### 5.2.2. Improving the selection mechanism of incubation projects

From the previous analysis, it is found that more than half of the provinces have output insufficient, indicating that the input resources do not have the maximum impact. On the one hand, the wave of mass entrepreneurship and innovation has doubled the number of innovation and entrepreneurship projects, which covering electronic information, new materials, new energy, and cultural and creative fields. However, many projects lack of market research, lack of understanding of the industry, unclear objectives and profit model, which make them have low ability of market competitiveness. On the other hand, in order to enhance the number of incubation projects, many incubators neglect the quality requirements of incubation projects in order to complete the number of start-ups. As a result, the projects with no prospect occupy the incubation resources, but the final output is not ideal, which affects the incubation efficiency of the incubator. Therefore, the selection mechanism of incubation projects should be improved by adopting the third-party evaluation, improving the requirements of project reviewers, standardizing the selection indexes of incubation projects, and strengthening the all-round investigation of incubation projects. So as to improve the quality of incubation projects and ensure that limited resources are used for projects with real potential.

### 5.2.3. Establishing an integrated incubation service system

Although the research shows that the technology and management level of incubator is high, many provinces have not been able to avoid the waste of resources. The fundamental reason lies in the fact that the incubator has not been able to achieve accurate resource allocation due to its barriers exist. Therefore, it necessary to strengthen the integration of incubators, build public platforms, establish government support platforms and technical support platforms. Distinguish basic service, professional service, intermediary service and value-added service. According to different levels of services, different human, material and financial resources are allocated to provide more refined services, so as to improve the efficiency of resources and speed up the incubation of science and technology projects.

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