

# Research on the Evaluation of Technological Innovation Capability of China's Biopharmaceutical Industry

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## Abstract

**Objective:** To analyze the innovation capability of China's biopharmaceutical industry to explore ways to enhance innovation capability. **Methods:** This paper firstly constructs an evaluation system of technological innovation capability of biopharmaceutical industry based on the summary of previous research. The biopharmaceutical industry data from 2014 to 2019 were used to analyze the technological innovation capacity of biopharmaceutical industry in each province and city by using factor analysis and SPSS24.0 software. **Results:** The top three technological innovation capacity scores of provinces and cities in 2014-2019 are Jiangsu, Shandong and Zhejiang, with 1.95, 1.62 and 1.10 respectively. **Conclusion:** Provinces and cities with high innovation capacity are generally concentrated in the coastal area of East China, forming a high-quality innovation region with Jiangsu, Zhejiang and Guangdong as typical representatives.

## Keywords

Technological Innovation Capability, Technological Innovation Efficiency, Biopharmaceutical Industry, Coordination

## 1. Introduction

Pharmaceutical industry is one of the basic national industries, and among the pharmaceutical industry, biopharmaceuticals are developing particularly rapidly. Along with the pace of world economic development, scientific and technological progress, the change in public health concepts and the increase in global population aging, the biopharmaceutical industry has been developed in the past decades, especially in the context of the global spread of the new crown pneu-

monia epidemic, and the biopharmaceutical industry is becoming a new driving force of global economic development (Zhang, 2019). In this paper, a comparative analysis of the technological innovation capability of the biopharmaceutical industry in each province of China over several years using factor analysis can compare the comprehensive scores of the evaluation system in different time periods and further distinguish the main factors in the evaluation indexes that are more closely related to technological innovation capability by extracting the common factors from them.

In this paper, we use factor analysis to analyze the technological innovation capability of biomedical industry in Chinese provinces and cities, and explore strategies to enhance the innovation capability.

## 2. Methods

### 2.1. Research Design

Through the analysis of the connotation of innovation capability, this paper creates 13 specific indicators, which are shown in **Table 1**, based on the analysis of factors affecting the biomedical industry and the principles of selecting evaluation indicators with reference to academic research results.

In research on technological innovation efficiency and innovation capacity of pharmaceutical manufacturing industry in Hebei Province (Sun & Yu, 2012), the equivalent full-time equivalent of R&D activity personnel, the internal expenditure amount of R&D funds and the expenditure amount of technical transformation funds are adopted as innovation input indicators, and the output value of new products, the sales revenue of new products, the ratio of sales revenue of new products to the main business revenue, and the number of patent applications are adopted as innovation output indicators.

In research on Innovation Capability of Pharmaceutical Manufacturing Industry in Jiangsu Province (Cheng, Yang, & Shan, 2020), R&D investment funds and R&D personnel are selected as innovation input indicators, and patent creation and new product development indicators are selected to reflect innovation output capability. This evaluation system was used to analyze the innovation input and output capacity of pharmaceutical manufacturing industry in Jiangsu Province, and suggestions were made to improve the innovation capacity of pharmaceutical manufacturing enterprises in Jiangsu Province.

In this article on the evaluation of the innovation capability of Jiangsu pharmaceutical manufacturing industry based on factor analysis (Zeng, Li, & Wang, 2018), in addition to the common technological innovation input capacity indicators and innovation output capacity indicators, the funds from governmental science and technology activities are also included in the technological innovation environment support capacity indicators. Besides, the patent situation is considered to be one of the main factors affecting innovation capacity (Szabolcs & Alvaro, 2010).

Considering the evaluation system constructed by previous scholars, and

**Table 1.** Evaluation index of technological innovation capability of biopharmaceutical industry.

Category	Specific indicators	Description
Innovation investment capacity	R&D personnel equivalent full-time equivalent (person-years) $X_1$	
	R&D internal expenditure (billion yuan) $X_2$	
	R&D investment intensity (%) $X_3$	Internal expenditure/main business income
Innovation output capacity	Number of new product development projects (items) $X_4$	
	Number of invention patent applications (pieces) $X_5$	
	Number of patent applications (pieces) $X_6$	
	Revenue from main business (billion yuan) $X_7$	
	Sales revenue of new products (billion yuan) $X_8$	
	Percentage of new product sales revenue (%) $X_9$	New product sales revenue/main business revenue
Innovation environment support capacity	Number of enterprises (pcs) $X_{10}$	
	Number of R&D institutions (pcs) $X_{11}$	
	Government funding (billion yuan) $X_{12}$	
	Percentage of government funding (%) $X_{13}$	Government funding/R&D internal funding expenditure

considering the availability of data, the index system established in this paper is shown in **Table 1**.

This paper adopts R&D personnel full-time equivalent and R&D internal expenditure as the main input indicators of innovation subjects such as enterprises and R&D institutions; the number of new product development projects, patent applications and new product sales revenue as the main output indicators. The number of new product development projects, patent applications, and new product sales revenue are used as the main output indicators. The number of new product development projects, patent applications and new product sales revenue are used as the main output indicators. The government, as a supporter and creator of innovation environment, becomes the main innovation environment support indicator in this paper. Thus, this paper constructs an index sys-

tem for evaluating the technological innovation capability of biopharmaceutical industry.

## 2.2. Selection of Evaluation Methods

In this paper, we decided to use the factor analysis method for statistical analysis. The reasons for this are: the data sources analyzed in the paper are complete and the correlation between the data is strong, which satisfies the conditions that factor analysis has; there is a large selection of data indicator parameters, and factor analysis method allows to statistically analyze numerous indicators and select a few common factors that explain the variable indicators (Xu & Hei, 2020).

Factor analysis is a multivariate statistical analysis method that identifies hidden representative factors among many variables and groups variables of the same essence into a single factor, which serves as a generalization of the observed variables. The factor evaluation model uses principal component analysis to extract the common factors, and then the maximum variance orthogonal rotation method is used to calculate the factor loadings, and then regression is used to generate the factor score coefficients to derive the final factor score equation.

## 2.3. Data Sources and Setting

In this paper, we select the data from 2014-2016 and 2018-2019 from the China High-Tech Industry Statistical Yearbook, which mainly involves the data of pharmaceutical manufacturing industry, and the data of 2017 are missing because the 2018 China High-Tech Industry Statistical Yearbook is not published. The number of provinces and cities in the selected sample is 23 because there are eight provinces with more serious missing data.

## 3. Results

This paper evaluates the technological innovation capability of China's biopharmaceutical industry with the data of 2018 as an example.

Firstly, SPSS24.0 software was used to dimension lessly process the raw data, and KMO and Bartlett's sphericity tests were performed to determine whether the data were suitable for factor analysis. The closer the KMO value was to 1, the more suitable the data were for factor analysis, and the KMO value was less than 0.5, which indicated that the raw data were not suitable for factor analysis. In Bartlett's sphericity test, if the P value was less than the significance level of 0.05, it indicates that the data are suitable for factor analysis.

The first step is the reliability test. The data from 23 provinces and cities were analyzed by SPSS24.0 software, and the KMO value of the data was 0.851, and the P-value of Bartlett's sphericity test was 0, which was less than 0.05, so the data involved in this paper were better for factor analysis.

In the second step, the common factors were extracted and the eigenvalues and the cumulative contribution of variance were analyzed. The common factor

was extracted by principal component analysis, and three factors were extracted according to the principle of eigenvalue greater than 1. The cumulative variance explained by these three factors accounted for 92.943%, indicating that these three factors contained most of the information and played a role in dimensionality reduction of the data.

In the third step, the factors were named and analyzed. To increase the explanatory power of the factors, the initial factor loading matrix was rotated using the maximum variance method for the three extracted common factors to establish the factor loading matrix of the original variables, and the rotated factor loading component matrix and the factor score coefficients were obtained.

As seen from the rotated component matrix, the role of  $F_1$  is very obvious, it mainly explains the 10 factors except  $X_3$ ,  $X_9$  and  $X_{13}$ , reflecting the relationship between the absolute values of inputs and outputs, and it can be named as the innovation scale factor. And  $F_2$  mainly explains  $X_3$  and  $X_9$ , which reflects the relative intensity of inputs and outputs, and can be considered as the innovation intensity factor. The share of government funds in the internal expenditure of R&D funds has a larger loading on  $F_3$ , so the third factor can be named as the innovation environment factor.

According to the factor score coefficient matrix, the factor score function can be obtained:

$$F_1 = 0.075X_1 + 0.085X_2 + \dots + 0.089X_{12} + 0.067X_{13};$$

$$F_2 = 0.068X_1 + 0.030X_2 + \dots + 0.082X_{12} - 0.024X_{13};$$

$$F_3 = -0.053X_1 - 0.104X_2 + \dots + 0.308X_{12} - 0.809X_{13}.$$

Finally, according to the scores of each common factor and the variance contribution rate of each common factor as weights, the comprehensive score of innovation capability was obtained:  $F = (63.709F_1 + 19.506F_2 + 9.728F_3)/92.943$ .

To further analyze whether the strength of technological innovation capability of China's biopharmaceutical industry has regional clustering characteristics, China's economic regions are divided into four major regions: eastern, central, western and northeastern according to the division criteria released by the National Bureau of Statistics, and provinces such as Xinjiang, which have missing data in this paper, are excluded from the study. In this paper, the results of the above table are averaged for the innovation scale factor  $F_1$  score, innovation intensity factor  $F_2$  score, innovation environment factor  $F_3$  score and comprehensive score  $F$  for the eastern, central, western and northeastern regions to obtain the results of innovation capability factor score by region.

From the results in **Table 2**, it is obvious that the technological innovation capability of China's biopharmaceutical industry in 2018 is weakened in decreasing order from the eastern region to the central and western regions, especially the western region, whose comprehensive factor scores are very different from those of the eastern region, which is mainly due to the geographical factors in the western region that lead to the weak foundation of its innovation capability, which is still mainly relying on the traditional industrial economic growth

**Table 2.** Innovation capability factor scores of biomedical industry by region in 2018.

Region	$F_1$ score	$F_2$ score	$F_3$ score	F composite score	Composite score Ranking
Eastern	0.4046	0.7242	-0.0772	0.4213	1
Central	-0.0499	-0.2245	-0.5784	-0.1419	2
West	-0.3675	-0.4665	0.80764	-0.2653	3
Northeast	-0.5012	-0.9459	0.04268	-0.5376	4

model, and the regional innovation is still in the developing This is mainly due to the fact that the western region has a weak innovation capability base due to geographical factors, and is still relying on the traditional industrial economic growth model (Zhang & Zhang, 2015). The eastern region, on the other hand, has obvious advantages due to its strong technological innovation capacity brought about by its rich basic geographical and economic resources, the good innovation environment for high-tech industries formed by the gathering of a large number of higher education institutions and research institutes, the great development potential of urban clusters in the Pearl River Delta and Yangtze River Delta regions, and the trend of agglomeration of biomedical industry economies (Gao, Ou, & Cai, 2018), making it the most innovative region in the country. In contrast, the northeast region has further aggravated the weakened condition of its innovation capacity due to serious brain drain and local financial constraints in recent years.

Based on the above steps measured year by year, this paper extracts the innovation capability public factors of the biopharmaceutical industry in 23 Chinese provinces and cities from 2014 to 2019, and calculates the composite factor score of innovation capability for each year.

From Table 3, it can be seen that the provinces and cities with high innovation capacity are generally concentrated in the coastal areas of East and South China, and high level innovation regions with Jiangsu, Beijing, Zhejiang, Shandong and Guangdong as typical representatives have been formed, and each has its own characteristics. From the regional distribution of biopharmaceutical industry chain-related enterprises, listed enterprises in China's biopharmaceutical industry chain are mainly distributed in Guangdong, Zhejiang, Jiangsu, Beijing and other regions, and the trend of industrial agglomeration effect and integration is more obvious (Zeng, Li, & Wang, 2018). Among them, Jiangsu surpasses Beijing and Guangdong as the province with the highest level of innovation in biopharmaceutical industry, mainly because Jiangsu Province is located in the "Yangtze River Delta", which is an important agglomeration of biopharmaceutical industry in China and has strong bio-industrial resources and basic innovation capacity.

In summary, the provinces and cities with high innovation capacity in China's biopharmaceutical industry are mainly concentrated in the eastern and central

**Table 3.** Composite score of technological innovation capacity of provinces and cities, 2014-2019.

	2014	2015	2016	2018	2019	Mean value
Beijing	-0.021	0.055	-0.163	-0.030	0.015	0.050
Tianjin	0.278	-0.196	-0.198	-0.641	-0.541	-0.037
Hebei	0.097	0.317	-0.031	-0.204	-0.165	-0.096
Shanxi	-0.802	-0.803	-0.810	-0.869	-0.734	-0.752
Liaoning	-0.334	-0.320	-0.680	-0.634	-0.702	-0.458
Jilin	-0.213	-0.280	-0.202	-0.205	-0.628	-0.321
Heilongjiang	-0.776	-0.853	-0.826	-0.774	-0.905	-0.700
Shanghai	-0.047	-0.179	-0.009	-0.276	-0.011	-0.001
Jiangsu	1.646	1.485	1.745	1.743	2.395	1.946
Zhejiang	0.902	1.163	1.035	0.700	1.201	1.096
Anhui	-0.072	-0.139	0.292	0.285	0.264	-0.019
Fujian	-0.466	-0.263	-0.334	-0.472	-0.511	-0.424
Jiangxi	-0.652	-0.556	-0.286	-0.148	-0.137	-0.413
Shandong	1.947	2.090	2.134	1.629	1.678	1.615
Henan	-0.264	-0.196	-0.145	-0.049	0.003	-0.137
Hubei	0.055	0.018	0.019	0.035	0.210	0.048
Hunan	-0.067	-0.151	-0.011	-0.105	-0.081	-0.162
Guangdong	1.037	0.915	0.848	1.343	1.022	0.975
Guangxi	-0.693	-0.605	-0.645	-0.360	-0.831	-0.612
Chongqing	-0.482	-0.342	-0.290	-0.319	-0.351	-0.306
Sichuan	0.063	-0.087	-0.086	0.378	0.296	-0.120
Yunnan	-0.204	-0.321	-0.585	-0.500	-0.785	-0.519
Shaanxi	-0.933	-0.751	-0.774	-0.526	-0.701	-0.652

regions, while the innovation capacity of biopharmaceutical industry in the western and northeastern regions is weak, and the central and western regions should learn from the excellent experience of the development of the eastern regions to achieve synergistic innovation among different regions.

## 4. Suggestion

### 4.1. Increasing R & D Investment for Innovation in Biopharmaceutical Industry

Only by increasing R & D funding can a high-tech industry like the biopharmaceutical industry be transformed into an innovation-driven direction for competitive advantage (Lai, Xu, & Ge, 2020). The enhanced investment in R&D funding can not only increase the ratio of R&D funding to new product sales revenue year

by year, but also help biopharmaceutical-related enterprises to master core pharmaceutical technologies with independent intellectual property rights and continuously enhance their independent innovation of high-tech technologies to achieve the purpose of enhancing the core competitiveness of biopharmaceutical industry. For the government, it should formulate various incentive policies and provide financial and tax incentives for enterprises with technological innovation potential. In short, the government should help enterprises to expand the sources of R & D funds and mobilize biopharmaceutical enterprises and institutions to carry out technological innovation, so as to promote a good cycle of technological innovation activities.

#### 4.2. Increase the Investment in Human Capital

The quality and quantity of R & D personnel play an important role in the capability and efficiency of technological innovation. In view of the talent loss and shortage of talents in Chinese biopharmaceutical industry, on the one hand, we should strengthen the human resource development and optimal allocation of biopharmaceutical-related enterprises, cultivate and introduce scientific and technological talents with innovation potential, professionals with core technology, and managers with pioneering and innovative spirit; on the other hand, we should establish a good corporate culture of respecting knowledge, talent and innovation, establish an objective. On the other hand, we will establish a good corporate culture of respecting knowledge, talent and innovation, establish an objective and fair talent evaluation mechanism, promote the reform of personnel use and salary system, and fully mobilize the enthusiasm and creativity of R & D personnel.

#### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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