Postprint: Provincial-Level Basic Research Competitiveness Analysis of China's Medical Sciences Based on the National Natural Science Foundation of China

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Date: 2023-10-08T00:00:00+00:00

Abstract

[Purpose / Significance] The National Natural Science Foundation of China (NSFC), as the principal channel for supporting basic research in China, has become a crucial indicator for measuring the nation's basic research capacity. Analyzing the current status of NSFC funding in medical sciences across Chinese provinces and research institutions can help narrow inter-regional disparities and enhance basic medical science research nationwide. [Method / Process] This study refines the competitiveness index based on publicly available NSFC project data and prior scholarly research, and analyzes project funding amounts and project counts in medical sciences from 2006 to 2016, along with evolving trends in the competitiveness and rankings of basic medical science research across 31 provincial-level regions in China. [Results / Conclusion] The findings indicate that basic medical science research in China has improved substantially in recent years, yet significant provincial disparities persist.

Full Text

An Analysis of Provincial Medical Science Basic Research Competitiveness in China Based on the National Natural Science Foundation

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Abstract

[**Purpose/Significance**] The National Natural Science Foundation of China (NSFC) serves as the primary channel for supporting basic research in China and has become a crucial indicator for measuring the nation's basic research capacity. Analyzing the current status of NSFC funding for medical science at the provincial and institutional levels can help narrow regional disparities and enhance China's medical science basic research. [**Method/Process**] Based on publicly available NSFC project information and previous scholarly research, this paper refines the competitiveness index to examine project funding and quantities in medical science from 2006 to 2016, along with the evolving competitiveness and rankings of 31 provincial regions in medical science basic research. [**Result/Conclusion**] The findings reveal that China's medical science basic research has improved substantially in recent years, though significant provincial gaps persist.

Keywords: National Natural Science Foundation of China; basic research; competitiveness; medical science

1 Introduction

With the rapid rise of the knowledge economy, the frontier of comprehensive national power competition has extended from technological development to basic research. Basic research has become a hallmark of national or regional scientific and technological development, representing a country's or region's scientific and technological strength. Therefore, strengthening research on China's basic research competitiveness not only addresses the urgent needs of science and technology management departments, universities, research institutions, and scientific workers, but also helps analyze and grasp the current state of China's basic research competitiveness, providing recommendations for its rapid enhancement and laying a solid foundation for building a scientifically powerful nation.

The National Natural Science Foundation of China (NSFC), as one of the main channels supporting basic research in China, constitutes an important component of the national innovation system. Since its establishment, it has played a significant role in promoting the stable development of basic research in China. Its principles of openness, fairness, and impartiality have earned it a high reputation in the scientific community, and it is widely recognized by researchers as the most standardized, equitable, and competitive research fund in China. The ability to secure NSFC funding has become an important indicator for measuring the basic research level of various provinces and research institutions in China. This paper refines the "National Natural Science Foundation Competitiveness Index" (NCI), using medical science as a case study to analyze provincial basic research competitiveness in China and understand the current state of medical science research.

2 Research Status

Literature review reveals that no comprehensive, systematic, and quantitative indicator system currently exists for analyzing and evaluating national or regional basic research competitiveness. Existing research primarily approaches the issue from three perspectives: basic research input, basic research workforce and infrastructure, and basic research output. The most common approaches use NSFC as an entry point from the input perspective, and research papers as an entry point from the output perspective.

Numerous studies have analyzed China's basic research competitiveness from the NSFC perspective. Ma Tingcan et al. constructed a comprehensive basic research competitiveness index based on NSFC funding capacity, conducting systematic and dynamic interactive visual comparisons of basic research competitiveness across 31 Chinese provinces. Zhang Huiying et al. built a "Discipline Competitiveness Index" to examine disciplinary competitiveness and constructed a "Provincial Basic Research Efficiency Index" to assess researcher productivity. Zhang Zuo et al. utilized GIS tools and spatial analysis methods, primarily employing Moran's I index and G coefficient statistics, to analyze the overall spatial distribution of NSFC-funded projects at different spatial scales, including inter-provincial and urban funding distributions. Yang Xinquan et al., Liao Hai et al., and Gao Kai et al. examined funding distributions across provinces from single-discipline perspectives. Ma Tingcan et al. and Ding Yiran et al. analyzed the basic research competitiveness of universities and research institutions based on NSFC data.

3.1 NSFC Medical Science Department Overview

The development of medical science is an important foundation and support for safeguarding public health. Its basic research is crucial for improving people's health standards and holds significant meaning for perfecting the national innovation system and building an innovative country. Medical science is currently one of the most active fields in natural science research, and innovation in medical science has become a strategic priority for China's science and technology initiatives concerning people's livelihood. To adapt to current trends in medical science frontier development that focus on human subjects, the NSFC established the Medical Science Department in 2009, separating it from life sciences. The new Medical Science Department follows the "dual-force drive" principle of both free exploration and national demand orientation in scientific research, advocates disease prevention and control as objectives, emphasizes basic research and talent cultivation, focuses on integrating with international research and cooperation, promotes research with Chinese characteristics in traditional Chinese medicine and original innovation, and enhances the level of basic and applied basic research in medical science in China.

3.2 Data Sources

The raw data were obtained from the NSFC's Science Information Network System (ISIS). The data were collected, cleaned, organized, and integrated by the China Industrial Think Tank at the Wuhan Documentation and Information Center of the Chinese Academy of Sciences. The retrieval date was January 20, 2017. Project information with application code H (Medical Science Department) was retrieved.

3.3 Analysis Indicator System

Many scholars have studied basic research competitiveness based on NSFC. Among them, Ma Tingcan et al. proposed a medical science basic research competitiveness index based on NSFC funding capacity, considering the number of funded experts, funding amounts, and average levels across 31 provinces. The formula for calculating a province's medical science basic research competitiveness index (NCI) for a given year (based on project approval year) is as follows:

$$\text{NCI}_{\text{province-year}} = \frac{\text{Number of experts in province in year}}{\text{Average number of experts across 31 provinces in year}} \times \frac{\text{Funding amount in provinc}}{\text{Average funding amount across 31}}$$

Where the number of experts refers to the number of experts (i.e., project leaders) in a province who received NSFC funding in medical science in a given year, and the funding amount refers to the total funding received by a province in medical science in a given year.

Through research on the above calculation formula and publicly available NSFC project information, the author believes this indicator remains incomplete for calculating basic research competitiveness. To more systematically, comprehensively, and effectively analyze the basic research competitiveness of Chinese provinces, universities, and research institutions based on NSFC, constructing a more systematic and comprehensive evaluation indicator system is essential. Therefore, this paper improves the NCI concept and refines the NCI index. Taking provinces as the research object, four indicators are incorporated into the NCI: the number of funded projects, project funding, number of institutions, and number of project leaders, forming comprehensive NCI, discipline NCI, and project category NCI for provinces. The number of projects and funding in a province primarily reflect the current status and strength of basic research, while the number of institutions and project leaders receiving NSFC funding better reflect the potential and development prospects of basic research. Incorporating these four indicators into the NCI provides a more comprehensive and authentic representation of a province's basic research competitiveness. This paper focuses on discipline NCI, where "discipline" corresponds to the eight scientific departments of NSFC, as shown in Formula 1.

Formula 1: Provincial Basic Research Discipline NCI

$$\text{NCI}_{\text{province-discipline-year}} = \frac{A_i}{\overline{A}} \times \frac{B_i}{\overline{B}} \times \frac{C_i}{\overline{C}} \times \frac{D_i}{\overline{D}}$$

Where A_i represents the number of projects in a province, discipline, and year; $\overline{A}$ represents the average number of projects across 31 provinces for a discipline and year; B_i represents the funding amount in a province, discipline, and year; $\overline{B}$ represents the average funding amount across 31 provinces for a discipline and year; C_i represents the number of institutions in a province, discipline, and year; $\overline{C}$ represents the average number of institutions across 31 provinces for a discipline and year; D_i represents the number of project leaders in a province, discipline, and year; and $\overline{D}$ represents the average number of project leaders across 31 provinces for a discipline and year.

Similarly, taking universities and research institutions as research objects, the NCI incorporates the number of funded projects, project funding, and number of project leaders, forming comprehensive NCI, discipline NCI, and project category NCI for universities and research institutions. This paper focuses on discipline NCI, as shown in Formula 2.

Formula 2: University and Research Institution Basic Research Discipline NCI

$$\text{NCI}_{\text{institution-discipline-year}} = \frac{A_i}{\overline{A}} \times \frac{B_i}{\overline{B}} \times \frac{C_i}{\overline{C}}$$

Where A_i represents the number of projects in an institution, discipline, and year; $\overline{A}$ represents the average number of projects across all institutions for a discipline and year; B_i represents the funding amount in an institution, discipline, and year; $\overline{B}$ represents the average funding amount across all institutions for a discipline and year; C_i represents the number of project leaders in an institution, discipline, and year; and $\overline{C}$ represents the average number of project leaders across all institutions for a discipline and year.

4 Results and Analysis

4.1 Medical Science Project Quantity and Funding, 2006–2016

The trends in NSFC medical science project quantity and funding from 2006 to 2016 are shown in Figure 1 [Figure 1: see original paper]. As illustrated in Figure 1, 2006–2012 represented a prosperous period for medical science, with both project quantity and funding showing a linear upward trend. Project quantity grew from 2,192 in 2006 to 7,674 in 2012, representing an average annual growth rate of 23.15%; funding increased from ¥585.78 million in 2006 to ¥4.55 billion in 2012, with an average annual growth rate of 40.7%. This fully demonstrates NSFC's growing emphasis on basic medical research and independent medical innovation in China. The period from 2012 to 2016 was a stable phase, with project quantity and funding remaining relatively constant, though showing a slight decline from 2014 to 2016, indicating that medical science has entered a crucial transition period from quantitative expansion to qualitative improvement.

4.2 Provincial Basic Research Competitiveness in Medical Science, 2006–2016

Based on the provincial basic research discipline NCI calculation formula, we calculated and visualized the medical science NCI values and ranking trends for China's 31 provinces (excluding Hong Kong, Macao, and Taiwan) from 2006 to 2016, as shown in Table 1 . According to the definition and calculation formula of discipline NCI, its numerical magnitude reflects the strength of basic research competitiveness in medical science for a province or institution. Based on 2016 medical science NCI values, China's 31 provinces were divided into five tiers: Tier 1 (very strong basic research capacity, NCI ≥ 6); Tier 2 (strong capacity, $6 >$ NCI ≥ 2); Tier 3 (moderately strong capacity, $2 >$ NCI ≥ 1); Tier 4 (weak capacity, $1 >$ NCI ≥ 0.5); and Tier 5 (very weak capacity, $0.5 >$ NCI ≥ 0).

As shown in Table 1, Tier 1 in medical science includes Beijing and Shanghai, the two provincial leaders in basic medical science research. From 2006 to 2016, Beijing's NCI exhibited fluctuating trends, while Shanghai's NCI showed a gradual upward trajectory. In 2016, Shanghai surpassed Beijing in project quantity, funding, and number of project leaders in medical science, though its number of institutions lagged far behind Beijing's. Among the top 100 institutions, Beijing accounted for approximately one-fifth, while Shanghai had seven institutions. However, Table 4 reveals that among the top 20 institutions, Shanghai claimed five spots while Beijing had only two, indicating that although Shanghai has fewer institutions, they are relatively stronger, whereas Beijing has broader institutional coverage and participation.

Tier 2 includes Guangdong, Jiangsu, Hubei, and Zhejiang. From 2006 to 2016, these four provinces showed upward NCI trends and represent important forces in China's medical science basic research. Guangdong, Jiangsu, and Hubei maintained relatively stable rankings, consistently placing 3rd to 5th. Zhejiang's basic research competitiveness increased substantially, with its ranking rising rapidly from 13th in 2006 to 6th in 2016, continuing its upward momentum. Although Hubei and Zhejiang have relatively low proportions of institutions in the top 100, their institutions rank higher.

Tier 3 comprises Shandong, Shaanxi, Sichuan, Liaoning, Hunan, Chongqing, Tianjin, and Jiangxi. These eight provinces possess moderately strong basic research capacity with considerable room for improvement. Competition among these provinces is intense, with rankings continuously changing. Notably, Chongqing's ranking fluctuated between 6th and 7th from 2006 to 2011, then declined continuously, falling to 12th by 2016. Conversely, Jiangxi ranked around 20th from 2006 to 2013, then rose continuously, reaching 14th by 2016. Shandong has five institutions in the top 100.

Tier 4 includes Guangxi, Yunnan, Fujian, Heilongjiang, Henan, Anhui, Jilin, Guizhou, and Xinjiang. Although these nine provinces have relatively weak basic research capacity, their medical science NCI values have shown slight upward trends, indicating some development in basic research competitiveness. Rankings among these provinces have fluctuated considerably. Heilongjiang, Jilin, Xinjiang, and Anhui have experienced overall declining trends in medical science basic research. Heilongjiang dropped from 14th in 2006 to 20th in 2015, recovering slightly to 18th in 2016. Jilin fell from 16th in 2006 to 22nd in 2010, remaining between 20th and 22nd from 2010 to 2016. Xinjiang declined from 19th to 23rd, while Anhui experienced significant fluctuations, dropping from 17th in 2006 to 20th in 2016. Fujian, Henan, and Guizhou showed overall upward trends, with Fujian rising from 20th to 17th, Henan from 24th to 19th, and Guizhou steadily from 25th to 22nd.

Tier 5 includes Gansu, Hebei, Inner Mongolia, Ningxia, Shanxi, Hainan, Qinghai, and Tibet. These eight provinces, mostly located in central and western China, lag behind in medical science basic research. Shanxi and Hainan showed clear downward trends in competitiveness rankings, with Shanxi dropping from 22nd in 2006 to 28th in 2016, and Hainan from 23rd to 29th. Gansu experienced a slight upward trend, rising from 28th in 2006 to 24th in 2016. Qinghai and Tibet have shown slow NCI growth, consistently ranking at the bottom.

Table 2 presents the 2016 project funding and proportions for China's 31 provinces across different medical science project categories. The analysis focuses on representative project types: General Program projects, Young Scientists Fund projects, Regional Science Fund projects, Key Program projects, and Major Program projects. General Program projects, the most fundamental project type based on free exploration principles, saw Shanghai at the top, with its medical science General Program funding accounting for 18.08% of total funding, while Inner Mongolia, Qinghai, and Tibet had no General Program projects. The Young Scientists Fund aims to cultivate and develop promising young scientific researchers and, to some extent, represents a province's basic research development potential. Remote provinces such as Jiangxi, Guangxi, Yunnan, and Fujian had relatively low Young Scientists Fund funding, while Henan, Anhui, and Gansu, despite lower overall rankings, had relatively high Young Scientists Fund proportions, indicating significant potential for medical science basic research. The Regional Science Fund primarily supports researchers in scientifically underdeveloped regions, including remote and ethnic minority areas, to serve regional coordinated development and national innovation system construction. The top five provinces in medical science Regional Science Fund funding were Jiangxi, Guangxi, Yunnan, Guizhou, and Xinjiang. However, Qinghai and Tibet still had low project funding; these provinces should leverage national Regional Science Fund policy advantages to stabilize, attract, and cultivate scientific talent and strengthen medical science basic research. Key Program projects support systematic and in-depth innovative research in important research areas or new disciplinary growth points in China. Beijing, Shanghai, and Guangzhou are leaders in medical science Key Program projects, with the three provinces' combined funding accounting for nearly half of all Key Program funding. Major Program projects address major scientific issues urgently needed for national economic and social development. In 2016, Sichuan University led a joint application with Peking University, Fudan University, and the Shanghai Institute of Materia Medica, Chinese Academy of Sciences, for "Efficient Delivery Systems for Biomacromolecular Drugs," receiving direct funding of ¥14.4235 million.

4.3 Top 20 Universities and Research Institutions in 2016 (Medical Science)

Based on the university and research institution basic research discipline NCI calculation formula, we identified the top 20 universities and research institutions in medical science in 2016 and their competitiveness. The results show that the top five are Shanghai Jiao Tong University, Sun Yat-sen University, Fudan University, Huazhong University of Science and Technology, and Peking University. Shanghai Jiao Tong University ranks first with an NCI of 50.3396, far exceeding other universities and institutions. Among the top 20, nearly half are specialized medical universities. Shanghai accounts for four institutions, while Beijing accounts for two, as shown in Table 3 .

5 Conclusions

Through research and analysis, the following conclusions can be drawn:

(1) Overall, China's investment in medical science basic research has grown rapidly. Funding increased from ¥585.78 million in 2006 to ¥3.97 billion in 2016, with an average annual growth rate of 21.09%; project quantity grew from 2,192 in 2006 to 9,212 in 2016, with an average annual growth rate of 15.4%. However, China remains a developing country, and basic research development still faces numerous difficulties and challenges. Medical science basic research funding remains relatively low, with insufficient investment intensity, creating a gap with developed countries. Basic research is a long-term systematic project, and its investment structure and funding mechanisms need improvement. The proportion of local government and enterprise investment in basic research could be appropriately increased, though increasing central government investment in basic research remains the primary task and development priority.

(2) Significant disparities exist in provincial basic research competitiveness for medical science in China, with unreasonable provincial development patterns. Eastern regions lead far ahead, while central and western regions, despite national policy support, remain relatively backward in basic research development. The six provinces in Tier 1 (Beijing, Shanghai, etc.) account for 56.6% of total project funding, while the eight provinces in Tier 5 (Gansu, Hebei, etc.) account for less than 3% of total funding. This indicates unbalanced and highly differentiated development of medical science basic research in China. Therefore, the government, NSFC,

and relevant departments need to adopt active and effective measures in macro funding strategies, ensuring overall planning and coordination, and providing policy 倾斜 and support for backward provinces to promote balanced development of provincial medical science basic research and prevent a Matthew effect where "the weak become weaker and the strong become stronger."

(3) Strengthening inter-provincial exchange and cooperation is essential. Provinces with relatively weak or declining medical science basic research competitiveness should identify problems and breakthrough points from within, build upon their advantages and characteristics, strengthen cooperation and exchange with more competitive provinces, learn from their experiences, and continuously introduce high-level, capable, and innovative researchers. They should optimize the organization and management of scientific research activities, establish and improve provincial scientific research evaluation systems, talent selection mechanisms, and scientific research support and guarantee systems, and enhance scientific research management levels to provide institutional support and guarantees for basic research development. Additionally, provincial-level natural science foundations corresponding to NSFC could be established to provide more funding and support for medical science basic research and promote sustainable development. Remote and backward western regions should fully utilize national preferential policies and Regional Science Fund advantages to actively apply for Regional Science Fund projects, gradually enhancing basic research capacity and expanding influence.

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Author Contributions

Xing Xia: Manuscript writing;
Zhong Yongheng: Outline determination and manuscript revision;
Liu Jia: Data analysis;
Wang Hui: Data collection and organization.

Note: Figure translations are in progress. See original paper for figures.