

**EVALUATING THE RESEARCH EFFICIENCY
OF HIGHER EDUCATION INSTITUTIONS IN
CENTRAL AND WESTERN CHINA BASED ON
THE DEA METHOD**

TIAN YUZHEN

UNIVERSITI SAINS MALAYSIA

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THE DEA METHOD**

by

TIAN YUZHEN

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LIST OF ABBREVIATIONS

| | |
|------|--|
| BCC | Banker–Charnes–Cooper |
| CCR | Charnes–Cooper–Rhodes |
| CDEA | Centralized DEA |
| CPI | Consumer Price Index |
| CRS | Constant Returns to Scale |
| CSW | Common Set of Weights |
| DDF | Directional Distance Function |
| DEA | Data Envelopment Analysis |
| DMU | Decision Making Unit |
| DRS | Decreasing Returns to Scale |
| ESI | Essential Science Indicators |
| FDH | Free Disposal Hull |
| GML | Global Malmquist-Luenberger |
| GTE | Group Frontier Technical Efficiency |
| GTEI | Group Frontier Technical Inefficiency |
| HEI | Higher Education Institution |
| IRS | Increasing Returns to Scale |
| ME | Managerial Efficiency |
| MEI | Managerial Inefficiency |
| MOE | Ministry of Education |
| MOLP | Multiple Objective Linear Programming |
| MST | Ministry of Science and Technology |
| MTE | Meta-Frontier Efficiency |
| MTEI | Meta-Frontier Technical Inefficiency |
| NBS | National Bureau of Statistics of China |
| NDRS | Nondecreasing Returns to Scale |
| NIRS | Nonincreasing Returns to Scale |
| NSFC | National Natural Science Foundation of China |
| PPS | Production Possibility Set |
| PTE | Pure Technical Efficiency |
| R&D | Research and Development |

| | |
|-----|---------------------------|
| RE | Regional Efficiency |
| REI | Regional Inefficiency |
| RTS | Returns to Scale |
| S&S | Social Science |
| S&T | Science and Technology |
| SBM | Slack-Based Measure |
| SCI | Science Citation Index |
| SE | Structural Efficiency |
| SEI | Structural Inefficiency |
| TE | Technical Efficiency |
| TGR | Technology Gap Ratio |
| VIF | Variance Inflation Factor |
| VRS | Variable Returns to Scale |

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MENILAI KECEKAPAN PENYELIDIKAN INSTITUSI PENGAJIAN TINGGI DI CHINA TENGAH DAN BARAT BERDASARKAN KAEDAH DEA

ABSTRAK

Sains dan teknologi (S&T) merupakan pemacu utama dalam pembangunan sosial dan ekonomi. Sebagai hab utama bagi penyelidikan S&T, institusi pengajian tinggi (IPT) telah menarik banyak perhatian daripada kerajaan China. Walau bagaimanapun, IPT di wilayah tengah dan barat tidak berkembang sebaik berbanding dengan IPT di wilayah timur. Kekurangan perkembangan IPT di wilayah tengah dan barat telah menghalang pembangunan seimbang secara keseluruhan. Oleh itu, kerajaan telah mencadangkan "Pelan Pemulihan" untuk menyokong IPT di wilayah tengah dan barat serta meningkatkan kecekapan penyelidikan. Namun, terdapat kajian yang terhad bagi meneliti isu ini. Bagi mengisi jurang ini, kajian ini bertujuan untuk meneroka sama ada "Pelan Pemulihan" telah meningkatkan kecekapan penyelidikan IPT yang menerima sokongan dasar sepanjang tempoh kajian dengan menggunakan kaedah analisis selubung data (DEA) umum yang diperluas. Model ini dapat menangani peningkatan dari segi input dan output secara serentak. Selain penilaian kecekapan dalam kalangan IPT "Pelan Pemulihan", kajian ini juga menggunakan kaedah DEA meta-had pelbagai hierarki untuk menyelidik jurang kecekapan antara IPT "Pelan Pemulihan" dan IPT utama yang lain. Selain itu, satu kaedah DEA baharu yang menghubungkan had kecekapan yang berbeza telah dicadangkan bagi menyediakan laluan penambahbaikan. Akhir sekali, dengan mengambil kira peranan penting dana

penyelidikan, kajian ini membangunkan kaedah peruntukan sumber berasaskan DEA yang menggabungkan konsep kecekapan silang dan proses berulang untuk memperuntukkan semula dana kerajaan dalam kalangan IPT "Pelan Pemulihan" bagi mencapai penambahbaikan lanjut. Dapatan kajian menunjukkan bahawa kecekapan penyelidikan IPT "Pelan Pemulihan" meningkat berbanding tahap kecekapan pada tahun 2011, tetapi pelbagai jenis IPT menunjukkan tahap kecekapan yang berbeza. Di samping itu, penilaian jurang kecekapan menunjukkan wujudnya jurang kecekapan antara wilayah serta dalam wilayah tengah dan barat itu sendiri. Tambahan pula, kewujudan ketidakcekapan bagi kebanyakan IPT berpunca daripada masalah pengurusan dalaman. Oleh itu, laluan penambahbaikan dicadangkan melalui pengawalseliaan pemboleh ubah input dan output. Selain itu, peruntukan semula dana kerajaan dapat meningkatkan kecekapan keseluruhan dan hasil penyelidikan IPT "Pelan Pemulihan" ke tahap tertentu. Berdasarkan dapatan kajian, implikasi dasar yang bersesuaian turut disarankan, seperti sokongan dana yang berterusan dan diperuntukkan dengan baik serta kerjasama antara IPT pelbagai jenis dan di pelbagai wilayah. Secara keseluruhannya, kajian ini bukan sahaja menyumbang kepada pengembangan model DEA tetapi juga kepada literatur mengenai IPT di wilayah tengah dan barat China, yang akan membantu kerajaan menyesuaikan dasar serta mengurus pembangunan masa depan institusi-institusi ini.

**EVALUATING THE RESEARCH EFFICIENCY OF HIGHER
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BASED ON THE DEA METHOD**

ABSTRACT

Science and technology (S&T) are the driving forces of social and economic development. As major hubs for S&T research, higher education institutions (HEIs) have received much attention from the Chinese government. However, HEIs in the central and western regions have not developed as well as those in the eastern region, impeding the overall balanced development of HEIs. Therefore, the government proposed the “Revitalization Plan” to support central and western HEIs and to improve their research efficiency. However, few studies have focused on this issue. To fill this gap, this study first intends to explore whether the “Revitalization Plan” improved the research efficiency of HEIs that received support from the policy during the study period by using the extended generalized data envelopment analysis (DEA) method. This model can address the improvement from the input and output simultaneously. In addition to the efficiency evaluation among “Revitalization Plan” HEIs, this study employs the multi-hierarchy meta-frontier DEA method to further investigate the efficiency gap between “Revitalization Plan” HEIs and other key HEIs. Moreover, a novel DEA-based method that connects different frontiers is proposed to provide an improvement path. Finally, considering the essential role of research funds, this study develops a DEA-based resource

allocation method that integrates the concept of cross-efficiency and iterative process to reallocate government funds among “Revitalization Plan” HEIs to seek further improvement. The results show that the research efficiency of “Revitalization Plan” HEIs improved relative to that efficiency level in 2011, but different types of HEIs exhibited diverse levels of efficiency. In addition, the results of the efficiency gap evaluation revealed efficiency gaps between regions and within the central and western regions. Moreover, the inefficiency of most HEIs originates from internal managerial problems; therefore, improvement paths are given through the regulation of input–output variables. Furthermore, the reallocation of government funds further improves the overall efficiency and research output of “Revitalization Plan” HEIs to some extent. Based on the findings, corresponding policy implications are offered, such as continuous and well-allocated fund support and cooperation between HEIs of different types of HEIs and in different regions. Overall, this study contributes not only to the extension of the DEA model but also to the literature on Chinese central and western HEIs, which will help the government adjust policies and manage the future development of these institutions.

CHAPTER 1

INTRODUCTION

1.1 Overview

A higher education institution (HEI) is an institution that provides higher education to students after they have completed their senior secondary education and aims to cultivate professional talent with social responsibility, an innovative spirit, and practical technology. In the early days of the establishment of HEIs, the main functions of HEIs were spreading knowledge and training talent. However, the quick development of science and technology (S&T) and industry during the Industrial Revolution in the late 18th century led to an increased demand for research from HEIs, which promoted the transformation of HEIs from traditional education institutions to institutions focusing more on research.

Currently, with the arrival of the knowledge economic era, breakthroughs have consistently driven profound economic development and societal progress throughout the development of S&T. Consequently, S&T has been widely regarded as the primary productive force. Moreover, HEIs further place research in a critical position and serve as major hubs for research, where numerous significant research projects and cutting-edge studies are being conducted. As a result, more than 60% of fundamental research in developed countries is conducted by HEIs, and since the Second World War, 70% of Nobel Prize winners have been from HEIs (Li, 1999).

In the context of China, HEIs garnered more than 60% of the national S&T

awards in 2022 and contributed to more than 60% of fundamental research and 80% of the annual research funded by the National Natural Science Foundation of China (NSFC, 2022). In recent decades, the supply and the technology transfer of scientific achievements of HEIs have been significantly improved, with patent authorization increased by 346.4%. Moreover, research in HEIs is devoted to addressing key core technologies (Sun, 2022), which propelled China from being a technology follower to becoming a technology leader.

Hence, the Chinese government highly prioritized the development of HEIs and further formulated support policies for top Chinese HEIs in terms of extending privileged funds to improve their quality of education and research in the early 1990s. For example, the well-known “211 Project” and “985 Project” were implemented more than 30 years ago and have supported more than a hundred top HEIs, which have made many achievements during the project period (An et al., 2019; Jiang et al., 2020; Hou et al., 2021). However, environmental, geographical, and economic constraints have exacerbated the gap between the eastern region and the central and western regions, especially regarding the development of HEIs (Sun et al., 2023a). As a result, the key HEIs with project titles are mainly from the eastern region, while most central and western HEIs are still relatively underdeveloped.

Despite the disadvantages in development, there are approximately two-thirds of local HEIs in the central and western regions. Since HEIs not only serve as the main force driving S&T development but also play a vital role in contributing to local

economic development (Fu and See, 2022), these local HEIs also take responsibility for S&T efforts for regional development strategies, namely, projects such as “the “China western development ”, the “Rise of central China”, and the “Revitalization of Northeast China” projects. Specifically, the spillover effect of university activity on local economies is that local universities produce technology and innovation for local industry; therefore, technology demand from local industry comes out (Kantor and Whalley, 2014). Therefore, the relatively underdeveloped central and western regions need technology support from local HEIs. Moreover, due to environmental differences, developments in the central and western regions have specific demands for technology to aid in their development. For example, the climate and geographical environment of Inner Mongolia, China, are suitable for the development of animal husbandry. To meet the demands of the local economy, local governments would encourage local HEIs to develop related disciplines and technologies, such as animal husbandry and veterinary medicine, animal husbandry engineering technology, and grass industry technology. Hence, local HEIs serve the local economy. In summary, the central and western regions demands further development of local HEIs to meet their economic development needs.

Moreover, central and western HEIs are in urgent need of development. Due to their remote location and historical development, HEIs in the central and western regions generally face issues such as the loss of high-level talent, insufficient investment in research funding, and lagging construction of research platforms, which severely constrain the improvement of their research efficiency (Jiang, 2017).

Therefore, central and western HEIs are relatively underdeveloped compared to eastern HEIs (Jiang et al., 2020), which makes it difficult for HEIs to obtain educational policy support. This becomes a vicious cycle that traps these HEIs. Therefore, central and western HEIs are eager to receive educational policy support (Huang, 2017). As discussed above, local HEIs have their own special development path; thus, the plans and experiences of developed HEIs may not always be suitable for central and western HEIs. For example, the key HEIs in China have a vast amount of extensive funds available to them to carry out the overall development of their disciplines. However, under the limitations of their previous development levels, professional talent, and research funds, if local HEIs develop in the same way as other key HEIs, not only would research in advantageous disciplines not achieve sufficient improvement, but new disciplines would not meet standard levels. Thus, it is necessary to formulate a special educational policy and provide an appropriate path for the development of central and western HEIs.

Consequently, in terms of local economic development requirements and the need for the development of central and western HEIs, it is essential to improve the research of HEIs in central and western regions. Hence, to support educational reform and further support more local HEIs, the government launched an additional educational reform policy, that is, the “Central and Western Higher Education Revitalization Plan” (hereafter referred to as the “Revitalization Plan”). The “Revitalization Plan” is regarded as another important strategy of educational reform that followed the 211 and 985 Projects, and plans to provide more financial support

and development opportunities to central and western HEIs.

According to the goals of educational policy, supported HEIs are expected to improve, especially in terms of research, and are expected to narrow the gap with other key HEIs. However, such financial support for central and western HEIs may not be sufficient due to their long-standing underdevelopment in scientific research (Ng and Li, 2000). Therefore, these HEIs must fully utilize the funds provided by the government to pave the way for future development. Although only a small part of central and western HEIs can be supported by the “Revitalization Plan”, the development of these HEIs will take the lead and drive the development of the remaining HEIs in all of the central and western regions.

1.2 Background

This section analyzes the development status of central and western HEIs from three perspectives. First, considering the importance of educational policies to the development of Chinese HEIs, this study analyzes the need for an educational policy aimed at central and western HEIs from the historical development perspective of education reform policies over the years. Second, based on regional differences, this study discusses the development gaps between eastern HEIs and central and western HEIs from the perspectives of policy support and resources received. Third, considering the essential role of government research funds in the development of HEIs, descriptions of the fund composition and allocation system and the situation faced by central and western HEIs regarding research funds are provided.

1.2.1 Development of Educational Reform in China

The development of HEIs relies on the support of the national policy. In China, through educational policy, HEIs receive additional funds through the budgets of policies and obtain development opportunities. The first higher educational reform was revived in the 1950s. Early years of the People's Republic of China, the country needed enormous amounts of professional talent and technology for nation-building. Therefore, the government promulgated the "Resolution on the Scope of Work of Key Universities and Experts". The "Resolution" identified Renmin University of China, Peking University, Tsinghua University, Harbin Institute of Technology, Beijing Agricultural University, and Beijing Medical College as the first batch of key HEIs in the country (Liu, 2022), which aims to cultivate high-quality scientific research talent and lead other HEIs to move forward together (Zhang, 2016). Furthermore, in 1959, the "Decision on Designating a Group of Key Schools among Higher Education Institutions" increased by 16 key HEIs, and the trial recruitment of graduate students began (Wang, 2014). The enrollment of graduate students indicated that the emphasis on scientific research of HEIs rose to a new level. By the 1960s, the number of key HEIs increased to 67 through the "Decision of the Central Committee of the Communist Party of China to increase the number of key universities across the country", while in 1978, the number increased again to 88 key HEIs. Until the early days of reform and opening up, a total of 99 key universities had been titled (Hu, 2020).

During the reform and opening up in China, the development philosophy of economy and construction was transformed, which paved the way for higher education

to progress. Correspondingly, “835 Suggestions” was proposed to select the 5 top HEIs (i.e., Peking University, Tsinghua University, Fudan University, Shanghai Jiao Tong University, and Xi'an Jiaotong University) among the key HEIs. Among them, Peking University, Tsinghua University, and Fudan University each received financial support of RMB 100 million, and Shanghai Jiao Tong University and Xi'an Jiaotong University each received RMB 50 million in funds for development (Zhang, 2018). Such a way of supporting the selected HEIs in batches aims to concentrate on promoting the few top HEIs to achieve further progress first.

In the 1990s, economic development increasingly depended on scientific and technological progress. The then-Chinese President Jiang Zemin noted that economic construction must be transferred into a path that relies on scientific and technological progress and improving the quality of labor and regarded “implementing the strategy of rejuvenating China through science and education” as an important policy for socialist modernization. Due to the limitations of developing countries, educational policy still focuses on a few key HEIs. Based on previous educational policies, the central government further launched the “211 Project”, which aims to develop approximately 100 high-quality universities with strong research capabilities. Since the implementation of the policy in 1995, the government has allocated more than 10 billion additional resources to the “211 Project” HEIs through a priority funding budget (Liu, 2019). The entitled HEIs indeed perform exceptionally well in research (Yaisawarng and Ng, 2014); for instance, the number of Science Citation Index (SCI)-published papers from China has increased to seven times the original number, and the

number of subjects ranked in the top 1% of the world Essential Science Indicators (ESI) from China has risen (Huang, 2017). Therefore, the “211 Project” has been the largest and highest-level educational project since the founding of China and was thus regarded as a milestone in educational reform and development.

The “211 Project” aimed to support and improve all key HEIs, while the “985 Project” concentrated on the top HEIs among the key HEIs. The “985 Project” was proposed by the then-Chinese President Jiang Zemin on 4th May 1998. This was another major decision in regard to HEIs that was to make China’s top universities strive to earn the prestigious label of a “world-class university”. The first batch of “985 Project” universities included Peking University, Tsinghua University, University of Science and Technology of China, Fudan University, Shanghai Jiao Tong University, Xi'an Jiaotong University, Nanjing University, Zhejiang University, and Harbin Institute of Technology, for a total of 9 universities, which were later known as the C9 Group Alliance (Zhai and Wang, 2017). Until 2006, a total of 39 HEIs from the “211 Project” HEIs were titled the “985 Project” and received a total of RMB 90.476 billion for improvement (Bao et al., 2016). To date, the “985 Project” HEIs have undertaken almost 50% of the S&T research and 70% of the social science (S&S) projects in the whole country and have produced innovative achievements in philosophy and social sciences with important influence (NSFC, 2022). Consequently, the “985 Project” has improved the overall level and international competitiveness of HEIs, narrowed the gap with world-class HEIs, and promoted the strategy of reinvigorating China through science and education, and the strategy of strengthening the nation with talent.

Projects 211 and 985 are strategies for higher education reform and development made by the state in response to the development tasks of different periods (Zhang, 2015). Both strategies are based on key HEIs; thus, only HEIs with strong capacity have the opportunity to be selected (Song, 2018). Relatively few HEIs in the central and western regions can participate in the project. Therefore, to support more general HEIs in the central and western regions and meet the development demand of the local economy and HEIs, the Communist Party of China Central Committee and the State Department introduced the “National Education Reform and Development of Long-Term Planning Programs (2010-2020)”, which pointed out the problem of the structure of regional education.

Later, in 2011, the Ministry of Education (MOE) of China proposed the “Central and Western Higher Education Revitalization Plan” (i.e., “Revitalization Plan”), which aimed to support higher education in the central and western regions. This plan comprised the “National Basic Ability Construction Project of Western and Central China” and the “Comprehensive Ability Enhancement Project for Universities in Central and Western China”. The Basic Capacity Construction Project was first started by the National Development and Reform Commission and the MOE, and it involves a 5-year cycle. The first phase was during 2012-2015 period, which is exactly in the period of the 12th Five-Year Plan (2011-2015). Moreover, the central government invested RMB10 billion to support approximately 100 HEIs in 23 central and western provinces to enforce basic capacity. Almost simultaneously, the Comprehensive Ability Enhancement Project also started. With financing from the central and local

governments, this project aimed at provinces without HEIs directly administered by the MOE and supported 14 of the best local HEIs based on the principle of one province and one university. Moreover, the HEIs in this plan strive to play a leading role in the central and western regions and to further promote the development of local HEIs.

The ultimate goals of the “Revitalization Plan” are to improve central and western HEIs with a better structure and high quality and to further contribute to research, technology transfer, and social development ([Ministry of Education of the People's Republic of China, 2013](#)). In terms of research, recognizing the vital role of highly skilled researchers—including outstanding scholars, scientists, and experts both domestically and internationally—the government provides the privilege of introducing talent into central and western HEIs and encourages research cooperation with worldwide talent. Second, local governments gradually establish a special fund for local HEI research in addition to increasing funding from the government. Third, increasing support for natural science and social science projects, especially projects for regional development and research with regional characteristics, is given to central and western HEIs. For example, Nanchang University spends RMB 20 million on introducing talent for scientific research every year. Moreover, Guangxi University approved 1345 research projects and received RMB 304 million in project funds in 2015 ([Li et al., 2017](#)).

The “Revitalization Plan” is an educational reform policy that first aims at the

relatively underdeveloped central and western regions and is dedicated to supporting local HEIs. Such attention has never been given to central and western HEIs. Therefore, the “Revitalization Plan” is an opportunity and even a challenge for central and western HEIs to improve their research. Considering fund limitations, the key to improvement in research is to produce more output with less resource input. Research efficiency, which refers to the research outputs achieved by HEIs in scientific research given a certain level of research input, is a comprehensive indicator to measure the scientific research capabilities of HEIs. Hence, improving the research efficiency of central and western HEIs is an important goal of the “Revitalization Plan”.

1.2.2 Regional Differences in HEIs in China

Regional differences in economic development are a problem in every country; examples include the eastern and western regions of the U.S. and the northern and southern parts of India. Regional differences influence many fields, including the development of HEIs. Corresponding studies have been conducted based on the issue of regional differences, such as those by [Amendola et al. \(2023\)](#) and [Melo-Becerra et al. \(2020\)](#). Similarly, the evaluation of this study also considered regional differences. Thus, the following introduction is based on the division of regions and the corresponding differences in Chinese HEIs.

In the case of China, due to regional differences in natural conditions, economic resources, economic development levels, and geographical locations, the entire country can be divided into several regions. Early in the 7th Five-Year Plan period (1986-1990), the country was divided into three economic zones: eastern,

central and western. The eastern region generally developed best in terms of the level of economic development, the level of economic returns from production and construction, and science and technology. In contrast, despite being rich in territory, minerals, and other natural resources, the central and western regions showed relative underdevelopment in the economy (Fleisher et al., 2010). Furthermore, the “Strategy and Policy for Coordinated Regional Development” pointed out that the previous three economic zones could not meet the current research requirements. Therefore, in the 11th Five-Year Plan period (2006-2010), mainland China was divided into eastern, central, western, and northeastern regions, and these regions could be further divided into eight comprehensive economic zones: the eastern coastal, southern coastal, northeastern, northern coastal, middle Yellow River, middle Yangtze River, northwestern, and southwestern zones. For convenience, most studies of HEIs (e.g., Chu Ng and Li, 2000; Chen and Shu, 2021; Sun et al., 2023a) still analyze the results based on three economic zones.

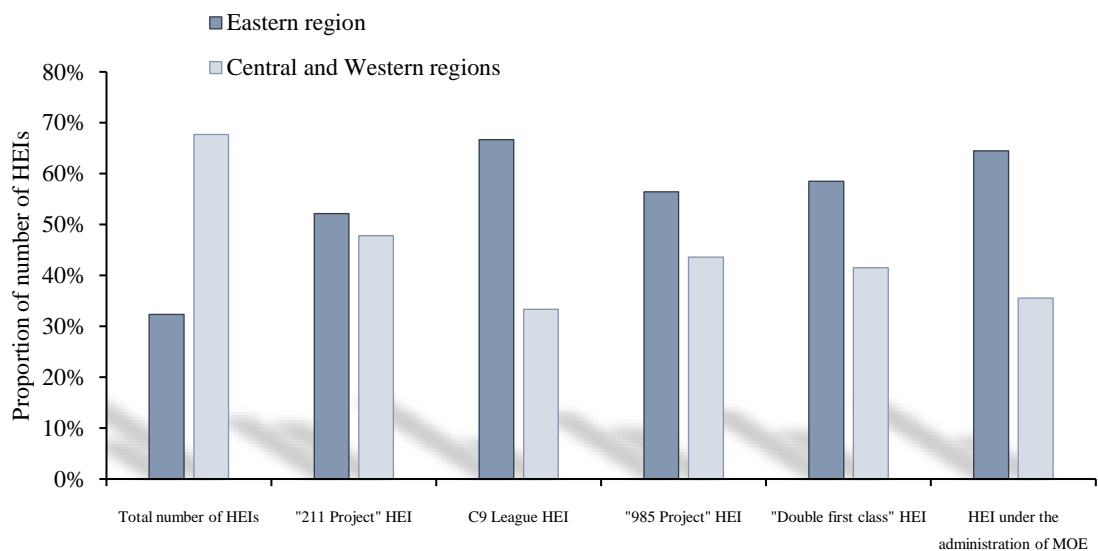
Among the three regions, the provinces in the eastern region, such as Beijing, Tianjin, Shandong, Shanghai, Jiangsu, Zhejiang, Fujian, and Guangdong, have long had the highest per capita GDP in China¹. Moreover, due to the strategy of “the East taking the lead in development”, most capital, talent, and educational resources have been concentrated on these 8 eastern provinces, which have paved the way for HEI development. Notably, Hebei and Hainan Provinces are located in eastern China, but they have not developed as well as other eastern provinces. In terms of higher

¹ China Statistical Yearbook 2010-2022. Can be obtained by <http://www.stats.gov.cn/>.

education, Hebei and Hainan do not have an HEI directly under the administration of the MOE. Additionally, the provinces in the northeastern region, such as Heilongjiang, Jilin, and Liaoning, face the problem of talent loss (Jiang, 2017), which harms the development of HEIs. Considering these deficiencies, the “Revitalization Plan” extends the scope of support for central and western provinces and includes HEIs in 23 provinces, cities, and autonomous regions to help more underdeveloped provinces improve higher education (i.e., Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hunan, Hubei, Hainan, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Ningxia, Qinghai, and Xinjiang). Based on the regional division in this policy, there are significant gaps in HEI development between the eastern region and the central and western regions (Liu and Ma, 2018; Hu, 2023).

HEIs in the eastern region have rapidly developed, and many of them, such as Tsinghua University, Peking University, Zhejiang University, and Shanghai Jiao Tong University, which are the top 4 universities in the ranking of the National Third-Party University Evaluation Institution, have become the top HEIs in China. Only about 30% of central and western HEIs are listed among the top 30 Chinese HEIs. According to different educational policies, Figure 1.1 compares the number of HEIs between the eastern region and the central and western regions. A total of 64.47% of the universities directly under the administration of the MOE, 52.17% of the “211 Project” HEIs, 56.41% of the “985 Project” HEIs, 66.67% of the C9 League HEIs, and 58.5% of the “Double First-Class” HEIs are located in these 8 eastern provinces. More specifically, among

75 key HEIs directly administered by the MOE, 32.89% are located in Beijing, 10.53% in Shanghai, and 9.21% in Jiangsu. In contrast, 13 central and western provinces, such as Inner Mongolia, Ningxia, and Hainan, do not have any HEIs directly administered by the MOE. Therefore, although nearly two-thirds of China's HEIs are in the central and western regions, the central and western HEIs are in a disadvantageous position compared to those in the eastern region in terms of policy support. Therefore, central and western HEIs have not developed as well as those in the eastern region. In other words, the key problem in the central and western regions is the lack of high-quality HEIs rather than the total number of HEIs.

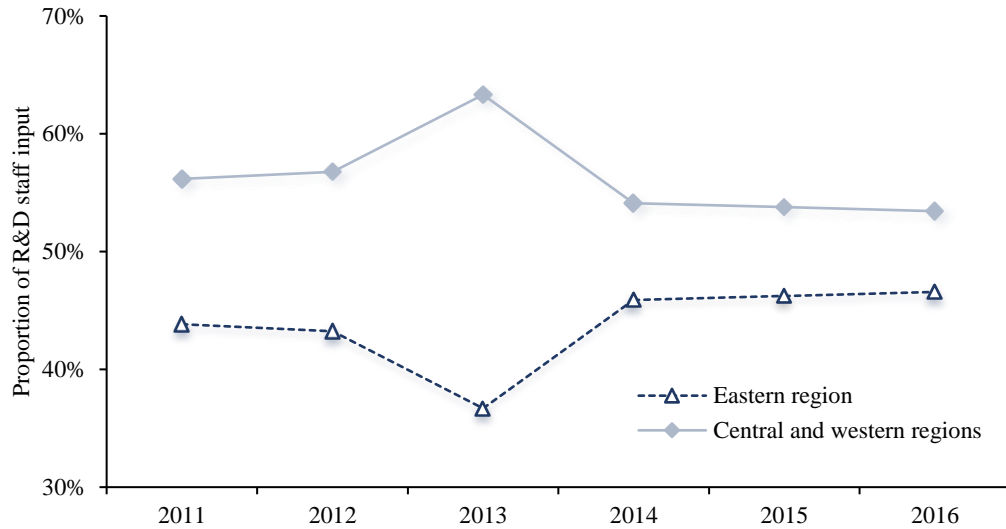


Note: The data is obtained from the National Bureau of Statistics of China (NBS)

Figure 1.1 Regional comparison of the number of HEIs under different policies

Furthermore, in terms of resource input, the proportion of research and development (R&D) staff in HEIs in 23 central and western provinces is slightly greater than that in 8 eastern provinces, as shown in Figure 1.2. Due to the difference in the number of HEIs, the gap in R&D staff input between regions is not too large.

However, the proportion of R&D staff in the central and western regions has been decreasing, which is in line with the fact that talent loss has occurred in central and western HEIs (Tian and Li, 2022).

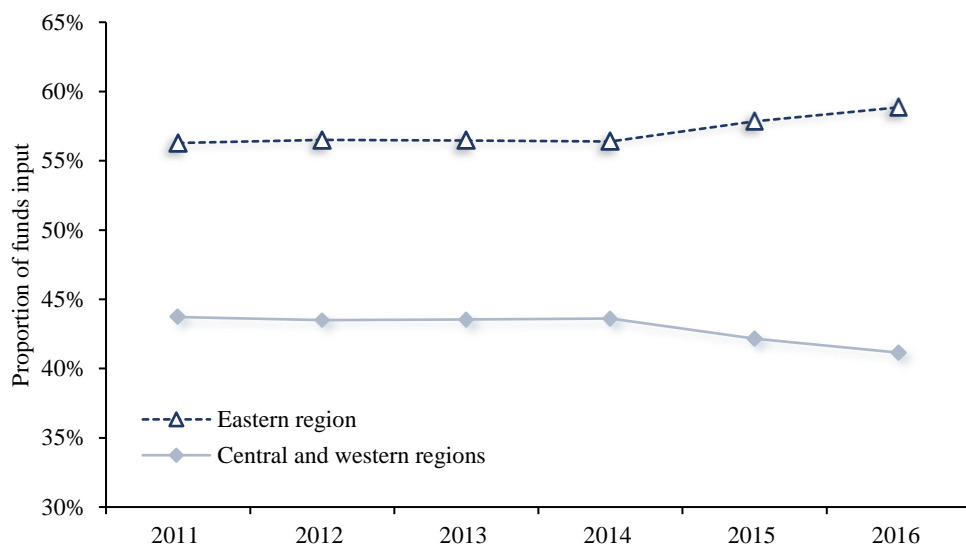


Note: The data is obtained from Summary Statistics on the Science and Technology of Higher Education Institutions

Figure 1.2 Regional comparison of R&D staff input in HEIs by years

In contrast, the imbalance in the distribution of funds between regions is more significant. As shown in Figure 1.3, the proportion of funds allocated to the HEIs in the 8 eastern provinces is significantly greater than that in the 23 central and western provinces; that is, a small number of HEIs have received the most funding. Moreover, this gap has existed for a long time. For example, the eastern provinces, such as Beijing, Shanghai, Guangdong, Tianjin, Jiangsu, and Zhejiang, have always received above-average funding, while only one central and western HEI, Shaanxi, received this level of funds (Xie, 2022). According to the budget of each HEI, in 2022, 20 HEIs received

funds from the government budget above RMB 10 billion. However, only 30% of these HEIs were in the central and western regions. For instance, the president of Guizhou University noted that the total amount of financial support allocated to Guizhou University over a period of 30 years was less than the funding allocated to Tsinghua University and Peking University in one year (Xinhua-Global Times, 2014). Such a situation where resource allocation has been excessively biased towards the eastern region for a long time has had an adverse impact on the development of central and western HEIs (Hong and Xie, 2020).



Note: The data is obtained from Summary Statistics on the Science and Technology of Higher Education Institutions

Figure 1.3 Regional comparison of funds input in HEIs by years

In addition, there is a difference between HEIs with and without policy support, although some HEIs are in the same region. For example, project HEIs can receive as much as 20 times the funding of nonproject HEIs (Zhang, 2015). Moreover, Peters and Besley (2018) noted that the government always allocates more resources to project

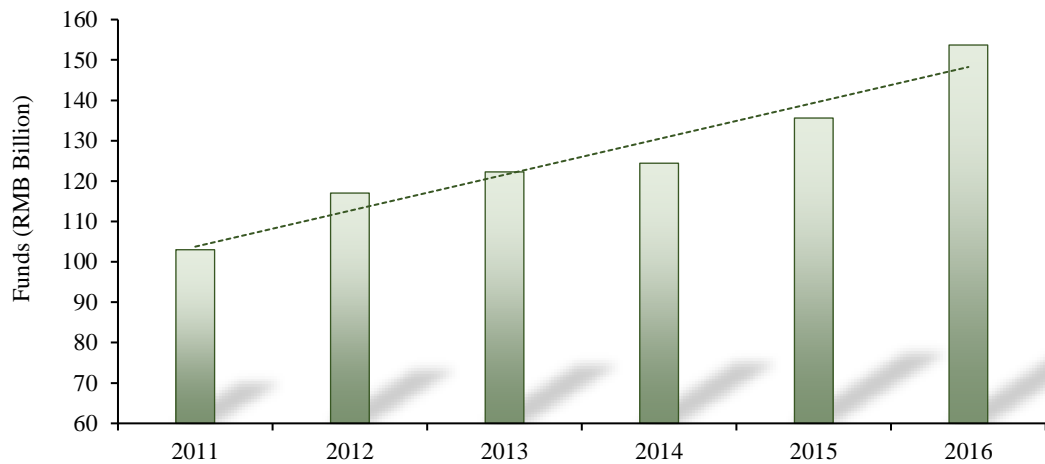
universities; thus, an uneven distribution of education resources results in a gap between them and local universities.

Consequently, the gaps in HEIs among regions or even policies can cause technical heterogeneity, which will affect the judgment of efficiency evaluation. Therefore, it is necessary to consider the heterogeneities caused by these gaps, particularly by analyzing the gaps among different regions or comparing HEIs under different policies.

1.2.3 Funds for Research in HEIs

In the process of performing research, research resources are indispensable and play a supportive role in promoting S&T innovation and the sustainable development of the economy. In particular, research funds, which can be used to support research projects, update equipment and laboratories, and cultivate and introduce talent, have received much attention from countries worldwide. For example, the United States is the world's largest research and development (R&D) investor. According to data from the National Science Foundation, in 2021, US universities and research institutes spent more than 89 billion dollars on scientific research. Moreover, Horizon 2020 in the European Union budgeted 80 billion euros for research and the development of innovation and technology in universities (Kalisz and Aluchna, 2012). In China, investment in research has increased rapidly for decades. According to reports by the NBS, the R&D expenditure of HEIs reached RMB 241.24 billion in 2022, reflecting a growth of 182% over ten years. In terms of S&T research, the total funds for the whole country's HEIs also showed an increasing trend during the 2011-2016 period, as

depicted in [Figure 1.4](#). Increasing funds ensure the continuous development of S&T, which results in significant progress in the research of Chinese HEIs. For instance, the World University Rankings 2023 by Times Higher Education showed that 8% of the top 100 HEIs are in mainland China from the perspective of research level.



Note: The data is obtained from Summary Statistics on the Science and Technology of Higher Education Institutions

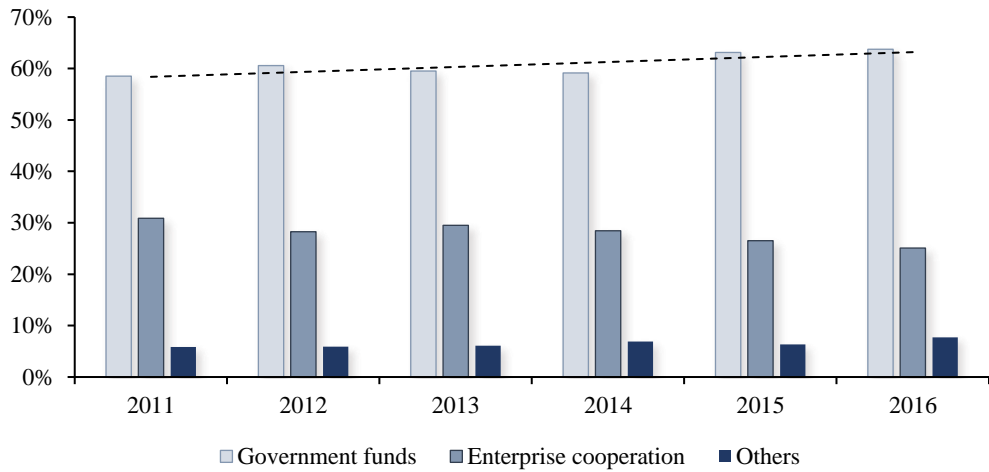
Figure 1.4 Trend of the total amount of research funds for HEIs from 2011-2016

Therefore, considering the foundation role of research funds, it is important to understand the composition of the funds in terms of Chinese HEIs. Before the 1980s, all funds for HEIs came from government appropriation; after the 1980s, research funds were obtained from multiple sources ([Ye and Ye, 2010](#)), such as governmental financial allocation, cooperation with enterprises, cooperation with international projects, personal donations, etc.

With respect to enterprise cooperation, HEIs obtain research funds from enterprises and institutions that entrust them to conduct targeted research or participate in an enterprise's research project. Moreover, HEIs can receive financial support by

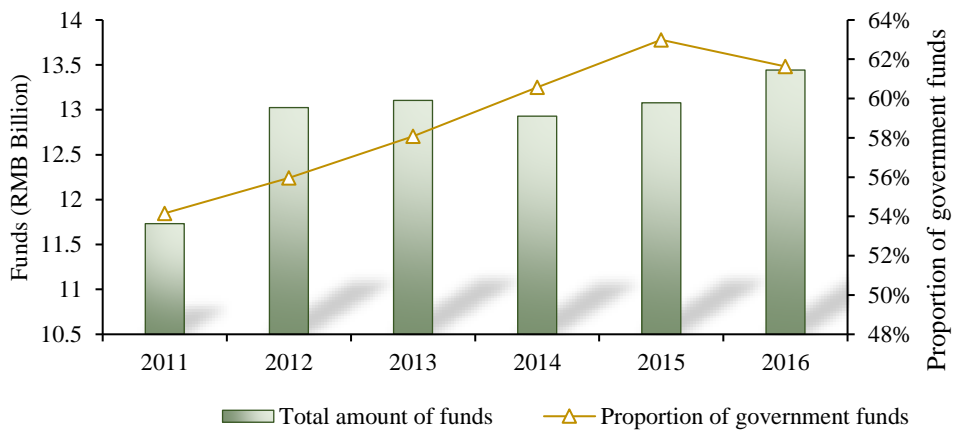
transferring technology to the market, which facilitates the application and commercialization of research achievements. Moreover, through cooperation with international research projects, HEIs can apply for foreign capital. Additionally, donations from alumni, entrepreneurs, and foundations can also be possible sources of research funds for HEIs.

Chinese HEIs are nonprofit institutions; thus, HEIs, and especially public HEIs, are unable to maintain operation through only the funds obtained from the above sources, revenue from tuition fees, or other possible benefits. Furthermore, based on a statistical analysis of R&D activities in China's colleges and universities (MST, 2022), HEI funds always rely on financial support from the governmental budget. In terms of research funds, [Figure 1.5](#) presents the specific proportion of funds from various sources during the 2011-2016 period. Research funds from enterprises and other path processes are a small part of the total funds, while government funds always dominate and show an increasing trend. A similar situation regarding government funding can be found in some central and western HEIs (see [Figure 1.6](#)). This is because fundamental research, key technology research, and national strategic research require a large amount of labor and funds and their research and development may take a long time, which is risky for enterprises. However, these studies are related to the development of the country and even the entire human race; therefore, they are mainly financed by the government. Therefore, the role of the government in fund allocation is very important.



Note: The data is obtained from Summary Statistics on the Science and Technology of Higher Education Institutions

Figure 1.5 Proportion of research funds from different sources from 2011-2016



Note: The data is obtained from Summary Statistics on the Science and Technology of Higher Education Institutions

Figure 1.6 Amount of research funds for HEIs and proportion of government funds in central and western regions from 2011-2016

Based on this, we further learn about the governmental allocation system. In terms of distribution channels, the State Council of the People’s Republic of China is in charge of planning and designing research for the whole country. Then, the MOE, Ministry of Science and Technology (MST), NSFC, and National Philosophy and

Social Sciences Planning Office allocate funds to each HEI (Xi et al., 2014). Specifically, the funds from the NSFC and the National Philosophy and Social Sciences Planning Office are available to each HEI where researchers applied for fund approval through their projects (Yang et al., 2023b). The MST allocates funds only through major national research plans, such as the National High-Tech R&D Programme (863 Programme) and the National Key Basic R&D Programme (973 Programme). The MOE directly allocates a portion of research funds to HEIs, and other research funds are allocated through MOE research projects. Local governments also provide financial support for the research of local HEIs through the local financial budget. Meanwhile, local research projects are open to researchers in local HEIs. This is why HEIs in developed areas have sufficient funds for research.

The allocation pattern is mainly based on input orientation in the early stages. That is, the government allocates funds based on the budget for the HEIs' workload each year, the number of staff and students, and the special budget for target activities (Huang and Qin, 2014). However, this pattern may lead to a situation in which HEIs obtain more funds through scale expansion rather than being dedicated to producing more output. As a result, large-scale HEIs may receive more funds, while smaller HEIs are unable to obtain the funds necessary to develop, although some small HEIs may have research advantages. Moreover, this method of allocation may result in low utilization and low return on investment. Therefore, the government has begun considering performance evaluations when allocating resources (Shen, 2015).

Notably, with the support of special educational policy (i.e., the “Revitalization Plan”), funds for central and western HEIs have significantly increased, as shown in [Figure 1.6](#). However, considering the requirement for performance-based allocation of research funds, reasonably allocating limited funds to each supported HEI will contribute to improving research.

1.3 Problem Statement

As the primary driver of research, HEIs play an indispensable role in contributing to local and national economic development in China ([Fu and See, 2022](#)). However, HEIs in the central and western regions do not develop as robustly as those in the eastern regions ([Johnes and Yu, 2008](#); [Liu and Ma, 2018](#); [Sun et al., 2023a](#)). Consequently, the “Revitalization Plan” was proposed to promote the research of HEIs in central and western China. Therefore, evaluating and improving research in central and western HEIs is essential for helping the government adjust policies for the future development of these institutions. Several issues are described as follows:

The first issue focuses on the research efficiency change under the policy support. The “Revitalization Plan” is an opportunity for central and western HEIs to improve their research efficiency. However, whether this policy works to improve research efficiency or whether HEIs can seize opportunities is highly related to future educational policy regulation and the internal management of HEIs. Previously, there have been many studies evaluating the efficiency of HEIs with policy support. For example, [Hu et al. \(2017\)](#) conducted a series of studies on the research efficiency of

the “211 Project” HEIs, which aimed to promote efficiency and provide a reference for the project’s decision makers. There have also been many studies based on the 211 and 985 projects, such as [An et al. \(2019\)](#), [Jiang et al. \(2020\)](#), [Hou et al. \(2021\)](#), [Chen et al. \(2021\)](#), and [Yang et al. \(2022\)](#), providing much helpful information for the development of educational policy and target HEIs. However, on the one hand, no studies have focused on the “Revitalization Plan” policy and the targeted central and western HEIs. Moreover, the suggestions for key HEIs proposed by previous studies, such as implementing the tenure track system for staff ([Yang et al., 2018](#)) and increasing contact with foreign-invested enterprises ([Hou et al., 2021](#)), may not be suitable for general central and western HEIs. Implementing these strategies could be challenging for such institutions due to their resource limitations and regional constraints. On the other hand, considering the advantages of addressing multiple inputs and outputs and freedom from preconceived structures imposed on the data ([Emrouznejad et al., 2023](#)), previous efficiency evaluations of HEIs have always been based on the conventional DEA method ([Majidi and Safaei Ghadikolaei, 2021](#)). However, due to frontier inconsistencies, assessing efficiency changes between periods is challenging for the conventional data envelopment analysis (DEA) method ([Ma, 2002, 2003](#)). Therefore, when investigating whether the efficiency of “Revitalization Plan” HEIs improved over the study period, the results based on different frontiers may lead to unreasonable comparisons across years ([Ma, 2002](#)). The generalized DEA method removes restrictions on the reference set and allows any year to be chosen as the fixed reference to evaluate all decision making units (DMUs)

depending on practical requirements (Ma, 2012). However, this method has not been extended or applied to the evaluation of HEIs. Overall, based on the “Revitalization Plan”, it is important to introduce a suitable method to determine whether the policy improved the target HEIs during the study period and to further investigate the factors influencing efficiency.

The second issue focuses on the research efficiency gap between “Revitalization Plan” HEIs and the other HEIs. That is because narrowing the gap with eastern HEIs is another important goal of the policy. However, information on comparisons among “Revitalization Plan” HEIs is far from sufficient to present the gap and advice for further progress. Therefore, the evaluation needs to be conducted based on both the internal and external aspects of “Revitalization Plan” HEIs to help recognize the technical gap and potential improvement opportunities in research efficiency. Since the conventional DEA method provides only within-group relative efficiency, the meta-frontier approach is used to evaluate between-group heterogeneity (O’Donnell et al., 2008). For example, considering regional heterogeneity, Sun et al. (2023a) utilized the meta-frontier super slack-based measure (SBM) model to estimate the regional gap when evaluating the efficiency of HEIs of provinces. However, although an efficiency evaluation based on provinces provides a complete picture of the provincial situation, it cannot provide target information for individual HEI. Agasisti et al. (2021) and Yaisawarng and Ng (2014) conducted a meta-frontier analysis of HEIs considering country or educational policy heterogeneity, but they ignored heterogeneity across regions. To date, no studies of HEIs have simultaneously considered the political and regional heterogeneities among HEIs, which can be a cause of inefficiency. The multi-hierarchy meta-frontier DEA method can be used to