frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 05 June 2024
DOI 10.3389/fsufs.2024.1384734

OPEN ACCESS

EDITED BY
Isabelle Piot-Lepetit,
INRAE Occitanie Montpellier, France

REVIEWED BY
Shuaib Ali,
Guangzhou University, China
Devon Ronald Dublin,
Ocean Policy Research Institute, Japan

*CORRESPONDENCE
Zhang Huijie
✉ zhanghuijie@caas.cn
Yue Huili
✉ yuehuili@caas.cn
Zhang Zhao
✉ okagri@163.com

†These authors have contributed equally to this work

RECEIVED 10 February 2024
ACCEPTED 21 May 2024
PUBLISHED 05 June 2024

CITATION
Yuan J, Huili Y, Zhao Z, Xu J, Khan N, Jiliang M and Huijie Z (2024) Assessing efficiency in sustainable allocation of agricultural scientific and technological talent: a spatial-temporal analysis in China. *Front. Sustain. Food Syst.* 8:1384734.
doi: 10.3389/fsufs.2024.1384734

Assessing efficiency in sustainable allocation of agricultural scientific and technological talent: a spatial-temporal analysis in China

Ji Yuan[1,2†], Yue Huili[1*†], Zhang Zhao[3*], Jiao Xu[4], Nawab Khan[5], Ma Jiliang[6] and Zhang Huijie[1*]

[1]Agricultural Information Institute, Chinese Academy of Agricultural Sciences, Beijing, China, [2]Graduate School of Chinese Academy of Agricultural Sciences, Beijing, China, [3]Institute of Vegetables and Flowers Chinese Academy of Agricultural Sciences, Beijing, China, [4]Department of Personnel, Chinese Academy of Agricultural Sciences, Beijing, China, [5]College of Management, Sichuan Agricultural University, Chengdu, China, [6]Institute of Agricultural Economics and Development, Chinese Academy of Agricultural Sciences, Beijing, China

Efficient allocation of agricultural scientific and technological talents (ASTTs) is crucial for agricultural innovation and economic development. This study aims to systematically evaluate ASTTs' allocation efficiency in provincial agricultural research institutions in China, aiding decision-making for local governments and research bodies. Utilizing data from 2009 to 2019 across 31 provinces, an output-oriented data envelopment analysis model measures ASTTs' allocation efficiency and analyzes its trends, regional differences, and spatial characteristics. Results show: (1) Provincial ASTTs' mean comprehensive technical efficiency (CTE) in China was 0.786, with room for improvement. (2) Enhanced CTE was driven by scale efficiency improvements, while pure technical efficiency declined, indicating a need for better management systems and technology applications. (3) Disparities in ASTTs' allocation efficiency among provinces decreased, with higher efficiencies in the East and Central-Southern China regions. At the provincial level, areas like Jiangsu, Shandong, Henan, and Sichuan demonstrated relatively high ASTTs allocation efficiencies. (4) Spatial agglomeration of ASTTs' allocation efficiency was localized in a few major agricultural provinces without a significant overall effect. These findings advocate for further optimization of ASTTs' regional layout and management mechanisms in China.

KEYWORDS

efficiency, agricultural scientific and technological talent, spatial–temporal evolution, allocation, data envelopment analysis, China

1 Introduction

Sustainable agricultural scientific and technological talents (ASTTs) are professionals possessing specialized knowledge and skills in agriculture, actively engaged in agricultural scientific research, education, popularization, and application (Organization Department of the CPC Central Committee, Ministry of Agriculture, Ministry of Human Resources and Social Security, etc., 2011). Sustainable ASTTs serve as a pivotal link in transitioning from traditional to modern agriculture, functioning as strategic assets to advance comprehensive rural revitalization (Ji et al., 2022). According to the theory of resource allocation, talent allocation pertains to the coordination of talent quantity and quality between the demand and supply within a specific social and economic framework. The allocation efficiency of ASTTs, meanwhile, gauges the output benefits of all input factors related to agricultural scientific and technological human resources through varying allocation methods across different temporal and spatial contexts within a technological framework (Wu and Liang, 2016). Drawing from the experiences and lessons of Japan, Europe, Latin America, and other nations in their modernization journeys, it becomes evident that the essence of economic catch-up lies in the advancement of human capital (Nan, 2020). Carried out early research on talent allocation abroad and found that efficient talent allocation is of great significance to economic growth (Murphy et al., 1991). The research by Strenze (2013) has confirmed that insufficient and excessive allocation of talent resources is not conducive to the effective utilization of resources and high-quality economic development.

In recent years, the scale of China's ASTTs scale has increased. According to the survey data from the Compilation of National Agricultural Science and Technology Statistics, the total number of personnel engaged in agricultural scientific and technological activities in agricultural research institutions in China has increased from 55,696 in 2009 to 71,173 in 2019, an increase of 27.78%. In the "13th Five Year Plan" Agricultural and Rural Science and Technology Development Report in China released by the Chinese government, the joint investment of project funds for agricultural research institutions was approximately 61.019 billion yuan (USD8435.03 million), an increase of 51.23% compared to the "12th Five Year Plan" period, and the total number of Chinese agricultural invention patent applications and papers published in agricultural science and technology output is among the top in the world (Yang, 2021).

Although the overall investment in ASTTs in agricultural research institutions in China is gradually increasing, as a developing country, there is still a gap in China's investment in ASTTs compared to developed countries. Furthermore, there exist differences in the intensity of investment in ASTTs among regions due to differences in location, economy, and other aspects among provinces in China. As a special and scarce resource, it is more significant to optimize the allocation of existing talent resources and promote the maximization of their utilization. This prompts several critical questions: Are the current scale and allocation efficiency of ASTTs in China justified? How does the allocation efficiency of ASTTs evolve across time and regions? Do significant regional disparities exist in the allocation efficiency of ASTTs among the provinces and regions in China? How can the rational allocation of ASTTs be realized?

Currently, the study has not found a systematic evaluation of the allocation efficiency of ASTTs in provincial-level agricultural research institutions in China. There is an urgent need to conduct relevant research to answer the above questions. The study aims to fully understand the specific level, evolutionary trends, regional differences and spatial agglomeration characteristics in the allocation efficiency of ASTTs in provincial agricultural research institutions in China, and the results can help research institutions and local governments obtain a more comprehensive understanding of development status and evolutionary trends of provincial-level ASTTs' allocation and make scientific decisions to maximize the utilization of talent resources and promote the development of agricultural technology and economy.

The main contributions and novelty of this article are as follows: First, the study conducts systematic research on the allocation efficiency of ASTTs in agricultural research institutions across 31 provinces of the Chinese Mainland from 2009 to 2019 for the first time. This paper emphasizes the measurement of ASTTs' allocation efficiency and further analyzes their temporal evolution, spatial disparities, and spatial agglomeration characteristics, providing multiple research perspectives for a comprehensive understanding of ASTTs' allocation efficiency in China. Second, based on the basic national condition that China is a developing country, the study properly employs an output-oriented data envelopment analysis model to evaluate ASTTs' allocation efficiency in various provinces over the past 11 years and decomposes it into scale efficiency and pure technical efficiency. The study separately examines the scale effect of regional agricultural science and technology talent allocation and the impact of institutions and technology on talent allocation efficiency. This method aligns with China's actual national conditions and provides a clearer understanding of the specific situation of ASTTs' allocation efficiency.

Another novelty of the research method lies in the design of input–output variables. Existing research only considers the quantity of talent input, neglecting talent quality indicators. The novelty of the indicator system design of the model lies in the introduction of talent structure indicators into the input factor variables to examine the benefits generated by talent quality, while the design of output variables fully considers the dual impact of talent allocation on agricultural technological innovation and agricultural economic development. All of these contribute to a more scientific evaluation of ASTTs' allocation efficiency in China. Third, based on the measurement of ASTTs' allocation efficiency in provincial China, the exploratory spatial data analysis method is first applied to further analyze the spatial clustering characteristics of ASTTs' allocation efficiency in 31 provinces. The research results will provide a more comprehensive and reliable theoretical reference for further optimizing the strategic and regional layout of ASTTs by provincial management institutions in China. The study is arranged as follows: Section 1 presents the introduction; Section 2 presents the literature review; Section 3 presents data samples, research methods, and empirical analysis; Section 4 presents the empirical research results; Finally, discussions and conclusions, limitations and further studies prospects are conducted in Section 5.

2 Literature review

From the perspective of the traditional economic growth theory, human capital as a kind of effective labor input, like other factors, enhances output through the amount of input, which is manifested as the scale effect of human capital on the improvement of efficiency. From the perspective of the new economic growth theory, human capital goes beyond the scope of simple factors, which improves "allocation ability" by recombining other production factors and is manifested as the allocation effect of human capital on the improvement of efficiency.

Abbreviations: ASTTs, Agricultural Scientific and Technological Talents; DEA, Data Envelopment Analysis; AHP, Analytic Hierarchy Process; R&D, Research and Development; ESDA, Exploratory Spatial Data Analysis; CTE, Comprehensive Technical Efficiency; PTE, Pure Technical Efficiency.

A large body of literature on rent-seeking, talent allocation, and economic growth has emerged abroad (Hsieh and Klenow, 2009; Acemoglu et al., 2013; Benjamin et al., 2017; Pothier, 2017). Through measuring labor allocation efficiency, Hsieh and Moretti found that the labor allocation between cities in the United States had not reached optimal levels, thus constraining national economic growth (Hsieh and Moretti, 2019). Saleh et al. (2020) revealed that both human resources and natural resources are determinants of the economic growth of Bulukumba Regency. Hsieh et al. (2019) found that improving talent allocation could potentially lead to a growth in aggregate market output per person by 20 to 40%. Jess and Mildred (2021) conducted an equilibrium model of "revenue diversion" by management, evaluating its effects on talent allocation and earnings distribution, and suggested that revenue diversion led to inefficient allocation. Natkhov and Polishchuk (2019) and Alexeev et al. (2024) demonstrated that institutions significantly affected talent allocation, with effective institutions being more attractive to ordinary and average talents, while top talents showed decreased sensitivity to systems. Jacob Fernandes França et al. (2023) explored the application of artificial intelligence technology in talent identification and potential evaluation, asserting that artificial intelligence technology can improve talent management efficiency.

There was also extensive research on ASTTs in China. Regarding the current situation of the development of ASTTs, Jiang and Jiang (2021) found that the trend of uneven regional distribution of ASTTs was increasingly prominent, and the talents were accelerating to gather in central cities in the Eastern and a few central Western regions of China. Meng and Li (2020) pointed out that China's ASTTs still existed problems including insufficient overall investment, uneven regional talent distribution, serious talent loss, unreasonable talent structure, and imperfect talent training mechanisms. They also proposed countermeasures and suggestions including innovating talent training models, optimizing talent incentive mechanisms, and developing interdisciplinary agriculture.

Chinese scholars have also conducted many studies on the measurement methods of talent allocation efficiency. Jiang Lin and Chen Biyun proposed a two-stage dual-objective matching method based on the prospect theory for the team of the new-type R&D institutions and the allocation of scientific and technological talents, including the elimination matching at the first stage and the selection matching at the second stage (Jiang and Chen, 2023). Liu et al. (2019) applied the super-efficiency DEA model to calculate the talent allocation efficiency of 16 administrative regions in Tianjin Municipality and revealed that the allocation efficiency of talents showed a downward trend and significant regional differences. Wang et al. utilized the Douglas production function to measure the allocation efficiency of talents in the Northeast China Region. Their research argued that the low efficiency of talent allocation and the high demand for human capital coexisted in the Northeast China Region (Wang and Wang, 2019). Ma et al. (2021) adopted the DEA model to evaluate the allocation efficiency of agricultural scientific and technological resources in the Ningxia Hui Autonomous Region. The results indicated that the allocation efficiency of scientific and technological resources in Ningxia Hui Autonomous Region showed a trend of nodal instability and fluctuation, and there was redundant input of agricultural technicians in some years.

Concerning the influencing mechanism of talent, Chinese scholars have conducted research in the following fields, evaluation of the growth environment of talent, analysis of talent agglomeration effect, and research on talent loss issues. Rui and Zhao (2023) used the "VHSD-EM" evaluation model and Moran index to evaluate the spatiotemporal characteristics and evolution rules of the growth environment of ASTTs in provinces in China from 2011 to 2020. The results revealed that the growth environment of ASTTs in China presents a distribution pattern of "East China>Central China>Northeast China>West." The agglomeration effect of the growth environment in the Eastern region of China was significantly higher than that in the other three regions. Liu (2021) found that the flow of high-level talent in China has obvious spatial agglomeration, and the distribution of talents conforms to the principle of rank and scale; Zhang and Ni used spatial Durbin and threshold models to study the relationship between technology talent agglomeration and regional innovation. The results showed that technology talent agglomeration significantly promoted regional innovation efficiency, but there was an optimal interval for technology talent agglomeration (Zhang and Ni, 2022). Fan et al. believed that excessive talent gathering affects the efficiency of talent resource utilization, and studies the effects of high education, relationship mobility, urban livability, and psychological contracts on talent's willingness to leave the city from the perspective of talent crowding. In recent years, Chinese scholars have begun to attach importance to studying the issue of talent loss (Fan et al., 2023). Yang Zhou et al. found that the flow of high-level talent has exacerbated the uneven development of China's regions. They believed that regional socio-economic differences, inadequate systems, and inefficient management were the main reasons for talent mismatch and high-level talent loss (Yang et al., 2018). Xia and Meng (2024) used a convolutional neural network model to predict the flow trend of young technical talents, providing policy references for management institutions.

In summary, current literature research results provide abundant research perspectives for the allocation of scientific and technological talents. The research scope covers scientific and technological talents including qualitative analysis of the construction of the scientific and technological talent team, evaluation of the talent development environment, influential mechanism of talent allocation efficiency, and evaluation of talent capabilities. Much research explored the role of scientific and technological talents as input factors and analyzed their impact on scientific and technological innovation or economic growth. The efficiency of talent allocation will significantly affect economic development, however, the comprehensive measurement and spatiotemporal differentiation characteristics of the efficiency of ASTTs allocation in provincial-level agricultural research institutions in China have not been found yet. Although the DEA method based on multi-input and multi-output situations is widely used in efficiency evaluation, there is also relatively little research on evaluating the efficiency of agricultural technology talent allocation. As a developing country, improving the allocation efficiency of agricultural science and technology talents in China is of great significance for maximizing the value of talents and increasing technological and economic development.

3 Methods and data sources

3.1 Measuring method of talent allocation efficiency

The ASTTs exist in agricultural research institutions, universities, governments, and enterprises across various regions. This study focused on using agricultural research institutions in 31 provinces, autonomous regions, and municipalities in the Chinese mainland as the fundamental evaluation units. The research then narrowed down to select provincial agricultural research institutions from these 31 provinces, autonomous regions, and municipalities, spanning the years between 2009 and 2019, as the primary subjects for examining the development status of ASTTs and the temporal and spatial evolution trends of their allocation efficiency.

Furthermore, these 31 provinces, autonomous regions, and municipalities of the Chinese mainland are categorized into six major regions: North China, Northeast North China, East North China, Central and Southern North China, Southwest North China, and Northwest China (as indicated in Table 1). We proceeded to analyze differences in the allocation efficiency of ASTTs from a regional perspective. In our examination of ASTTs within each province, we employed two distinct metrics. First, we gauged absolute differences in ASTTs allocation efficiency among the agricultural research institutions within each province using the range index, which measured the disparity between the maximum and minimum values. Second, we assessed relative differences in ASTTs allocation efficiency among these institutions by utilizing the variation coefficient, calculated as the standard deviation ratio to the average value.

The estimation of ASTTs' allocation efficiency primarily centered on assessing their impact on both agricultural scientific and technological innovation as well as economic development. Given that the allocation of ASTTs involves various inputs and outputs, we utilized the data envelopment analysis (DEA) method, well-suited for analyzing multi-input and multi-output efficiency, to evaluate the allocation efficiency of ASTTs. Noteworthy DEA models widely used in this context include the C^2R model and BC^2 model (Yang et al., 2013).

As the input and output of scientific and technological talents follow variable returns to scale, this study employed the output-oriented BC^2 model to calculate the comprehensive technical efficiency (CTE) of ASTTs' allocation. Essentially, this approach aims to expand outputs while maintaining existing inputs. There is a significant disparity in ASTTs' input intensity between developed countries and China, consequently, the output-oriented efficiency evaluation model aligns more closely with China's specific circumstances.

The allocation efficiency of ASTTs was measured by taking provincial regions as the basic decision units. There are the i inputs and the r outputs for any decision unit. For the jth decision unit, and the x_j and the y_j are the column vectors of input and output, respectively, then the CTE θ_j of the jth decision unit can be calculated from the following improved DEA model in Equation 1:

$$\min\left[\theta-\varepsilon\left(\hat{e}^T s^- + \hat{e}^T s^+\right)\right]$$

$$s.t.\begin{cases} \sum_{j=1}^{n} x_j\lambda_j + s^- = \theta x_0 \quad s^- = \left(s_1^-, s_2^-, \ldots, s_m^-\right) \\ \sum_{j=1}^{n} y_j\lambda_j - s^+ = y_0 \quad s^+ = \left(s_1^+, s_2^+, \ldots, s_m^+\right) \\ \sum_{j=1}^{n} \lambda_j \le 1\ \lambda_j \ge 0 \quad j=1,2,\ldots,n \ \ s^-, s^+ \ge 0 \\ \hat{e} = (1,1,\ldots,1)^T \in R_m \quad e = (1,1,\ldots,1)^T \in R_s \end{cases} \tag{1}$$

Where the x_j represents the input variable of the jth decision-making unit, the y_j represents the output variable of the jth decision-making unit, the θ represents a valid value of the decision-making unit and its optimal solution is the technical efficiency of the jth decision-making unit. The λ represents the linear combination coefficient of the decision-making unit. The slack variables s^+ and s^- are introduced and they represent output deficiency and input redundancy, respectively.

When $\theta \neq 1$, it indicates that the decision-making unit is below the production possibilities frontier and the DEA model is inefficient. When $\theta=1$ and when $s^+=0$ or $s^-=0$, the decision-making unit can be identified as the DEA effective, indicating that the decision-making unit is above the production possibilities frontier, and the output at this time is the optimal output. When $\theta=1$ and $s^+\neq 0$ or $s^-\neq 0$, it indicates that the technical efficiency of the decision-making unit does not reach the best and the decision-making unit can be identified as weak DEA effective.

The efficiency value of ASTTs allocation, as measured by DEA, falls within the range of 0 to 1, with higher values indicating greater allocation efficiency. When assessing integrated allocation efficiency,

TABLE 1 Division of 31 provinces, autonomous regions, and municipalities into 6 large regions.

Regions China	Provinces
North China	Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia
Northeast China	Liaoning, Jilin and Heilongjiang
East China	Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi and Shandong
Central and Southern China	Henan, Hubei, Hunan, Guangdong, Guangxi and Hainan
Southwest China	Chongqing, Sichuan, Guizhou, Yunnan and Tibet
Northwest China	Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang

DEA further dissects CTE into pure technical efficiency (PTE) and scale efficiency. CTE encompasses an extensive evaluation of various aspects, such as resource allocation and decision-making unit utilization. PTE, on the other hand, assesses production efficiency resulting from the system, management level, and technological applications of the decision-making unit, assuming that input returns to scale are variable. Meanwhile, scale efficiency reflects the disparity between the actual scale and the optimal input scale of the decision-making unit within the existing system and management framework. The key distinction between PTE and CTE lies in the fact that PTE does not account for efficiency losses stemming from input factor utilization.

3.2 Spatial autocorrelation analysis

We employed exploratory spatial data analysis (ESDA) to examine the spatial autocorrelation patterns in the allocation efficiency of provincial ASTTs. This analysis calculated the spatial autocorrelation coefficient for an attribute's value within a spatial object, enabling us to determine whether it exhibits high-high or low-low clustering or a high-low staggered distribution. ESDA encompasses both global and local autocorrelation analysis. Global autocorrelation analysis provides insight into the overall autocorrelation characteristics of the attribute across the entire region but does not capture the spatial correlations between different regions within the larger area. On the other hand, local autocorrelation analysis can identify potential spatial correlations, clusters, or heterogeneity between the attribute values of a local region and its neighboring areas (Hui-Li et al., 2021). In this study, we first applied the global autocorrelation index to analyze the overall spatial autocorrelation in the allocation efficiency of provincial ASTTs. Subsequently, we utilized the local autocorrelation index to examine aggregation patterns and distribution areas within each province.

Here, the global spatial autocorrelation is analyzed by Moran index I, and the formula is as follows in Equation 2:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i - \overline{x}\right)\left(x_j - \overline{x}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}\left(x_i - \overline{x}\right)^2} = \frac{\sum_{i=1}^{n}\sum_{j\neq i}^{n} w_{ij}\left(x_i - \overline{x}\right)\left(x_j - \overline{x}\right)}{s^2\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \qquad (2)$$

Where, the n represents the total number of studied regions, and the w_{ij} represents the spatial weight matrix. The x_i and the x_j represent the observed values for the regions i and j, respectively.

Moran's, I value ranges between −1 and 1. A Moran's I index greater than zero signifies a positive correlation, indicating spatial clustering where high values are adjacent to high values or low values are adjacent to low values. Conversely, a negative correlation suggests that high values are adjacent to low values. When Moran's I index approaches zero, it indicates no spatial correlation, and the distribution is considered random. Local spatial autocorrelation is also assessed through the local Moran's I index, which comprises the Moran scatter plot and the LISA significance map. The Moran scatter plot serves to illustrate the spatial stability of a local region, and one can discern the spatial correlation characteristics of a local area by observing its quadrant position concerning adjacent regions.

3.3 Data sources and index design

3.3.1 Data sources

The data sources of the study were the China Rural Statistical Yearbook, the Compilation of National Agricultural Science and Technology Statistics in China, and the local official website. Some indicators without direct data were calculated from the basic data. The research period was from 2009 to 2019, and the allocation efficiency of ASTTs in the 31 provinces, autonomous regions municipalities, and municipalities of China, including CTE, PTE, and scale efficiency, was calculated using the research models and the software DEAP.

3.3.2 Index design

Regarding the input indices for ASTTs, we considered factors such as talent scale, talent structure (including educational background and professional title), and fund allocation intensity. Among these factors, we adopted the number of personnel engaged in agricultural scientific and technological activities within agricultural research institutions (x_1) in each province to gauge the scale of ASTTs. Additionally, we assessed the talent structure by considering the number of personnel holding a doctorate per one thousand individuals engaged in scientific and technological activities (x_2), as well as the number of individuals with senior professional titles per one thousand individuals involved in these activities (x_3), to represent the presence of high-level ASTTs. Furthermore, we evaluated the intensity of fund allocation for ASTTs by examining the internal expenditure of funds dedicated to scientific and technological activities per individual engaged in these activities (x_4). This was calculated as the ratio of the total internal expenditure of funds allocated to scientific and technological activities to the number of personnel involved in these activities.

The output indices of ASTTs primarily manifest in scientific and technological innovation and their indirect impact on the agricultural economy. Consequently, the selection of ASTTs' output variables stems from agricultural scientific and technological innovation and key developmental indicators within the agricultural economy. Specifically, we measured ASTTs' innovation capacity and comprehensive scientific and technological prowess through variables such as the number of papers published internationally by agricultural research institutions (y_1) in each province and the count of authorized domestic patent applications (y_2). However, due to the absence of data about foreign technical services, the study utilized the index of the total output of agriculture, forestry, animal husbandry, and fishery (y_3) in each province (measured in RMB 10,000 yuan) as an indirect means to gauge ASTTs' contributions to the local agricultural economy. The input and output indices for ASTTs allocation in each province are given in Table 2, and the descriptive statistics for all variables are shown in Table 3.

4 Results

4.1 Overall development status of ASTTs of China

Between 2009 and 2019, there was an annual average increase of 1.1% in the number of individuals engaged in scientific and technological activities within agricultural research institutions nationwide. In terms of talent composition, there was an average

10.3389/fsufs.2024.1384734

TABLE 2 Design of input and output indices for ASTTs allocation in each province.

Output variables	The number of papers published internationally by agricultural research institutions (y_1)
	The count of authorized domestic patent applications by agricultural research institutions (y_2)
	The total output of agriculture, forestry, animal husbandry, and fishery in each province (y_3)
Input variables	The number of personnel engaged in scientific and technological activities by agricultural research institutions (x_1)
	Number of personnel holding a doctorate degree per one thousand individuals engaged in scientific and technological activities (x_2)
	The number of individuals with senior professional titles per one thousand individuals (x_3)
	The internal expenditure of funds dedicated to scientific and technological activities per individual (x_4)

TABLE 3 Descriptive statistics of ASTTS' inputs and outputs.

Variable	Mean	SD.	Minimum	Maximum
y_1	136	252	0	2,193
y_2	136	169	0	924
y_3	3045.46	2239.79	93.38	9671.67
x_1	2,204	1,123	391	6,519
x_2	86	73	1	381
x_3	315	75	131	517
x_4	279.72	131.53	720.61	80.36

annual increase of 11.7% in the number of personnel holding doctoral degrees in scientific and technological roles and a 4.06% annual increase in personnel holding senior professional titles. The internal expenditure allocated to scientific and technological activities saw an average annual increase of 9.11%. Notably, the proportions of personnel holding doctoral degrees and those holding senior professional titles per thousand individuals showed a consistent upward trend, signifying the continuous enhancement of both ASTTs' scale and fund allocation intensity. While the overall number of personnel involved in agricultural scientific and technological activities experienced gradual growth, the notable increases in the proportion of individuals holding doctoral degrees and those with senior professional titles per thousand individuals underscored significant improvements in the quality of ASTTs. These changes also reflected the ongoing optimization of the talent team structure within China's agricultural research institutions.

From 2009 to 2019, the regional distribution of ASTTs within agricultural research institutions exhibited imbalances across Chinese provinces. By analyzing the range and variation coefficient of talent-related data in provincial agricultural research institutions for each year, it became apparent that both the absolute and relative differences in the number of ASTTs in these institutions were on the rise. Considering talent composition, there were overarching trends in the increase of personnel holding doctoral degrees per thousand individuals and those holding senior professional titles per thousand individuals within agricultural research institutions in each province. Similarly, there was an overall trend of increasing variation in *per capita* internal expenditure on scientific and technological activities. This suggested that the proportion of ASTTs holding doctoral degrees and senior professional titles in each province was growing, along with the absolute difference in *per capita* fund allocation for scientific and technological activities. While the number of personnel holding doctoral degrees per thousand individuals and the variation coefficient of *per capita* internal expenditure on scientific and technological activities decreased, the relative differences in personnel holding senior professional titles exhibited fluctuation without a significant upward or downward trend.

4.2 Allocation efficiency of ASTTs in China

4.2.1 The overall situation of allocation efficiency of ASTTs in China

From 2009 to 2019, the provinces in China exhibited an average comprehensive efficiency of 0.786 in the allocation of ASTTs, with an average scale efficiency of 0.87 and an average PTE of 0.89. These findings indicate that over the past 11 years, the CTE, PTE, and scale efficiency in the allocation of ASTTs within the provinces of China have been relatively high. However, there remains significant room for improvement in CTE. As depicted in Figure 1, the average annual overall technical efficiency of provincial ASTTs allocation from 2009 to 2019 followed a "V"-shaped development trend. It decreased steadily from 2009 to 2013 but showed an upward trajectory from 2014 to 2019. These results suggest that as the scale of ASTTs increased and talent structure optimization took place, the overall trend in CTE for ASTTs allocation exhibited fluctuations but ultimately displayed an upward trajectory.

From 2009 to 2019, the annual average of PTE in the allocation of provincial ASTTs exhibited a gradual decline with fluctuations, starting at an average of 0.92 in 2009 and decreasing to 0.89 by 2019, reflecting a 3% decrease. This decline suggests a need for further improvements in the management mechanisms and technological application of agricultural research institutions in each province. In contrast, the annual average of scale efficiency in the allocation of provincial ASTTs displayed an overall upward trend. In 2009, the average scale efficiency stood at 0.85, and by 2019, it had increased to 0.95, marking an impressive 11.8% improvement. This trend signifies

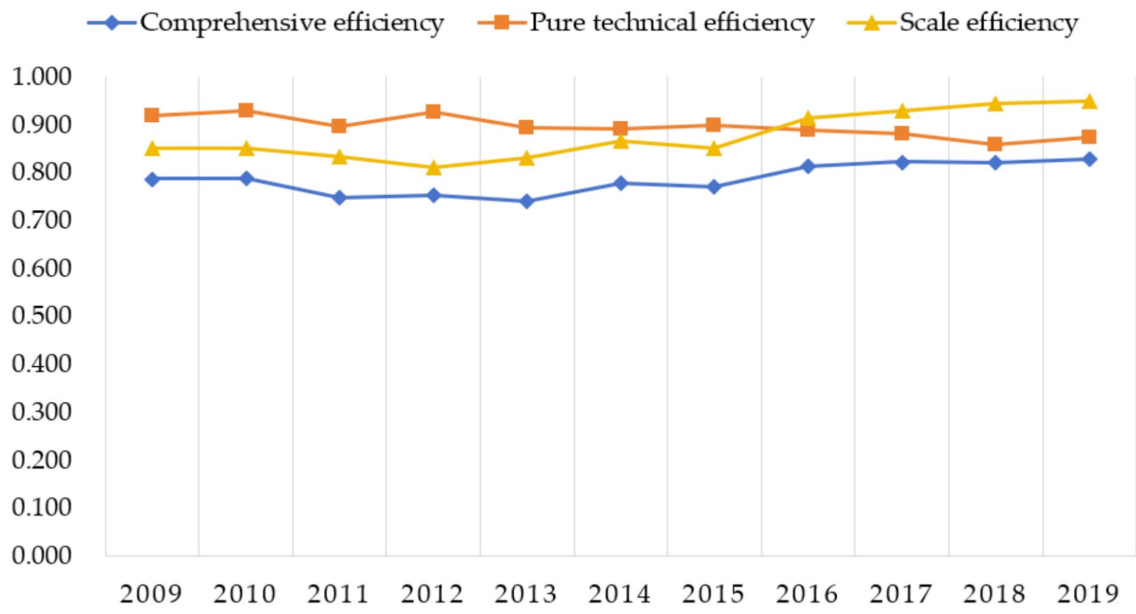

FIGURE 1
Displays the annual averages of CTE, PTE, and scale efficiency for the allocation of provincial ASTTs of China spanning from 2009 to 2019.

the continuous enhancement of the scale effect in the talent allocation of provincial agricultural research institutions. Moreover, an examination of specific provinces revealed that Beijing, Jiangsu, Anhui, Shandong, Henan, Sichuan, and Shaanxi operated within the realm of fully effective returns to scale. Meanwhile, Liaoning, Heilongjiang, Hubei, and Yunnan experienced decreasing returns to scale as they increased in size. Hebei transitioned from effective returns to scale to decreasing returns. The remaining provinces and municipalities were in the stage of increasing returns to scale. These findings underscore that the enhancement in ASTTs' comprehensive efficiency primarily results from improved scale efficiency. Expanding the scale effect of talent investment further could consequently enhance the allocation efficiency of ASTTs.

4.2.2 Allocation efficiency of ASTTs in each province or municipality of China

Because of variations in talent scale, composition, development environment, and funding inputs among provinces, the comprehensive allocation efficiency of ASTTs also differed across each province or municipality, as outlined in Table 4.

Table 4 presents the average allocation efficiency of ASTTs in each province, revealing that 58.1% of provinces exceeded the overall average of 0.786. Notably, 14 provinces and municipalities, including Beijing, Anhui, Shandong, Henan, Sichuan, and Jiangsu, achieved allocation efficiencies surpassing 0.9, with Beijing, Shandong, Anhui, and Henan reaching a perfect score of 1. This indicates that these regions led in comprehensive efficiency for ASTTs allocation, and they maintained a consistent return to scale. On the other hand, Tianjin, Inner Mongolia, Ningxia, Chongqing, Qinghai, Jilin, and Tibet exhibited lower ASTT allocation efficiencies, falling below 0.6. When considering both ASTTs input and output for each province or municipality, it becomes apparent that Shandong, Henan, Heilongjiang, Anhui, Jilin, Jiangsu, Hebei, Sichuan, and Hunan, with high talent allocation efficiency, not only invested heavily in ASTTs but also demonstrated robust agricultural economic development. In contrast, regions with low ASTT allocation efficiency had relatively limited talent input and output.

Analyzing the trend in allocation efficiency of ASTTs over the past 11 years, several provinces and municipalities, such as Fujian, Ningxia, Qinghai, Guizhou, Shanxi, Guangdong, and Inner Mongolia, saw a consistent increase, suggesting that regions with initially lower allocation efficiency have significant room for improvement. Conversely, Tianjin and Jilin experienced a decline in allocation efficiency. Jilin, despite a relatively high number of personnel in scientific and technological activities, suffered from low *per capita* fund allocation and limited scientific and technological output and economic development. As a centrally governed municipality, Tianjin had a small scientific and technological workforce, and although it allocated substantial *per capita* funding, its talent allocation efficiency, and scientific and technological output remained comparatively low. Most other provinces exhibited fluctuating trends in average allocation efficiency. Over the last 11 years, there has been a continuous decrease in the variation coefficients and ranges of ASTTs allocation efficiency across provinces, with a more pronounced narrowing trend since 2016. This indicates diminishing absolute and relative differences in the allocation efficiency of ASTTs among agricultural research institutions in each province.

4.2.3 Allocation efficiency of ASTTs in six large regions of China

Figure 2 reveals a ranking of comprehensive efficiency from high to low, with East China region, Central and Southern China region, North China region, Northwest China region, Northeast China region, and Southwest China region in that order. Notably, the East China region and Central and Southern China regions demonstrated relatively high ASTTs allocation efficiency. Upon closer examination,

TABLE 4 Displays the average values of comprehensive efficiency, PTE, and scale efficiency in the allocation of ASTTs of China for each province or municipality.

Province or municipality	Comprehensive efficiency	PTE	Scale efficiency	Province or municipality	Comprehensive efficiency	PTE	Scale efficiency
Beijing	1.000	1.000	1.000	Zhejiang	0.825	0.844	0.977
Anhui	1.000	1.000	1.000	Heilongjiang	0.809	0.827	0.979
Shandong	1.000	1.000	1.000	Fujian	0.784	0.857	0.918
Henan	1.000	1.000	1.000	Jiangxi	0.726	0.897	0.826
Sichuan	0.996	0.997	1.000	Gansu	0.724	0.894	0.824
Shaanxi	0.994	1.000	0.994	Hainan	0.645	0.906	0.721
Jiangsu	0.992	0.992	1.000	Shanxi	0.641	0.877	0.728
Hebei	0.988	0.997	0.991	Guizhou	0.617	0.860	0.740
Hunan	0.950	0.974	0.975	Tianjin	0.558	0.761	0.734
Hubei	0.940	0.973	0.966	Inner Mongolia	0.546	0.611	0.907
Xinjiang	0.938	0.948	0.990	Ningxia	0.529	0.938	0.570
Shanghai	0.929	0.954	0.972	Chongqing	0.521	0.604	0.873
Guangdong	0.926	1.000	0.926	Qinghai	0.494	0.841	0.552
Yunnan	0.906	0.938	0.964	Jilin	0.471	0.505	0.934
Guangxi	0.871	1.000	0.871	Tibet	0.197	0.937	0.237
Liaoning	0.850	0.862	0.986	Average	0.786	0.896	0.876

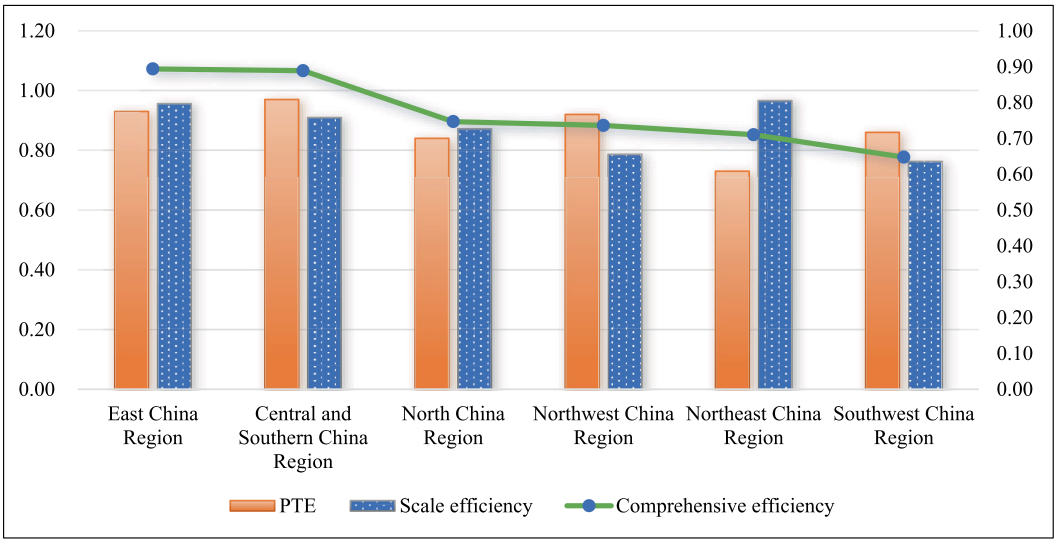

FIGURE 2
Presents the comprehensive efficiency, PTE, and scale efficiency of ASTTs allocation in the six large regions of China from 2009 to 2019.

it became evident that the ranking of ASTTs allocation efficiency in each large region generally corresponds to the agricultural economic development level of that region. However, significant differences existed in ASTT allocation efficiency among provinces and municipalities within each large region. In particular, the variations in ASTTs allocation efficiency were minimal in the East China region and South region, but they were substantial in the other four large regions. For instance, consider the North China region, where the average comprehensive allocation efficiency of ASTTs in Inner Mongolia was 0.546, while in Beijing, it was notably high at 1 (see Table 4).

Regarding the vertical evolution trend of ASTTs' allocation efficiency in the six large regions over the past 11 years, the Central and Southern China regions, Southwest China region, and Northwest China region exhibited a consistent upward trajectory. In contrast, the Northeast China region experienced a declining trend, while both the North China region and East China region displayed a "W"-shaped fluctuation pattern.

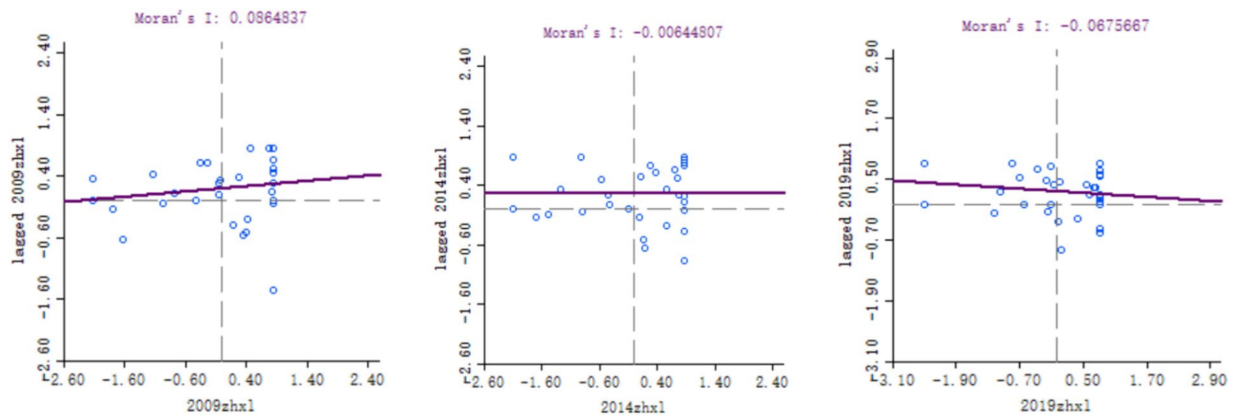

FIGURE 3
Displays a scatter chart depicting the allocation efficiency of provincial ASTTs of China in the years 2009, 2014, and 2019.

The rankings of pure technical efficiencies for ASTTs in the six large regions are as follows, from highest to lowest: Central and Southern China region, East China region, Northwest China region, Southwest China region, North China region, and Northeast China region. Over the past 11 years, while PTE remained relatively stable in Central and Southern China regions and East China region, the other four large regions witnessed more frequent fluctuations, primarily showing a downward trend overall. Notably, the Northwest China region, Southwest China region, and Northeast China region experienced a significant decrease in PTE.

The rankings for scale efficiencies of ASTTs in the six large regions, from highest to lowest, were as follows: Northeast China region, East China region, Central and southern China region, North China region, Northwest China region, and Southwest China region. Over the past 11 years, scale efficiencies increased consistently year by year in the Central and Southern China regions, the Southwest China region, and the Northwest China region. Meanwhile, the East China region, North China region, and Northeast China region displayed a fluctuating trend in scale efficiency.

4.2.4 Spatial agglomeration analysis on allocation efficiency of ASTTs of China

The global spatial autocorrelation analysis was conducted to assess the overall efficiency of agricultural research institutions in each province. The analysis revealed a shift in Moran's I global autocorrelation index from positive to negative. Interestingly, there was an alternating change pattern observed between spatial positive and negative correlations. However, it's worth noting that these correlations did not reach statistical significance. This suggests that during 2009 and 2010, there was a weak spatial positive correlation in the allocation efficiency of ASTTs in each province. Nonetheless, starting from 2011, this correlation shifted towards a weak spatial negative correlation. In other words, the allocation efficiency of ASTTs in one province began to exhibit a contrasting trend compared to that of its neighboring provinces.

The results of the local spatial autocorrelation analysis reveal spatial agglomeration characteristics in the allocation efficiency of provincial ASTTs over the past 11 years. In 2009, significant high-high agglomeration was observed in the allocation efficiencies of ASTTs in Shandong, Jiangsu, and Anhui in the East China region, and Xinjiang in the Northwest China region. Conversely, Jiangxi in the east China region exhibited a significant low-high agglomeration during the same year. Moving to 2019, high-high agglomeration was evident in the allocation efficiencies of ASTTs in Shandong, Henan, and Jiangsu, while Tianjin and Jiangxi showed low-high agglomeration patterns. Figure 3 illustrates that in 2009, the allocation efficiency of provincial ASTTs displayed notable divergence, with high agglomeration observed in some provinces. By 2014, the overall divergence in allocation efficiency became more pronounced, with only a slight relative agglomeration trend in 2019, still maintaining an overall pattern of divergence. This suggests that strong spatial heterogeneity characterized the allocation efficiency of provincial ASTTs over the past 11 years, and an overall spatial agglomeration effect had not been established, except for the spatial agglomeration observed in some provinces in the East China Region.

5 Discussions and conclusions

To the best of our knowledge, no previous study has comprehensively examined the allocation efficiency of ASTTs at the provincial levels in China, to address this research gap, this study employed the output-oriented DEA model to analyze the Spatio-temporal evolution trend and the spatial agglomeration characteristics of allocation efficiency of ASTTs at both provincial and regional levels. The study contributed to a comprehensive understanding allocation efficiency of ASTTs in China, and the results were significant for the managers of agricultural research institutions, who can conduct in-depth research and develop corresponding systems and measures to improve the allocation efficiency of ASTTs in provinces based on the relevant conclusions. Firstly, the study reveals that the mean CTE of ASTTs allocation in Chinese provinces during 2009–2019 is 0.786, which means that CTE of ASTTs allocation is at a loss of around 0.214. The CTE of ASTTs allocation exhibits a fluctuating upward trend, indicating substantial room for improvement. The scale efficiency of ASTTs allocation shows an upward trend, while the PTE of ASTTs allocation demonstrates a declining trend, indicating that the enhancement of provincial ASTTs allocation efficiency primarily stems from improvements in scale efficiency. This confirms the problem of insufficient investment in agricultural technology personnel in most provinces of China, which is consistent with the research findings of Meng and Li (2020). Therefore, it is necessary to increase the scale and investment of ASTTs. Currently, the proportion of stable support of the funds for scientific and technological activities in agricultural research institutions in China remains low. Drawing inspiration from talent management policies in developed countries like the United States and the European Union can provide valuable insights, which can ensure sustained and stable talents and financial support for agricultural scientific and technological activities.

Secondly, the study found that the decrease in PTE of ASTTs allocation demonstrates a declining trend. Since PTE represents the efficiency brought by institutions and technology, the results indicate the need for further improvements in the management mechanisms and technology application for agricultural research institutions in provinces of China. As Natkhov and Polishchuk (2019) confirmed the system was the dominant factor affecting the allocation of talent, optimizing talent management mechanisms means that the systems for talent introduction and training, talent incentives, and management need to be optimized. Although this is a relatively difficult and complex issue, it is necessary to conduct a comprehensive evaluation of the internal driving force and external environment for the development of existing talents (Rui and Zhao, 2023). Additionally, agricultural research institutions and management departments in China should actively apply information technologies such as artificial intelligence and big data in ASTTs management processes to improve the allocation efficiency of talents, as proposed by Jacob Fernandes França et al. (2023) and Xia and Meng (2024).

Thirdly, based on the analyzes, there exists a significant disparity in the allocation efficiency of ASTTs across various regions in China. The comprehensive efficiency ranking from high to low is as follows: East China Region, Central and Southern China Region, North China Region, Northwest China Region, Northeast China Region, and Southwest China Region. This conclusion is consistent with Rui and Zhao (2023)'s evaluation result of the agricultural talent environment in provinces of China as mentioned earlier, and it indicates that regions with better ASTTs growth environments have a higher efficient allocation of talent. From the provincial level, major agricultural provinces such as Jiangsu, Shandong, Henan, Sichuan, Guangdong, Hubei, Hunan, Hebei, and Guangxi also demonstrate relatively high allocation efficiency. The findings of Strenze (2013) also support our results, indicating that the provinces with high efficiency in talent allocation have better economic growth. Meanwhile, the result reveals that China provides greater support for major agricultural provinces, but it may lead to a greater difference in agricultural inputs among provinces. Therefore, the Chinese government should strengthen the ASTTs layout and management of provinces or regions with low allocation efficiency.

Although we found the absolute and the relative differences in the allocation efficiency of ASTTs were decreasing among the agricultural research institutions in provinces, it is still necessary to further narrow the differences in the allocation efficiency of ASTTs among the provinces. The Chinese government also emphasized the need to promote rational regional distribution and coordinated development of talents (The State Council, The People's Republic of China, n.d.). According to the unique conditions, functional roles, and industrial development requirements of each province, the governments should enhance the strategic planning for ASTTs and formulate corresponding and suitable ASTTs allocation strategies and mechanisms.

Notably, this study found that the scale efficiency and pure technical efficiency of a few economically underdeveloped provinces were quite different. Such as the pure technical efficiency of Ningxia and Tibet appeared relatively high, while the scale efficiency of Jilin was particularly high, which was similar to the findings of Strenze (2013), he found talent sometimes appears to be more efficiently allocated in poorer societies. This is surprising, it might be related to the limited sample size of our research.

Fourthly, from the perspective of spatial agglomeration effect, Provincial ASTTs allocation showed some localized spatial agglomeration characteristics, primarily observed in major agricultural provinces like Jiangsu, Shandong, and Henan, while no significant spatial agglomeration effect is evident overall. The discovery is similar to the research results of Zhang and Ni (2022), they found that the spatial agglomeration effect of the talents scale and growth environment in eastern China are relatively significant. Obviously, the eastern region of China is economically developed, and various policies and dividends attract the talents to flow to the eastern region. This indicates that the full potential of knowledge-based talent spillover has yet to be realized, and a high-quality talent growth environment is crucial. Considering these findings, a set of measures is proposed to address these challenges: (i) We recommend the establishment of an alliance among strong units and the implementation of a counterpart assistance and development mechanism, eliminating obstacles to the mobility of ASTTs between different areas. (ii) Decision-making departments should especially promote the allocation of ASTTs to underdeveloped regions, such as the Northeast China Region, Northwest China Region, and Southwest China Region. This strategic approach aims to facilitate the sharing of ASTTs resources across regions and construct a layout of coordinated development and mutual advancement among regional ASTTs.

The present study has some limitations that should be further analyzed in future research. Firstly, we only conducted research for 11 years, and we hope to obtain data for a longer period, and better reveal the characteristics of spatiotemporal evolution about the allocation efficiency of ASTTs in China, we believe that the results will be more meaningful. Secondly, we utilized the DEA model to measure the allocation efficiency of ASTTs; future researchers can apply a wider selection of variables and other methods to evaluate the allocation efficiency of ASTTs. Thirdly, we did not analyze the impact mechanism of ASTTs allocation efficiency, the further study will focus on a more in-depth analysis and discussion of the allocation efficiency of ASTTs and its impact factors in the regions with higher allocation efficiency in ASTTs in the province of China.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JY: Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. YH: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. ZZ: Writing – review & editing, Supervision, Investigation, Conceptualization. JX: Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization, Software, Methodology, Formal analysis. NK: Writing – review & editing, Investigation. MJ: Writing – review & editing, Validation, Conceptualization. ZH: Writing – review & editing, Supervision, Project administration, Investigation, Conceptualization.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was supported by the earmarked fund for CARS-08.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Acemoglu, D., Akcigit, U., and Alp, H. (2013). Innovation, reallocation, and growth. *Pier Working Paper Archive* 23, 205–221. doi: 10.1257/aer.20130470

Alexeev, M., Natkhov, T., and Polishchuk, L. (2024). Institutions, abilities, and the allocation of talent: evidence from Russian regions. *J. Comp. Econ.* 52, 271–296. doi: 10.1016/j.jce.2023.11.003

Benjamin, B., Charles, G., and Gou Weyl, E. (2017). Taxation and the allocation of talent. *J. Polit. Econ.* 125, 1635–1682. doi: 10.1086/693393

Fan, J., Fan, Y., and Wang, H. (2023). The impact of overqualification on the intention of urban withdrawal from the perspective of talent crowding. *Heliyon* 9:e16174. doi: 10.1016/j.heliyon.2023.e16174

Hsieh, C.-T., Hurst, E., Jones, C., and Klenow, P. J. (2019). The allocation of talent and US economic growth. *Econometrica* 87, 1439–1474. doi: 10.3982/ECTA11427

Hsieh, C., and Klenow, P. J. (2009). Misallocation and manufacturing TFP in China and India. *Q. J. Econ.* 124, 1403–1448. doi: 10.1162/qjec.2009.124.4.1403

Hsieh, C. T., and Moretti, E. (2019). Housing constraints and spatial misallocation. *Am. Econ. J. Macroeco.* 11, 1–39. doi: 10.1257/mac.20170388

Hui-Li, Y., Zhao, Z., Hui-Jie, Z., Sheng-Ping, L., and Jie, Z. (2021). The spatial and temporal evolution, regional correlations and economic coordinated development effect for Chinese agricultural science and technology level: taking provincial public agriculture research institutions as an example. *Sci. Agric. Sin.* 54, 5251–5265. doi: 10.3864/j.issn.0578-1752.2021.24.008

Jacob Fernandes França, T., São Mamede, H., Pereira Barroso, J. M., and VM, P. D. D. S. (2023). Artificial intelligence applied to potential assessment and talent identification in an organisational context. *Heliyon* 9:e14694. doi: 10.1016/j.heliyon.2023.e14694

Jess, B., and Mildred, H. (2021). Revenue diversion, the allocation of talent, and income distribution. *Math. Soc. Sci.* 112, 138–144. doi: 10.1016/j.mathsocsci.2021.03.017

Ji, Y., Wang, H. F., Zhang, H. J., and Li, H. S. (2022). Thoughts on strengthening the construction of high-level agricultural scientific and technological talents in China in the new era. *Chin. Sci. Technol. Talents* 6, 62–69.

Jiang, L., and Chen, B. A. (2023). Two-stage bilateral matching study of teams-technology talents in new R&D Institutions Based on Prospect theory. *Sustain. For.* 15:3494. doi: 10.3390/su15043494

Jiang, B., and Jiang, Y. (2021). Regional distribution characteristics and trends of science and technology talents in China: analysis based on RD personnel data. *China Sci. Technol. Talents* 5, 22–30.

Liu, X. (2021). The scale distribution characteristics and spatial structure of high-level scientific and technological talents migration in China. *Sci. Technol. Talents China* 5, 31–40.

Liu, B., Li, Q., and Liang, L. (2019). Dynamic evolution and influencing factors of talent allocation efficiency in Tianjin: based on the super-efficiency DEA and Malmquist index. *J. Hebei Univ. Technol.* 11, 16–23. doi: 10.14081/j.cnki.cn13-1396/g4.000097

Ma, Y. Y., Yi-Bo, T., and Jia-Ying, L. V. (2021). Evaluation on efficiency of agricultural science and technology resource allocation in Ningxia based on DEA model. Jiangsu. *Agric. Sci.* 49, 224–231. doi: 10.15889/j.issn.1002-1302.2021.03.040

Meng, H., and Li, S. (2020). Current situation and countermeasures for the development of agricultural science and technology talents in China. *Jiangsu Agric. Sci.* 48, 308–312. doi: 10.15889/j.issn.1002-1302.2020.11.058

Murphy, K., Shleifer, A., and Vishny, R. (1991). The allocation of talent: implication for growth. *Q. J. Econ.* 106, 503–530. doi: 10.2307/2937945

Nan, Y. (2020). China's human capital gap in high-quality development based on the perspective of human capital structure and allocation efficiency. *J. Beijing Univ. Technol.* 20, 30–39. doi: 10.12120/bjutskxb20200430

Natkhov, T., and Polishchuk, L. (2019). Quality of institutions and the allocation of talent: cross-national evidence. *Kyklos* 72, 527–569. doi: 10.1111/kykl.12211

Organization Department of the CPC Central Committee, Ministry of Agriculture, Ministry of Human Resources and Social Security, etc. Medium- and long-term planning for the construction of rural practical talents and agricultural science and technology talents (2010–2020). Farmer's daily, 2011-10-17(002).

Pothier, D. (2017). Occupational segregation and the (Mis) allocation of talent. *Scand. J. Econ.* 120, 242–267. doi: 10.1111/sjoe.12206

Rui, H., and Zhao, Z. (2023). The spatial-temporal evolution and influencing factorsof the growth environment for agricultural science and technology talents in China: analysis based on provincial data from 2011to 2021. *J. Huazhong Agric. Univ.* 25, 90–102. doi: 10.13300/j.cnki.hnwkxb.2023.04.010

Saleh, H., Surya, B., Annisa Ahmad, D. N., and Manda, D. (2020). The role of natural and human resources on economic growth and regional development: with discussion of open innovation dynamics. *J. Open Innov.: Technol. Mark. Complex.* 6:103. doi: 10.3390/joitmc6040103

Strenze, T. (2013). Allocation of talent in society and its effect on economic development. *Intelligence* 41, 193–202. doi: 10.1016/j.intell.2013.03.002

The State Council, The People's Republic of China. Xi Jinping: hold high the great banner of socialism with Chinese characteristics and work in Unity for the comprehensive construction of a socialist modernized country — report on the 20th National Congress of the CPC, Available at: https://www.gov.cn/xinwen/2022-10/25/content_5721685.htm (Accessed March 19, 2024).

Wang, Z. H., and Wang, Y. (2019). Research on the impact of human capital loss and allocation efficiency on economic development in Northeast China. *J. Harbin Univ. Comm.* 2, 98–112. doi: 10.3969/j.issn.1671-7112.2019.02.009

Wu, D., and Liang, X. X. (2016). Study on evaluation of technological human resource allocation efficiency in China. *Res. Dev. Market* 32, 394–399+452. doi: 10.3969/j.issn.1005-8141.2016.04.003

Xia, L., and Meng, F. (2024). Integrated prediction and control of mobility changes of young talents in the field of science and technology based on convolutional neural network. *Heliyon* 10, e25950–e28440. doi: 10.1016/j.heliyon.2024.e25950

Yang, S. China's overall agricultural technology strength has entered the forefront of the world. Guang Ming Daily, 2021-11-22(001).

Yang, Z., Guo, Y., and Liu, Y. (2018). High-level talent flow and its influence on regional unbalanced development in China. *Appl. Geogr.* 91, 89–98. doi: 10.1016/j.apgeog.2017.12.023

Yang, G. L., Liu, W. B., and Zheng, H. J. (2013). Review of data envelopment analysis. *J. Syst. Eng.* 28, 840–860. doi: 10.3969/j.issn.1000-5781.2013.06.014

Zhang, L., and Ni, Z. (2022). Scientific and technological talent agglomeration and regional innovation efficiency—empirical test based on spatial spillover and threshold effect. *Soft Sci.* 36, 45–50. doi: 10.13956/j.ss.1001-8409.2022.09.07