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Research article

Financial resources utilization efficiency in sports infrastructure development, determinant of total factor productivity growth and regional production technology heterogeneity in China

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ABSTRACT

Despite China's heavy investment in sports infrastructure development in the last decades, the financial resources utilization efficiency (FRUE), regional technological gap (TGR), and total factor productivity change (TFPC) in sports infrastructure development are undiscovered and worth investigating. To this end, this study employed DEA-SBM, Meta-frontier analysis, and Malmquist productivity index on the data set of 31 Chinese provinces and 3 regions for the years 2014–2021 to gauge the FRUE, TGR, and TFPC in sports infrastructure development. The results indicate that the average FRUE is 0.4859, with a growth potential of 51.41% in financial resource utilization efficiency for sports infrastructure development. Further Eastern region is more efficient as compared to the Central and western regions. Beijing, Shanghai, Tibet, Hainan, and Guangdong are top performers in FRUE. Further, the value of TGR in the East is 0.9787 which is higher than in Central (0.4977), and Western (0.5821) regions. It indicates that the eastern region contains superior production technology in the development of the sports infrastructure in China. Moreover, the average TFPC value is 1.035 witnessed a 3.5% growth, primarily determined by technological change (TC). As TC = 1.0273 is higher than efficiency change EC = 0.997. The eastern region has a higher average TFPC of 1.048, indicating higher total factor productivity growth in sports infrastructure development. Beijing, Liaoning, Tianjin, Shanghai, and Zhejiang are the top performers in the TFP growth over the study period. Finally, the Kruskal-Wallis test proved the statistically significant difference in three regions of China for FRUE, TGR, and TFPC in sports infrastructure development.

1. Introduction

Sports play a crucial role in enhancing the physical and mental well-being of communities across various dimensions. Regular participation in athletic activities promotes cardiovascular health, muscular strength, and flexibility, addressing sedentary lifestyles and reducing the risk of chronic diseases [1]. Sports also contribute to mental well-being by reducing stress and anxiety through the release of endorphins. Beyond individual benefits, sports foster social interaction and community cohesion, with team sports cultivating teamwork and communication skills [2]. The social dimension extends to a broader community, fostering inclusivity and

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mutual assistance. Moreover, sports instill life skills such as discipline and resilience, contributing to character development. As a powerful tool for cultural exchange, sports break down barriers and promote understanding [3]. From a public health perspective, investing in sports facilities can lead to a healthier population, alleviating the strain on healthcare systems. Leveraging the widespread appeal of sports presents an opportunity for governments and communities to address public health issues and promote preventative measures. The significance of sports in promoting the physical and mental well-being of a given culture is diverse [4]. The concept extends beyond just physical fitness, covering other dimensions such as mental health, social cohesiveness, character development, and even public health effects. Promoting engagement in sports, both at the individual and community levels, plays a pivotal role in fostering the development of physically and mentally healthier individuals, enhancing overall well-being, and fostering stronger social connections within societies [5].

The establishment and enhancement of sports infrastructure play a crucial role in fostering a healthier society across all dimensions. Sufficient sports facilities provide inclusive environments that foster participation in physical activities among individuals across various age groups, hence fostering an active lifestyle and combating sedentary behaviors [6]. In addition to the advantages it offers to individual well-being, a robust sports infrastructure plays a significant role in promoting public health through the provision of facilities that enable regular physical activity, thereby aiding in the prevention and management of diverse health conditions [7]. Furthermore, these facilities function as central points for community involvement, providing venues for structured athletic competitions, leisurely pursuits, and communal assemblies that enhance social connections and cohesiveness. In addition, the presence of sports infrastructure is of paramount importance in the development of young individuals, as it offers opportunities for both training and leisure activities that contribute to their overall growth and development [8]. The impact of this phenomenon encompasses inclusivity and diversity, as it effectively dismantles boundaries and cultivates a feeling of belonging among individuals from all origins and with different skills. Moreover, the presence of sports infrastructure carries significant economic ramifications, as it contributes to the generation of money, the creation of employment prospects, and the attraction of tourism [9]. The establishment of these facilities plays a crucial role in the identification of talent, hence contributing to the fostering of national pride and identity through notable accomplishments in international contests. The presence of sports infrastructure also facilitates opportunities for stress reduction and the enhancement of mental well-being, as participation in sports activities has been shown to provide favorable consequences for mental health [10]. The establishment of sports infrastructure is fundamental in fostering a society that places importance on physical fitness, community involvement, and the holistic welfare of its inhabitants [11].

Effective governmental allocation of financial resources is crucial for societal welfare and economic sustainability. Prudent distribution supports the efficient provision of essential public services, such as healthcare and education, while also addressing poverty and promoting social welfare initiatives [12]. Additionally, managing funds strategically contributes to the development of human capital, fostering a proficient and healthy labor force for long-term economic growth. Governments can use financial resources to encourage innovation, support technical progress, and ensure environmental sustainability, addressing enduring challenges [13]. Due to the multifaceted nature of the impact of sports infrastructure development, efficient financial resource allocation is of the utmost importance. By optimizing the return on each financial investment, projects can attain elevated benchmarks while avoiding avoidable expenditures, thereby guaranteeing the long-term viability of facilities. This efficacy fosters a sense of ownership among residents by facilitating the incorporation of diverse needs and preferences, thereby contributing to community engagement [14]. In addition, benefactors and investors who are interested in reputable and accountable endeavors are drawn to organizations with sound financial management. Additionally, efficiency necessitates comprehensive risk assessment and planning, which reduces the likelihood of cost overruns or delays [15]. Incorporating the distinct requirements of spectators and athletes into the optimization of facility design constitutes an additional consequence of effective financial management. Positive economic effects that result from the attraction of visitors and events contribute to the advancement of the local community. Ensuring adherence to regulatory standards and maintaining financial accountability fosters confidence, particularly in initiatives that are publicly funded [16]. Lastly, effective utilization of financial resources enables long-term planning, which guarantees that facilities will continue to be competitive and pertinent in the long run. Fundamentally, it plays a critical role in determining the achievement, long-term viability, and civic assimilation of sports infrastructure initiatives [17].

The strategic allocation of financial resources by the Chinese government for the development of sports infrastructure at various administrative levels, including national, province, city, and village, holds significant significance. At the national level, significant financial allocations demonstrate a dedication to enhancing the country's international standing in the realm of sports [18]. At the provincial level, customized allocations are implemented to effectively serve the specific demands of different regions and promote the development of unique sports cultures, hence facilitating the identification of potential. At the municipal level, the strategic allocation of funds facilitates the integration of sporting facilities into urban planning, thereby fostering a more health-conscious lifestyle and generating economic advantages through various events [19]. Significantly, the endeavors mentioned above are extended to rural regions at the village level, thereby guaranteeing the provision of fundamental infrastructure and promoting the cultivation of sports at the grassroots level. The comprehensive nature of this strategy demonstrates a dedication to achieving high levels of athletic performance as well as recognizing the wider societal advantages associated with a flourishing sports culture [20].

In the last decade, the Chinese government heavily invested in sports infrastructure development. The sports infrastructure investment by the Chinese government encompasses several administrative levels, including national, provincial, municipal, and village levels [21]. This investment extends to the development of top-tier facilities such as world-class stadiums and high-performance centers at the national level. At the provincial level, there are specialized venues that are designed to meet the specific demands of different regions, thereby facilitating the development of talent. Cities strategically include sports facilities in their urban planning endeavors, thereby fostering a more health-conscious lifestyle among residents and providing a platform for organizing various sporting events [22]. At the local level, the presence of fundamental infrastructure facilitates the advancement of grassroots sports, thereby exemplifying a holistic dedication to fostering a sports-oriented culture across all tiers [23,24].

However, the levels of efficiency and productivity growth pertaining to the allocation of financial resources towards the development of sports infrastructure in China have not yet been thoroughly examined and require further research. It is of the utmost importance to comprehend the extent to which these substantial investments yield concrete results, including improved athletic performance, heightened community involvement, or economic gains. Conducting an extensive examination of the efficiency and productivity growth within this particular framework can yield valuable insights that can inform forthcoming approaches to resource allocation optimization. Furthermore, the effective allocation of financial resources towards the development of sports infrastructure in China is closely intertwined with regional production technologies. The efficiency of resource utilization is significantly influenced by the disparities in technological capabilities across different regions, which is attributable to the enormous expanse of the country. Comprehending the intricacies of these regional subtleties is vital in order to customize investment plans, thereby guaranteeing that the allocation of financial resources is in accordance with the distinct technology landscapes prevalent in each respective region. The acknowledgment of regional variation in production technologies is crucial for optimizing the effectiveness of investments and promoting the sustainable development of sports infrastructure throughout the various technological landscapes of China.

To this end, this study contributes to the existing literature in a number of ways. Firstly, the research employed DEA-SBM to gauge the financial resource utilization efficiency (FRUE) in sports infrastructure development in 31 Chinese provinces over the study period of 2014–2021. It evaluates the level of success in the efficient utilization of financial resources over the study period. Secondly, the study employed a Meta-frontier Analysis to measure the production technology heterogeneity (TGR) to utilize the financial resources in the development of the sports infrastructure among three different regions (East, Central, and West) of China. Thirdly, the study uses the Malmquist productivity index to gauge the Total factor productivity change (TFPC) of financial resources utilization in sports infrastructure development. It not only gauges productivity growth but also investigates the determinant of productivity change (efficiency change or technology change). Finally, to strengthen the study results, we employed the Kruskal- Wallis test to gauge the statistically significant difference among three different regions of China for FRUE, TGR, and TFPC. The rest of the study is organized as follows. A literature review is presented in Section 2. Section 3 presents the methodologies employed in this study. Section 4 illustrates the variables selection and data sources. The results and discussion are explained in Section 5. Section 6 presents the conclusion of the study.

2. Literature review

DEA has been applied extensively to evaluate the resource utilization efficiency in different sections around the globe. Cheng et al. [25] examine how COVID-19 has increased academic and industrial interest in economic sustainability and ESG practices. DEA is used to analyze the efficiency of ESG targets and their link with financial performance for 1108 Chinese enterprises using MSCI ESG data from 2015 to 2019. Environmental and Social pillars are dominant strategies among sampled organizations to improve ESG performance, often at the price of Governance. Proportional efficiency improves financial performance, but pillar mix efficiency has mixed results. ESG performance and financial performance trade-offs are seen in technology. Enhancing proportionate and pillar mix efficiencies for technology corporations may lower stock valuation, unlike non-technology firms. He [26] examines China's growing securities market and securities businesses' rapid growth during the pandemic. Despite a drop in transaction volume, securities firms see higher profits, loose liquidity, and policy budget surpluses. The research analyzes securities companies' resource use and conditions to improve industry efficiency. The study uses the DEA-Malmquist index and super-efficiency DEA methodologies to examine 25 securities businesses' operating efficiency from 2016 to 2020. Technical progress drives operating productivity improvement. Varying securities companies have varying efficiency levels, with size efficiency often limiting technological efficiency. To improve operating efficiency, large securities firms should restrict scale, stimulate innovation, and strengthen cost management and risk response. Zhang et al. [27] discuss financial graduates' employment prospects and problems in China's economic transition. Financial graduates are vital to the nation's economic and social development. The research develops a two-stage DEA Tobit approach to evaluate financial graduates' employment efficiency. As job quality is directly linked to individual and society values, the study aims to maximize social human resource allocation, increase financial graduate training quality, and improve employer human resource management. The research creates a quality evaluation index system and model using DEA Tobit's two-stage model quantitative analysis and qualitative and quantitative approaches. The findings illuminate financial graduates' employment efficiency and offer specific counsel to boost their prospects, helping companies optimize human resource management techniques. Sarkar [28] uses cost-oriented data envelopment analysis (DEA) to evaluate decision-making units (DMUs). Eigenvectors from the first main component of certain covariance matrices define DMU outputs in the proposed method. The model, a modified multiplier of BCC DEA, measures DMU cost orientation under continuous return to scale in six pre-primary institutions. Findings show an optimum cost frontier and address return to scale, providing a more complete assessment. The directional distance model and non-central Principal Component Analysis to settle target outputs make the study unique. Despite the small sample size, the research shows how lean techniques can establish benchmarks and solve educational needs in impoverished nations. Bhandari and Vipin [29] examined the food processing production units' contributions to India's economic growth and employment from 2000 to 2015. The study produces technical efficiency (TE) scores for production units using data envelopment analysis (DEA) and a two-stage technique and examines technological variety across subsectors using the technology closeness ratio. Dairy and sugar units had lower TE scores than vegetable oil units. The technology closeness ratio shows technological upgrading could boost specific subsectors. The study also finds that R&D intensity and infrastructure elements improve performance, suggesting that government actions may help the food processing industry provide facilities and promote research. DEA has been applied to numerous research studies to evaluate the efficiency of banking financial funds [30–32]. Yin et al. [33] address cricket performance evaluation issues and present a comprehensive tool using three estimation indices for batting, bowling, and fielding efficiency in all three formats. The DEA Super-SBM model and statistics from 1877 to 2019 show that Sir Bradman, Sachin Tendulkar, and Virat Kohli are the most efficient batsmen in each format, while Muralitharan, Mitchell Starc, and Umar Gul are the most efficient bowlers. Saleem Yousuf, Luke Ronchi, and Scott Edwards excel at fielding. England, Australia, and India bat well, the West Indies, Australia, and Pakistan bowl well, and Australian (Test & ODIs) and South African teams field well. The study emphasizes its indices' accuracy in assessing player performance above traditional measures. Zhang et al. [34] examined the China's efficient utilization of sports resources during the past two decades, particularly in infrastructure development. The study examines Sports Resource Utilization Efficiency (SRUE), Technological Gap Ratio (TGR), and Productivity Growth (MI) in China's provinces and regions from 2010 to 2021 using Data Envelopment Analysis-Slack Based Measure, Meta Frontier Analysis, and Malmquist Productivity Index. Sports resource use is 36.93% inefficient, with Beijing, Chongqing, Henan, Shaanxi, Shanghai, and Tianjin demonstrating efficiency. SRUE shows moderate and persistent growth, according to the study. Technology is more advanced in the East. The Malmquist Productivity Index shows a 5.39% productivity gain, mostly due to technology. Kruskal-Wallis shows that the Central region beats the Eastern and Western regions in productivity growth, indicating considerable regional disparities in efficiency, productivity, and technological innovation. Except this many research studies employed the DEA to evaluate the financial efficiency in different industries [35–45]. However, the financial resource utilization efficiency in sports infrastructure is undiscovered and worth investigation.

3. Methodology

DEA (Data Envelopment Analysis) is a commonly used mathematical method that utilizes linear programming to evaluate the efficiency of similar Decision-Making Units (DMUs) [46,47]. The traditional DEA model, pioneered by Charnes et al. [48], assumes a constant return to scale (CSR). Based upon this, Banker et al. [49] modified the model to incorporate a variable return to scale (VSR). A preliminary investigation by Tone [50] introduced the Slack-based Measure (SBM) model. Subsequently, Karou Tone [51] devised a method for ranking the most effective DMUs. The selection of DEA-SBM for estimating forestry resources efficiency is attributed to its capacity to evaluate systems with multiple inputs and outputs. Specifically, it compares forestry units (provinces) based on inputs (Forest area, investment) and outputs (Forestry output value, Timber output, Forest storage). DEA-SBM uses the efficiency frontier as a measure to evaluate unit performance. Importantly, DEA-SBM is suitable for situations where it's difficult to establish a specific functional form for the production frontier, distinguishing it from SFA (Stochastic Frontier Analysis). Unlike SFA, which assesses inefficiency by comparing it to a particular form, DEA-SBM's non-parametric approach offers flexibility in evaluating the efficiency of China's varied forest resources.

3.1. DEA-SBM model

The Slacks-Based Measure (SBM) represents a non-radial approach to assessing DEA (Data Envelopment Analysis) efficiency. Its primary strength lies in its capacity to assess excess inputs and insufficient outputs directly. When determining efficiency, it takes into consideration the slack, which represents the difference between inputs and outputs at the production frontier. This method operates based on the following principles:

Suppose we have a study with n Decision-Making Units (DMUs) referred to as "Provinces". M input indicators and s output indicators characterize each DMU. Let B_j, represent the jth DMU, where j ranges: $j = 1, 2, \ldots, n, [x_{ij}]$, represents the $m \times 1$ input indicators of DMU B_j, with i ranging from 1 to m, $[y_{rj}]$ represents the $s \times 1$ output indicators of DMU B_j, with r ranging from 1 to s. The relative efficiency value of the DMU j_0-th DMU's is denoted as h_{j0} (*See equation* 1 *to* 3). Now, let's discuss how the output-focused SBM-DEA model with variable returns to scale operatfes:

$$\text{Min } h_{j0} = \theta$$

$$\text{s.t}\begin{cases}\sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{ij0}, i = 1, \ldots, m & (1)\\ \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{ij}, r = 1, \ldots, s & (2)\\ \sum_{j=1}^{n} \lambda_j = 1, \lambda_j \ge 0, j = 1, \ldots., n & (3)\end{cases}$$

The efficiency value at the j-th position is represented as θ, where λ_j is a nonnegative vector. A DMU is considered efficient if and only if θ equals 1, indicating that it is operating at maximum efficiency. If θ is not equal to 1, it means the DMU is inefficient and has room for improvement.

3.2. DEA-meta frontier model

The utilization of the Meta-frontier Model yields enhanced precision in the evaluation of DMU efficiency across distinct groups. Consequently, given that all DMUs within a given group operate under equivalent technological conditions, the most prudent approach is to undertake efficiency comparisons within the confines of the same group. The technological gap ratio (TGR) metric presented in Eq. (4) proves instrumental in gauging the extent of divergence in technological progress between specific groups [52].

$$TGR = \frac{MFRUE}{GFRUEi} \tag{4}$$

Financial resources efficiency (FRUEs) is computed for the complete set of Decision-Making Units (DMUs) under consideration. In this context, GFRUE *i* represents the FRUE applicable to DMUs categorized within a specific group. In contrast, MFRUE pertains to the *Meta*-FRUE associated with DMUs spanning the entire population, including all distinct groups. By comparing the discrepancy between a meta-frontier technology and the frontier technology specific to a given group, the Technology Gap Ratio (TGR) functions to numerically characterize the discrepancy between these two cohorts of DMUs [53]. An equivalent of TGR equaling one denotes the absence of a technological rift between the Meta frontier and the group frontier, thus establishing TGR as a prevalent instrument for evaluating territorial disparities.

3.3. DEA-Malmquist productivity index

Malmquist productivity indices provide a valuable tool for a Decision-Making Unit (DMU) to track improvements in efficiency over time. To effectively utilize this index, it is assumed that there exists a production function that accurately represents the current technological environment. DEA models are used to pinpoint the location of this production function's threshold precisely. The difference in output between periods t and t+1 defines a specific DMU, referred to as (DMU_0) [54].

$$M_0 = \frac{D_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)}{D_0^t\left(x_0^t y_0^t\right)} \left[\frac{D_0^t\left(x_0^{t+1}, y_0^{t+1}\right)}{D_0^t\left(x_0^t, y_0^t\right)} \frac{D_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)}{D_0^{t+1}\left(x_0^t y_0^t\right)}\right]^{1/2} \tag{5}$$

where:

- $D_0^t(x_0^t, y_0^t)$ Shows the TE estimation of the DMU_0 for period t,
- $D_0^{t+1}(x_0^{t+1}, y_0^{t+1})$ illustrate the TE estimation for period t+1.
- $D_0^t(x_0^{t+1}, y_0^{t+1})$ specifies the variation in TE from time t to t+1.
- $D_0^{t+1}(x_0^t, y_0^t)$ represents the technical efficiency of a specific DMU_0. This efficiency is computed by replacing its data from period t with the corresponding data from period t+1.
- The initial segment of Eq. (5) without parentheses denotes the variation in the technical efficiency of DMU_0 between time t and t+1. The timeframe enclosed within the square brackets illustrates the advancement in technology for the same DMU. If the index value exceeds 1, it signifies that DMU_0 achieved a greater output during the second period compared to the first. Two hypotheses can be put forth to elucidate this substantial rise in output. Firstly, it is plausible that DMU_0 embraced state-of-the-art methodologies, enhancing its efficiency.

3.4. Kruskal–Wallis test

The Kruskal-Wallis test is a non-parametric statistical method used to assess the presence of statistically significant differences between three or more independent groups or treatments [55]. The Kruskal-Wallis test differs from the Mann-Whitney *U* test, which is designed to compare two independent groups by not assuming a normal distribution of the data. Instead, it determines whether the medians of the groups are comparable by rating all values collectively and then determining whether these ranked values exhibit significant disparities across groups. When the Kruskal-Wallis test identifies a statistically significant difference, it indicates that at least one group differs concerning the investigated variable. This test proves invaluable when ordinal or continuous data fails to satisfy the requirements of parametric tests such as analysis of variance (ANOVA). The Kruskal-Wallis test is frequently used in social sciences, healthcare, and environmental studies to compare groups with non-normally distributed data. The Kruskal Wallis test distinguishes the significant statistical difference among the three Chinese regions for average FRUE, TGR, and TFPC. The hypotheses are as follows:

H 01 The distribution of FRUE is the same across the categories of 3 Chinese Regions.

H 02 The distribution of TGR is the same across the categories of 3 Chinese Regions.

H 03 The distribution of TFPC is the same across the categories of 3 Chinese Regions.

4. Data collection and variable selection

Data Envelopment Analysis (DEA) relies on input and output choices to accurately assess decision-making units (DMUs) in a system. The choice of variables is crucial to DEA since it evaluates these units' efficiency in turning inputs into outputs. The identification of efficient and inefficient DMUs depends on input and output selection [56]. Inaccurate variables can distort efficiency estimations, concealing inefficiencies or exaggerating unit performance. Thus, input-output selection must be based on a thorough grasp of the sector or setting [57]. A careful selection guarantees that the DEA model gives relevant insights into DMU performance, helping decision-makers enhance and optimize resource allocation. Efficiency considerations change with corporate contexts. Updated input-output sets keep DEA analysis relevant and accurate to the changing landscape [58]. Therefore, the selection of inputs and outputs in the estimation of financial resources utilization efficiency of sports infrastructure development in China is carefully selected from previous research studies [59,60]. Table 1 presents the detailed inputs-outputs selected for the DEA analysis. The data of the following variables for 31 Chinese provinces is extracted from the Statistical Yearbook of China's Sports Industry for the years 2014–2021.

Table 2 presents the regional distribution of Chinses provinces to gauge the level of FRUE, TGR, and TFPC in sports infrastructure development in three different regions during the study period.

5. Results and discussion

The detail results of DEA-SBM, Meta frontier analysis, and Malmquist productivity index are presented in the following sections: 5.1, 5.2, and 5.3. The statistically significant difference results through the Kruskal-Wallis test are illustrated in Section 5.4.

5.1. DEA-SBM results

A comprehensive summary of Financial Resources Utilization Efficiency (FRUE) pertaining to Sports Facilities Development in China from 2014 to 2021 is presented in Table 3 and Fig. 2. The FRUE values, which range from 0 to 1, indicate the efficiency level of financial resource utilization in the development of sports facilities for each specific year. The scores serve as an indicator of the efficacy with which resources were managed throughout each period, whereby higher scores signify greater efficiency. The average value of 0.4859 functions as a unified indicator of the efficacy of financial resource utilization throughout the entire period. The average value of 0.4859 indicates a higher level of inefficiency in financial resource utilization for sports infrastructure development. It indicates that a potential of 51.41 % exists to enhance the FRUE in sports infrastructure development in China. The average, as mentioned above, provides a comprehensive evaluation, revealing the general trajectory and efficiency of resource management in the development of sports facilities over the designated period. A slow but upward growth in FRUE was witnessed over the study period as FRUE increased from 0.4945 in 2014 to 0.5087 in 2021. Several studies investigated the strategies to optimize the allocation of financial resources towards the development of sports infrastructure [61]. It is imperative to prioritize and streamline the allocation of financial resources in the development of sports facilities by designating critical areas. It requires the execution of a comprehensive cost-benefit analysis in order to allocate resources toward initiatives that yield the greatest possible influence. Furthermore, the implementation of input reduction strategies is critical for enhancing overall efficiency. It may involve the identification of excessive or non-essential inputs during the development phase and the subsequent reallocation of resources to domains with greater potential for return. Furthermore, the investigation of environmentally friendly methods and economical technologies can make a substantial contribution to the efficient utilization of resources [62]. Acknowledging the significance of output growth is equally critical in order to optimize efficiency. A concerted effort must be devoted to augmenting the overall productivity of sporting infrastructure initiatives. It may entail the augmentation of project magnitude, the investigation of collaborations with private organizations, and the diversification of revenue sources via sponsorships and events.

The average inefficiency in the utilization of financial resources for sports infrastructure development in China suggests substantial room for improvement despite the fact that the upward trend in Financial Resources Utilization Efficiency (FRUE) from 2014 to 2021 indicates progress. Through the implementation of strategic measures such as input reduction, resource allocation optimization, and output growth promotion, China possesses the capacity to substantially augment the efficacy of financial resources allocated to the development of sports facilities [63].

The study divided the 31 Chinese provinces into three different regions, namely Eastern, Central, and Western Regions (see Fig. 1 and Table 2), to gauge the regional difference in financial resource utilization in sports infrastructure development. Fig. 3 and Table A1 present the FRUE in sports infrastructure development for the three regions over the study period. Results illustrate that FRUE in eastern regions is always higher than in central and western regions. The average FRUE of eastern regions is 0.664. Similarly, the average FRUE in the Central region is 0.4265. At the same time, the average value of FRUE in the western region is 0.4635. This scenario indicates that the Eastern region of China is the best performer in financial resources utilization to develop the sports infrastructure. In contrast, Western provinces are found to be ranked second in financial resource utilization. Finally, results illustrate that central provinces are most inefficient in the financial resource utilization for sports infrastructure development.

The results suggest that the FRUE is consistently higher in Eastern regions compared to Central and Western regions. In particular, Eastern regions exhibit a notable average FRUE of 0.664, which signifies a superior degree of efficacy in the allocation of financial resources toward the development of sporting infrastructure. On the contrary, the Central region exhibits a mean FRUE of 0.4265,

Table 1
Inputs and Outputs used to estimate the FRUE and Productivity growth.

Inputs	Outputs
Investment in sports and fitness facilities for village-level infrastructure (Million Yuan)	Village-level sports and fitness facilities (square Meters)
Investment in sports and fitness facilities in township infrastructure (Million Yuan)	Township sports and fitness facilities (square Meters)
Investment funds for national fitness path facilities infrastructure (Million Yuan)	National Fitness Path Facilities (square Meters)
Funds invested in the National Fitness Activity Center infrastructure (Million Yuan) (Million Yuan)	National Fitness Activity Center (square Meters)
Investment in outdoor fitness facilities infrastructure (Million Yuan)	Outdoor fitness facilities (square Meters)
Investment funds for other venue facilities infrastructure (Million Yuan)	Other venue facilities (square Meters)

Table 2
The regional distribution of China.

East	Center	West
Beijing	Anhui	Gansu,
Fujian	Henan	Guangxi
Guangdong	Heilongjiang	Guizhou
Hainan	Hubei	Inner Mongolia
Hebei	Hunan	Ningxia
Jiangsu	Jilin	Qinghai
Liaoning	Jiangxi	Shaanxi
Shandong	Shanxi	Sichuan
Shanghai		Tibet
Tianjin		Xinjiang
Zhejiang		Yunnan
		Chongqing

Table 3
Financial resources utilization efficiency in Sports facilities development.

Year	FRUE
2014	0.4945
2015	0.4739
2016	0.4668
2017	0.4678
2018	0.472
2019	0.4945
2020	0.509
2021	0.5087
Average	0.4859

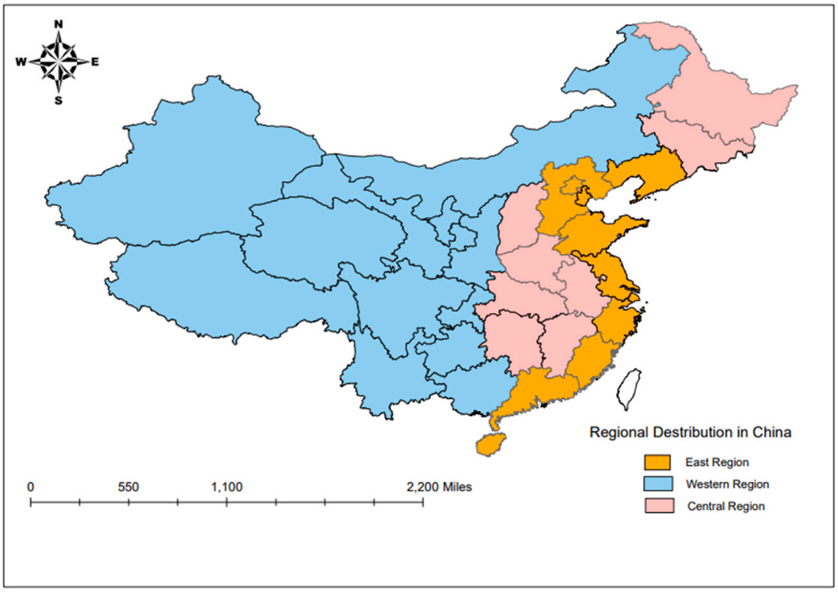

Fig. 1. Regional distribution of China for Sports resources.

which signifies a comparatively diminished degree of efficiency. The Western region exhibits an average FRUE of 0.4635, which places it in the second-best performance category, situated between the two. The findings of this study reveal a notable regional discrepancy, wherein the Eastern provinces demonstrate the highest level of financial resource utilization efficiency for the development of sports infrastructure. Similarly, the Western provinces exhibit a praiseworthy albeit marginally diminished level of efficacy. It is worth noting that the Central provinces demonstrate the least effective utilization of financial resources, underscoring the necessity for focused interventions aimed at improving the efficiency of sporting infrastructure development. In summary, the regional discrepancies that have been identified highlight the significance of geographic placement in determining the effectiveness of allocating financial

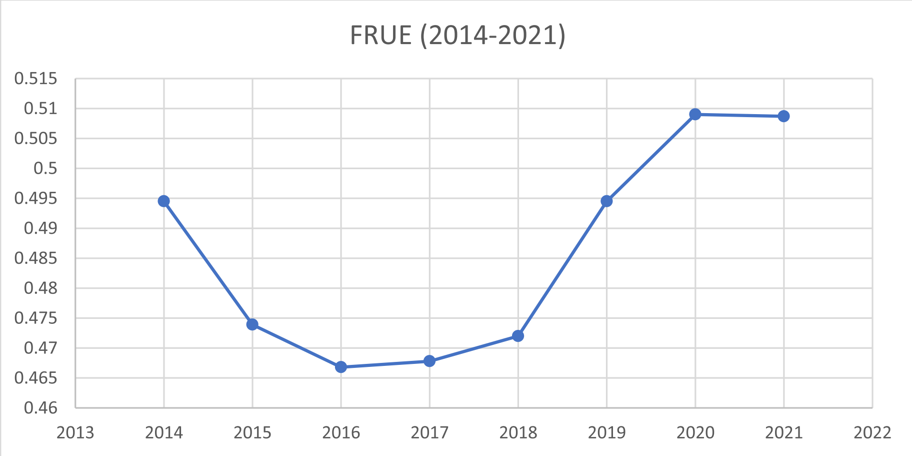

Fig. 2. FRUE in sports infrastructure development (2014–2021).

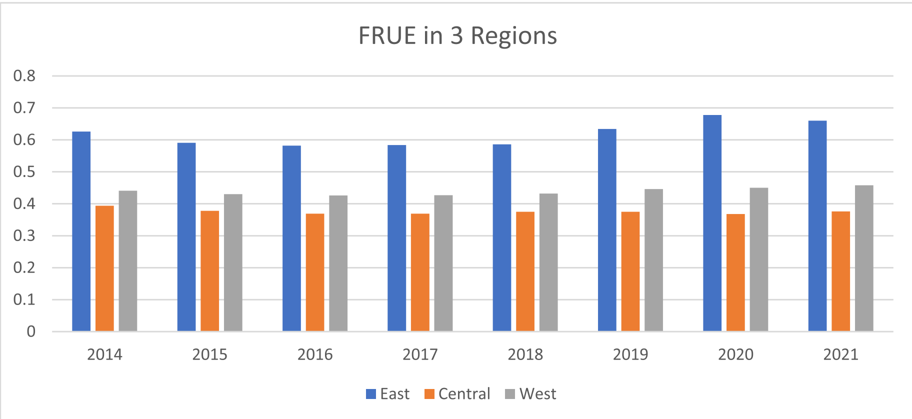

Fig. 3. FRUE in all three regions of China over the study period of 2014–2021.

resources toward sports infrastructure initiatives in China. Comprehending these regional dynamics is of the utmost importance for policymakers in order to customize approaches that effectively tackle the unique obstacles encountered by each region, thereby promoting development that is both fair and effective throughout the country [64,65].

The discrepancies in Financial Resources Utilization Efficiency (FRUE) among different regions in China highlight the implementation of distinct operational approaches by provinces when it comes to sporting infrastructure development. The Eastern regions exhibit a significantly higher average FRUE of 0.664, suggesting that they place considerable emphasis on thorough planning and novel financing models. It demonstrates a strategic orientation towards maximizing the efficiency of sports initiatives and optimizing the allocation of financial resources. On the other hand, the Central region exhibits difficulties or inefficiencies in the utilization of financial resources, as evidenced by its average FRUE of 0.4265. It may suggest the presence of economic limitations, governance concerns, or an imperative for enhanced strategic planning. The Western region demonstrates a moderate average FRUE of 0.4635, indicating a more equitable distribution of financial resources and potentially a strategic congruence between resource availability and development objectives. The aforementioned regional discrepancies in operational strategies underscore the importance of customized methodologies to tackle particular obstacles and capitalize on exemplary standards. Such adjustments will ultimately enhance the efficiency and fairness of allocating financial resources towards the development of sports infrastructure throughout the varied provinces of China [66]. In order to enhance the efficiency of their financial resource utilization (FRUE) in the development of sports infrastructure, the Eastern regions can offer valuable lessons to the Western and Central regions of China regarding the successful strategies they have adopted. Eastern regions exhibit a higher average FRUE, which indicates a greater emphasis on strategic planning, prioritization, and novel financing models. The Western and Central regions ought to implement systematic planning procedures, give precedence to projects that will have the greatest impact, and investigate alternative funding models like public-private partnerships to optimize their operations. By drawing insights from the Eastern regions' streamlined project management practices, the Western and Central regions can enhance the efficiency of their operations, thereby promoting coordinated efforts and timely execution. Furthermore, significant progress has been made in the East towards resource optimization through the implementation of sustainable practices and cost-effective technologies. By implementing capacity-building initiatives, skill enhancement programs, and collaborative knowledge exchange platforms, the Western and Central regions can be additionally enabled to enhance their FRUE, thereby promoting a more sustainable and efficient approach to the development of sporting infrastructure [67,68].

5.2. Meta-frontier analysis results

The estimation of the technology gap ratio is of utmost importance in order to comprehend and rectify discrepancies in technological progress across regions. This metric offers valuable insights into the progress of economic development, facilitating the formulation of focused policies aimed at closing disparities. By identifying regions characterized by lower ratios, best practices can be emulated, whereas strategic interventions can be implemented in areas with greater disparities. Additionally, the technology gap ratio promotes collaboration and the exchange of knowledge, which contributes to a more equitable distribution of innovation. Moreover, it plays a crucial role in regulating regional efforts to attract investments and talent in order to maintain competitiveness amidst the swiftly changing technological environment on a global scale. In general, this estimation is critical for facilitating well-informed decision-making and promoting resilience and fair development in various regions. Therefore, in this study, where financial resource utilization efficiency is gauged for different regions of China, the estimation of production technology heterogeneity in different regions of China has great importance. This study used different inputs and outputs for 31 Chinese provinces. It employed the DEA Meta-Frontier analysis to gauge the FRUE for meta frontier, group frontier, and technology gap ratio among three different regions. As shown in Table 4, the findings of the meta-frontier analysis offer valuable insights regarding the Financial Resources Utilization Efficiency (FRUE) in the 31 provinces of China, categorized by region as Central, Eastern, or Western. The Technological Gap Ratio (TGR) and FRUE values for the meta-frontier and group frontier are also provided.

Results indicate that Beijing (1.000), Shanghai (1.000), Tibet (1.000), Hainan (0.831), and Guangdong (0.778) are top performers in meta frontier (FRUE). In contrast, Guizhou (0.349), Shaanxi (0.375), Shanxi (0.384), Henan (0.384), and Anhui (0.389) are found to be the least efficient in utilization of financial resources to develop the sports infrastructure. Similarly, Beijing, Shanghai, Tibet, Hainan, Heilongjiang, Jilin, Chongqing, and Inner Mongolia are top performers in the group frontier with FRUE of 1. Hebei Shandong, Guizhou, Liaoning, and Jiangsu gained the lowest efficiency score in the group frontier. Finally, the TGR vale of Beijing, Shanghai, Tibet, Guangdong, Zhejiang, Jiangsu, Liaoning, Shandong, and Hebei is 1. It indicates that these provinces retain the superior production technology to develop the sports infrastructure. On the contrary, Jiangxi, Inner Mongolia, Shanxi, Sichuan, and Chongqing

Table 4
Meta frontier, group frontier, and TGR in 31 Chinese provinces.

Region	Province	FRUE (meta)	FRUE (group)	TGR
Central	Anhui	0.389	0.785	0.526
	Heilongjiang	0.570	1.000	0.570
	Henan	0.384	0.660	0.600
	Hubei	0.424	0.833	0.535
	Hunan	0.426	0.917	0.485
	Jiangxi	0.394	0.977	0.404
	Jilin	0.441	1.000	0.441
	Shanxi	0.384	0.948	0.421
Avg. Central		**0.4265**	**0.89**	**0.4977**
East	Beijing	1.000	1.000	1.000
	Fujian	0.617	0.62	0.993
	Guangdong	0.778	0.778	1.000
	Hainan	0.831	1.000	0.831
	Hebei	0.396	0.396	1.000
	Jiangsu	0.548	0.548	1.000
	Liaoning	0.543	0.544	1.000
	Shandong	0.448	0.448	1.000
	Shanghai	1.000	1.000	1.000
	Tianjin	0.593	0.628	0.942
	Zhejiang	0.550	0.550	1.000
Avg. East		**0.664**	**0.6829**	**0.9787**
West	Chongqing	0.437	1.000	0.437
	Gansu	0.397	0.755	0.545
	Guangxi	0.408	0.919	0.443
	Guizhou	0.349	0.525	0.665
	Inner Mongolia	0.411	1.000	0.411
	Ningxia	0.456	0.573	0.794
	Qinghai	0.523	0.761	0.695
	Shaanxi	0.375	0.697	0.537
	Sichuan	0.412	0.981	0.421
	Tibet	1.000	1.000	1.000
	Xinjiang	0.403	0.791	0.532
	Yunnan	0.391	0.783	0.506
Avg. West		**0.4635**	**0.8154**	**0.5821**

retain the most inferior production technologies in sports infrastructure development.

The findings that have been presented offer significant insights regarding the effectiveness with which Chinese provinces allocate financial resources towards the development of sporting infrastructure. In order to mitigate prevailing inequalities and reduce the technological gap ratio, it is possible to implement a comprehensive strategy. When considering the adoption of best practices and benchmarking, provinces with lower efficiency levels can gain insights from the achievements of more efficient regions, including Beijing, Shanghai, Tibet, and Hainan. Through a meticulous examination of the elements that contribute to their exceptional efficiency scores, these provinces have the opportunity to imitate effective strategies in order to improve their performance. In less efficient provinces, capacity-building and training initiatives are crucial for officials and administrators involved in sports infrastructure development. Investing in programs that augment their expertise and competencies will invariably enhance their capacity to strategize, execute, and oversee projects efficiently. The principle of transparent resource allocation is fundamental to the enhancement of efficiency. Provinces that are characterized by lower efficiency should give precedence to the establishment of mechanisms that ensure accountability and transparency in the allocation of financial resources. The implementation of safeguards against mismanagement or diversion of funds will enhance the overall efficiency of resource allocation. The investigation of public-private partnerships (PPPs) provides provinces with lower efficiency with the chance to distribute the financial strain and gain access to supplementary knowledge. Additionally, the collaborative character of PPPs may facilitate the introduction of novel funding models that are advantageous for the development of sports infrastructure. Knowledge exchange and technology transfer are crucial approaches for bridging the technological divide [59,69].

Through the facilitation of technology and knowledge transmission from more developed provinces to those that are less efficient, collaboration and partnerships have the potential to reduce disparities in the development of sports infrastructure significantly. The implementation of robust performance monitoring and evaluation mechanisms is crucial in order to gauge the effects of sports infrastructure projects accurately. By leveraging performance data, processes, and resource allocation strategies can be continuously enhanced, thereby increasing overall efficiency. A cost-effective approach entails maximizing the utilization of pre-existing sports infrastructure facilities. Maximizing returns on investment and improving overall efficiency can be achieved by identifying opportunities for multi-purpose use and ensuring that these facilities are utilized to their maximum capacity. It is vital to formulate a strategic plan that is in accordance with the distinct requirements and priorities of every province. By prioritizing projects according to their potential impact and ensuring that they are in line with the overarching development objectives of the province, sports infrastructure development can be approached in a focused and effective manner. Incentives for enhancing operational efficiency serve as a motivating mechanism for provincial governments. Incentivizing and acknowledging accomplishments related to the optimization of financial resource utilization fosters an environment that is conducive to ongoing enhancement. Promoting regional collaboration via collaborative initiatives and the exchange of knowledge cultivates a cooperative ethos in the face of shared obstacles. The establishment of regional forums or networks enhances communication and collaboration, thereby promoting the development of sports infrastructure across provinces in a more unified and efficient manner. Through the implementation of these all-encompassing strategies, provinces that are currently less efficient can strive to bridge the technological divide, enhance the efficiency of their financial resource utilization, and promote the sustainable development of sporting infrastructure [70,71].

Further explaining the regional differences in FRUE, the East region is higher in both meta-frontier and group frontier analyses, standing at 0.664. Provinces such as Beijing, Shanghai, and Guangdong demonstrate optimal financial resource utilization by attaining maximal efficiency (1.000). Provinces situated in the Western region, namely Tibet and Chongqing, exhibit notable FRUE values in the meta-frontier (1.000 and 0.437, respectively), which signify effective utilization of financial resources. On the other hand, provinces such as Shaanxi and Guizhou exhibit diminished efficiency along the meta-frontier, indicating potential for enhancement. Results conclude that provinces perform better in their particular group frontier instead of the meta frontier. Further Provinces within the Central region demonstrate diverse degrees of efficiency. The meta-frontier analysis reveals that Anhui and Henan have FRUE values of 0.389 and 0.384, respectively, which are below optimal levels of financial resource utilization. On the contrary, provinces such as Heilongjiang and Jilin demonstrate superior efficacy (0.570 and 0.441, respectively) in the meta-frontier, indicating a more effective allocation of resources.

The Technological Gap Ratios (TGR) serve to magnify the discrepancies in regional technological progress. The TGR for the Central region is 0.4977, while that for the East is 0.9787, and for the West, it is 0.5821. These ratios indicate the relative technological disparities between regions, with the East exhibiting the smallest discrepancy. Finally, the meta-frontier analysis uncovers discrepancies in the efficiency of financial resource utilization across provinces in China, which carries significant ramifications for approaches to regional development. Results concluded that the efficiency of the East region is higher than that of the Central and Western regions, which exhibit varying degrees of effectiveness. Studies found that to optimize the utilization of financial resources (FRUE) and reduce the technological disparity ratio at the regional level; underperforming areas should give precedence to strategic planning and project prioritization. It is crucial to allocate resources toward comprehensive capacity-building initiatives for officials and administrators. Additionally, optimization endeavors can be informed by benchmarking against more efficient provinces' best practices. In order to mitigate mismanagement, it is imperative to establish transparent mechanisms for resource allocation. To this end, an examination of Public-Private Partnerships (PPPs) may unveil novel funding models. Critical measures include facilitating the transfer of technology and knowledge from more developed provinces, establishing rigorous performance monitoring systems, and optimizing current facilities. Enhancing efficiency through the implementation of incentive programs and promoting regional cooperation via forums and networks will serve to promote further the development of sports infrastructure that is more equitable and balanced [72–74].

5.3. Malmquist productivity index results

In this section study applied the Malmquist productivity index to gauge the dynamic change in the financial resource's utilization efficiency. Table 5 and A2 provide an overview of the technical change (TC), efficiency change (EC), and total factor productivity change (TFPC) in relation to the allocation of financial resources for the development of sports infrastructure from 2014 to 2015 to 2020–2021. The TFPC, which measures changes in overall productivity, consistently exceeds 1, suggesting that provinces' ability to allocate financial resources effectively has improved. The average TFPC value is 1.035. It indicates that, on average, Chinese provinces gained 3.5 % growth in TFPC over the study period. The average value of TC = 1.0273 is higher than EC = 0.997. It illustrates that technological change is the primary determinant of TFPC.

Further Chinese province witnessed a growth of 2.73 in technological improvement. On the contrary, the efficiency change declined by 0.3 percent. The average Efficiency Change (EC) values are slightly below 1, indicating a slight reduction in the efficiency of allocating financial resources towards the development of sporting infrastructure. On the contrary, the Technical Change (TC) values consistently surpass 1, which indicates favorable progressions in technology or development technologies in sports infrastructure development. The data indicates a complex trend of technological advancements and productivity gains in the development of sports infrastructure, offset by a slight average decline in efficiency.

Studies proved that technological advancement is essential for the development of Total Factor Productivity Change (TFPC) since it significantly influences the efficiency and effectiveness of production processes. The importance of technological progress in the growth of TFPC is complex and has multiple aspects. Firstly, it improves efficiency by enabling a more efficient utilization of inputs, leading to increased output without a corresponding increase in resources. Furthermore, technological advancements promote originality and inventiveness, facilitating the creation of new approaches that enhance productivity and TFPC expansion [75,76]. Furthermore, it enhances resource allocation, reducing inefficiency and maximizing productivity from a specific set of resources. Enhanced technology frequently aligns with superior product or service quality, amplifying productivity and exerting a beneficial influence on total factor productivity growth. Technological developments enable economies of scale, which in turn contribute to the growth of total factor productivity (TFPC) by allowing for more production at reduced costs.

Moreover, having a strong technological advantage allows authorities to gain a favorable position in the global market, promoting economic growth and long-term viability. Technological advancements bolster the ability of enterprises and economies to successfully respond to changing market demands, therefore increasing their flexibility in a dynamic economic environment. In essence, sustainable technological advancement serves as a driving force for sustained economic expansion, fostering innovation, research and development, and ongoing enhancements that form the basis for long-term growth in total factor productivity. Therefore, it is crucial to adopt and allocate resources to technological breakthroughs in order to achieve continuous enhancements in productivity and promote lasting economic prosperity [77,78].

Chinese provinces can significantly enhance their Total Factor Productivity Change (TFPC) in the field of sports infrastructure development by prioritizing the improvement of Efficiency Change (EC) in financial resource usage. In order to accomplish this, provinces should give priority to investing in comprehensive training programs for officials and administrators involved in the development of sports infrastructure. It will help improve their skills and expertise, hence enhancing project design and implementation. Studies found that it is crucial to build transparent and accountable methods for allocating financial resources in order to ensure the efficient use of cash and minimize mismanagement. In addition, provinces can gain significant knowledge by examining and implementing the successful techniques of more efficient counterparts, resulting in improved usage of financial resources. Promoting Public-Private Partnerships (PPPs) provides opportunities for cooperation, distributing financial responsibility, and using inventive finance structures that can improve overall effectiveness. Enabling the transfer of technology and sharing of information from technologically advanced provinces, along with strong monitoring and evaluation systems, can help identify areas that need development and lead to enhanced efficiency. By optimizing the current sports infrastructure facilities and implementing strategic planning and prioritizing, the distribution of resources can be made more efficient. By actively prioritizing the enhancement of Efficiency Change through these specific tactics, Chinese provinces can increase their TFPC (Total Factor Productivity of Capital) in the exploitation of financial resources for the construction of sports infrastructure. It would promote more efficient and sustainable growth in the sports sector across the country [34,79].

Table 6 presents the Total Factor Productivity Change (TFPC), Efficiency Change (EC), and Technical Change (TC), related to the use of financial resources in the development of sports infrastructure in different regions and provinces of China. The center region exhibits a mean Total Factor Productivity Change (TFPC) of 0.997, showing a slight decline in overall productivity. Additionally, the

Table 5
TFPC, EC, and TC in financial resources for sports infrastructure development.

Years	TFPC	EC	TC
2014–2015	1.019	0.9609	1.0297
2015–2016	1.0064	0.9552	1.0653
2016–2017	1.0091	0.9816	1.0234
2017–2018	1.0104	0.9993	1.0078
2018–2019	1.0196	1.0096	0.9991
2019–2020	1.1107	1.0415	0.9888
2020–2021	1.0738	1.0314	1.0773
Average	1.035	0.997	1.0273

average Efficiency Change (EC) is 0.968, suggesting a drop in efficiency. However, a TC value of 1.029 indicates a simultaneous positive shift in technology or processes. These results indicate that the TFPC in the central region has declined by 0.3 percent over the study period, and efficiency change is the main culprit in the decline of TFPC, as technological change gained a growth of 2.9 percent.

The eastern region is notable for its higher average total factor productivity (TFPC) of 1.048, indicating an enhancement in overall productivity. The mean EC is 0.988, indicating a minor decline in efficiency, but the favorable TC of 1.064 underscores progress in technological growth. Conversely, the western region exhibits a slight reduction in TFPC (0.982), and both EC (0.987) and TC (0.996) are the culprits in the decline of TFPC. In general, the national mean Total Factor Productivity Change (TFPC) stands at 1.035, indicating a favorable shift in productivity. Conversely, the average Efficiency Change (EC) of 0.997 implies a minor decline in efficiency. A TC value of 1.0273 indicates a general increase in technology. These findings highlight the differences between regions and provide significant information for creating targeted strategies to improve productivity and efficiency in the development of sports infrastructure throughout China.

The analysis of Table 6 reveals notable patterns in Total Factor Productivity Change (TFPC), Efficiency Change (EC), and Technical Change (TC) throughout different regions of China, highlighting specific areas that need to be addressed in order to improve TFPC. The central area had a little decrease of 0.3 percent in Total Factor Productivity Change (TFPC), which can mainly be attributed to a decrease in Efficiency Change (EC) with an average value of 0.968. The decrease in TFPC highlights the significance of tackling efficiency-related elements to strengthen TFPC. Nevertheless, the TC value of 1.029 indicates that technological progress has had a beneficial impact on the total production in the central region. It is advisable to concentrate on enhancing relative Efficiency Change to enhance TFPC (Total Factor Productivity Change).

On the other hand, the eastern region is notable for its commendable Total Factor Productivity Change (TFPC) of 1.048, which suggests a general increase in productivity. Although there was a small decrease in Efficiency Change (EC) with an average of 0.988, the positive TC value of 1.064 indicates significant advancements in technical development. This region exemplifies the successful integration of efficiency and technical progress. In order to sustain and enhance the TFPC (Total Factor Productivity Change), the eastern area should continue to capitalize on its existing capabilities while also addressing or sustaining Efficiency Change. Concurrently, the western region undergoes a modest decrease in Total Factor Productivity Change (TFPC) with a value of 0.982. This drop can be linked to both Efficiency Change (EC) and Technical Change (TC) values that are slightly less than 1. It is crucial to enhance both of these parameters in order to increase TFPC. Simultaneously implementing strategies to improve efficiency and technology improvements is crucial for promoting overall productivity in the western area. At a national level, the average Total Factor Productivity

Table 6
TFPC, EC and TC of Financial resources in sports infrastructure development.

Region	Province	TFPC	EC	TC
	Anhui	0.995	0.961	1.035
	Henan	1.002	0.965	1.038
	Heilongjiang	0.963	0.94	1.024
	Hubei	1.01	0.97	1.041
	Hunan	0.999	0.963	1.037
	Jilin	1.001	0.974	1.027
	Jiangxi	0.997	0.973	1.024
	Shanxi	1	0.993	1.008
Avg. central		**0.997**	**0.968**	**1.029**
	Beijing	1.101	1	1.101
	Fujian	1.008	0.944	1.068
	Guangdong	1.047	0.952	1.1
	Hainan	0.974	1	0.974
	Hebei	0.999	0.969	1.031
	Jiangsu	1.045	0.975	1.072
	Liaoning	1.09	1.04	1.048
	Shandong	1.024	0.979	1.046
	Shanghai	1.062	1	1.062
	Tianjin	1.087	0.99	1.098
	Zhejiang	1.058	0.976	1.084
Avg. East		**1.048**	**0.988**	**1.064**
	Gansu	0.988	0.988	1
	Guangxi	0.991	0.967	1.026
	Guizhou	0.979	0.982	0.997
	Inner Mongolia	1.013	0.998	1.015
	Ningxia	0.975	1.008	0.968
	Qinghai	0.973	1.011	0.963
	Shaanxi	0.997	0.98	1.017
	Sichuan	1.013	0.975	1.039
	Tibet	0.872	1	0.872
	Xinjiang	0.981	0.977	1.004
	Yunnan	0.976	0.96	1.017
	Chongqing	1.016	0.99	1.026
Avg. West		**0.982**	**0.987**	**0.996**
Avg. all		**1.035**	**0.997**	**1.027**

Change (TFPC) of 1.035 suggests a general increase in productivity. In contrast, the average Efficiency Change (EC) of 0.997 indicates a slight decrease in efficiency. The TC rating of 1.0273 indicates an overall rise in technology, which has a favorable impact on the national TFPC. In order to further improve the effectiveness of TFPC on a national scale, specific initiatives can be implemented to address efficiency issues and encourage ongoing technological progress. These findings highlight the regional differences in TFPC, EC, and TC, providing significant information for developing targeted strategies to enhance productivity and efficiency in sports infrastructure development throughout China. Focusing on targeted improvements, such as increasing efficiency in the center region and adopting a balanced approach in the western region, can greatly help the overall objective of strengthening TFPC across the entire country. Numerous research studies highlight the importance of efficiency enhancement to boost the TFPC in financial resource utilization [80,81].

Results further illustrate that TFPC witnessed growth in Beijing (1.101), Liaoning (1.09), Tianjin (1.087), Shanghai (1.062), Zhejiang (1.058), Guangdong (1.047), Jiangsu (1.045), Shandong (1.024), Chongqing (1.016), Inner Mongolia (1.013), Sichuan (1.013), Hubei (1.01), Fujian (1.008), Henan (1.002), Jilin (1.001) and Shanxi (1). While Hebei, Hunan, Jiangxi, Shaanxi, Anhui, Guangxi, Gansu, Xinjiang, Guizhou, Yunnan, Ningxia, Hainan, Qinghai, Heilongjiang and Tibet witnessed a decline in the TFPC over the study period. It also explains that technological change is the main determinant in these provinces, and EC is the culprit of TFPC decline. Moreover, results found that except for Guizhou, Hainan, Ningxia, Qinghai, and Tibet the TC of all the provinces witnessed growth as their TC is higher than 1. Beijing, Guangdong, Tianjin, Zhejiang, Jiangsu, and Fujian are top performers in technological change growth over the study period.

The findings emphasize the crucial influence of technology advancements in defining the Total Factor Productivity development (TFPC) among different provinces in China. It highlights the importance of technological development as the primary factor driving growth in various advanced regions. The provinces that witnessed significant development in Total Factor Productivity Change (TFPC), such as Beijing, Liaoning, Tianjin, and Shanghai, displayed a constant upward trend in technical advancement, with scores above 1. It highlights the essential role of technical improvements in enhancing productivity in these provinces.

In contrast, provinces experiencing a decrease in Total Factor Productivity Change (TFPC), such as Hebei, Hunan, Jiangxi, and Shaanxi, had issues principally related to Efficiency Change (EC). These findings highlight the urgent necessity to improve efficiency in resource allocation in order to mitigate the decrease in total factor productivity growth. Implementing strategies that focus on streamlining procedures, enhancing resource allocation mechanisms, and ensuring transparency can play a crucial role in addressing efficiency issues and generating a beneficial influence on TFPC.

Furthermore, the general rise in Technical Change (TC) among provinces, except for a few, indicates a wider pattern of technical progress. Beijing, Guangdong, and Tianjin stand out as leading regions in terms of TC growth, demonstrating their proactive strategies and successful use of advanced technologies across many industries. In order to achieve the same level of success and improve TFPC, other provinces can learn valuable lessons from these technological frontrunners. It can be done by cultivating an environment that encourages innovation, allocating resources to research and development, and creating partnerships between academic institutions and enterprises.

The findings highlight the crucial significance of technical advancements in stimulating total factor productivity growth in various regions of China. In order to improve overall performance, provinces experiencing decreases in Total Factor Productivity Growth (TFPC) should give priority to implementing measures that boost efficiency. Additionally, they should take advantage of the favorable progress in technical advancements observed in other areas. It includes creating a favorable atmosphere for innovation, allocating resources to education and skill enhancement, and encouraging cooperative endeavors to narrow the technology divide. Provinces can achieve sustained economic growth and competitiveness in the changing global context by addressing efficiency challenges and adopting technological advancements [82,83].

5.4. Kruskal-Wallis test results

The results in Sections 5.1, 5.2, and 5.3 indicate that FRUE, TGR, and TFPC in three regions of China are at different levels. But are these differences being statistically different is a question of great concern for the research community. Therefore, to gauge the statistically significant difference among the three regions of China for the FRUE, TGR, and TFPC, this study employed the Kruskal-Wallis test. The results of the Kruskal-Wallis test presented in Table 7 and Figs. A1–A3 provide valuable insights into the comparative examination of Financial Resource Utilization Efficiency (FRUE), Technological Gap Ratio (TGR), and Total Factor Productivity Change (TFPC) across three different Chinese regions. For FRUE, if the null hypothesis is rejected at a significance level of 0.003, it means that there are substantial differences in the efficiency of financial resource consumption among the areas. It highlights the necessity for customized approaches to tackle distinct difficulties associated with the management of financial resources in various regions.

Table 7
Kruskal–Wallis test Results.

Hypothesis Test Summary				
	Null Hypothesis Test Sig. Decision			
1	The distribution of FRUE is the same across the categories of 3 Chinese Regions.	Independent-Samples Kruskal– Wallis Test	0.003	Reject the null hypothesis.
2	The distribution of TGR is the same across the categories of 3 Chinese Regions.		0.001	Reject the null hypothesis
3	The distribution of TFPC is the same across the categories of 3 Chinese Regions.		0.003	Reject the null hypothesis

Moreover, the null hypothesis for TGR and TFPC is rejected at significance levels of 0.001 and 0.003, respectively, indicating significant variations in technical gaps and overall productivity change among the regions. These findings emphasize the significance of implementing policies tailored to distinct regions in order to address the various efficiency and technology obstacles. Policymakers are advised to utilize these statistically significant differences to undertake focused interventions that match the individual characteristics of each region, promoting more efficient and nuanced strategies for regional sports infrastructure development [84,85].

Asymptotic significances are displayed. The significance level is 0.050.

6. Conclusion and policy implications

In the last decade, the Chinese government has made significant investments in the construction of sporting facilities at many levels of administration, including national, provincial, municipal, and village levels. This commitment entails the creation of state-of-the-art facilities, such as top-notch stadiums and high-performance centers at the national level, specialized venues at the province level that cater to regional requirements, and the incorporation of sports facilities into urban planning at the municipal level. Although substantial investments have been made, there is a lack of research on the efficiency and productivity growth resulting from the deployment of financial resources for sports infrastructure development in China. An extensive analysis of efficiency and productivity growth in this particular environment might offer useful insights for optimizing strategies for allocating resources. Furthermore, the efficient distribution of financial resources is closely connected to regional production technologies, where differences in technological capacities among various regions impact the efficiency of resource usage.

To this end, this study used the DEA-SBM to evaluate the financial resource utilization efficiency in the development of sports infrastructure across 31 Chinese provinces from 2014 to 2021. Furthermore, Meta-frontier Analysis quantifies the variation in production technology when it comes to employing financial resources in the East, Central, and West areas of China. The Malmquist productivity index assesses the Total Factor Productivity Change in the utilization of financial resources for the development of sports infrastructure. It investigates the factors that influence changes in productivity. Finally, the Kruskal-Wallis test is used to determine if there are significant differences among the three regions in terms of financial resource utilization efficiency, production technology heterogeneity, and total factor productivity change. The results indicate a consistent and ongoing inefficiency in the use of financial resources, suggesting that there is a growth potential of 51.41 in FRUE in Chinese provinces. The regional analysis reveals significant disparities, with the Eastern provinces demonstrating higher utilization of financial resources, followed by the Western region and a comparatively less efficient Central region. The FRUE of the eastern region is 0.664, the FRUE of the Central region is 0.4265, and the FRUE of the western region is 0.4635. Beijing, Shanghai, Tibet, Hainan, and Guangdong are top performers in meta frontier (FRUE). Guizhou, Shaanxi, Shanxi, Henan, and Anhui are found to be the least efficient in the utilization of financial resources to develop the sports infrastructure. Similarly, Beijing, Shanghai, Tibet, Hainan, Heilongjiang, Jilin, Chongqing, and Inner Mongolia are top performers in the group frontier with FRUE of 1.

Moreover, the analysis of the technical Gap Ratio (TGR) reveals substantial disparities in production technologies employed in infrastructure development between various regions. The TGR for the Central region is 0.4977, while that for the East is 0.9787, and for the West, it is 0.5821. It indicates that the eastern region contains the superior production technology to develop the sports infrastructure. The Eastern provinces consistently demonstrate superior performance compared to other regions, exhibiting a higher degree of innovation and technological development. Conversely, the Central region faces challenges in terms of efficiency, and the Western region displays a reasonable level of efficiency in allocating resources for the development of sports facilities. The existence of these discrepancies highlights the significance of comprehending regional dynamics in order to develop efficient policies that correspond to the distinct requirements of each region. The Technological Gap Ratios (TGR) serve to magnify the discrepancies in regional technological progress. TGR vale of Beijing, Shanghai, Tibet, Guangdong, Zhejiang, Jiangsu, Liaoning, Shandong and Hebei is 1. It indicates that these provinces retain the superior production technology to develop the sports infrastructure.

The average TFPC value is 1.035. It indicates that, on average, Chinese provinces gained 3.5 % growth in TFPC over the study period. The average value of TC = 1.0273 is higher than EC = 0.997. It illustrates that technological change is the primary determinant of TFPC. Further Chinese province witnessed a growth of 2.73 in technological improvement. On the contrary, the efficiency change declined by 0.3 percent. The results show varied TFPC, EC, and TC trends among Chinese regions. Efficiency Change (EC) drops to 0.968, causing TFPC to drop 0.3% in the central region. This reduction is largely compensated by a positive Technological Change (TC) of 1.029, showing simultaneous technological or process advances. However, the eastern region has a higher average TFPC of 1.048, indicating higher productivity. Despite a small drop in Efficiency Change (EC) to 0.988, the positive TC rating of 1.064 shows significant technical growth. TFPC (0.982) decreases in the West due to EC (0.987) and TC (0.996). The mean TFPC is 1.035 nationally, indicating a productivity boost despite a little decline in EC to 0.997. The positive TC rating of 1.0273 implies national technology growth. TFPC witnessed growth in Beijing (1.101), Liaoning (1.09), Tianjin (1.087), Shanghai (1.062), Zhejiang (1.058), Guangdong (1.047), Jiangsu (1.045), Shandong (1.024), Chongqing (1.016), Inner Mongolia (1.013), Sichuan (1.013), Hubei (1.01), Fujian (1.008), Henan (1.002), Jilin (1.001) and Shanxi (1). Finally, the Kruskal-Wallis test proved the statistically significant difference in three regions of China for FRUE, TGR, and TFPC.

The examination of the extensive development of sports infrastructure in China throughout the previous decade has yielded several significant policy recommendations. To begin with, considering the persistent inefficiency in the allocation of financial resources, there exists a substantial opportunity for development of 51.41% in the domain of Financial Resource Utilization Efficiency (FRUE) throughout the provinces of China. Policymakers must prioritize the implementation of strategies that aid in optimizing the efficiency of resource allocation, with a specific emphasis on investments in sporting infrastructure. The study's findings regarding regional disparities underscore the criticality of customizing policies to address the unique requirements of individual regions. Eastern provinces demonstrate superior technological development, FRUE, and overall performance. As a result, policies ought to promote the exchange of best practices and knowledge from these high-performing regions to improve operations in other sectors. In the interim, the Central region is confronted with inefficiencies that require specific interventions to optimize the processes of resource allocation. Policies in the Western region, where efficiency is merely adequate but not ideal, ought to prioritize additional enhancements.

The Technical Gap Ratios (TGR) highlight the necessity of implementing focused interventions to narrow technological discrepancies between different regions. Policymakers must give precedence to endeavors that advance technological progress in areas characterized by lower TGR values, thereby nurturing innovation and reducing regional disparities. Moreover, considering the significant role that Technological Change (TC) plays in determining Total Factor Productivity Change (TFPC), it is imperative that policies actively encourage the integration of technological advancements into the development of sports infrastructure. It encompasses the promotion of research and development, the establishment of an environment that encourages innovation, and the financing of cutting-edge technology implementation.

Determining which provinces are the most and least efficient serves as a foundation for implementing focused policy interventions. Prominent performance can be observed in provinces such as Beijing, Shanghai, Tibet, Hainan, and Guangdong, which can serve as models for other regions to emulate. On the other hand, provinces characterized by lower efficiency, including Guizhou, Shaanxi, Shanxi, Henan, and Anhui, necessitate targeted policy interventions to improve their financial resource utilization for the development of sporting infrastructure. In summary, the results of the research provide significant knowledge for policymakers to develop focused and geographically specific approaches. By recognizing and rectifying inefficiencies and technological disparities, as well as adopting strategies from regions with exceptional performance, China has the potential to maximize the return on its sports infrastructure investments, thereby promoting a society that is healthier, more active, and technologically advanced.

Despite the significance of the research, it has a few limitations. Data availability for inputs and outputs before the year 2014 is a study limitation because a more stretched period can give more trustworthy results and could give more insights into financial resource utilization efficiency in sports infrastructure development. More research could be done on the contextual variable that could impact the FRUE and TGR in sports infrastructure development.

Data availability statement

Data was collected from the Statistical Yearbook of China's Sports Industry. Data is freely available at: https://www.sport.gov.cn/.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Xiaowei Xu: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Chen Huang:** Visualization, Validation, Supervision, Software, Methodology, Formal analysis, Conceptualization. **Wasi Ul Hassan Shah:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1
FRUE in all three regions of China.

Year	East	Central	West
2014	0.626	0.394	0.441
2015	0.591	0.378	0.43
2016	0.582	0.369	0.426
2017	0.584	0.369	0.427
2018	0.586	0.375	0.432
2019	0.634	0.375	0.446
2020	0.678	0.368	0.45
2021	0.66	0.376	0.458
Average	0.664	0.4265	0.4635

A2
FRUE in 31 Chinese provinces for sports infrastructure development

Rejion	Province	2014	2015	2016	2017	2018	2019	2020
Central	Anhui	0.351	0.343	0.34	0.341	0.341	0.34	0.326
Central	Henan	0.349	0.345	0.344	0.342	0.339	0.34	0.333
Central	Heilongjiang	0.451	0.428	0.428	0.455	0.462	0.45	0.448
Central	Hubei	0.373	0.368	0.375	0.38	0.38	0.37	0.362
Central	Hunan	0.382	0.378	0.378	0.381	0.375	0.37	0.356
Central	Jilin	0.409	0.405	0.412	0.418	0.422	0.42	0.42
Central	Jiangxi	0.362	0.36	0.353	0.357	0.36	0.36	0.35
Central	Shanxi	0.349	0.342	0.336	0.343	0.341	0.34	0.427
Avg.	**Central**	**0.378**	**0.371**	**0.371**	**0.377**	**0.377**	**0.37**	**0.378**
East	Beijing	1	1	1	1	1	1	1
East	Fujian	0.512	0.505	0.511	0.515	0.514	0.51	0.472
East	Guangdong	0.662	0.656	0.672	0.635	0.684	0.59	0.526
East	Hainan	0.595	0.568	0.561	0.552	1	1	1
East	Hebei	0.36	0.354	0.349	0.355	0.352	0.35	0.343
East	Jiangsu	0.502	0.499	0.499	0.514	0.509	0.49	0.47
East	Liaoning	0.427	0.418	0.414	0.432	0.458	1	1
East	Shandong	0.415	0.407	0.415	0.422	0.415	0.4	0.404
East	Shanghai	1	1	1	1	1	1	1
East	Tianjin	0.518	0.523	0.536	0.55	0.569	0.6	0.609
East	Zhejiang	0.515	0.495	0.494	0.498	0.493	0.48	0.461
Avg.	**East**	**0.591**	**0.584**	**0.586**	**0.588**	**0.636**	**0.68**	**0.662**
Western	Gansu	0.346	0.342	0.339	0.341	0.355	0.36	0.417
Western	Guangxi	0.367	0.363	0.363	0.366	0.357	0.37	0.356
Western	Guizhou	0.324	0.317	0.315	0.317	0.322	0.32	0.319
Western	Inner Mongolia	0.38	0.384	0.386	0.401	0.424	0.43	0.431
Western	Ningxia	0.423	0.431	0.431	0.437	0.472	0.49	0.515
Western	Qinghai	0.47	0.475	0.477	0.485	0.568	0.58	0.624
Western	Shaanxi	0.343	0.34	0.341	0.35	0.356	0.36	0.355
Western	Sichuan	0.383	0.376	0.376	0.379	0.382	0.37	0.366
Western	Tibet	1	1	1	1	1	1	1
Western	Xinjiang	0.372	0.36	0.351	0.355	0.357	0.36	0.357
Western	Yunnan	0.35	0.344	0.343	0.346	0.356	0.35	0.342
Western	Chongqing	0.406	0.408	0.424	0.428	0.43	0.44	0.443
Avg.	**West**	**0.43**	**0.428**	**0.429**	**0.434**	**0.448**	**0.452**	**0.46**

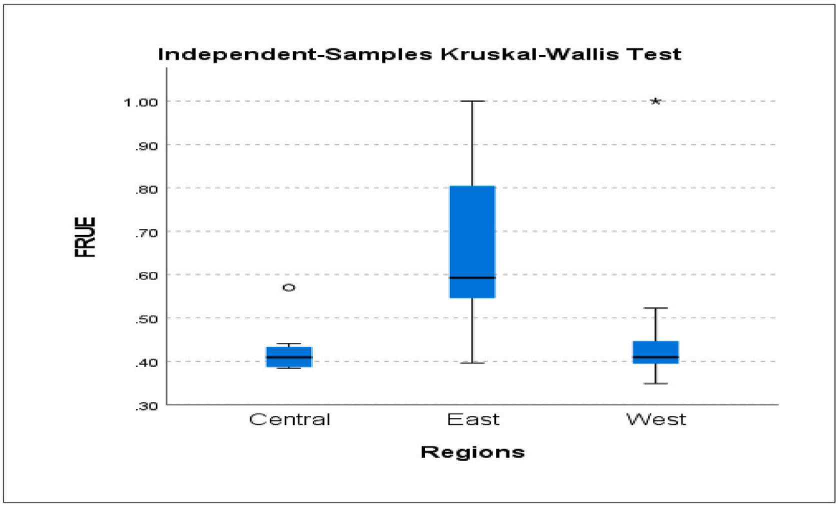

Fig. A1. Distribution of FRUE across three regions.

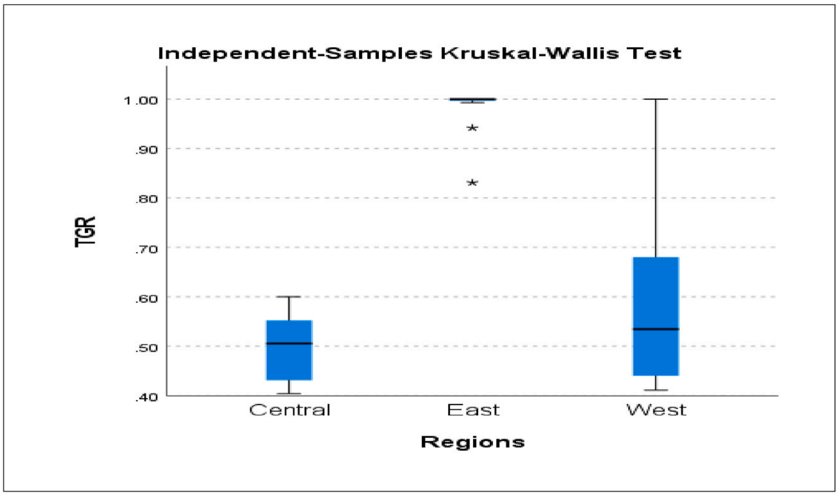

Fig. A2. Distribution of TGR across three regions.

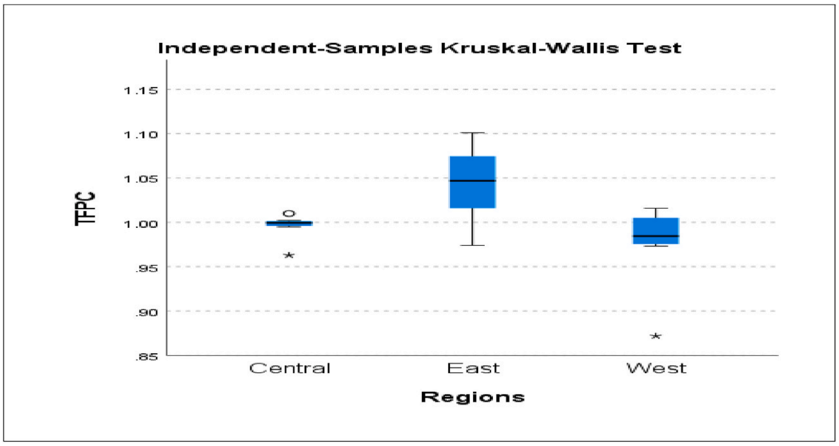

Fig. A3. Distribution of TFPC across three regions.

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