Educational Resource Allocation Efficiency for Urban and Rural High School in China

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Abstract There is a significant asymmetry in the allocation of educational resources between rural and urban areas, and across regions in China. Besides, general high school education, which serves as a bridge between compulsory education and higher education in China, experiences inadequate and unbalanced development across regions. In this paper, taking both static and dynamic perspectives into account, DEA and Malmquist index models are constructed to comprehensively evaluate the efficiency of resource allocation and total factor productivity of high school education in both urban and rural areas of China from 2007 to 2022, while a comparative analysis is conducted between urban and rural areas. The results show that the overall efficiency of high school educational resource allocation in China is inadequate, with rural areas experiencing lower efficiency than urban areas. Furthermore, disparities in resource allocation efficiency are distinguishable between urban and rural areas in the eastern, central, and western regions. Therefore, in order to enhance the efficiency of resource allocation in regular high schools, it is crucial to formulate an integrated planning for educational resource allocation in both urban and rural regions. In addition, technical guidance should be intensified in areas with inefficient resource allocation, and the evaluation system of resource investment performance must be enhanced.

Key words High school education, Educational resources, Allocation efficiency, DEA-Malmquist

0 Introduction

The view that education, science and technology, and human resources provide the fundamental and strategic framework for the comprehensive construction of a modernized country has been highly and unanimously endorsed by many scholars, which fully embodies the significant role of education in Chinese-style modernization. As an important link in national education, senior high school education plays a key role in the education system, serving as a necessary intermediary between China's nine-year compulsory education and higher education, and the scale and level of its development has a bearing on the quantity and quality of higher education students and the level of human capital in the social workforce, thus affecting the development of a country's economy. For a considerable period, China's urban-rural dual social structure has not only brought about an imbalance in socio-economic development, but also led to an asymmetric pattern of educational development level "binary division" between urban and rural areas, as well as between the east and west. This circumstance, in turn, has resulted in problems such as "school-choice fever" in economically advanced areas and "insufficient investment in education and inadequate construction of high-quality schools" in underdeveloped areas. These problems are shortcomings and weaknesses that impede the development of high school education, and are rooted in the irrational structure of input factor resources. In addition, general high school education persists as a relatively weaker aspect in the contemporary era of China's educational system across all levels and categories. Therefore, how to ensure efficient allocation of educational resources on the premise of realizing educational equity, while promoting well-coordinated and high-quality development of urban and rural high education, is an issue of particular concern to all sectors of the community.

1 Literature review

The rational allocation of educational resources has long been a contested issue in the field of educational economics. The term "educational resources" encompasses all human, material, and financial resources dedicated by the government and society to various types of education. The fair allocation of educational resources to different levels, categories, and regions by the government or society based on specific guidelines is what we refer to as the allocation of educational resources. The purpose of allocating educational resources is to achieve efficiency[1], which involves the critical issue of balancing various levels and types of education with social demand. Therefore, it is a crucial theoretical and practical issue that scholars have long been concerned with researching.

In terms of research objects, numerous studies have examined the allocation efficiency of various types of educational resources at the micro level. Lin *et al.* [2] conducted research on the efficiency of Taiwan's compulsory education system and its internal primary and secondary school subsystems, and found that excessive investment in teachers and staff is the primary cause of low allocation efficiency. Queirozet *et al.* [3] conducted an objective assessment of primary education efficiency in Brazil and concluded that investing in school infrastructure might lead to improvements. C. O. Henriques *et al.* [4] analyzed data from Program for Interna-

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tional Student Assessment (PISA) to assess the efficiency of 159 high schools in Ecuador, and concluded that the mean score for all abilities in Ecuadorian high schools is inferior to that of countries in Latin America and the Caribbean. Zhang *et al.* [5] assessed the efficiency of resource allocation for higher education across provinces in the Chinese mainland, and found that higher education in eastern China is comparatively developed, while improvement is needed in some other provinces, thereof the disparity between underdeveloped and developed regions requires attention. Ramzi *et al.* [6] assessed the efficiency of primary and secondary education across 24 Tunisian provinces and found disparities in educational efficiency among these regions. Agasisti *et al.* [7] conducted a thorough efficiency analysis of around 10 600 public primary schools in Brazil in 2017, and the findings showed an average efficiency score of 87%, but there were also notable variations across different regions of the country. Aristovnik *et al.* [8] evaluated the technical efficiency of secondary education in both EU and OECD member nations, and empirical findings indicated substantial variations in the technical efficiency of secondary education across most EU and OECD countries.

From a research methodology perspective, it has become a prevalent practice to use empirical techniques in assessing the efficiency of educational resource allocation. Various methods can be employed, such as marginal analysis, structural analysis, capability analysis, mathematical statistics, parametric analysis, and non-parametric analysis to evaluate efficiency. Since the DEA method does not impose rigorous constraints on input-output indicators[9], Data Envelopment Analysis (DEA) is commonly employed by researchers to examine the efficiency of resource allocation[10]; Daryani Z. S *et al.* [11], Cheng *et al.* [12] Popovi M *et al.* [13], Tavares *et al.* [14] developed the Network Data Envelopment Analysis (NDEA) to measure the efficiency of higher education institutions. See *et al.* [15] proposed a relatively objective method-Hierarchical Data Envelopment Analysis (H-DEA) to rank higher education systems. Sun *et al.* [16] proposed a dual boundary parallel data envelopment analysis model to evaluate the performance of higher education systems. Huang *et al.* [17] analyzed the efficiency of resource allocation in preschool education based on random finite sets and random matrices.

After examining a broad range of existing research, it is evident that the utilization of DEA method for assessing the efficiency of educational resource allocation has reached a state of maturity. Previous research has extensively examined the efficiency of educational resource allocation across all levels and types, yielding plentiful research outcomes. However, it is evident that despite numerous research studies, there remains a distinct lack of investigation into the efficiency of educational resources in high school education. While numerous studies have explored the allocation of high school education resources, few have assessed the efficiency of such allocation holistically. Moreover, there is a scarcity of research on the efficiency of high school educational resource allocation from an urban-rural perspective. Based on this, to comprehend the efficiency of high school educational resource allocation in both urban and rural regions of China, this paper uses the DEA model to carry out a static evaluation. The Malmquist index is utilized to dynamically appraise the overall factor efficiency of high school education resources in urban and rural areas, with the aim of discovering a practical strategy to facilitate the comprehensive, balanced, and symmetrical development of high school education in both urban and rural areas of China from static and dynamic perspectives.

2 Research methods

2.1 DEA model The input-oriented CCR (constant return to scale) model and the dyadic form of the BCC (variable return to scale) model are widely used and will not be reiterated. The efficiency measures are overall technical efficiency (*TE*), scale efficiency (*SE*), and pure technical efficiency (*PTE*). The relationship between the three is $TE = SE \times PTE$, where all efficiency values range between 0 and 1. A value closer to 0 indicates inefficient operation, whereas a value closer to 1 implies optimal effectiveness. This study utilizes the CRS model with constant return to scale and the VRS model with variable return to scale to analyze the efficiency of allocating resources for high school education in China. Overall efficiency is indicative of the overall capacity of high school educational resource allocation, whereas technical efficiency is influenced primarily by management factors, technical factors, and relevant systems. Scale efficiency is the production efficiency impacted by the scale factor of high school education resources, which is used to show whether the optimal state of high school education resource scale can be reflected in current provinces.

2.2 Malmquist productivity index The efficiency values gauged by conventional DEA models fail to capture the dynamic changes in investment performance over a period of time. In view of this, this study introduces the Malmquist Total Factor Productivity Index (TFP) to enable the dynamic evaluation of high school educational resource allocation efficiency in different provinces (autonomous regions, municipalities) and regions across China. The Malmquist productivity index was first put forward by Sten Malmquist, a Swedish economist and statistician, in 1953, and later, it was developed by Caves *et al.* Nowadays, it is widely used to measure the efficiency of resource allocation. The calculation formula (1) represents the Malmquist total factor productivity index from period t to $t+1$.

Assuming a constant scale efficiency, the Malmquist productivity index can be decomposed into the product of the technical efficiency change index and the technical progress change index, as shown in formula (2).

Under the assumption of variable scale efficiency, the technical efficiency change index (EC) is further decomposed into pure technical efficiency change (PECH) and scale efficiency change (SECH). The decomposition formula is as follows (3):

$$M(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left[\frac{D^t(Y_t, X_t)}{D^t(Y_{t+1}, X_{t+1})} \times \frac{D^{t+1}(Y_t, X_t)}{D^{t+1}(Y_{t+1}, X_{t+1})}\right]^{-\frac{1}{2}} \quad (1)$$

$$M(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left[\frac{D^t(Y_t, X_t)}{D^{t+1}(Y_{t+1}, X_{t+1})}\right]^{-1} \times \left[\frac{D^{t+1}(Y_{t+1}, X_{t+1})}{D^t(Y_{t+1}, X_{t+1})} \times \frac{D^{t+1}(Y_t, X_t)}{D^t(Y_t, X_t)}\right]^{-\frac{1}{2}} \quad (2)$$

$$M(Y_{t+1}, X_{t+1}, Y_t, X_t) = EC \times TE = (PECH \times SECH) \times TE \quad (3)$$

2.3 Input-output indicator The resource allocation efficiency primarily depends on the rationality of input-output combinations. Therefore, this study aims to establish an indicator system for assessing the efficiency of resource allocation in urban and rural high school education, based on these two fundamental factors. Investment in education comprises of resources and elements allocated by government departments towards the progression of high school education, typically including financial, human, and material resources. Based on previous research[18-21], this study has chosen input indicators, including number of full-time teachers, number of teachers with bachelor's degree or above, educational expenses, number of books, number of computers for teaching, total value of instrument and equipment, sports facility area, and school building area. Considering output variables, the number of students on campus is selected as a quantitative output indicator, and the number of graduates is selected as a quality output indicator, as shown in Table 1.

Table 1 Indicator system for educational resource allocation efficiency in urban and rural high schools

Level 1 index	Level 2 index	Level 3 index
Input indicator	Human resources	Number of full-time teachers
		Number of teachers with bachelor's degree or above
	Financial resources	Average education expenditure per student
		Number of books
	Material resources	Number of computers for teaching
		Total value of instrument and equipment
Output indicator	Number of students	Sports facility area
		School building area
		Number of students on campus
		Number of graduates

2.4 Data source description Given the availability of data, this paper has chosen to the allocation of urban and rural high school education resources in 30 provinces (autonomous regions, municipalities directly under the central government) in China, excluding Tibet, as the research object. The sample period covers the years 2007 to 2022, and the *China Educational Statistical Yearbook and China Educational Finance Statistical Yearbook* are used as the primary data sources. In addition, when analyzing and comparing the efficiency of resource allocation for urban and rural high school education in various regions, this paper draws on the division methods of other scholars' papers for the eastern, central, and western regions to divide the three major regions. The eastern region includes 11 provinces: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan, and the central region includes 8 provinces: Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan, while the western region includes 11 provinces: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

3 Result analysis

3.1 Analysis of static changes in resource allocation efficiency

3.1.1 Analysis on the resource allocation efficiency in urban and rural high school education. The DEA model is employed to calculate the overall technical efficiency of resource allocation for high school education in China from 2007 to 2020, as presented in Table 2. The results show that the efficiency of resource allocation for urban and rural high school education is relatively low. During the sample period, the general technical efficiency of educational resource allocation to urban and rural high schools in China did not attain DEA efficiency, suggesting that the present investment factors across different resources in China's urban and rural high school education have not achieved their optimum combination and are declining annually. In addition, during the sample period, there are 5 years in which some provinces in cities achieved DEA efficiency in high school educational resource allocation, namely in 2007 (5), 2008 (3), 2010 (5), 2011 (2), and 2012 (3), while in rural areas, only some provinces achieved DEA efficiency in 2007 (7), 2008 (5), 2009 (2), 2011 (2) and 2012 (2). From the average overall efficiency of each province (autonomous region, municipality) during the comprehensive sample period (as shown in Fig. 1), it can be observed that urban high schools have much higher technical efficiency in allocating education resources than rural areas.

To further analyze the underlying causes, this paper decomposes overall technical efficiency into pure technical efficiency and scale efficiency. Over the sample period, China's high school educational resource allocation was inefficient due to the joint impact of scale efficiency and pure technical efficiency. However, the gap between overall scale efficiency and pure technical efficiency is increasing annually. The primary cause for the inadequate allocation of high school education resources in China is the low efficiency regarding the utilization of high school education infrastructure. By analyzing the provinces (autonomous regions, municipalities) with ineffective scales, it is found that the majority of such provinces (autonomous regions, municipalities) are experiencing an increase in scale, indicating that the efficiency of high school educational resource allocation can be improved by increasing the scale of resource investment.

Table 2 Efficiency of resource allocation for urban and rural high school education in China from 2007 to 2022

Year	Crste		Vrste		Scale	
	Urban	Rural	Urban	Rural	Urban	Rural
2007	0.877 (5)	0.851 (7)	0.913 (5)	0.897 (7)	0.961 (5)	0.949 (7)
2008	0.856 (3)	0.823 (5)	0.896 (3)	0.873 (5)	0.955 (3)	0.942 (5)
2009	0.829 (0)	0.801 (2)	0.865 (0)	0.851 (2)	0.958 (0)	0.941 (2)
2010	0.835 (5)	0.791 (0)	0.872 (5)	0.863 (0)	0.959 (5)	0.923 (0)
2011	0.815 (2)	0.780 (2)	0.852 (2)	0.847 (2)	0.958 (2)	0.925 (2)
2012	0.795 (3)	0.749 (2)	0.834 (3)	0.816 (2)	0.956 (3)	0.922 (2)
2013	0.765 (0)	0.713 (0)	0.804 (0)	0.790 (0)	0.955 (0)	0.910 (0)
2014	0.738 (0)	0.677 (0)	0.779 (0)	0.752 (0)	0.951 (0)	0.908 (0)
2015	0.714 (0)	0.658 (0)	0.753 (0)	0.737 (0)	0.953 (0)	0.903 (0)
2016	0.687 (0)	0.639 (0)	0.726 (0)	0.733 (0)	0.951 (0)	0.894 (0)
2017	0.669 (0)	0.620 (0)	0.704 (0)	0.714 (0)	0.954 (0)	0.891 (0)
2018	0.663 (0)	0.614 (0)	0.698 (0)	0.704 (0)	0.952 (0)	0.893 (0)
2019	0.659 (0)	0.609 (0)	0.691 (0)	0.698 (0)	0.956 (0)	0.896 (0)
2020	0.653 (0)	0.606 (0)	0.685 (0)	0.694 (0)	0.957 (0)	0.897 (0)
2021	0.655 (0)	0.607 (0)	0.691 (0)	0.689 (0)	0.954 (0)	0.901 (0)
2022	0.658 (0)	0.599 (0)	0.698 (0)	0.679 (0)	0.951 (0)	0.904 (0)

NOTE The values in parentheses represent the number of valid provinces (autonomous regions, municipalities).

3.1.2 Efficiency of resource allocation for urban and rural high school education in the eastern, central, and western regions. To gain a better understanding of the variances in the allocation efficiency of high school education resources between urban and rural areas in China, this paper examines the allocation efficiency of high school education resources in the urban and rural regions of eastern, central, and western China, as shown in Table 3. Overall, throughout the sample period, the efficiency of high school educational resource allocation in urban areas in the eastern, central and western regions of China was significantly higher than in rural areas. Additionally, it is worth noting that in both urban and rural settings, the overall technical efficiency, pure technical efficiency, and scale efficiency of the allocation of high school education resources are considerably higher in the central region compared to the eastern and western regions (as shown in Fig. 2). However, the inefficiency in overall efficiency from the perspective of pure technical and scale efficiency is observed both in urban and rural areas. This inefficiency is caused by the combination of pure technical inefficiency and scale inefficiency. Nevertheless, a notable difference is observed in the eastern region, where the inefficiency in overall efficiency is mainly due to pure technical inefficiency, while the impact of scale efficiency is relatively low. The ineffective efficiency of scale in the western region has a more significant impact on overall efficiency compared to rural areas. This implies an irrational pattern of invest-

Table 3 National high school education total factor productivity index and decomposition from 2007 to 2020

Year	Urban					Rural				
	EC	*TC*	*FEC*	*SEC*	*TFP*	*EC*	*TC*	*FEC*	*SEC*	*TFP*
2007 – 2008	1.007	0.964	1.006	1.002	0.971	1.016	0.932	1.002	1.014	0.946
2008 – 2009	0.996	0.960	0.989	1.007	0.956	1.017	0.927	1.007	1.010	0.942
2009 – 2010	0.984	1.025	0.988	0.997	1.008	0.995	0.974	1.011	0.990	0.970
2010 – 2011	1.003	0.967	1.006	0.996	0.969	1.007	0.976	1.006	1.001	0.982
2011 – 2012	0.994	0.972	0.990	1.005	0.966	1.000	0.962	1.002	0.999	0.962
2012 – 2013	1.017	0.942	1.004	1.013	0.959	0.992	0.936	1.000	0.993	0.928
2013 – 2014	1.001	0.965	1.001	1.000	0.967	0.990	0.591	0.988	1.002	0.584
2014 – 2015	0.984	0.973	0.987	0.997	0.957	0.975	0.985	0.990	0.985	0.960
2015 – 2016	1.006	0.948	0.997	1.009	0.954	0.983	0.996	0.995	0.988	0.949
2016 – 2017	0.988	0.977	0.997	0.991	0.965	1.006	0.959	1.002	1.004	0.964
2017 – 2018	0.992	0.986	1.006	0.986	0.978	0.980	0.996	0.988	0.993	0.976
2018 – 2019	1.004	0.968	0.999	1.005	0.972	1.026	0.948	1.005	1.021	0.972
2019 – 2020	1.008	0.927	1.008	1.000	0.935	1.013	0.919	1.015	0.998	0.931
2020 – 2021	1.026	0.981	1.023	1.003	1.006	1.035	0.973	1.017	1.018	1.006
2021 – 2022	1.018	0.981	1.009	1.009	0.999	1.018	0.978	1.013	1.006	0.996

NOTE *TFP* is the total factor productivity change index; *TC* is the technical progress changes index; *EC* is the technical efficiency change index; *PEC* is the pure technical efficiency change index; *SEC* denotes the scale efficiency change index. The same below.

ment in factors within the eastern region of China, which involves excessive and pointless expenditure of both human and financial resources. Furthermore, factor investment in the western region suffers from an unreasonable structure and a lack of scale investment, particularly in rural areas where education resource investment is conspicuously inadequate.

3.2 Analysis of dynamic changes in resource allocation efficiency Based on the static analysis of high school education resources in the previous section and the panel data of high school education resource input-output from 30 provinces in China spanning from 2007 to 2022, the total factor productivity and various decomposition indicators of high school education in 30 provinces from 2007 to 2022 are measured and dynamically analyzed and evaluated using the Malmquist index method.

3.2.1 Annual average total factor productivity of urban and rural high school education from 2007 to 2022. As delineated in Table 3, the total factor productivity (TFP) of urban-rural senior high school educational resources in China exhibited an overall declining trajectory throughout the sample period. Positive growth was confined exclusively to urban sectors during the 2009 – 2010 and 2020 – 2021, and to rural sectors solely in the 2020 – 2021 period. Overall, despite the fluctuation of total factor productivity in Chinese high school education, there has been an overall downward trend. The decline in urban regions is relatively minor, with an average decrease of 2.92 percentage points, whereas in rural areas, it has decreased by 6.21%. In contrast, the decline in rural areas is even greater. The changes in TFP are jointly influenced by EC and TC. Further analysis indicates that the primary cause of the decline in total factor productivity (TFP) of high school education resources in urban and rural China during the sample period was the reduction in the technology progress index. In urban areas, the average technical efficiency (TC) decreased by 3.09%, which is consistent with the decline in TFP, while the efficiency change (EC) increased by 0.19%. In rural areas, the average TC decreased by 6.32%, which is almost equivalent to the decline in TFP, whereas EC increased by 0.35%. A comparative analysis reveals a marked asymmetry in educational resource allocation between rural and urban areas in China. Urban high schools receive better coverage compared to rural counterparts, particularly following a fluctuation in rural technology levels between 2017 and 2018, which brought about a considerable decrease. This decrease was subsequently the leading cause of the decrease in the general factor level of rural high school education. However, the high school educational resource allocation's technical efficiency index displays a consistent fluctuation trend, with a "downward-upward" pattern, in both urban and rural areas. Before 2017 – 2018, it experienced a varying degree of decline, followed by an irregular degree of upward trend.

3.2.2 Total factor productivity index of urban and rural high school education and its decomposition. As delineated in Table 4, the dynamic evolution of total factor productivity (TFP) in urban and rural senior high school education across China's provinces (including autonomous regions and municipalities directly under the central government) reveals a pervasive downward trajectory throughout the sample period. Specifically, the TFP change indices for all 30 provincial-level administrative units were less than unity, indicating varying degrees of decline in the productivity of urban senior high school resource allocation.

Table 4 Total factor productivity index and decomposition of urban and rural high school education in all provinces (autonomous regions, municipalities) of China from 2007 to 2020

Province	Urban					Rural				
	EC	*TC*	*FEC*	*SEC*	*TFP*	*EC*	*TC*	*FEC*	*SEC*	*TFP*
Beijing	1.007	0.976	1.005	1.003	0.983	1.015	0.976	1.001	1.016	0.989
Tianjin	1.009	0.970	1.009	1.002	0.978	1.027	0.962	1.007	1.022	0.987
Hebei	1.001	0.968	1.001	1.001	0.968	1.008	0.915	1.013	0.996	0.920
Shanxi	0.995	0.965	0.995	1.001	0.960	1.000	0.896	0.998	1.003	0.895
Inner Mongolia	0.985	0.962	0.986	1.000	0.948	0.988	0.910	0.984	1.004	0.900
Liaoning	1.001	0.941	1.000	1.001	0.941	1.002	0.925	1.000	1.002	0.928
Jilin	1.000	0.961	1.000	1.000	0.961	1.000	0.919	1.000	0.999	0.922
Heilongjiang	1.000	0.968	1.000	1.000	0.968	1.000	0.900	1.000	1.000	0.900
Shanghai	0.988	0.971	0.984	1.004	0.960	1.000	0.968	1.022	0.988	0.968
Jiangsu	1.005	0.972	1.007	0.999	0.977	1.006	0.958	1.005	1.000	0.964
Zhejiang	1.004	0.978	1.005	1.000	0.981	1.005	0.975	1.003	1.002	0.979
Anhui	0.999	0.971	0.999	1.000	0.970	0.993	0.944	0.998	0.995	0.937
Fujian	1.017	0.975	1.016	1.001	0.992	1.016	0.958	1.016	1.000	0.973
Jiangxi	1.010	0.970	1.006	1.004	0.979	1.004	0.908	1.006	0.998	0.911
Shandong	0.994	0.970	1.000	0.994	0.963	1.000	0.938	1.003	0.997	0.936
Henan	1.000	0.948	1.000	1.000	0.948	1.000	0.882	1.000	1.000	0.882
Hubei	0.998	0.959	0.999	1.000	0.958	1.001	0.926	1.001	1.000	0.927
Hunan	1.009	0.971	1.008	1.001	0.979	1.014	0.942	1.014	1.000	0.954
Guangdong	1.008	0.968	1.013	0.997	0.975	1.004	0.954	1.008	0.997	0.956

(To be continued)

(Continued)

Province	Urban					Rural				
	EC	*TC*	*FEC*	*SEC*	*TFP*	*EC*	*TC*	*FEC*	*SEC*	*TFP*
Guangxi	1.002	0.973	1.001	1.001	0.975	1.007	0.908	1.006	1.001	0.915
Hainan	1.007	0.973	0.998	1.010	0.980	0.995	0.940	0.995	1.000	0.935
Chongqing	1.011	0.975	1.004	1.007	0.986	1.003	0.967	1.000	1.003	0.970
Sichuan	0.977	0.974	0.998	0.998	0.971	1.003	0.946	1.010	0.994	0.948
Guizhou	0.996	0.975	0.996	1.000	0.971	1.001	0.930	1.002	0.999	0.931
Yunnan	1.013	0.978	1.009	1.004	0.990	1.014	0.931	1.016	0.999	0.945
Shaanxi	0.996	0.973	0.996	1.000	0.969	0.985	0.945	0.985	0.999	0.930
Gansu	0.992	0.978	0.995	0.997	0.970	0.988	0.939	0.988	1.000	0.927
Qinghai	1.009	0.973	1.000	1.009	0.980	1.001	0.907	0.997	1.006	0.910
Ningxia	1.007	0.969	1.000	1.007	0.974	1.014	0.944	0.999	1.015	0.959
Xinjiang	0.995	0.972	0.996	0.999	0.966	1.015	0.929	1.010	1.005	0.941
Eastern	1.004	0.969	1.003	1.001	0.973	1.007	0.952	1.006	1.002	0.958
Midland	1.001	0.964	1.001	1.001	0.966	1.001	0.915	1.002	0.999	0.916
Western	1.000	0.973	0.998	1.002	0.973	1.002	0.932	1.000	1.002	0.934
China	1.002	0.969	1.001	1.001	0.970	1.004	0.933	1.003	1.001	0.936

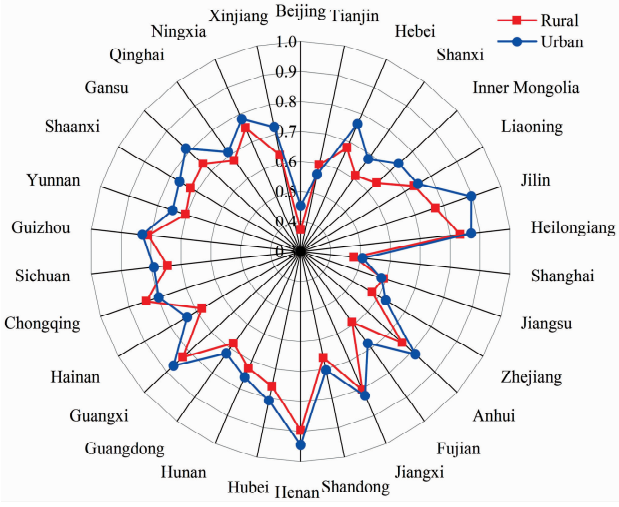

Fig. 1 Overall efficiency of resource allocation for urban and rural high school education from 2007 to 2022

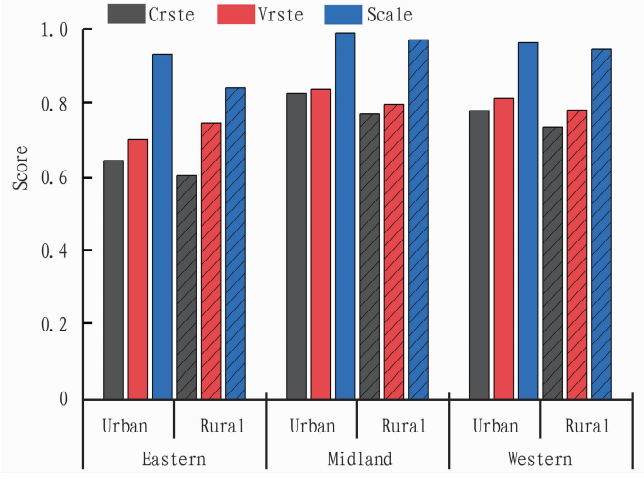

Fig. 2 Evolution trend of resource allocation efficiency of urban and rural high school education in the east, central, and west regions

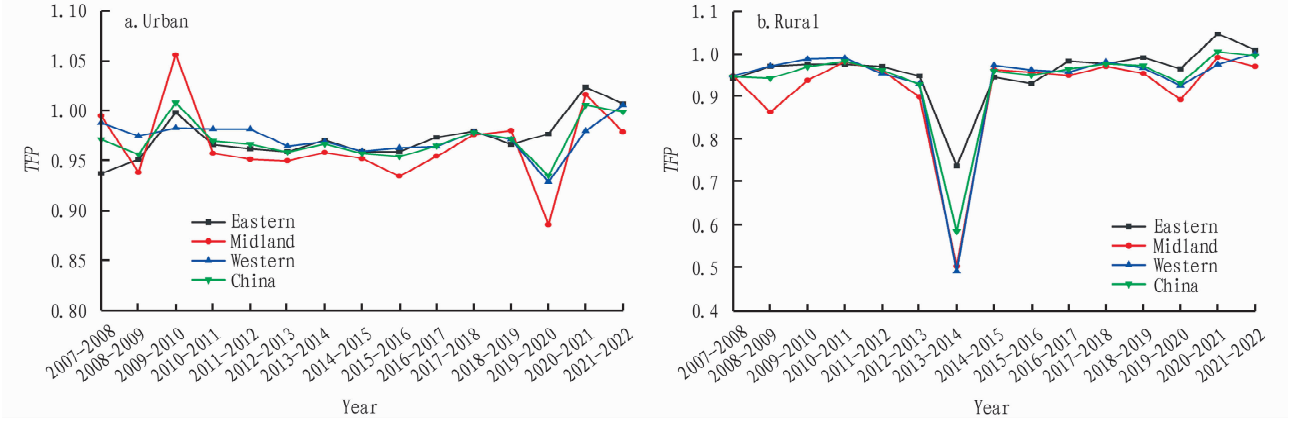

Fig. 3 Evolution of total factor productivity index for high school educational resource allocation in urban and rural areas of east, central, and west regions

In those provinces where the urban TFP change index fell below 1, the technical progress index was predominantly less than 1, whereas the technical efficiency index generally exceeded 1. This pattern suggests that the deceleration in technical progress consti-

tutes the primary driver behind the overall deterioration in TFP for urban-rural senior high school resource allocation in China. Nevertheless, it should be acknowledged that the decline in TFP across numerous provinces was also partially attributable to reductions in technical efficiency.

In contrast to urban areas, the TFP change indices for rural senior high school education remained consistently below 1 during the sample period, reflecting a nationwide trend of declining productivity in rural senior high school resource allocation between 2007 and 2022. This downturn is primarily ascribed to the fact that the technical progress index for rural senior high school resource allocation remained below 1 throughout the observation window. In particular, only three provincial-level units (Beijing, Tianjin, and Shanghai) exhibited higher rural TFP levels compared to their urban counterparts; in the remaining 27 provinces, rural TFP lagged behind urban performance.

Overall, both urban and rural sectors experienced a generalized decline in the TFP of senior high school resource allocation. Of particular concern is the pronounced reduction in the technical progress index, which decreased at a faster rate in rural areas than in urban ones. This disparity further underscores how China's dualistic urban-rural educational structure perpetuates an asymmetric allocation of senior high school resources. As a result, the imbalanced and inadequate development of senior high school education remains a critical challenge, while issues pertaining to the inequitable distribution of urban-rural educational resources and the broader quest for educational equity have yet to be fundamentally resolved.

3.2.3 Analysis of regional differences in the total factor productivity index and its decomposition of urban and rural high school educational resource allocation. To comprehend the changing patterns in the total factor productivity of urban and rural high school educational resource allocation across different Chinese regions, the total factor productivity index for urban and rural high school educational resource allocation across the eastern, central, and western regions of China is calculated, as shown in Fig. 3. It can be observed that total factor productivity of high school educational resource allocation in urban and rural areas of the eastern, central, and western regions of China is declining. Rural areas are experiencing a more significant decline than urban areas. From the analysis of productivity changes, the primary factor leading to the decline in total factor productivity for the allocation of educational resources in urban and rural high schools in the eastern, central, and western regions of the city is the reduction in the technical progress index. The decline in the total factor productivity of education resources allocation in urban high schools is not only affected by the reduction in the technical progress index, but also by the decline in the technical efficiency index. In rural high school resource allocation, only the decrease in total factor productivity in the eastern region is impacted by the decline in the technical efficiency index. The technical proficiency index in the central and western regions displays an increasing or unchanged trend, which exemplifies the national support bolstering the central and western regions.

4 Conclusions and policy recommendations

4.1 Conclusions In this study, the DEA model and Malmquist index method are applied, pertinent data from 30 provinces (autonomous regions, municipalities directly under the central government) in China are analyzed, the static ranking and dynamic evolution trend of high school educational resource allocation in each province and city are calculated, and differences between urban and rural areas within each region are further analyzed. Based on the calculation results, the following conclusions are drawn.

4.1.1 The efficiency of resource allocation in China's high school education is generally low, and rural areas are at lower level than urban areas. First, the empirical assessment reveals that the overall efficiency of senior high school educational resource allocation in China remains suboptimal. While urban areas exhibit relatively higher scale efficiency compared to their rural counterparts, a nuanced divergence is observed in comprehensive TE. Historically, urban TE was generally lower than that of rural areas; however, a structural reversal occurred in 2012, after which urban TE consistently surpassed rural levels. Of particular note is the precipitous decline in rural TFP during the 2013 – 2014 period, where TFP plummeted to 0.584 and the TC index dropped to 0.591, marking historical lows. This anomaly underscores the inherent fragility of rural educational resource allocation mechanisms. Although a transient rebound in TFP was observed across both urban and rural sectors in 2020 – 2021, the subsequent retreat in 2021 – 2022 indicates that such efficiency improvements lack sustainability. Throughout the sample period, the TFP of senior high school resource allocation in China's urban-rural divide remained at a low level with a general downward trajectory, with rural areas experiencing a more pronounced contraction than urban areas. Decomposition analysis identifies negative technical progress as the primary constraint hindering TFP growth, whereas the contribution of technical efficiency change to TFP variations was statistically insignificant. At the provincial level, Liaoning recorded the most substantial decline in urban TFP, whereas Henan exhibited the sharpest deterioration in rural TFP. Furthermore, an analysis of input slacks clearly demonstrates that resource wastage is more severe in rural regions than in urban ones. This disparity in input utilization further corroborates the finding that the efficiency of senior high school resource allocation is systematically lower in rural areas.

4.1.2 There are disparities in the efficiency allocation of high school education resources in urban and rural areas across the eastern, central, and western regions. During the sample period, both the comprehensive technical efficiency and pure technical efficiency of urban senior high school resource allocation in China's eastern, central, and western regions were lower than those in rural areas. In particular, the eastern region outperformed both the central and western regions in these two efficiency metrics for both

urban and rural sectors. Across all three regions, comprehensive technical efficiency and pure technical efficiency for urban-rural senior high school resource allocation exhibited an upward trajectory, reflecting continuous optimizations in operational institutions and management technologies. This improvement was particularly pronounced in rural areas. In terms of scale efficiency, performance remained relatively stable for both urban and rural sectors in the eastern and western regions; however, a downward trend was observed specifically in the rural sector of the central region. Regarding the TFP of senior high school resource allocation across the eastern, central, and western regions, the magnitude of decline in urban areas was significantly smaller than that in rural areas. Decomposition analysis reveals that the changes in urban TFP across all three regions were primarily driven by a decline in technical progress (technological change), whereas the impact of technical efficiency change was statistically insignificant.

4.2 Policy recommendations (i) It is recommended to formulate an integrated planning for educational resource allocation in both urban and rural regions, optimize the structure of resource allocation, and avoid blind investment. The central and local governments shall enhance the overall planning of high school educational resource allocation across urban and rural regions. Based on the current state of high school education development across various provinces, cities, and urban and rural areas, as well as in each individual province and region, it is essential to make scientific predictions on specific needs for an on-demand and precise allocation. Additionally, optimizing the spatial layout of high school educational resource allocation in urban and rural areas is crucial. In areas with limited resources, detailed analysis is crucial to determine which areas need to be further invested, and how much to invest, to avoid duplicate investment of resources, and to appropriately reduce investment in provinces and regions with excess and redundant resources. For example, for provinces and cities with high levels of economic development in the eastern coastal areas, or areas with relatively backward western regions but strong policy support, resource investment should be controlled, and special attention should be paid to avoiding blind investment in rural areas.

(ii) It is necessary to strengthen technical guidance for inefficient resource allocation areas and improve utilization efficiency. According to the research findings of this paper, the inadequate efficiency of high school educational resource allocation in either urban or rural areas cannot solely be attributed to insufficient resource inputs. In addition, the imperfect management systems of educational institutions, unreasonable personnel allocation, decision-making errors and poor management by managers also contribute to this inefficiency. Therefore, the government must endeavour to bolster aid for the management technology of high school institutions, especially in rural areas with relatively underdeveloped economies in the western region and various provinces and cities.

(iii) It is recommended to establish a performance evaluation mechanism and improve the construction of resource investment performance evaluation system. The government shall establish a system for performance management and enforce strict regulations for managing the investment performance of high school education resources. In case of provinces with low performance scores, it is crucial to identify the reasons, amplify investment in areas with inadequate spending, enhance the standardization of regular high schools, and efficaciously improve the operational infrastructure of regular high schools. In addition, it is crucial to clarify the responsibilities and duties of relevant department entities, overcome the management challenges posed by the "binary division" between urban and rural areas, and introduce real-time monitoring and dynamic evaluation at multiple levels for comprehensive oversight.

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