Study on the Urban Efficiency of Guangdong- Hong Kong-Macao Greater Bay Area Based on DEA and Malmquist Model

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Abstract. This study selects land, capital, labor, and information technology as input indicators, and regional GDP as an output indicator, and uses DEA model and Malmquist index method to analyze the urban efficiency and its variation of 11 cities in Guangdong-Hong Kong-Macao Greater Bay Area in 2011, 2013, and 2015. Through the research, it has been found that: ① The overall efficiency of Guangdong-Hong Kong-Macao Greater Bay Area, an economically developed area in China, is not high, and only a few cities such as Guangzhou, Foshan, Hong Kong, and Macao have achieved the optimal overall efficiency, and the scale efficiency is the main factor determining the optimal overall efficiency; ② From the perspective of three major economic sectors, the overall efficiency of "Guangzhou-Foshan-Zhaoqing" sector is higher than that of "Shenzhen-Dongguan-Huizhou-Hong Kong" Sector and "Jiangmen-Zhongshan-Zhuhai-Macao" sector; from the perspective of urban size, there is no obvious correlation between urban efficiency and the size of urban population; ③ From the perspective of variation trend, the variability index of urban overall efficiency and productivity shows weak declining trend, and the main factor affecting the change of overall efficiency and productivity is the change of scale efficiency; the urban overall efficiency decline of Shenzhen-Dongguan-Huizhou-Hong Kong sector is the most obvious. Except for medium-sized cities, the overall efficiency of mega cities and big cities is declining.

Keywords: DEA model; Malmquist index; urban efficiency; Guangdong-Hong Kong- Macao Greater Bay Area

1 Introduction

As the gathering center of the production factors of the country and regions, the city's development level not only reflects the scale of the input and output of the city and the population growth, but also includes the efficiency and quality of urban development. In the context of economic globalization, the cities' competition has intensified, and the issue of urban development efficiency has attracted widespread attention. At present, there are parametric and nonparametric studies on efficiency in academia. The former mainly include Stochastic Frontier Analysis (SFA), Distribution Free Approach (DFA),

V. Escudero et al. (Eds.): BADS 2022, AHCS 11, pp. 300–312, 2023.
https://doi.org/10.2991/978-94-6463-102-9_33

Thick Frontier Approach (TFA), while the latter mainly include Data Envelopment Analysis (DEA), Index Analysis (IN), Free Disposal Hull (FDA), and Mixed Optimal Strategy (MOS). However, Charnes believes that DEA method is particularly suitable for the evaluation of urban system efficiency [1].

Since the introduction of DEA method into China, it has been widely used in the fields including industrial resource allocation [2-5], land development and utilization [6-8], enterprise management [9], and urban management [10-11], and in the research on the urban efficiency of different levels. Yang Kaizhong and Xie Xie (2002) used DEA method to analyze the input-output efficiency of the municipalities directly under the Central Government and provincial capitals in China, and found that the input-output efficiency of western regions was much lower than that of eastern regions, and that larger city size did not mean greater output [12]. Li Xun, Xu Xianxiang, and Chen Haohui (2005) measured the spatio-temporal changes of China's urban efficiency from 1990 to 2000 by using DEA model. It was found that the urban efficiency of China was lower and presented the spatial pattern consistent with the economic development pattern and urban administrative hierarchy of the three major sectors. And it was believed that Chinese cities have great potential for development from the perspective of scale efficiency [13]; Wang Yiqing and Zhang Sihan (2011) evaluated the efficiency of urban economic development from the perspective of input and output in 18 cities in Henan Province, calculated the relative efficiency value of each city, and proposed some policy recommendations for improving the economic development efficiency of cities [14]. Chen Xueting, Song Tao, and Cai Jianming (2015) studied the urban metabolic efficiency of 31 cities in China by using DEA and Malmquist index. The results showed that Chinese cities have higher metabolic efficiency, overall efficiency, pure technical efficiency, and scale efficiency of cities in eastern and central China were higher than that of the western regions, and the efficiency of large cities was higher than that of mega cities and super large cities [15].

Domestic scholars have conducted effective studies on the efficiency of regional cities by using DEA models, but mainly focusing on the measurement of urban efficiency at a larger regional scale, and lacking research on the efficiency of medium-sized cities and smaller cities; many existing studies also focus on the horizontal comparisons among multiple cities, while research from the perspective of temporal and spatial evolution is less. Nowadays, as the implementation target of the new national regional development strategy, the development of Guangdong-Hong Kong-Macao Greater Bay Area has become the focus of all walks of life. At present, there are few studies on the efficiency of Guangdong-Hong Kong-Macao Greater Bay Area by using relative models. Therefore, based on the existing research results, this paper uses the DEA method and Malmquist index model to explore and analyze the efficiency of cities of different scale units in Guangdong-Hong Kong-Macao Greater Bay Area.

2 Research Model and Indicators

2.1 DEA Method

Data Envelopment Analysis (DEA) was first proposed by Fanel (1957) and was later developed by A.Charnes and W.W.Copper (1978). It is a quantitative analysis method to conduct relative effectiveness evaluation on units of the same type based on the study of relative efficiency [14]. Based on the CCR mode (or C2R mode) in the context of constant return to scale proposed by A.Charnes, W.W.Copper, and E.Rhodes, Banker, Charnes, and Copper[15] proposed DEA correction model of variable return to scale (VRS) in 1984, namely BCC model. Compared with CCR model, BCC model excludes the impact of scale efficiency, so that it can reflect the evaluation object more accurately. This study selects the BCC mode of DEA model. The DEA model can be divided into input-oriented type and output-oriented type [16]. The input-oriented type solves the decision-making problem of minimizing the input at a given output level, while output-oriented type solves the decision-making problem of maximizing the output under a given input condition. This study uses the input-oriented DEA model.

Suppose there are n decision making units (DMU), and each DMU has m input indicators and s output indicators. In the DEA method, it is generally required that the number n of decision units, the input indicator m and the output indicator s should satisfy the relation 2(m+s) ≦n, otherwise the credibility of the evaluation result would be reduced [14]. Suppose x_{mj} is the input amount of No. m resource of DMU_j, y_{sj} is the No. s output amount of DMU_j, for the input-oriented BCC mode, No. j ($j = 1,2,\ldots n$) DMU has following DEA model[18]:

$$\begin{cases} \min\theta \\ s.t.\sum_{j=1}^{n} x_j\lambda_j \leq \theta x_0 \\ \sum_{j=1}^{n} y_j\lambda_j \geq y_0 \\ \sum \lambda_j = 1, \lambda_j \geq 0, j = 1,2,\cdots,n \end{cases} \tag{1}$$

In the formula, θ is efficiency evaluation index, λ_j is the weight vector of each city's input and output. Through the calculation of this formula, the pure technical efficiency value (PTEC) of each city can be obtained, and the comprehensive efficiency value (EC) can be obtained by removing the convexity assumption ($\sum \lambda_j = 1$).

2.2 Malmquist Model

The Malmquist index was originally proposed by Malmquist in 1953, and Caves, Christensen, and Diewert first applied this index to the measurement of production efficiency variation in 1982. In 1994, RolfFäre et al. combined a nonparametric linear programming method of this theory with the data envelopment analysis (DEA), thus making the

Malmquist index widely used. Referring to the relevant literature, there is the following Malmquist productivity variation index model based on constant return to scale [16]:

$$TPFC=EC(CRS)\times TC(CRS) \quad (2)$$

The overall efficiency index is the product of the pure technical efficiency change index (VRS) and the scale efficiency change index (CRS, VRS), that is,

$$EC(CRS) = PTEC(VRS) \times SEC(CRS,VRS) \quad (3)$$

Therefore, Formula (2) can be further expressed as Malmquist productivity change index model including the variable return to scale [16]:

$$TPFC = PTEC(VRS) \times SEC(CRS,VRS) \times TC(CRS) \quad (4)$$

$TPFC$ in Formula(4) is CRS-based Malmquist productivity change index, and $PTEC(VRS)=\frac{D_v^t(x^{t+1},y^{t+1})}{D_v^{t+1}(x^t,y^t)}$ is VRS-based pure technical efficiency change index; $SEC(CRS,VRS)=\frac{D_v^t(xt,yt)}{D_c^t(xt,yt)}\times\frac{D_c^{t+1}(x^{t+1},y^{t+1})}{D_v^{t+1}(x^{t+1},y^{t+1})}$ is scale efficiency change index based on CRS and VRS; $TC(CRS)=[\frac{D_c^t(x^{t+1},y^{t+1})}{D_c^{t+1}(x^{t+1},y^{t+1})}\times\frac{D_c^t(x^t,y^t)}{D_c^{t+1}(x^t,y^t)}]^{\frac{1}{2}}$ is technical change index based on CRS in the period of time t and $t+1$, and D_c and D_v are distance functions based on CRS and VRS respectively, that is effective function value of input-oriented DEA model.

For the overall efficiency index, $EC(CRS)>1$ indicates that the DMU efficiency increases during the period of time t and $t+1$; $EC(CRS)=1$ indicates that the efficiency of the DMU has not changed during this period; $EC(CRS)<1$ indicates that the efficiency of the DMU decreases during this period. For the technology change index TC, the productivity change index $TPFC$, the pure technical efficiency change index $PTEC$ and the scale efficiency change index SEC, they have the same meaning of change [16].

2.3 Indicator Selection Description

How to optimize the input of various factors in the city has always been a core issue that urban economics is trying hard to solve. The output of a city is a function of various input factors. Yang Kaizhong and Xie Xie (2002) studied the efficiency of 30 municipalities directly under the Central Government and provincial capitals in China by taking the land use area, capital input amount and the number of laborers as input, and

GDP as output [12]. Guo Tengyun, Xu Yong, and Wang Zhiqiang (2009) selected capital, natural resources and human resource elements as input from the aspect of generalized elemental resources, in which total investment in fixed assets and circulating funds are used as capital input, land area represents the input of natural factor resources and all employees represents the input of human resources, and conducted in-depth study on the resource efficiency and changes of China's mega cities from 1990 to 2006 [16]. Wang Yiqing and Zhang Sihan (2011) studied the development efficiency of 18 cities in Henan Province by using capital and labor as input and measuring output in terms of economic aggregates and benefits. Investment in capital was expressed as fixed-asset investment and local fiscal budgetary expenditures, and output indicators were measured by GDP [14]. According to the availability of data, this study selected four elements of land, capital, labor and information technology as input indicators, and selected regional GDP as the output indicator. Among them, the urban built-up area, urban fixed-asset investment, the total number of employees, and the number of mobile phone users represent land resources, capital, labor and information input respectively. The data used in this paper are from "Statistical Yearbook of Chinese Cities" (2013-2018).

3 Analysis on the Urban Efficiency of Guangdong-Hong Kong-Macao Greater Bay Area

3.1 Urban Efficiency and Its Decomposition Analysis

By using the above DEA model, the overall efficiency (OE), pure technical efficiency (PTE) and scale efficiency (SE) of 11 cities in Guangdong-Hong Kong-Macao Greater Bay Area in 2013, 2015 and 2018 are respectively calculated. The results are shown in Tab.1.

Table 1. Efficiency of Cities in Guangdong-Hong Kong-Macao Greater Bay Area

Decision unit	2013				2015				2018			
	OE	TE	SE	Return to scale	OE	TE	SE	Return to scale	OE	TE	SE	Return to scale
Guang-zhou	1.000	1.000	1.000		1.000	1.000	1.000		1.000	1.000	1.000	
Shenzhen	0.805	1.000	0.805	drs	0.699	0.997	0.701	drs	0.751	0.981	0.766	drs
Zhuhai	0.873	1.000	0.873	irs	0.924	1.000	0.924	irs	0.978	1.000	0.978	irs
Foshan	1.000	1.000	1.000		1.000	1.000	1.000		1.000	1.000	1.000	
Huizhou	0.680	0.824	0.826	irs	0.713	0.809	0.881	irs	0.723	0.812	0.890	irs
Dongguan	0.989	1.000	0.989		1.000	1.000	1.000	irs	0.938	0.938	1.000	
Zhongshan	0.813	1.000	0.813		0.839	1.000	0.839	irs	0.939	1.000	0.939	irs
Jiangmen	0.655	1.000	0.655		0.743	0.986	0.754	irs	0.813	0.973	0.836	irs
Zhaoqing	0.671	1.000	0.671	irs	0.827	1.000	0.827	irs	0.906	1.000	0.906	irs
Hong Kong	0.895	1.000	0.895		1.000	1.000	1.000	drs	1.000	1.000	1.000	
Macao	1.000	1.000	1.000		1.000	1.000	1.000		1.000	1.000	1.000	
Average value	0.853	0.981	0.869		0.886	0.954	0.929		0.919	0.963	0.952	

3.1.1 Comprehensive Efficiency Analysis.

From Tab.1, it can be seen that the overall efficiency of 11 cities in Guangdong-hong Kong-macao Bay area did not reach the optimal level in all three years. In 2013,2015 and 2018, the average comprehensive efficiency of Guangdong-hong Kong-macao Bay area was 0.853,0.886 and 0.919 respectively. In 2013, only Guangzhou, Foshan and Macau had DEA efficiency, accounting for 27.27 percent of the total, while Huizhou, Jiangmen and Zhaoqing had lower overall efficiency of 0.680,0.655 and 0.671 respectively. In 2015, the DEA of Guangzhou, Foshan, Dongguan, Hong Kong and Macau was effective, accounting for 45.45 percent of all cities. The overall efficiency of the remaining six cities was not optimal, while that of Shenzhen, Huizhou and Jiangmen was low, the overall efficiency of Zhuhai, Zhuhai, Dongguan, Zhongshan, Zhaoqing and Hong Kong were 0.699,0.713 and 0.743 respectively, higher than in 2013. In 2018, only Dongguan did not achieve the best overall efficiency, and the performance of the other 10 cities was similar to that of 2015. The cities with the best overall efficiency were Guangzhou, Foshan, Hong Kong and Macau, among the other cities that did not achieve the best overall efficiency, Zhuhai, Zhongshan and Zhaoqing saw large increases in overall efficiency.

3.1.2 Pure Technical Efficiency Analysis.

In terms of pure technical efficiency, the situation of Guangdong-hong Kong-macao Bay area is better than that of comprehensive efficiency and scale efficiency. In the three years, the pure technical efficiency is 0.981,0.954 and 0.963 respectively. In 2013, the cities with the highest pure technical efficiency were Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan, Zhongshan, Jiangmen, Zhaoqing, Hong Kong and Macau. Only Huizhou did not achieve pure technical efficiency. In 2015, Guangzhou, Zhuhai, Foshan, Dongguan, Zhongshan, Zhaoqing, Hong Kong and Macau achieved the highest pure technical efficiency, with Shenzhen, Huizhou and Jiangmen achieving a pure technical efficiency of 0.997,0.809 and 0.986 respectively, these three cities failed to achieve pure technical efficiency. In 2018, except for Shenzhen, Dongguan, Huizhou and Jiangmen, all cities in east China achieved the highest pure technical efficiency. Huizhou's purely technical efficiency, while the lowest, is higher than in 2015.

3.1.3 Scale Efficiency Analysis.

Scale efficiency is the main factor that determines the optimum comprehensive efficiency. As can be seen from table 1, the most efficient cities of scale in 2013 were Guangzhou, Foshan and Macau, which became five cities in 2015, Guangzhou, Foshan, Dongguan, Hong Kong and Macau, while the situation was similar in 2018 and 2015, guangzhou, Foshan, Dongguan, Hong Kong and Macau are still five cities, while the rest are not the most scale efficient. From the three years, we can see that the change trend of scale efficiency is similar to that of comprehensive efficiency. In terms of returns to scale, in the three years of 2013,2015 and 2018, the number of cities with increasing returns to scale were 6,5 and 6 respectively, while in the three years of Shenzhen, returns to scale kept decreasing. The scale efficiency of Guangzhou, Foshan and Dongguan in Guangdong-hong Kong-macao Bay area is ideal, which shows that the existing city scale level is reasonable and the factor resource allocation efficiency is high. Cities such as Zhuhai, Huizhou, Zhongshan, Jiangmen and Zhaoqing should be scaled up to make them more efficient. Especially in cities such as Zhongshan and Jiangmen, the scale return has changed from constant in 2013 to increasing in 2015 and 2018, and the scale effect is obvious. Through the analysis on the above three aspects, it can be found that for Guangdong-Hong Kong-Macao Greater Bay Area, the pure technical efficiency is higher, overall efficiency and scale efficiency are lower, and scale efficiency is the decisive factor of overall efficiency. The possible explanation is that the development of cities in Guangdong-Hong Kong-Macao Greater Bay Area is fast, and the utilization degree of the invested resources of the cities is higher. However, the development of existing industries is still extensive, and the situation that labor-intensive industries account for a relatively large proportion in most cities still exists. Under the existing technological conditions in various years, the expansion of the city scale shows extensive features. If the scale of the city can be reasonably and effectively expanded and steadily promoted, under the current level of investment, the urban efficiency of Guangdong-Hong Kong-Macao Greater Bay Area can be improved a lot.

3.2 Urban Efficiency and Urban Classification Analysis

3.2.1 Comparison of Urban Efficiency of the Three Major Economic Sectors.

From the perspective of geographical proximity and spatial agglomeration, Guangdong-Hong Kong-Macao Greater Bay Area can be divided into Guangzhou-Foshan-Zhaoqing (GFZ) sector, Jiangmen-Zhongshan-Zhuhai-Macao (JZZM) sector and Shenzhen-Dongguan-Huizhou-Hong Kong (SDHH) sector. From the calculation of various types of efficiency of various cities in the three sectors, it is known that in 2011, 2013 and 2015, the urban overall efficiency of GFZ sector and JZZM sector was higher than that of SDHH sector. Among them, the urban overall efficiency of GFZ sector was higher than that of JZZM sector both in 2013 and 2015, indicating that compared with the other two sectors, the internal synergistic effect of the GFZ sector was relatively obvious, the degree of regional integration was high and the level of resource utilization was advantageous. The other two sectors can be improved a lot in the aspects of regional integration and cross-regional joint development.

Table 2. Efficiency of Different Cities of Guangdong-Hong Kong-Macao Greater Bay Area

Economic sectors	2013			2015			2018		
	Overall efficiency	Technical efficiency	Scale efficiency	Overall efficiency	Technical efficiency	Scale efficiency	Overall efficiency	Technical efficiency	Scale efficiency
GFZ	0.890	1.000	0.890	0.942	1.000	0.942	0.942	1.000	0.942
JZZM	0.835	1.000	0.835	0.877	0.997	0.879	0.837	0.967	0.866
SDHH	0.842	0.947	0.886	0.853	0.877	0.970	0.700	0.812	0.862
Average	0.856	0.982	0.870	0.891	0.958	0.930	0.858	0.918	0.935

3.2.2 Comparison of the Urban Efficiency of Cities of Different Sizes.

If the city scale is divided on the basis of urban resident population size, less than 500,000, 500,000 to 1 million, 1 to 5 million, and more than 5 million, the mega cities in Guangdong-Hong Kong-Macao Greater Bay Area are Hong Kong, Guangzhou and Shenzhen, the large cities are Foshan, Dongguan and Zhuhai, and the medium-sized cities are Zhongshan, Huizhou, Jiangmen, Zhaoqing and Macao. In 2011, 2013, and 2015, the overall efficiency of mega cities in Guangdong-Hong Kong-Macao Greater Bay Area was 0.916, 0.900, and 0.900 respectively, the overall efficiency of large cities was 0.919, 0.812 and 0.864 respectively, and that of medium-sized cities was 1.000, 1.000, and 1.000 respectively. In 2013, 2015 and 2018, the overall efficiency of medium-sized cities was the highest, and the overall efficiency of mega cities and large cities showed irregular changes, which show that there is no clear correlation between urban efficiency and urban population size in Guangdong-Hong Kong-Macao Greater Bay Area.

Table 3. Urban Efficiency Values of Cities of Different Scales in Guangdong-Hong Kong-Macao Greater Bay Area

Decision unit	2013			2015			2018		
	Overall efficiency	Technical efficiency	Scale efficiency	Overall efficiency	Technical efficiency	Scale efficiency	Overall efficiency	Technical efficiency	Scale efficiency
Mega cities	0.916	0.940	0.970	0.900	0.988	0.910	0.900	0.900	1.000
Large cities	0.919	0.977	0.940	0.812	0.975	0.832	0.864	0.971	0.889
Medium-sized cities	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Average	0.945	0.972	0.970	0.904	0.988	0.914	0.921	0.957	0.963

4 Variation Trend of Urban Efficiency and Its Analysis

The Malquist index model is used to calculate the overall efficiency change (effch), technical change (techch), pure technical efficiency change (pech), scale efficiency change (sech) and productivity change index (tfpech) of the 11 cities in Guangdong-Hong Kong-Macao Greater Bay Area from 2013 to 2018. The results are shown in Tab.4.

Table 4. Urban efficiency index of Guangdong-hong Kong-macao Bay area in 2013-2018

Decision unit	effch	techch	pech	sech	tfpch
Guangzhou	1.000	1.037	1.000	1.000	1.037
Shenzhen	0.978	1.013	0.969	1.009	0.990
Zhuhai	0.992	1.036	1.000	0.992	1.027
Foshan	1.000	0.992	1.000	1.000	0.992
Huizhou	1.014	0.976	1.007	1.007	0.990
Dongguan	1.000	0.953	1.000	1.000	0.953
Zhongshan	0.966	0.984	1.000	0.966	0.950

Decision unit	effch	techch	pech	sech	tfpch
Jiangmen	0.942	0.959	0.997	0.945	0.904
Zhaoqing	0.995	0.985	1.000	0.995	0.980
Hong Kong	1.000	1.032	1.000	1.000	1.032
Macao	1.000	1.041	1.000	1.000	1.041
Average	0.990	1.001	0.998	0.992	0.991

4.1 Decomposition Analysis of Urban Efficiency Change

From the perspective of overall efficiency change, only Guangzhou, Foshan, Huizhou, Dongguan, Hong Kong and Macao had a positive growth rates between 2013 and 2018, of which Huizhou had the fastest growth, increasing by 1.4%, while the remaining five cities were in a declining trend. In general, the overall efficiency change of cities in Guangdong-Hong Kong-Macao Greater Bay Area showed a weak declining trend. The decomposition of the overall efficiency shows that the changes of pure technical efficiency and scale efficiency are both less than 1, which affects the improvement of overall efficiency to a certain extent, but the scale efficiency is the main factor that determines the overall efficiency.

From the perspective of technical change, the technical change index of Guangdong-Hong Kong-Macao Greater Bay Area from 2013 to 2018 was 1.001, of which the technical change indices of Guangzhou, Shenzhen, Zhuhai, Hong Kong and Macao were all greater than 1. This shows that during this period, Guangdong-Hong Kong-Macao Greater Bay Area as a whole had made progress in technology, promoting the improvement of the productivity change index of Guangdong-Hong Kong-Macao Greater Bay Area to a certain extent. The decline in the productivity index of Guangdong-Hong Kong-Macao Greater Bay Area is largely due to the decline in scale efficiency. Guangzhou and Hong Kong are major innovators in Guangdong-Hong Kong-Macao Greater Bay Area. In recent years, technical innovation is entering a critical stage, but the technical innovation effect needs a certain period of time to show. In the short term, the urban efficiency would be lower than that in the initial period of reform.

4.2 City Classification Analysis of Urban Efficiency Change

4.2.1 Characteristics of Changes in the Urban Efficiency of the Three Economic Plates.

From 2013 to 2018, the overall efficiency of the cities in the three sectors of Guangdong-Hong Kong-Macao Greater Bay Area declined (shown in Fig.1). The decline of the JZZM sector is the most pronounced (0.975). In particular, the overall urban efficiency changes of Zhongshan and Jiangmen in this sector were lower than the average of the entire Greater Bay Area. This is because the combined decline in the pure technical efficiency and scale efficiency of the city leads to the decline in overall efficiency, with the effect of urban scale efficiency being even more pronounced. The main reason for the relatively low change in overall efficiency of the GFZ sector is the relatively low change in the scale efficiency, while in the SDHH sector, it is due to the relatively low change in pure technical efficiency. From 2013 to 2018, except for Shenzhen, Dongguan, Huizhou and Hong Kong, the technical changes of the rest cities in Guangdong-Hong Kong-Macao Greater Bay Area were all in an upward trend, and the levels of technical change in GFZ and JZZM sector were the same. As the decline of urban overall efficiency is obvious, the positive impact brought by technological progress has been eliminated to some extent. Therefore, between 2013 and 2018, the productivity change of the GFZ sector showed a weak upward trend, while the productivity changes of JZZM sector and SDHH sector showed a downward trend.

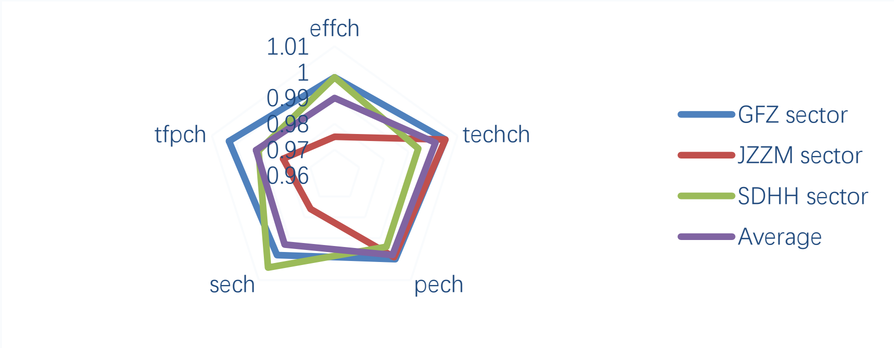

Fig. 1. Urban Efficiency Change of three major sectors in Guangdong-Hong Kong-Macao Greater Bay Area from 2013 to 2018

4.2.2 Analysis on the Urban Efficiency Changes of Cities of Different Sizes.

From 2013 to 2018, the overall efficiency change indices of mega cities, large cities and medium-sized cities in Guangdong-Hong Kong-Macao Greater Bay Area were 0.993, 0.987 and 1.000 respectively. It can be seen that, except for medium-sized cities, the overall efficiency changes of cities of all sizes showed a downward trend while the decline in large cities was the most obvious (Shown in Figure 2).

The main reason for the decline in the overall efficiency of large cities was the impact brought by the decline in scale efficiency. The overall efficiency of medium-sized cities showed a weak increase trend, mainly because the changes in both pure technical efficiency and scale efficiency were not obvious. The reason for the change in overall efficiency of mega cities was opposite to that of large cities, which was the decline in the pure technical efficiency. From 2013 to 2018, the technical changes in mega cities and medium-sized cities all showed a progressive trend, among which the technical progress of medium-sized cities was more obvious. Technical progress plays a promoting role in the improvement of productivity change index. However, due to the negative effect brought by the decline in overall efficiency, productivity changes in large cities had been declining from 2013 to 2018, while productivity changes in mega cities and medium-sized cities were on the rise.

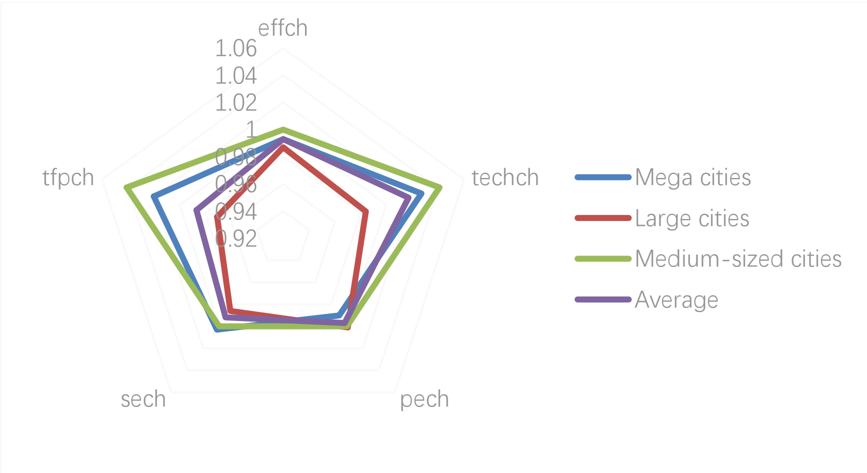

Fig. 2. Urban Efficiency Changes of cities of different sizes in Guangdong-Hong Kong-Macao Greater Bay Area from 2013 to 2018

5 Conclusion

This paper uses the DEA model and Malmquist index model to analyze the urban efficiency and its changes of 11 cities in Guangdong-Hong Kong-Macao Greater Bay Area, and gets the following conclusion.

(1) In terms of overall level, the overall efficiency level of Guangdong-Hong Kong-Macao Greater Bay Area is average, and only a few cities such as Guangzhou, Foshan, Hong Kong and Macao achieve the optimal overall efficiency. These cities have a good economic foundation, are advantageous in capital, technology and talent attraction and are prone to generate agglomeration effects. In recent years, the number of cities with the best scale efficiency has decreased significantly. In 2013, 2015 and 2018, the overall efficiency of Shenzhen did not achieve the optimal level.

(2) Judging from the regional classification of Guangdong-Hong Kong-Macao Greater Bay Area, the overall efficiency of Guangzhou-Foshan-Zhaoqing sector is higher than that of other regions. The level of industrial development in the Guangzhou-Foshan-Zhaoqing sector, especially the level of manufacturing, is higher, industry collaboration is close, and the development degree of regional integration is high. From the analysis on urban scale classification, it can be seen that the correlation between urban efficiency and urban population size in Guangdong-Hong Kong-Macao Greater Bay Area is not obvious.

(3) From the perspective of overall efficiency change, only Guangzhou, Foshan, Huizhou, Dongguan, Hong Kong and Macao had a positive growth rates between 2013 and 2018, of which Huizhou had the fastest growth, while the remaining five cities were in a declining trend. In general, the overall efficiency change of cities in Guangdong-Hong Kong-Macao Greater Bay Area showed a weak declining trend. From the perspective of technical change, from 2013 to 2018, Guangdong-Hong Kong-Macao

Greater Bay Area as a whole had made progress in technology, promoting the improvement of the productivity change index of Guangdong-Hong Kong-Macao Greater Bay Area to a certain extent. The decline in the productivity index of Guangdong-Hong Kong-Macao Greater Bay Area was largely due to the decline in scale efficiency.

(4) From 2013 to 2018, from the perspective of the sector, the overall efficiency of the cities in the three sectors of Guangdong-Hong Kong-Macao Greater Bay Area all declined. And the decline of Jiangmen-Zhongshan-Zhuhai-Macao sector is the most obvious. Except for Shenzhen, Dongguan, Huizhou and Hong Kong, the technical changes of the rest cities in Guangdong-Hong Kong-Macao Greater Bay Area were all in an upward trend, and the levels of technical change in Guangzhou-Foshan-Zhaoqing and Jiangmen-Zhongshan-Zhuhai-Macao sector were the same. The productivity change of the Guangzhou-Foshan-Zhaoqing sector showed a weak upward trend, while the productivity changes of Jiangmen-Zhongshan-Zhuhai-Macao sector and Shenzhen-Dongguan-Huizhou-Hong Kong sector showed a downward trend. Judging from the scale of the city, from 2013 to 2018, except for medium-sized cities, the overall efficiency of other cities in Guangdong-Hong Kong-Macao Greater Bay Area showed a downward trend, and the decline of mega cities was the most significant.

Data Availability

The indicator data from 2013 to 2018 were selected as the sample for this study, which were taken from the corresponding year of the "Guangdong Statistical Yearbook" "Statistical Yearbook of nine cities in the Pearl River Delta" "Hongkong Statistical Yearbook" and "Macau Statistical Yearbook".

Acknowledgments

This work was sponsored by "*Soft Science Research Program of Guangdong Province*" (No.2020A1010020057).

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