Research Article

Study on Sugarcane Production Efficiency Based on DEA-Malmquist Index: A Case Study of 8 Cities in Guangdong Province

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This article takes the evaluation model of data envelopment analysis (DEA) and Malmquist index change and its decomposition method, from 2014 to 2018, of sugarcane production in 8 cities in Guangdong province as the research object and the selection of sugarcane production output and production factors as a model output variable and input variable, respectively, according to the eight cities of Guangdong province in 2014–2018 statistics and analyzes the sugarcane production efficiency of 8 cities in Guangdong province. The research results show that there are significant differences in the regional development level of sugarcane production comprehensive efficiency and the regional development imbalance of sugarcane industry in the eight cities of Guangdong province. The lower TPI of the eight cities is mainly due to the lower level of technological innovation. So as to put forward countermeasures which are university resource orientation for the sugarcane comprehensive efficiency in cities less than 1, transportation and telecommunication infrastructure, enhancement of the strength, the establishment of Guangdong province agricultural science and technology innovation alliance, and increase in sugarcane industry with modern manufacturing and the butt joint degree of the international marketing environment, the government actively build international BBS in sugarcane industries.

1. Introduction

Guangdong is one of the three major sugarcane-producing areas in China. In the past five years, the planting area and total output of sugarcane in Guangdong ranked third in China after Guangxi and Yunnan. In terms of cash crop cultivation in Guangdong province, the annual output value of sugarcane is basically stable at the top 2, which is the pillar industry of agriculture in Guangdong province and the key industry pillar for farmers to get rich.

In February 2019, The State Council of China implemented the Outline of the Development Plan for the Guangdong–Hong Kong–Macao Greater Bay Area (herein-after referred to as the "Outline"). As an extension of the “One Belt And One Road” strategy, the outline puts forward the goals and plans of comprehensively improving the transportation system in the Pearl River Delta and building a modern industrial system to deepen cooperation and jointly participate in the "One Belt And One Road" construction, creating good incentive factors for sugarcane processing, and exporting and invigorating farmers’ production enthusiasm in Guangdong province.

In addition, at present, China’s domestic sugar supply is still short of demand. According to the report data provided by the "Forecast of China’s Sugar Consumption from 2015 to 2030", China’s domestic sugar shortage may increase to nearly 13 million tons in the next 10 years, thus further deepening the severe challenge faced by China’s sugar supply and demand balance. To ensure the supply of sugar to meet the increasing demand of the phase and improve the market competitiveness of domestic sugarcane, improve the standard of peasants’ daily life, promote rural modernization...
level, enhance sugarcane production efficiency for the stable domestic sugar industry, narrow the gap between the income of urban and rural residents in Guangdong province, and further solve the problem of "agriculture, rural areas, and farmers" are particularly important. Therefore, this article is based on eight pieces of data from the municipal bureau of statistics released in Guangdong province, by using data envelopment analysis (DEA) and Malmquist index analysis. Sugarcane main production in Guangdong province cities and sugarcane production efficiency were studied, so as to provide a reference for the sugarcane industry development, "to improve the level of farmers and rural development and promote sugarcane industry development quality improvement", and to improve the virtuous circle to the sugarcane industry regurgitation feeding farmers and rural areas.

2. Literature Review

Research on sugarcane production efficiency mainly focuses on the promotion of mechanized production. Chunjie [1] believes that Zhanjiang is an important sugarcane producing area in China. Through empirical research, it was proved that the comprehensive technical efficiency of sugarcane decreased first and then increased, and mechanized production played a positive role in improving comprehensive productivity. Rixing [2] proposed strengthening technological innovation and capital investment, optimizing sugarcane variety structure, implementing measures to boost sugarcane production by science and technology, and striving to improve sugarcane yield per unit area. Xiaohong [3] believes that the core of the whole mechanization of sugarcane production is not only the production machine, but the follow-up of the scale of planting land, the improvement of agronomics, and other related supporting measures is more important. Chengun [4] believes that, at present, sugarcane production is faced with many conditions, such as rising cost, low production efficiency, and insufficient labor force, and the application of mechanized production means to sugarcane production can greatly improve the deficiencies in sugarcane production and improve the quality of sugarcane production.

2.1. Theoretical Method. Data Envelopment Analysis (DEA), based on the theory of relative efficiency, is a nonparametric statistical method used to evaluate whether multi-input and multioutput decision-making units of the same type are technically effective [5]. In the extensive application of the DEA relative efficiency evaluation method, THE BCC model assumes that the decision unit (DMU) is variable production scale return (VRS), and then the pure technical efficiency value (PTE) can be obtained. The CCR model assumes that the production status of DMU is fixed scale reward (CRS), and then the overall technical efficiency value (TE) can be obtained. BCC model and CCR model can interact and complement each other, that is, the total technical efficiency value is decomposed by pure technical efficiency value, and then the scale efficiency (SE) can be obtained. If there are scale inefficiencies in the analysis results, it can be further calculated to determine that the marginal is in the increasing return to scale (IRS), decreasing return to scale (DRS), or fixed return to scale (CRS).

DEA evaluation model can be decomposed into output-oriented and input-oriented. Among them, output-oriented refers to the study of the target efficiency level from the perspective of increasing the quantity of output, that is, how to maximize the quantity of output while maintaining the constant level of the actual amount of input [6]. Input-oriented means to study the efficiency level from the perspective of reducing the amount of input, that is, how to achieve the minimum amount of input while keeping the actual amount of output constant. In general, the gain of production efficiency can be the maximization of output under certain conditions of input or the minimization of input under certain conditions of output [7].

In this paper, the BCC model and CCR model in the DEA evaluation model are adopted to study sugarcane production efficiency in some areas of Guangdong province from 2014 to 2018. Due to different areas, between different cities, there is a dominant direction of regional development strategy and resource allocation difference to be marked, and between 2014 and 2018, there are pesticides in Huizhou city of Guangdong province in 2015. SheChun found that the numerical gap is larger than 2014 and 2016 year by year, and Zhuhai of Guangdong province continues to shrink the phenomenon such as sugarcane planting area, indicating that the sugarcane production in Guangdong province in factors of production in certain conditions binds, so this paper will focus on how to improve the position of the sugarcane output level, thereby taking output-oriented approach.

On the other hand, in order to make up the standard of longitudinal comparison of missing data in various production periods when BCC model and CCR model are used, Malmquist index of DEA evaluation model and its decomposition method are selected to calculate the time-varying regularity of productivity in some areas of Guangdong province. As shown in formula (1), the Malmquist index is calculated as follows:

\[
M_t\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left[\frac{d^*_t\left(x^{t+1}, y^{t+1}\right)}{d^*_0\left(x^t, y^t\right)} \times \frac{d^*_0\left(x^{t+1}, y^{t+1}\right)}{d^*_0\left(x^t, y^t\right)}\right]^{1/2}.
\]

(1)

\(\left(x^{t+1}, y^{t+1}\right)\) and \(\left(x^t, y^t\right)\) represent the input and output vectors in periods \(t + 1\) and \(t\), respectively. \(d^*_t\left(x^t, y^t\right)\) and \(d^*_0\left(x^{t+1}, y^{t+1}\right)\) represent the technical efficiency level expressed by the technology of the current period, \(d^*_0\left(x^{t+1}, y^{t+1}\right)\) represents the technical efficiency level of the period \((t + 1)\) expressed by the technology of the period \(t\), and \(d^*_0\left(x^t, y^t\right)\) represents the technical efficiency level of the period \(t\) expressed by the technology of the period \(t + 1\).

If the total factor production efficiency index <1, the total efficiency of sugarcane production decreased. If the total factor production efficiency index is >1, the total production efficiency of sugarcane increased. If the total...
factor production efficiency index = 1, the total production efficiency of sugarcane does not change.

The main factors that affect the growth of total factor production efficiency are uncertain [8]. The total factor production efficiency index can be decomposed into technical efficiency index and technical progress index [9], and the calculation formula is as follows.

2.1.1. Technical Efficiency Index.

\[
EC = \frac{d_0(x', y')}{d_0(x^{t+1}, y^{t+1})}.
\]  

(2)

2.1.2. Index of Technological Progress.

\[
TC = \left[\frac{d_0^{t+1}(x', y')}{{d_0^t}(x^{t+1}, y^{t+1})} \times \frac{d_0^{t+1}(x^{t+1}, y^{t+1})}{{d_0^t}(x^t, y^t)}\right]^{1/2}.
\]  

(3)

2.2. Data Sources. In this paper, 8 sugarcane-producing cities in Guangdong province were taken as decision-making units. In order to ensure the reliability of the model analysis, the sum of the number of output variables and input variables in the analysis data was 6.

Considering Shenzhen, Guangzhou, Dongguan, and Foshan, Guangdong province, a total of four cities and urbanization rate are located in more than 90%, and the purpose of this study was to measure sugarcane production efficiency in the countryside under the influence of each variable and to promote the coordinated development of rural areas, agriculture, and farmers, and Shenzhen urbanization rate was 100%. Sugarcane efficiency in Guangzhou, Dongguan, and Foshan is bigger compared with other cities in Guangdong. In order to further ensure the credibility of model analysis, this article does not see the four cities in the DEA model of decision-making units.

In this paper, in the selection of various indicators, the data of output variables and input variables of the measurement model were obtained from the Statistical Yearbook of 8 cities in the decision-making unit. In terms of input variables, the indexes of application amount of pure chemical fertilizer (ton), agricultural, forestry, animal husbandry, and fishery workers, pesticide use amount (ton), the planting area of sugarcane (mu), and total power of agricultural machinery (kw) were comprehensively considered.

Since 2020 is an important year for China to achieve overall poverty alleviation, in order to improve the fitting degree between the research results and the development trend of “agriculture, rural areas, and farmers” in the new period, this paper tries to use the data of the recent five years in the selection of indicators, but the 2019 Statistical Yearbook has not been released by many cities in Guangdong province. Therefore, in terms of output and input variables, this paper selected the statistical data of 8 sugarcane producing cities representing the Pearl River Delta, west Guangdong, north Guangdong, and east Guangdong from 2014 to 2018 in Zhaoqing, Zhuhai, Zhongshan, Huizhou, Shanwei, Chaozhou, Jiangmen, and Jieyang in Guangdong.

2.3. Description of Variable Selection

2.3.1. Practitioners of Agriculture, Forestry, Animal Husbandry, and Fishery. The labor force is an important part of sugarcane production, and an experienced labor force with skilled planting technology has a strong promoting effect on sugarcane production. Even though sugarcane production has gradually shifted from pure manpower to agricultural machinery production, the mechanization degree of sugarcane production in most prefecture-level cities in Guangdong province is relatively deficient, manpower production still plays an important role, and sugarcane production workers are also the main source of agricultural machinery operation. Therefore, the practitioners of agriculture, forestry, animal husbandry, and fishery were incorporated into the model analysis as input variables in this paper.

2.3.2. Application Amount of Reduced Pure Fertilizer (ton). As a variable of capital input, the application amount of reduced pure fertilizer often includes nitrogen fertilizer, potash fertilizer, phosphate fertilizer, and compound fertilizer, and its input amount is an important indicator of land fertility. Although excessive use of reduced pure fertilizer will lead to soil pollution, fertilizer is still the main input in agricultural production because of its significant effect on improving land fertility.

(1) Pesticide Usage (Tons). The amount of pesticides and the amount of converted chemical fertilizers are both capital input variables, which generally include mineral pesticides and biogenic pesticides. Although the amount of pesticide used in many cities in the decision-making unit is decreasing year by year, pesticide still plays an active role in the prevention and elimination of diseases, insects, and grass. Therefore, the amount of pesticide used was also included as a variable.

2.3.3. Planting Area of Sugarcane (Mu). The planting area of sugarcane, as a land element, is the basic part of sugarcane production. The expansion of sugarcane sown area plays a key role in promoting the exponential or multiple growths of sugarcane yield based on technology, capital, and human resources. In the absence of technology, capital, or human resources, the role of land in promoting production will be limited.

2.3.4. Total Power of Agricultural Machinery (kW). The total power of agricultural machinery is the technical factor of sugarcane production, including sugarcane planter and sugarcane harvester. With the improvement of transportation infrastructure, the popularization of artificial intelligence, and economic growth, the mechanization of agricultural production has gradually covered all aspects of
agricultural production. It is of great significance to include the total power of agricultural machinery into the variable and to study the agricultural production efficiency in the new era.

3. Empirical Results and Analysis of Sugarcane Production Efficiency Studies in 8 Cities of Guangdong Province

3.1. Efficiency Value Analysis. In this paper, Stata 15.0 software was used to model and analyze the sugarcane production data of 8 cities in Guangdong province from 2014 to 2018, and the relative values and margins of the corresponding comprehensive technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE) were obtained, respectively.

3.2. Comprehensive Technical Efficiency. According to the data in Table 1, in the sugarcane production process of eight cities in Guangdong province from 2014 to 2018, the comprehensive technical efficiencies of Chaozhou and Jiangmen were all 1, indicating that the production and operation efficiencies of these two cities were relatively stable. Although the average comprehensive efficiency of Zhaoqing, Shanwei, and Jieyang remained within 0.9 and was relatively stable between the fluctuations of 2014–2018, the average comprehensive efficiency of Zhaoqing, Shanwei, and Jieyang was all below 0.8; in particular, the peak of Shanwei was only 0.65. The sugarcane production efficiency of these three cities was often lower than the average of 8 cities in 5 years. The sugarcane production efficiency in Zhuhai, Zhongshan, and Huizhou fluctuated from 2014 to 2018. Zhuhai showed a downward trend in 2014–2016 and 2017–2018 and an upward trend in 2016–2017. Zhongshan was on the decline in 2015–2016 and 2017–2018 and on the rise in 2014–2015 and 2016–2017. Huizhou decreased in 2015–2016 and 2017–2018 and increased in 2014–2015 and 2016–2017. In the field of mean value, sugarcane production efficiency was generally stable in the past 5 years. This phenomenon and data show that there are significant differences in the regional development level of comprehensive sugarcane production efficiency in 8 prefecture-level cities in Guangdong province and the regional development of the sugarcane industry is unbalanced.

3.3. Pure Technical Efficiency. Pure technical efficiency is to analyze the input and utilization condition on the basis of excluding the influence of scale reward factor [10]. As can be seen from the pure technical efficiency shown in Table 1, the average interval of sugarcane production efficiency in 8 cities in Guangdong province from 2014 to 2018 is [0.84, 0.91]. The pure technical efficiency of Zhuhai, Chaozhou, and Jiangmen has been maintained at 1 throughout the past five years, far higher than the average of 8 cities and in a leading position among regions. The resources invested in these three cities have been fully utilized. Zhaoqing, Shanwei, and Jieyang are always below 0.9 or the regional average. In particular, Zhaoqing and Shanwei are below 0.9 for 5 years, which is the invalid area of DEA. However, Jieyang is in the invalid area of DEA for the remaining 4 years except for the year 2017 when it reaches 0.91. Zhongshan and Huizhou were in a state of turbulence from 2014 to 2018. Zhongshan showed a downward trend from 2014 to 2016, while the value of pure technical efficiency from 2016 to 2017 remained at 1. From 2017 to 2018, it was in a downward trend. Huizhou was on the rise in 2014–2015 and 2016–2017 and on the decline in 2017–2018. In general, Zhaoqing, Shanwei, and Jieyang are less technologically effective than the other five cities.

3.4. Scale Efficiency. Scale efficiency refers to the process of incorporating the factor of scale return into the analysis of input variables and represents the effective state of production scale [11]. The scale efficiency values of 8 cities in Guangdong province from 2014 to 2018 are shown in Table 1. The average value of the scale efficiency of 8 cities in 5 years is within the range [0.9, 0.99] but generally fluctuates. The scale efficiency values of Zhaoqing, Huizhou, Chaozhou, and Jiangmen remained at 1 from 2014 to 2018, indicating that the resources invested in sugarcane production in these four cities were fully utilized and the resource allocation efficiency was relatively high. The scale efficiency of Zhuhai city in 5 years is always below 0.9, which indicates that the sugarcane production in Zhuhai city is inefficient in scale economy. In 2015, it reached 1.22, while in the other four years, it was below 0.9. This indicates that, in addition to the ineffective state of scale economy, Zhongshan also has a serious imbalance in resource allocation, with the phenomenon of resource mismatch. During 2014–2018, the scale efficiency of Shanwei and Jieyang was above 0.9 all year round, indicating that these two cities were close to scale efficiency and effective.

As shown in Table 2, as the boundary between pure technical efficiency value and scale efficiency value in DEA model is 0.9, this classification can be regarded as four quadrants in the plane Cartesian coordinate system in the research process with the mean value of each city during 2014–2018 as the unit. The first quadrant is the "high-high" type, indicating that both the pure technical efficiency value and the scale efficiency value are higher than 0.9. Chaozhou and Jiangmen are included in the decision-making unit of this study. The second quadrant is "high-low", indicating that the pure technical efficiency value is higher than 0.9 and the scale efficiency value is lower than 0.9. The decision-making unit in this study includes Zhuhai, which indicates that expanding the industrial scale is also an important direction [12]. The third quadrant is the "low-high" type, indicating that the pure technical efficiency value is lower than 0.9 and the scale efficiency value is higher than 0.9. The decision-making unit in this study includes Zhaoqing, Huizhou, Shanwei, and Jieyang. The fourth quadrant is the "low-low" type, indicating that both the pure technical efficiency value and the scale efficiency value are lower than 0.9. The decision-making unit in this study includes Zhongshan city.
### Table 1: Relative efficiency of sugarcane production in 8 cities of Guangdong province from 2014 to 2018.

<table>
<thead>
<tr>
<th>DMU</th>
<th>TE (integrated technical efficiency)</th>
<th>PTE (pure technical efficiency)</th>
<th>SE (scale efficiency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhaoqing</td>
<td>0.73, 0.71, 0.72, 0.75, 0.80</td>
<td>0.73, 0.71, 0.72, 0.75, 0.80</td>
<td>1, 1, 1, 1, 1</td>
</tr>
<tr>
<td>Zhuhai</td>
<td>0.86, 0.70, 0.65, 0.74, 0.53</td>
<td>1, 1, 1, 1, 1</td>
<td>0.85, 0.70, 0.65, 0.74, 0.53</td>
</tr>
<tr>
<td>Zhongshan</td>
<td>0.56, 0.53, 0.70, 0.53</td>
<td>0.74, 0.82, 1, 1, 0.72</td>
<td>0.82, 1.22, 0.63, 0.70, 0.73</td>
</tr>
<tr>
<td>Huizhou</td>
<td>0.89, 0.92, 0.66, 0.94, 0.82</td>
<td>0.90, 0.92, 0.67, 0.94, 0.82</td>
<td>1, 1, 1, 1, 1</td>
</tr>
<tr>
<td>Shanwei</td>
<td>0.65, 0.63, 0.60, 0.64, 0.65</td>
<td>0.68, 0.65, 0.62, 0.65, 0.60</td>
<td>0.96, 0.97, 0.97, 1.08</td>
</tr>
<tr>
<td>Chaozhou</td>
<td>1, 1, 1, 1, 1</td>
<td>1, 1, 1, 1, 1</td>
<td>1, 1, 1, 1, 1</td>
</tr>
<tr>
<td>Jiangmen</td>
<td>1, 1, 1, 1, 1</td>
<td>1, 1, 1, 1, 1</td>
<td>1, 1, 1, 1, 1</td>
</tr>
<tr>
<td>Yeyang</td>
<td>0.73, 0.74, 0.74, 0.80, 0.79</td>
<td>0.75, 0.75, 0.75, 0.94, 0.91</td>
<td>0.98, 0.99, 0.98, 0.85, 0.98</td>
</tr>
<tr>
<td>Mean</td>
<td>0.81, 0.84, 0.75, 0.82, 0.77</td>
<td>0.85, 0.86, 0.85, 0.91, 0.84</td>
<td>0.95, 0.99, 0.90, 0.91, 0.92</td>
</tr>
</tbody>
</table>

Note. The data in the cell shows the data analysis results from 2014 to 2018 successively from left to right.

### Table 2: Double efficiency analysis results of sugarcane production in 8 cities of Guangdong province from 2014 to 2018.

<table>
<thead>
<tr>
<th>Type</th>
<th>Quadrant</th>
<th>Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;High-high&quot;</td>
<td>First quadrant</td>
<td>Chaozhou, Jiangmen</td>
</tr>
<tr>
<td>&quot;High-low&quot;</td>
<td>Second quadrant</td>
<td>Zhuhai</td>
</tr>
<tr>
<td>&quot;Low-high&quot;</td>
<td>Third quadrant</td>
<td>Zhaoqing, Huizhou, Shanwei, Yeyang</td>
</tr>
<tr>
<td>&quot;Low-low&quot;</td>
<td>Forth quadrant</td>
<td>Zhongshan</td>
</tr>
</tbody>
</table>

#### 3.5. Marginal. As shown in Table 3, the rewards to the scale of 8 cities in Guangdong province tended to be stable in 2014–2018, among which the rewards to scale of Chaozhou and Jiangmen remained unchanged in 5 years, indicating that the allocation of resources was relatively reasonable. The scale returns in Zhuhai, Zhongshan, Huizhou, Shanwei, and Jieyang were increasing in the past five years, which indicated that the sugarcane industry in these five cities should continue to expand sugarcane production in the business scope.

There are variable inputs to create greater profits. In 2014, 2016, and 2017, Zhaoqing city showed increasing returns to scale and decreased returns to scale in 2015 and 2018, indicating that the development process of the sugarcane industry in Zhaoqing city was very unstable. Attention should be paid to strengthen and improve technical efficiency while continuing to expand the scale of sugarcane production.

#### 3.6. Dynamic Comparative Analysis of Malmquist Index. Based on the analysis model of the Malmquist index and its decomposition index adopted in this paper, the author used Stata 15.0 software to measure the output and input data of sugarcane production in 8 cities in Guangdong province, analyzed its spatial-temporal variation characteristics [13], and obtained corresponding analysis results (Tables 4–6).

#### 3.7. Total Factor Production Efficiency Index. Index of total factor productivity (TFP) refers to exclude input contribution of results; after [14], the index can be decomposed into technical efficiency change and technological progress index of the product, and the growth rate of the index can reflect the dynamic economic growth efficiency level [15]; in this article, it is mainly used in the determination of technological changes caused by the sugarcane production efficiency change of direction in 8 cities of Guangdong. As shown in Table 4, the total factor productivity index of Zhaoqing, Shanwei, and Jieyang from 2014 to 2018 was higher than 1, indicating that the overall productivity of sugarcane in these three cities showed a positive growth trend. The total factor productivity index of Zhuhai, Zhongshan, Huizhou, Chaozhou, and Jiangmen is lower than 1, which indicates that the overall productivity of sugarcane in these five cities shows a downward trend and a negative growth. In particular, Zhuhai declines at an annual rate of 11%. In the same period, the average total factor production efficiency of the 8 cities decreased by 2% and showed a negative growth overall, mainly due to the reduction of technological progress.

#### 3.8. Technical Efficiency Change Index. Effch was used in this paper to measure the level of technical popularity in sugarcane production in 8 cities of Guangdong province. According to the report results shown in Table 4, the technical efficiency values of Zhaoqing, Zhongshan, Huizhou, Shanwei, and Jieyang from 2014 to 2018 were greater than 1, which indicated that the production of sugarcane in these five cities could fully leverage the advantages of cutting-edge production and planting technologies. The technical efficiency value of Chaozhou and Jiangmen is 1, which indicates that the technical efficiency of the two cities will remain basically unchanged from 2014 to 2018. However, Zhuhai is the only one among the eight cities whose technical efficiency is lower than 1, which indicates that technologies related to sugarcane production were not fully utilized in Zhuhai from 2014 to 2018; thus, sugarcane production efficiency was hindered by low technical efficiency. In the same period, according to the decomposition data shown in Table 6, the average technical efficiency of the 8 cities increased by 0.47%, and the overall growth was positive. The growth of the technical efficiency index also slowed down the decline of the total factor production efficiency index.

#### 3.9. Technological Progress Index. In this paper, the technology progress index (Tech) is mainly used to measure the innovation level of sugarcane production technology in 8
According to the report, data are not present in the decision-making units (2014–2018 cities) belonging to the technical progress index which is greater than or equal to 1. It shows that eight cities of the Guangdong province in the years of the main reason for the decline in sugarcane production efficiency lie in the low level of sugarcane production technology innovation; eight cities of sugarcane production level have a relatively low level of technological innovation. Among the 8 cities, Huizhou and Zhuhai had a low technological progress index of 0.96048 and 0.96778, respectively. The technical progress index of Jiangmen and Zhaoqing was higher, and the adverse effects were less; the values were 0.99744 and 0.98141, respectively. In the same period, according to the decomposition data shown in Table 6, the average technological progress index of the 8 cities decreased by nearly 3%, and the overall growth was negative. The decline of the technological progress index also played a major role in the decline of the
total factor production efficiency index. As the proportion of the increase of technological efficiency change index is lower than that of the decline of technological progress index, it can be seen that the main reason for the decline of sugarcane production efficiency in 8 cities of Guangdong province from 2014 to 2018 is the low level of technological innovation.

4. Suggestions and Countermeasures

In this paper, by taking 8 pieces of sugarcane production output and input data of the municipal bureau of statistics released by the Guangdong province in 2014–2018, using DEA and Malmquist index evaluation method and its decomposition analysis method, the relative efficiency of sugarcane production in 8 cities of Guangdong province is analyzed. The sugarcane was decomposed, the total factor productivity was determined, and the sugarcane production efficiency differences and deficiencies and dynamic conditions of 4 areas of Guangdong province were analyzed. Then, according to the related problem, the following suggestions and countermeasures were put forward.

A. Colleges and universities’ scientific research and talent resources oriented to help the comprehensive efficiency of sugarcane in cities less than 1.

Guangdong province should make good use of the educational resources of local colleges and universities [16]. South China Agricultural University, Zhongkai College of Agricultural Engineering, and other colleges and universities in Guangdong province have established research institutions of agricultural production science and technology. Research institutes should pay attention to increasing the number of high-quality and high-capacity R&D personnel [17], reduce the input of idle scientific and technological personnel [18], avoid resource waste to a certain extent, provide support for scientific and technological innovation and advanced production equipment for agricultural production, and promote the progress of agricultural production from the perspective of scientific and technological equipment. Colleges and universities’ graduates lack the rural household registration and directional students’ agricultural talent cultivation; these college graduates are often more skillful than farmers in using new technology innovations and have a unique vision as young people. If there is a combination of college students and farmers to cooperate in sugarcane production activities and also in the implementation of directional support activities and if the college students participate in the upgrading plan of the functions of rural migrant worker skills [19], it is easy to realize the combination between traditional vision and vision in the new period, thus, promoting sugarcane production mode innovation.

Therefore, Guangdong provincial government should strengthen the mobilization of agricultural research institutions and college graduates of provincial universities to connect the sugarcane industry and accelerate the positive interaction between sugarcane production information and agricultural production equipment scientific research information. They should encourage students as technical personnel to the countryside counseling farmers to use new sugarcane production equipment. Students with management skills are encouraged to innovate sugarcane production mode with farmers. While assisting farmers in production, college students also regularly report farmers’ sugarcane production information to relevant research institutes of universities to promote the transfer and transformation of scientific and technological achievements [20]. Further technology introduction and “farmer-college students” exchange to promote farmers’ comprehensive quality and “production-innovation” integration, so as to keep the innovation level of sugarcane production active state and realize the sustainable development of rural sugarcane production.

B. Continuously strengthen the improvement of transportation and telecommunications infrastructure.

Transportation infrastructure is the basis for the external transportation of sugarcane and its finished products and is also important support for the importation of scientific and technological innovation resources and agricultural production equipment into sugarcane producing areas in the Greater Bay Area of Guangdong, Hong Kong, and Macao. Telecommunication infrastructure is the basis for the communication between sugarcane producing farmers and foreign commercial sources, scientific and technological innovation resources, and other sugarcane production and business entities. It is also the basis for the integration and application of advanced telecommunications technology and fixed assets of sugarcane production in the future by giving full play to the advantages of 5G, AI, Internet of Things, and other advanced telecommunications technologies.

Therefore, in order to safeguard farmers’ living standards, the economic income of farmers in Guangdong province has risen steadily and increases the sugarcane yield in Guangdong province, to fill the domestic sugar supply gap, and to enhance the market competitiveness of China’s sugarcane and its products, the Guangdong provincial government should constantly improve rural infrastructure facilities in the province and the structure of the telecommunications infrastructure and pay attention to prevent the use of existing inefficient resources or wasteful problem [21], to strive for advanced infrastructure in important sugarcane production node for the whole province, promote management service mode to network and information [22], and accelerate the sugarcane industry and rural modernization.

C. Establish Guangdong Agricultural Science and Technology Innovation Alliance and actively include sugarcane industry, science, and innovation enterprises and university research institutes.

The market information of sugarcane and its processed products can reflect the gap between their quality and quantity relative to the expectation of consumers, thus conveying the information that the input factors of sugarcane production need to be improved. Scientific innovation enterprises and university research institutes can aim at the demand in the sugarcane production process and then give play to the scientific research strength of enterprises and universities to improve the technology of input variables.
such as fertilizers and pesticides, so as to improve the quality of sugarcane output per unit from the production end and improve the output capacity of input variables per unit of sugarcane production.

Guangdong provincial government to guide the rural production cooperatives, sugarcane processing, and sales enterprise, Kechuang enterprise, and institutes, colleges, and universities jointly build the sugarcane production in Guangdong province science and technology innovation alliance, set up a scientific and technological innovation of social network [23], relying on the platform of Internet and Internet of things, promote multilateral information and the flow of funds, to further expand scientific and technological innovation main body to be able to get the sugarcane production and the demand information in time, make timely feedback response in the sugarcane processing and sales information to the sugarcane production side, and at the same time also make technology innovations timely and effectively applied in sugarcane production.

D. Relying on the radiation effect of the Guangdong-Hong Kong-Macao Greater Bay Area, to improve the docking degree of the sugarcane industry with the modern manufacturing industry and international sales environment, in Hong Kong and Macao, the big bay area development planning outline contains comprehensive consumption in the Pearl River Delta region and the transportation system and builds a modern industrial system to deepen international cooperation in the area along the "construction target and planning, such as sugarcane production in Guangdong province in Hong Kong and Macao to rely on the bay area to expand economic openness and the development trend of trade extension. Positive and Pearl River Delta modern manufacturing standards" give full play to the bay area manufacturing level of ascension and the expansion of manufacturing, middle in the process of sugarcane sold to reduce costs, improve the unit sugarcane production efficiency, and thus improve the added value of sugarcane and its products.

On the other hand, the Guangdong-Hong Kong-Macao Greater Bay Area actively attracts investment from all over the country and the world. Domestic retailers can go out of the country through the Guangdong-Hong Kong-Macao Greater Bay Area, while overseas retailers can enter the Chinese market through the Guangdong-Hong Kong-Macao Greater Bay Area. Sugarcane production in Guangdong province agricultural cooperatives can be based on the environmental development trend of internationalization of the bay area sales, under the condition of fierce competition between distributors actively with the domestic and foreign distributors to build strategic partnership and gradually enhance the level of more sugarcane industry enterprise of Guangdong province and build and cultivate leading enterprises, to improve sugarcane sales, expand sales channels, and thus improve the standard of peasants' disposable income and rural comprehensive development level, narrow the gap between urban and rural development, and stimulate the sugarcane industry in Guangdong province Kechuang elements related to the major sugarcane producing area of Guangdong province.

E. Relying on the good international environment of the Pearl River Delta, the Guangdong government actively builds an international forum on the sugarcane industry.

The influence of the Pearl River Delta international platform in Guangdong province continues to expand with the local economic development, and a good international communication environment can stimulate the speed of information flow at home and abroad. Government or local government shall be the Pearl River Delta of Guangdong province economic and cultural trend of internationalization, actively build international BBS and sugarcane industry development to India, Brazil, and Thailand, invite the world's major sugarcane producers, guide Guangdong province and sugarcane in the communication industry with the international sugarcane industry in China, made Guangdong province and China's sugarcane industry multilateral main body in the process of the exchange of learning, and give feedback to their own development.

Technological innovation activities need a good external environment [24]. For Guangdong sugarcane industry, the industry of rural production cooperatives, sugarcane processing, and marketing enterprises can, through the BBS for international sugarcane production platform and with the international sugarcane industry, build a relationship with the manufacturers and distributors, introduce advanced production equipment, and can draw lessons from foreign sugarcane production mode, in order to improve the production efficiency. Science and innovation enterprises can expand cooperation partners in exchanges, accumulate research funds, and improve the comprehensive level of scientific research. Universities and colleges can enrich research materials and experience in international exchanges, so as to improve the solutions to problems related to agriculture, rural areas, and farmers.

5. Conclusion

In this paper, DEA relative efficiency analysis model is adopted to conduct mathematical analysis on the output variables and input variables of sugarcane production in 8 cities in Guangdong province, and the change direction of comprehensive technical efficiency, pure technical efficiency, scale efficiency, and scale return of sugarcane production in 8 cities in Guangdong province is obtained. The results show the following. (1) From 2014 to 2018, there are significant differences in the regional development level of sugarcane production comprehensive efficiency in 8 prefectures and cities in Guangdong province, and the regional development of the sugarcane industry is unbalanced. (2) Zhaoqing, Shanwei, and Jieyang, compared with the other 5 cities, have insufficient technical effectiveness; that is, they are in the invalid area of DEA. (3) In the field of scale efficiency, Chaozhou and Jiangmen are of the "high-high" type, Zuhai of the "high-low" type, Zhaoqing, Huizhou, Shanwei, and Jieyang of the "low-high" type, and Zhongshan of the "low-low" type. (4) In the marginal direction, the development process of the sugarcane industry in Zhaoqing city was very unstable, and the changes of scale returns in the other 7 cities were in a nondecreasing state.
At the same time, the Malmquist index change and its decomposition method were used to analyze sugarcane production in 8 cities in Guangdong province, and the total factor production efficiency index, technical efficiency index, and technical progress index were obtained. The results showed the following. (1) The average total factor production efficiency of sugarcane production in 8 cities in Guangdong province decreased by 2% mainly because of the decrease of technological progress. (2) The growth of the technical efficiency index in sugarcane production in 8 cities of Guangdong province slowed down the decline of the total factor production efficiency index. (3) The main reason for the decline of sugarcane production efficiency in 8 cities of Guangdong province in 5 years is the low level of technological innovation.

The main difficulties in the development of the sugarcane industry are the slow progress of sugarcane breeding, single product varieties, serious degradation, high production cost, deep processing lag, and low-risk ability. The natural conditions of the sugarcane production area are backward and the ability to resist natural disasters is low. Based on research results, in order to promote the sugarcane production efficiency of Guangdong province, the rural modernization, and the narrow income gap between urban and rural areas, “to improve the level of farmers and rural development quality of sugarcane industry”, and to improve the virtuous cycle to “the sugarcane industry regeneration feeding farmers and countryside”, so in this article, the following suggestions and countermeasures are put forward. (1) There should be universities’ scientific research and talent resources orientation for the sugarcane comprehensive efficiency in cities less than 1. (2) We will continue to strengthen efforts to improve transportation and telecommunications infrastructure. (3) The Guangdong Agricultural Science and Technology Innovation Alliance should be established, and the sugarcane industry, science and innovation enterprises, and university research institutes should be actively included. (4) We have to rely on the radiation effect of the Guangdong-Hong Kong-Macao Greater Bay Area, to improve the docking degree of the sugarcane industry with the modern manufacturing industry and international sales environment. (5) Relying on the good international environment of the Pearl River Delta, the Guangdong government actively builds the international forum of the sugarcane industry. (6) The research and development of sugarcane machinery should be strengthened to improve the mechanization level of sugarcane production.

**Data Availability**

In this paper, in the selection of various indicators, the data of output variables and input variables of the measurement model were obtained from the Statistical Yearbook of 8 cities in the decision-making unit. In terms of output and input variables, this paper selected the statistical data of 8 sugarcane producing cities representing the Pearl River Delta, west Guangdong, north Guangdong, and east Guangdong from 2014 to 2018 in Zhaoqing, Zhuhai, Zhongshan, Huizhou, Shanwei, Chaozhou, Jiangmen, and Jieyang in Guangdong.

**Conflicts of Interest**

The authors declare that they have no conflicts of interest.

**References**


