Measuring convergence in the sugarcane industry in China’s Guangxi province

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Abstract

Using the agricultural industry convergence framework, we analyzed the main sugarcane producing areas in China’s Guangxi province from 2010 to 2017. We selected the key elements on sugarcane industry convergence and on the benefit derived from industry convergence and development. We selected six secondary indexes and 18 tertiary indexes and used them to construct an overarching index system for measuring the convergence degree of sugarcane in the primary, secondary, and tertiary industries. We calculated the index’s system weight using the AHP and entropy method, and then the integrated development indicator of the sugarcane industry. Finally, we analyzed the convergence the development stage, achievements, and benefits of the sugarcane industry, as well as the shortage of convergence development. Our findings can provide guidance for the future development of the sugarcane industry in China from the perspective of industry convergence.

Introduction

In the past decade, agricultural industry convergence has developed rapidly around the world. In large part, agricultural growth has been achieved by promoting the integrated development among the secondary and tertiary agricultural sectors. Existing studies have mainly focused on areas such as connotation, value, mode and path of convergence [1–6]. Xiang-mei Li [7] and Ya-fei Ma [8] evaluated the convergence development of agricultural industry in Beijing, Gansu and other places in China. Fewer studies have focused on the convergence of sugarcane industry. Sugarcane is the main sugar-producing crop in the tropical and subtropical regions of China. The Guangxi province is the most important sugarcane producing area in China. Until 2018, this region was ranked highest in terms of sugarcane yield and harvesting in the entire country. Since 2012, the planting area of sugarcane in Guangxi has been reduced [9]. Owe to the high yield and high sugar content bases construction, sugarcane production capacity grew rapidly. The per unit area yield increased from 6.66 kg/m² in 2011 to 8.14 kg/m² in 2017 [10]. In this paper, we constructed a model to measure the integrated development in the sugarcane industry. We specifically analyzed data of the primary, secondary, and tertiary industry sectors in Guangxi from 2010 to 2017. Based on our results, we made suggestions on how to promote the process of industry convergence in China.
Research method

Index system construction

According to existing academic research, promoting industry convergence could expand the agricultural industry chain [11]. In this paper, we constructed an integrated development index for sugarcane industry taking two aspects into consideration: industry convergence achievements and benefits derived from industry convergence [12]. We hope this study would be a useful supplement to the current research. Our index system comprises which consist of the primary, secondary and tertiary index. It is shown in Table 1. Among them, C13 ~ C18 indexes should be explained as follows. Sugarcane industry is the leading agricultural industry in Guangxi, farmers engaged in sugarcane cultivation, processing and sales related industries accounted for up to 70%. The driving benefit of sugarcane industry development is regarded as highly positive correlation with farmers’ income and urban-rural convergence.

The data used in this study were obtained from the Statistical Yearbook of Guangxi Zhuang Autonomous Region (2010–2018), the Guangxi Yearbook (2010–2018), and Compilation of Cost and Income Information of Chinese Agricultural Products (2010–2018). We used Formula (1) to (18) to deal with the data and calculate the result. It is shown in Table 2.

The evaluation index system

By industry convergence achievements, we refer to the level of agricultural industry upgrading due to the convergence of industries. First, we used the index for the modernization of sugarcane planting to measure the degree to which modern scientific, technological, and managerial practices were applied to agriculture. Second, we used the index for the ecologization of the sugarcane industry to measure the ecological benefits of the industry. Third, we used the index for the sugarcane industry’s chain extension to measure the convergence degree between agriculture and agricultural products processing, sales, and scientific research services. Fourth, we used the index for sugarcane multifunctional development to measure the degree to which diversified choices are provided for improving the industry benefits.

By industry convergence benefits, we refer to the effects of convergence development on the planting areas and on sugarcane growers. First, we used the index for farmers’ income to measure the convergence effect. Second, we used the index for urban-rural convergence to measure the level of social and economic convergence between urban and rural areas.

Research methods and model construction

There are different kinds of methods available for the comprehensive evaluation of multiple indexes. These could be categorized as subjective and objective methods, each of which has its own advantages and disadvantages. This study adopted a comprehensive weighted evaluation approach, combining the AHP and entropy methods. This approach can overcome the deviation of randomness and conjecture caused by the subjective weighting method. In addition, by using the difference coefficient of the entropy method, the weight value of the subjective weighted evaluation can be modified, this solving the problem of information overlap between multi index variables. Therefore, the weights obtained in this comprehensive way are more scientific [13].

Through consultation with experts, AHP evaluates the importance of an index through pairwise comparison. When the consistency index of the hierarchical total ranking surpasses 0.10, it can be concluded that the results of the hierarchical total ranking are consistent with each other.
The entropy method performs well when it comes to reflecting the variability of index information because it retains the characteristics of index information to the greatest extent. Its calculation formula is shown in Formula (19).

\[ e_j = - (\ln(m))^{-1} \sum_{i=1}^{m} (Q_{ij} \times \ln Q_{ij}), j = 1, 2, \ldots, n \]  

In the formula, \( m \) represents the number of evaluated objects, \( n \) represents the number of evaluation indexes, \( e_j \) represents the entropy of index \( j \), and \( Q_{ij} \) represents the proportion of the i-
On the basis of known entropy, the objective weight of each index could be calculated. Its calculation formula is shown in Formula (21). In the formula, \( W_j \) represents the weight of index \( j \).

\[
W_j = \left(1 - e_j\right) / \sum_{j=1}^{n} \left(1 - e_j\right)
\]  

(21)

The sugarcane industry convergence is in the dynamic development stage, thus the measurement of its convergence degree needs to be calculated by systematic analysis. The study adopted synthetic indicators method to analyse the convergence development level of sugarcane industry in Guangxi Province. Industry convergence index could be obtained by accumulation. Its calculation formula is shown in Formula (22).

\[
ACDIS = P_1 + P_2
\]  

(22)

In the model, ACDIS represents Agriculture Convergence Development Indicator of Sugarcane, \( P_1 \) represents indicator of industry convergence achievements, \( P_2 \) represents indicator of benefits driven by industry convergence. Its calculation formula is shown in Formula (23).

\[
P = \sum_{i=1}^{n} \rho_i \omega_i
\]  

(23)

In the formula, \( P_i \) represents the realization degree of corresponding indicators, \( W_i \) represents the weight of each tertiary index. According to different index nature, formula (24) is used to calculate positive index, formula (25) is used to calculate negative index. In the

### Table 2. Index data of sugarcane industry convergence.

| Index / Year | 2010    | 2011    | 2012    | 2013    | 2014    | 2015    | 2016    | 2017    |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|
| C1           | 6.66    | 6.66    | 6.94    | 7.20    | 7.35    | 7.71    | 7.85    | 8.14    |
| C2           | 0.53    | 0.53    | 0.55    | 0.54    | 0.46    | 0.55    | 0.65    | 0.68    |
| C3           | 39.4    | 41      | 43.2    | 46.92   | 49.82   | 55      | 57.11   | 59.11   |
| C4           | 11.40\times10^{-4} | 11.55\times10^{-4} | 13.35\times10^{-4} | 16.05\times10^{-4} | 15.30\times10^{-4} | 15.00\times10^{-4} | 14.40\times10^{-4} | 13.95\times10^{-4} |
| C5           | 9.06\times10^{-2} | 8.83\times10^{-2} | 9.34\times10^{-2} | 9.99\times10^{-2} | 9.99\times10^{-2} | 10.28\times10^{-2} | 10.36\times10^{-2} | 9.72\times10^{-2} |
| C6           | 0.12    | 0.12    | 0.13    | 0.13    | 0.14    | 0.16    | 0.17    | 0.17    |
| C7           | 0.93    | 1.13    | 1.5     | 1.64    | 2.05    | 1.88    | 1.69    | 1.88    |
| C8           | 19.9    | 21.8    | 13.6    | 10.8    | 10.1    | 18.2    | 15.9    | 18.3    |
| C9           | 12.06   | 12.12   | 12.03   | 11.78   | 12.08   | 12.16   | 11.51   | 12.29   |
| C10          | 0       | 1.81    | 3.51    | 3.59    | 3.76    | 3.57    | 4.14    | 4.85    |
| C11          | 27.7    | 30.36   | 34.83   | 37.72   | 42.56   | 35.91   | 31.26   | 32.02   |
| C12          | 1.53    | 1.56    | 1.82    | 2.04    | 2.19    | 2.26    | 2.35    | 2.63    |
| C13          | 48.50   | 43.80   | 42.80   | 40      | 36.90   | 35.40   | 34.50   | 32.20   |
| C14          | 35      | 36      | 36      | 40      | 34      | 34      | 34      | 35      |
| C15          | 0.29    | 0.26    | 0.23    | 0.20    | 0.12    | 0.21    | 0.30    | 0.31    |
| C16          | 3.76    | 3.54    | 3.54    | 3.43    | 2.84    | 2.79    | 2.73    | 2.69    |
| C17          | 10.27   | 10.54   | 9.96    | 9.33    | 10.2    | 10.76   | 30.24   | 33.69   |
| C18          | 12.96   | 12.37   | 12.36   | 11.59   | 11.24   | 12.24   | 12.91   | 13.18   |

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formula, \( G \) represents target value, \( C \) represents performance value.

\[
\rho_i = \frac{C}{G} \times 100
\]

(24)

\[
\rho_i = \frac{G}{C} \times 100
\]

(25)

**Industry convergence stages**

By referring to the relevant literature, such as Yun-Li’s in 2017 and Vieira’s in 2018. The study specifies the division of the sugarcane industry’s convergence stages. It is shown in Table 3.

**Results and analysis**

**Description of the data**

We used the min max normalization method to achieve data standardization. Formula (26) was used to analyze the positive index. Formula (27) was used to is used to analyze the negative index. In the formula, \( Y_j \) represents the value of the standardized index, \( X_j \) represents the value of the index before standardization, \( \max X_j \) represents the maximum value in each year for this index, and \( \min X_j \) represents the minimum value in each year for this index. The data processing result is shown in Table 4.

\[
Y_j = \frac{X_j - \min X_j}{\max X_j - \min X_j}
\]

(26)

\[
Y_j = \frac{\max X_j - X_j}{\max X_j - \min X_j}
\]

(27)

**Using the minimum relative information entropy method to determine combination weights**

After the data standardization, we evaluated the index system using the entropy weighting method. We used the Lagrange multiplier method to optimize the formula for combination.
weights. Its calculation formula is shown in Formula (28).

\[
W_j = \left( \omega_j w_j \right)^{0.5} / \sum_{i=1}^{n} \left( \omega_i w_i \right)^{0.5}
\]  (28)

In formula (10), \( \overline{W} \) represents the optimize weight value, \( \omega_j \) represents the weight of AHP, \( w_j \) represents the weight of entropy. The result of combination weight is shown in Table 5.

### Solution of the convergence index model

To obtain the solution for the convergence index model, we first set the target value as the value specified in the future development plan of the national sugarcane industry. We compared this value with the original index data, and finally obtained the standard value for sugarcane industry convergence. It is shown in Table 6. In order to perceive it intuitively, we used Fig 1 to show the target control value of index data on industry convergence achievements degree. Target control value of index data on benefits driven from industry convergence degree is shown in Fig 2.

According to Formula (22), we calculated the final score, as shown in Fig 3. Both the indicator of sugarcane industry convergence achievements (P1) and the indicator of benefit driven by sugarcane industry convergence (P2) are increasing year by year from 2010 to 2017.

### Conclusion

#### Analyzing of the sugarcane industry convergence stages

As shown in Table 6, the convergence development of the sugarcane industry was in its early stage from 2010 to 2014. In 2015, it was in its growing stage. In large part due to the development of high-quality sugarcane fields, the production capacity of sugarcane in Guangxi has grown rapidly. This indicates that the output value of sugarcane industry in Guangxi has been driven effectively.

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| Index / Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|-------------|------|------|------|------|------|------|------|------|
| C1          | 0.000| 0.001| 0.191| 0.368| 0.469| 0.708| 0.801| 1.000|
| C2          | 0.311| 0.319| 0.426| 0.379| 0.000| 0.421| 0.881| 1.000|
| C3          | 0.000| 0.081| 0.193| 0.382| 0.529| 0.791| 0.899| 1.000|
| C4          | 1.000| 0.968| 0.581| 0.000| 0.161| 0.226| 0.355| 0.452|
| C5          | 0.850| 1.000| 0.667| 0.240| 0.240| 0.052| 0.000| 0.421|
| C6          | 0.961| 0.950| 0.974| 1.000| 0.964| 0.941| 0.142| 0.000|
| C7          | 0.000| 0.179| 0.509| 0.634| 1.000| 0.848| 0.679| 0.848|
| C8          | 0.838| 1.000| 0.299| 0.060| 0.000| 0.692| 0.496| 0.701|
| C9          | 0.705| 0.782| 0.667| 0.346| 0.731| 0.833| 0.000| 1.000|
| C10         | 0.000| 0.373| 0.724| 0.740| 0.775| 0.736| 0.854| 1.000|
| C11         | 0.000| 0.179| 0.480| 0.674| 1.000| 0.552| 0.240| 0.291|
| C12         | 0.000| 0.027| 0.264| 0.464| 0.600| 0.664| 0.745| 1.000|
| C13         | 0.000| 0.288| 0.350| 0.521| 0.712| 0.804| 0.859| 1.000|
| C14         | 0.167| 0.333| 0.333| 1.000| 0.000| 0.000| 0.000| 0.167|
| C15         | 0.922| 0.764| 0.595| 0.404| 0.000| 0.499| 0.974| 1.000|
| C16         | 0.000| 0.206| 0.206| 0.308| 0.860| 0.907| 0.963| 1.000|
| C17         | 0.039| 0.050| 0.026| 0.000| 0.036| 0.059| 0.858| 1.000|
| C18         | 0.887| 0.582| 0.577| 0.180| 0.000| 0.515| 0.861| 1.000|
Analyzing the achievements and benefits of the sugarcane industry convergence

As shown in Fig 1, among the tertiary indexes, an indicator score above 80 includes the comprehensive production capacity of sugarcane, the conversion rate of sugarcane in the sugar industry, the ratio of sugarcane productive service industry to output value of sugarcane, and rural financial expenditure ratio. First, our results indicate that the development of high-

Table 5. Weights result for the sugarcane industry convergence evaluation index.

| The Primary Index | The Weight of Primary Index (Combination Weight) | The Secondary Index | The Weight of Secondary Index (Combination Weight) | The Tertiary Index | The Weight of Tertiary Index |
|-------------------|-----------------------------------------------|---------------------|-----------------------------------------------|-------------------|------------------------------------------|
| Industry Convergence Achievements | 0.7758 | Modernization of Sugarcane Planting | 0.1796 | Comprehensive Production Capacity of sugarcane | 0.0714 | 0.053 | 0.0684 |
| | | | | Sugarcane Land Productivity | 0.0714 | 0.057 | 0.0709 |
| | | | | Comprehensive Mechanization Rate of Sugarcane | 0.0238 | 0.055 | 0.0402 |
| | | Ecologization of the Sugarcane Industry | 0.1103 | Application Intensity of Pesticide | 0.0156 | 0.056 | 0.0329 |
| | | | | Application Intensity of Chemical Fertilize | 0.0156 | 0.054 | 0.0323 |
| | | | | Water Saving Irrigation Coefficient | 0.0311 | 0.053 | 0.0451 |
| | | Sugarcane Industry’s Chain Extension | 0.2942 | Ratio of Output Value of Sugar Industry to Output Value of Sugarcane | 0.1164 | 0.051 | 0.0857 |
| | | | | Profit Margin of Sugar Enterprises | 0.0733 | 0.058 | 0.0725 |
| | | | | Conversion Rate of Sugarcane in Sugar Industry | 0.2771 | 0.054 | 0.1360 |
| | | | | Ratio of Leisure Agricultural Output Value to Agricultural Output Value | 0.1100 | 0.059 | 0.0896 |
| | | | | Ratio of Sugarcane Productive Service Industry to Output Value of Sugarcane | 0.0462 | 0.056 | 0.0566 |
| | | | | Agricultural Credit Input Per Unit | 0.0291 | 0.058 | 0.0457 |
| Benefits Driven from Industry Convergence | 0.2242 | Farmers’ Income | 0.1840 | Rural Engel Coefficient | 0.0164 | 0.056 | 0.0337 |
| | | | | Proportion of Rural Non-agricultural Employment | 0.0463 | 0.050 | 0.0535 |
| | | | | Cash Income from Sugarcane Production | 0.0872 | 0.059 | 0.0798 |
| | | Urban-rural Convergence | 0.0402 | Per Capita Income Ratio of Urban and Rural Areas | 0.0042 | 0.056 | 0.0171 |
| | | | | Investment Ratio of Fixed Assets Per Capita in Urban and Rural Areas | 0.0026 | 0.057 | 0.0135 |
| | | | | Rural Financial Expenditure Ratio | 0.0099 | 0.058 | 0.0266 |

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quality sugarcane fields in Guangxi was successful. Second, by eliminating the backward pro-
duction capacity of the sugar industry, Guangxi has effectively integrated superior production
capacity and laid a foundation the multi-function development. Third, the proportion of sug-
arcane productive services was far higher than the average level in Guangxi. Thus, these ser-
vices make a positive contribution in the promotion of promoting sugarcane industry
convergence. Fourth, the ratio of rural financial expenditure in Guangxi is higher than the
national average level. This indicates that the government could play an important role in pro-
moting the development of the sugarcane industry.

| Index / Year | Target Value | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   |
|--------------|--------------|--------|--------|--------|--------|--------|--------|--------|--------|
| C1           | 7.5          | 88.80  | 88.80  | 92.53  | 96.00  | 98.00  | 100.00 | 100.00 | 100.00 |
| C2           | 0.92         | 57.61  | 57.61  | 59.78  | 58.70  | 50.00  | 59.78  | 70.65  | 73.91  |
| C3           | 85           | 46.35  | 48.24  | 50.82  | 55.20  | 58.61  | 64.71  | 67.19  | 69.54  |
| C4           | 4.95’10–4    | 43.42  | 42.86  | 37.08  | 32.35  | 32.35  | 33.00  | 34.38  | 35.48  |
| C5           | 3.0’10–2     | 33.11  | 33.98  | 32.12  | 30.03  | 30.03  | 29.18  | 28.96  | 30.86  |
| C6           | 0.56         | 21.43  | 21.43  | 23.21  | 23.21  | 25.00  | 28.57  | 30.36  | 30.36  |
| C7           | 3.0:1        | 31.00  | 37.67  | 50.00  | 54.67  | 68.33  | 62.67  | 56.33  | 62.67  |
| C8           | 30           | 66.33  | 72.67  | 45.33  | 36.00  | 33.67  | 60.67  | 53.00  | 61.00  |
| C9           | 12           | 100.00 | 100.00 | 100.00 | 98.17  | 100.00 | 100.00 | 95.92  | 100.00 |
| C10          | 10           | 0.00   | 18.10  | 35.10  | 35.90  | 37.60  | 35.70  | 41.40  | 48.50  |
| C11          | 20           | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| C12          | 5            | 30.60  | 31.20  | 36.40  | 40.80  | 43.80  | 45.20  | 47.00  | 52.60  |
| C13          | 29.2         | 60.21  | 66.67  | 68.22  | 73.00  | 79.13  | 82.49  | 84.64  | 90.68  |
| C14          | 80           | 43.75  | 45.00  | 45.00  | 50.00  | 42.50  | 42.50  | 42.50  | 43.75  |
| C15          | 0.69         | 42.03  | 37.68  | 33.33  | 28.99  | 17.39  | 30.43  | 43.48  | 44.93  |
| C16          | 1.8          | 47.87  | 50.85  | 50.85  | 52.48  | 63.38  | 64.52  | 65.93  | 66.91  |
| C17          | 25.1         | 41.08  | 42.16  | 39.94  | 37.32  | 40.80  | 43.04  | 100.00 | 100.00 |
| C18          | 9.9          | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

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Fig 1. Target control value of index data on industry convergence achievements degree.

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Analyzing the sugarcane industry convergence restriction factor

As shown in Table 6, among the tertiary indexes, after 2015, an indicator score below 60 includes the application intensity of pesticides, the application intensity of chemical fertilizer, the water saving irrigation coefficient, the ratio of leisure agricultural output value to

![Fig 2. Target control value of index data on benefits driven from industry convergence degree.](https://doi.org/10.1371/journal.pone.0244617.g002)

![Fig 3. Convergence development result for sugarcane.](https://doi.org/10.1371/journal.pone.0244617.g003)
agricultural output value, the agricultural credit input per unit, the proportion of rural non-
agricultural employment, the cash income from sugarcane production, and the investment
ratio of fixed assets per capita in urban and rural areas. These factors hinder the comprehen-
sive convergence of the sugarcane industry.

Suggestions
Replacing traditional cultivation techniques with modern sugarcane science and technology

China’s sugarcane producing areas are mainly concentrated in the Pearl River Delta, Guangxi,
Guangdong, Yunnan, and Hainan [14]. There are several problems with sugarcane produc-
tion. First, because of poor soil condition, a long period of continuous cropping, and soil de-
gradation, a large amount of fertilizer is applied in order to improve sugarcane yields. Second,
due to the small size of the cultivated area, the low educational level of farmers, and the lack of
scientific knowledge about fertilization, large amounts of chemical fertilizer are used in an
unregulated way. This causes water and land pollution in China [15]. The scope of these prob-
lems could be reduced by adopting modern science and technology, reducing the high effi-
ciency cultivation technology, and applying fertilizer in a scientific way. Therefore, we suggest
the adoption of modern cultivation technology to replace the traditional sugarcane cultivation
method, which involves intensive cultivation and high input with low yield. Under the pres-
sure of mechanization adaption and machine tool selection, sugarcane producers should adopt
breeding species and light simplification of production management technology. They should
select appropriate sugarcane species to arrange the collocation layout covered during early,
middle and late maturing. To improve soil quality, producers should return the filter mud
from the sugar factory to the field, as well as the alcohol waste liquor and the broken leaves
after the harvest. They should adhere to the implementation of biological control and maintain
a healthy ecological environment on their farmland.

The sugarcane industry as a whole needs to adopt modern technology, specifically when it
comes to machinery. At present, due to the small area of cultivation and a reduction in the
area available for sugarcane production, the mechanical level of the sugarcane industry in
China is low. Various management aspects, including field work, ditching, fertilizing, weeding,
ridging, and covering, have not yet incorporated technology of high efficiency. Integration in
field operation has not been realized due to an incompatibility between agricultural machinery
and farm implements. In general, the mechanization level of sugarcane in China is much
lower than in Australia, Brazil, the United States, India, Thailand, and South Africa. Due to the
poor site conditions and ecological complexity, decision-makers should promote mechaniza-
tion that is compatible with local conditions through the combination of large and medium
sized machinery, as well as by matching agricultural machinery with agronomy.

Improving the sugarcane industry

Currently, 95% of the sugarcane processing factories in China employ the sulfuric acid method
to extract sucrose [16]. The method lags behind more advanced techniques because most sug-
arcane processing products are bagasse and molasses, so there is a lack of diversity in the by-
products. In recent years, the global sugarcane industry has been affected by resource con-
straints and environmental problems. The most effective way to overcome difficulties and
increase competitiveness is to increase the added value of sugarcane by-products and to diver-
sify products. Bagasse is the main by-product of sugarcane, which accounts for about 24 to
27 percent of the total sugarcane product. Using biotechnology for compound enzyme
preparation can effectively improve the efficiency of enzymatic hydrolysis for bagasse. In China, Approximately 24 million tons of bagasse are produced annually (equivalent to 14,400,000 tons of dry bagasse). Developing resources for processing bagasse by-products and converting them into high value-added functional materials and biomass chemicals is an effective way to improve the technological level and competitiveness of the sugarcane industry.

**Developing sugarcane-themed tourism services**

From the perspective of industrial integration, the development of tertiary industries is an important way to further enhance the comprehensive output value of the sugarcane industry. Sugarcane planting and processing should be combined with leisure tourism [17]. For example, sugarcane could be grown into a variety of labyrinth styles, which visitors could explore and enjoy. Moreover, educational centers could be established where visitors learn about sugarcane growth [18]. At the same time, fruit cane planting should be implemented to provide fresh food. The traditional sugarcane squeezing process should be shown to tourists, allowing them to experience this traditional technique and the satisfaction that comes with squeezing out the sugarcane juice, filtering the bagasse, boiling the sugarcane water, stirring the sugarcane syrup, airing the sucrose, etc. At the same time, producers should utilize modern technology for producing distilled liquor, such as rum, as well as other types of distilled liquor from molasses. The processing mechanism could be displayed and factories can implement tourist sightseeing areas, so that visitors can also see the sugarcane processing mechanism that uses modern technology. Developing a sugarcane culture and encouraging sugarcane planting in suitable areas would help develop sugarcane culture and industry. Decision makers should systematically organize the knowledge on sugarcane planting, the data for its processing technology, as well as traditional folk art materials. These could be stored and displayed in a sugarcane culture exhibition hall, which can serve as a demonstration base for scientific research and education.

**Establishing a more effective mechanism for connecting various participants**

Our study revealed that few benefits were derived from the sugarcane industry convergence. While the industrial chain has been extended, a close connection with the industry participants has not been formed. It is necessary for the Chinese government to establish a more effective mechanism for connecting various participants. More consideration should be given to how to connect farmers, cooperatives, and other production organizations as participants in the industrial chain.

**Supporting information**

S1 Data.

(XLS)

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References
1. Sarker Tushar Chandra Azam Shah Md Golam Gousul Bonanomi Giuliano, 2017. Recent Advances in Sugarcane Industry Solid By-Products Valorization. Waste and Biomass Valorization. 96(4). pp.241–266.
2. Patil Dilip S., Mohanty J.N. Analysis of Financial Statements in the Sugar Industry. 2017. SSRN Electronic Journal. 26(2).pp.769–781.
3. Vieira A. L., Lima L. F., Conceição W. A. S., Andrade C. M. G. 2018. Energy and Exergy Analysis of Sugarcane Industry Using Free Simulator. Revista de Engenharia Térmica. 15(1).pp.9–17.
4. Omprakash Sahu. 2018. Assessment of Sugarcane Industry: Suitability for Production, Consumption and Utilization. Annals of Agrarian Science. 16(8). pp. 121–130.
5. Ndlangamandla Knowledge Kibirige Douglas Rugambisa Jeremiah I. 2017. Determinants of Competitiveness of the Swaziland Sugar Industry. Journal of Agricultural Studies. 26 (4). pp.93–102.
6. Michael Weeks. 2017. Sugar State: Industry, Science, and the Nation in Colorado’s Sugar Beet Fields. Western Historical Quarterly. 48(2). pp.367–391.
7. Li Xiang-mei, Min Min, Tan Chuan-feng. 2015. The functional assessment of agricultural ecosystems in Hubei Province, China. Ecological Modelling. 27(1).pp.68–79.
8. Yafei-Ma. 2019. Efficiency evaluation of rural industrial integration development in Gansu Province. Productivity Research. 4(4):39–43, 53.
9. Sal Antonio Gómez, García Alberto González. 2016. A comprehensive assessment of multifunctional agricultural land-use systems in Spain using a multi-dimensional evaluative model. Agriculture, Ecosystems and Environment. 39 (1). pp.83–92.
10. Nieder-Heitmann Mieke; Haigh Kathleen F.; Gorgens Johann F. (2019). Life Cycle Assessment and Multi-criteria Analysis of Sugarcane Biorefinery Scenarios. Journal of Cleaner Production. 239 (12). pp. 203–215.
11. Austry L. Jean Claude; Jolly L.; de Perindorge P. Leste. (2018) “Competitiveness of Different Sugarcane Industries in an Era Follow Sugar Prices”, Sugar Tech. 45(2), pp.94–103.
12. Diamini M.M., Worth S. (2019) “Readiness of the Swaziland Sugar Industry towards the Use of Information and Communication Technology”, South African Journal of Agricultural Extension. 32(5), pp. 36–45.
13. Xu Dong-dong. 2016. Journal of Landscape ResearchEntropy Method-based Performance Evaluation of the Tourism Industry in Xinjiang. Journal of Landscape Research. pp. 8(6):137–141.
14. Farzad Somayeh, Mandegari Mohsen Ali, Guo Miao, et al. 2017. Multi-product bio refineries from lignocelluloses: a pathway to revitalisation of the sugar industry?. Ecological Modelling. 29(1), pp. 17–28.
15. Caldarelli Carlos Eduardo Gillo Leandro. 2018. Expansion of the sugarcane industry and its effects on land use in San Paulo: Analysis from 2000 through 2015. Land Use Policy. 76(2). pp. 264–274.
16. Soltangheisi Amin, Withers Paul J. A., Pavinato Paulo Sergio, et al. 2019. Improving phosphorus sustainability of sugarcane production in Brazil. *GCB Bioenergy*. 11(12):1444–1455. https://doi.org/10.1111/gcbb.12650 PMID: 31894185

17. Nhamo Godwell, Mhlanga-Ndlovu Bon’ sile F.N. 2019. Small-Scale Farmers Associations’ adaptive capacity to climate change in Swaziland sugarcane industry. *Jamba (Potchefstroom, South Africa)*. 11 (2):1–9. https://doi.org/10.4102/jamba.v11i2.697 PMID: 31308890

18. Gómez-Sal Antonio, Belmontes Juan-Alfonso, Nicolau José-Manuel. 2013. Assessing landscape values: a proposal for a multidimensional conceptual model. *Ecological Modelling*. 25 (3). pp.72–79.