Evaluation research and development suggestion on the low-carbon transformation of regional industry: Take Quangang District as an example

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Abstract. Quangang is an emerging petrochemical base in Fujian Province. This paper evaluated the low-carbon transformation of Quangang industry, and put forward suggestions. The statistic data of Quangang from 2007 to 2015 were collected. Through the frequency statistical analysis and framework analysis of the indicators in 78 related references, combined with the actual situation of the development of the industry in Quangang, 14 indicators were selected as the evaluation index system of low-carbon transformation for Quangang industry. The data was processed, analyzed and evaluated mainly using the CRITIC method. In 2007-2015, the total evaluation scores of the industrial sectors of Quangang showed a fluctuated upward trend. Among them, the total evaluation scores from 2007 to 2008 showed an upward trend, and it fell back from 2008 to 2010, then the scores increased greatly from 2010 to 2012 and decreased slightly from 2012 to 2015, and the peak of 0.420 appeared in 2012. The following suggestions were put forward: among the advantage industrial sectors, the key development ones would be Processing of Petroleum, Coking, Processing of Nucleus Fuels (9), Production and Distribution of Electricity and Heating Power (24), Manufacture of Foods (2), Production and Distribution of Gas (26), Printing and Recording Media Reproduction Industry (10); among the disadvantaged industrial sectors, the key adjustment ones for the low-carbon industrial transformation would be Manufacture of Rubber products (13), Manufacture of Pressing of Ferrous Metals (16), Production and Distribution of Water (25), Manufacture of Paper and Paper Products (7), Manufacture of Pressing of Non-ferrous Metals (17), Manufacture of Chemical Raw Materials and Chemical Products (10).

1. Introduction
Industrial low-carbon transformation is an important task to deal with climate change and improve industrial economic efficiency, and low-carbon transformation evaluation is one of its main research fields [1-5].

Quangang District is located in the central coastal area of Fujian Province. It has a land area of 341 km², a sea area of 119 km² and a population of 420,700[6]. The main industry of Quangang is petrochemical industry. The Quangang Petrochemical Industrial Park has a planned area of 29.6 km² and 20.88 km² of it has been developed. In 2015, the output value of petrochemicals reached 67.2
billion yuan, accounting for 61.20% of the output value of industry above designated size\(^1\) in the district[7]. In 2018, the output value of petrochemicals reached 101 billion yuan. From 2013 to 2018, it had been ranked among the top 20 national chemical industry park for six consecutive years. It was the petrochemical base with complete public facilities and excellent logistics conditions in Fujian Province[6]. In such an emerging petrochemical city, the low-carbon transformation of the industry is particularly important.

The low-carbon transformation of the industry is to promote the transformation of high-carbon industries and develop low-carbon emerging industries through innovation, and reduce the use of energy and the emissions of pollutants in production to reduce the negative impact of the economy on the environment[8].

Table 1. Comprehensive evaluation index system of low-carbon transformation for Quangang industrial sectors.

| Index                               | Calculation method of index                                                                 |
|-------------------------------------|---------------------------------------------------------------------------------------------|
| GDP per capita                      | GDP/Year-end employed persons                                                               |
| Scale of added value (The ratio of added value of the industrial sectors to GDP) | Added value of the industrial sectors/GDP                                                  |
| The ratio of average annual net value of fixed assets to its original value | Annual average balance of net value of fixed assets/Total original value of fixed assets |
| Labor remuneration of employees of each industrial sector | Labor remuneration of employees of each industrial sector |
| The ratio of total profits and taxes to total assets of industrial sector | Total profits and taxes of each industrial sector/Total assets of the sector |
| Ratio of profits to costs           | Total profit of each industrial sector during the reporting period/Total cost and expense of the sector during the reporting period |
| Contribution rate of total assets   | (Total profits+Total tax+Interest expenses)/Average total assets×100%                      |
| Sales rate of products              | Total sales of the products of each industrial sector/Gross output value of the products |
| Location entropy                    | (Output value of each industrial sector/Gross output value of all sectors in the region)/(National output value of the sectors /National GDP) |
| Energy consumption per output value | Comprehensive energy consumption of each industrial sector/                                 |
|                                     | Gross output value of the sector                                                              |
| Direct carbon emission coefficient  | Direct energy consumption coefficient×Carbon emission coefficient of energy                  |
| Raw coal consumption ratio          | Raw coal consumption of each industrial sector/Total energy consumption of the sector       |
| Primary energy consumption intensity| Total consumption of the fossil energy of each industrial sector/Gross output value of the sector |
| Carbon productivity                | Added value of each industrial sector/Total carbon dioxide emissions of all sectors          |

\(^1\) According to the rule of National Bureau of Statistics of China, the designated size is 5 million yuan during 2007-2010, and it is 20 million yuan during 2011-2015. See: http://www.stats.gov.cn/tjzs/cjwtjd/201311/t20131105_455942.html
2. Research methods

2.1. Selection of indicators and CRITIC method

2.1.1. Selection of indicators. This paper selected 78 articles related to the evaluation indicators of regional industrial transformation, and collected all relevant indicators in the articles. By analyzing the frequency of the indicators, 22 indicators were identified. Finally, based on the actual situation and framework analysis of the industrial development of Quangang, 14 evaluation indicators were selected and divided into three categories as shown in Table 1.

According to the Classification and Codes of Sectors in National Economy (GB/T 4754-2017)[9] and combined with the industrial status of Quangang, 26 industrial sectors as shown in Table 2 were selected for analysis from the industry above designated size listed in Quangang Statistical Yearbook (2008-2016)[10].

Table 2. The codes and the corresponding names of industrial sectors.

| Code | Code | Code | Code |
|------|------|------|------|
| 1    | 10   | 19   | |
| 2    | 11   | 20   | |
| 3    | 12   | 21   | |
| 4    | 13   | 22   | |
| 5    | 14   | 23   | |
| 6    | 15   | 24   | |
| 7    | 16   | 25   | |
| 8    | 17   | 26   | |
| 9    |      |      | |

2.1.2. CRITIC method. CRITIC (Criteria Importance Through Inter-criteria Correlation) method that is a method of determination of objective weights and was proposed by Diakoulaki[11] was used to evaluate the situation of Quangang. The CRITIC method is simple in principle and high in sensitivity. It is considered as a calculation method that can comprehensively reflects the objective weight of indicators, and has been widely used. The results were calculated by formulae as follows:
First, standardize the original data. Z-score method is used to standardize the original data. Second, calculate the amount of information.

\[ C_j = \sigma_j \sum_{i=1}^{y} (1 - r_{ij}) \quad (i=1,2,3,\ldots, x ; j=1,2,3,\ldots,y) \]

Third, calculate the objective weight of each indicator.

\[ W_j = \frac{C_j}{\sum_{j=1}^{y} C_j} \quad (j=1,2,3,\ldots, y) \]

Fourth, calculate the total evaluation score of each industry sector.

\[ V_i = \sum_{j=1}^{y} W_j d_{ij} \quad (i=1,2,3,\ldots, x ; j=1,2,3,\ldots, y) \]

Where \( C_j \) is the amount of information contained in the indicator \( j \), \( \sigma_j \) is the standard deviation of the indicator \( j \), \( r_{ij} \) is the correlation coefficient between evaluation indicator \( i \) and evaluation indicator \( j \), \( W_j \) is the objective weight of indicator \( j \), \( V_i \) is the total evaluation score, and \( d_{ij} \) is the data normalized by the original data.

3. Results and discussion

3.1. Evaluation scores of CRITIC method
The statistical data came from Statistical Yearbook of Quangang District (2008-2016)[10]. According to the formula of CRITIC method, the total evaluation scores and rankings of each industrial sector in 2007-2015 were calculated as shown in Table 3.

3.2. Discussions
As can be seen from Table 3, from 2007 to 2015, the industrial sector 9 and 24 ranked stably in the overall evaluation score, with the average score ranking in the first two places, and the average score of sector 9 was 0.404 and that of sector 24 was 0.415. This showed that these two industrial sectors were the leading industries in Quangang and Quangang was a city with a high degree of industrialization. Sector 2 had a high ranking and the overall ranking fluctuated around the fifth place that implied it was a well-developed department. The average score of sector 26 ranked behind, but the overall ranking showed an upward trend; among them, the overall evaluation rankings of 2007-2009 were in the last place, and the rankings of 2010-2015 were rising rapidly and remained in the top ten, thus it can be seen that sector 26 had developed rapidly in recent years. The ranking of sector 8 fluctuated greatly within the top 10 except in 2007 that meant it was a well-developed industrial sector.

From 2007 to 2015, the average scores of sector 13 and 16 ranked in the last two places and sector 25, 7 and 17 ranked relatively low and fluctuated greatly that meant they were developed slowly. Sector 10 is Manufacture of Chemical Raw Materials and Chemical Products, ranking in the middle and lower position and relatively stable; however, in such an emerging petrochemical city, this sector should be promoted quickly by take full advantage of petrochemical industry; therefore, sector 10 should be taken as a key adjustment sector.

Thus, the following sectors could be taken as advantageous sectors and the key development sectors in future: Processing of Petroleum, Coking, Processing of Nucleus Fuels (9), Production and Distribution of Electricity and Heating Power (24), Manufacture of Foods (2), Production and Distribution of Gas (26), Printing and Recording Media Reproduction Industry (10); the following sectors could be taken as disadvantageous sectors and the key adjustment sectors in future: Manufacture of Rubber products (13), Manufacture of Pressing of Ferrous Metals (16), Production and Distribution of Water (25), Manufacture of Paper and Paper Products (7), Manufacture of Pressing of Non-ferrous Metals (17), Manufacture of Chemical Raw Materials and Chemical Products (10).
## Table 3. Total evaluation score of each industrial sector by the CRITIC method from 2007 to 2015 (to be continued).

| Sector code | Total evaluation score and ranking | 2007 | Ranking | 2008 | Ranking | 2009 | Ranking | 2010 | Ranking | 2011 | Ranking | 2012 | Ranking | 2013 | Ranking | 2014 | Ranking | 2015 | Ranking | Average value | Ranking |
|-------------|------------------------------------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|------|---------|-------------|---------|
| 1           | 0.312                              | 3    | 0.341   | 3    | 0.237   | 14   | 0.180   | 16   | 0.226   | 15   |         |      |         |      |         |      |         |      |         |             |         |
| 2           | 0.285                              | 5    | 0.293   | 7    | 0.266   | 12   | 0.293   | 6    | 0.362   | 3    |         |      |         |      |         |      |         |      |         |             |         |
| 3           | 0.215                              | 16   | 0.208   | 22   | 0.157   | 22   | 0.113   | 24   | 0.230   | 14   |         |      |         |      |         |      |         |      |         |             |         |
| 4           | 0.190                              | 20   | 0.311   | 6    | 0.229   | 16   | 0.199   | 15   | 0.291   | 8    |         |      |         |      |         |      |         |      |         |             |         |
| 5           | 0.272                              | 8    | 0.286   | 8    | 0.198   | 20   | 0.151   | 19   | 0.204   | 18   |         |      |         |      |         |      |         |      |         |             |         |
| 6           | 0.172                              | 23   | 0.238   | 17   | 0.381   | 4    | 0.325   | 4    | 0.280   | 11   |         |      |         |      |         |      |         |      |         |             |         |
| 7           | 0.261                              | 9    | 0.190   | 23   | 0.247   | 13   | 0.250   | 11   | 0.206   | 17   |         |      |         |      |         |      |         |      |         |             |         |
| 8           | 0.190                              | 21   | 0.271   | 9    | 0.287   | 10   | 0.392   | 1    | 0.327   | 6    |         |      |         |      |         |      |         |      |         |             |         |
| 9           | 0.339                              | 2    | 0.485   | 1    | 0.371   | 5    | 0.336   | 3    | 0.385   | 2    |         |      |         |      |         |      |         |      |         |             |         |
| 10          | 0.211                              | 17   | 0.261   | 11   | 0.334   | 7    | 0.152   | 18   | 0.231   | 13   |         |      |         |      |         |      |         |      |         |             |         |
| 11          | 0.209                              | 18   | 0.319   | 4    | 0.353   | 6    | 0.277   | 7    | 0.287   | 10   |         |      |         |      |         |      |         |      |         |             |         |
| 12          | 0.193                              | 19   | 0.315   | 5    | 0.145   | 23   | 0.231   | 13   | 0.180   | 23   |         |      |         |      |         |      |         |      |         |             |         |
| 13          | 0.223                              | 14   | 0.250   | 15   | 0.184   | 21   | 0.114   | 23   | 0.198   | 21   |         |      |         |      |         |      |         |      |         |             |         |
| 14          | 0.229                              | 13   | 0.261   | 10   | 0.299   | 8    | 0.269   | 9    | 0.201   | 20   |         |      |         |      |         |      |         |      |         |             |         |
| 15          | 0.247                              | 12   | 0.259   | 12   | 0.204   | 19   | 0.141   | 21   | 0.207   | 16   |         |      |         |      |         |      |         |      |         |             |         |
| 16          | 0.017                              | 25   | 0.019   | 25   | 0.006   | 25   | 0.000   | 25   | 0.031   | 26   |         |      |         |      |         |      |         |      |         |             |         |
| 17          | 0.252                              | 11   | 0.222   | 20   | 0.228   | 17   | 0.119   | 22   | 0.148   | 24   |         |      |         |      |         |      |         |      |         |             |         |
| 18          | 0.256                              | 10   | 0.226   | 19   | 0.232   | 15   | 0.296   | 5    | 0.252   | 12   |         |      |         |      |         |      |         |      |         |             |         |
| 19          | 0.281                              | 6    | 0.160   | 24   | 0.421   | 3    | 0.235   | 12   | 0.122   | 25   |         |      |         |      |         |      |         |      |         |             |         |
| 20          | 0.280                              | 7    | 0.257   | 13   | 0.465   | 1    | 0.274   | 8    | 0.347   | 5    |         |      |         |      |         |      |         |      |         |             |         |
| 21          | 0.132                              | 24   | 0.208   | 21   | 0.222   | 18   | 0.141   | 20   | 0.184   | 22   |         |      |         |      |         |      |         |      |         |             |         |
| 22          | 0.217                              | 15   | 0.245   | 16   | 0.277   | 11   | 0.153   | 17   | 0.202   | 19   |         |      |         |      |         |      |         |      |         |             |         |
| 23          | 0.303                              | 4    | 0.257   | 14   | 0.292   | 9    | 0.226   | 14   | 0.327   | 7    |         |      |         |      |         |      |         |      |         |             |         |
| 24          | 0.418                              | 1    | 0.451   | 2    | 0.436   | 2    | 0.369   | 2    | 0.409   | 1    |         |      |         |      |         |      |         |      |         |             |         |
| 25          | 0.184                              | 22   | 0.231   | 18   | 0.128   | 24   | 0.251   | 10   | 0.358   | 4    |         |      |         |      |         |      |         |      |         |             |         |
| 26          | 0.014                              | 26   | 0.019   | 26   | 0.006   | 26   | 0.000   | 26   | 0.287   | 9    |         |      |         |      |         |      |         |      |         |             |         |
6 0.280 7 0.356 11 0.261 8 0.287 12 0.282 6
7 0.206 23 0.218 21 0.189 21 0.177 19 0.213 20
8 0.327 10 0.314 6 0.331 5 0.300 6 0.301 4
9 0.385 1 0.466 1 0.446 1 0.437 2 0.404 2
10 0.231 22 0.230 22 0.179 17 0.194 21 0.219 17
11 0.287 14 0.268 14 0.246 15 0.212 13 0.267 8
12 0.180 13 0.275 12 0.259 10 0.265 8 0.238 12
13 0.198 26 0.035 26 0.008 26 0.009 25 0.114 25
14 0.201 17 0.248 16 0.240 14 0.221 11 0.246 11
15 0.207 11 0.286 15 0.240 7 0.292 10 0.238 14
16 0.031 24 0.179 24 0.152 20 0.184 22 0.082 26
17 0.148 3 0.392 2 0.401 23 0.134 23 0.215 19
18 0.252 21 0.236 10 0.280 9 0.275 14 0.252 9
19 0.122 8 0.317 4 0.390 24 0.116 24 0.228 16
20 0.347 20 0.242 9 0.289 11 0.255 7 0.299 5
21 0.184 12 0.285 19 0.212 18 0.191 9 0.204 21
22 0.202 18 0.245 23 0.168 22 0.141 18 0.203 22
23 0.327 5 0.369 17 0.226 13 0.226 20 0.267 7
24 0.409 2 0.446 3 0.394 2 0.408 1 0.415 1
25 0.358 25 0.036 25 0.009 25 0.010 26 0.135 24
26 0.287 4 0.388 7 0.302 4 0.333 4 0.183 23

**Figure 1.** Evaluation results of CRITIC method of industrial sectors in Quangang from 2007 to 2015.

As can be seen from Figure 1, from 2007 to 2015, the total evaluation scores of the industrial sectors showed a fluctuated upward trend. Among them, the total evaluation scores from 2007 to 2008 showed an upward trend, and it fell back from 2008 to 2010, then the scores increased greatly from 2010 to 2012 and decreased slightly from 2012 to 2015, and the peak of 0.420 appeared in 2012.

During the interview, it was known that FREP (Fujian Refining & Petrochemical Company Limited) had implemented a circular economy transformation project invested about 100 million yuan from 2011 to 2014[12]. That was consistent with the highest total evaluation score appeared in 2012.
It can be seen that the low-carbon transformation of industrial sectors in Quangang had been effective in recent years, and the level of low-carbon development had reached a new stage and is now in a relatively stable stage. Because Quangang was mainly based on heavy industry, to further improve the level of low-carbon development, it may require more investment and more advanced technology in the future.

4. Conclusions
In 2007-2015, the total evaluation scores of the industrial sectors of Quangang showed a fluctuated upward trend. Among them, the total evaluation scores from 2007 to 2008 showed an upward trend, and it fell back from 2008 to 2010, then the scores increased greatly from 2010 to 2012 and decreased slightly from 2012 to 2015, and the peak of 0.420 appeared in 2012.

Among the advantage industrial sectors, the key development ones would be Processing of Petroleum, Coking, Processing of Nucleus Fuels (9), Production and Distribution of Electricity and Heating Power (24), Manufacture of Foods (2), Production and Distribution of Gas (26), Printing and Recording Media Reproduction Industry (10).

Among the disadvantaged industrial sectors, the key adjustment ones for the low-carbon industrial transformation would be Manufacture of Rubber products (13), Manufacture of Pressing of Ferrous Metals (16), Production and Distribution of Water (25), Manufacture of Paper and Paper Products (7), Manufacture of Pressing of Non-ferrous Metals (17), Manufacture of Chemical Raw Materials and Chemical Products (10).

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