The competitiveness analysis of Chinese automobile industry based on Improved Porter Diamond Model

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Abstract. With the rapid development of Chinese automobile industry, it has become one of the pillar industries of the national economy, which plays an increasingly important role in the rapid growth of the national economy. This paper aims to investigate the competitiveness of Chinese automobile industry in different provinces and cities and to quantify the core competitiveness. Improved Porter Diamond Model is adopted to evaluate the factors that affect the Chinese automobile industry, including Industrial structure, Production factors, Demand conditions, Related and supporting industries. The data used for the analysis mainly comes from China Automobile Yearbook. Entropy Method and TOPSIS are applied to calculate the weights of each factor and evaluate the quality level of the indexes. According to the analysis, Guangdong, Jiangsu, Shanghai, Jilin, Shandong, Hubei, Zhejiang, and Beijing have higher scores and top ranking, showing strong core competitiveness, which is consistent with the reality. Tibet, Qinghai, and Ningxia ranked last because of their geographical location, which restricted the development of their automobile industry. The model can truly rank the province's automobile core competitiveness quantitatively, which is consistent with the reality and has high practical application value. Overall, these results shed light on guiding further exploration of the evaluation and quantification of core competitiveness in different industries.

Keywords: Improved Porter Diamond Model, Automobile Industry, Core competitiveness, Entropy method, TOPSIS.

1. Introduction

Porter Diamond Model is a four-factor model of industrial competitiveness proposed Michael Porter, a famous strategic management scientist of Harvard Business School [1], which is mainly used to study the influencing factors of industrial competitiveness. Contemporaily, numerous scholars have applied Porter Diamond Model to different industries and economic issues. Lu used Porter Diamond Model to analyze the automobile industry clusters in Chongqing [2]. The study has been done from 6 factors: demand qualification, production factors, relevant and supporting industries, opportunities and government, structure, and competition. The paper studied the current situation of automobile industry in Chongqing Finally, the paper provided countermeasures from government and companies' point of view which may contribute a lot to the development of automobile industry clusters in Chongqing [2].

Erboz used Porter Diamond Model as a framework to provide a dynamic view of Industry 4.0 competitiveness in Turkey [3]. It drew the conclusion that factors (e.g., labor and capital) are the most significant aspects influencing the future of Industry 4.0 competitiveness in the country. For labor conditions, the quality of employees and the technologies played the most important role. With regard to capital conditions, as the former factor are highly capital intensive, companies wouldn't pursue it unless they needed. Finally, it predicted that government's influence and some chances can contribute to the position of competitiveness in Turkey [3].

Wang and Li applied Porter Diamond Model to measure the competitiveness of high-tech industries in Nanjing [4]. The paper pointed out the existing problems of the 6 elements: opportunities of Nanjing High-tech industry, Status of production factors, Infrastructure, Demand status, Supporting the development of industries and related industries, High-tech enterprise strategy, organization and structure, Government action. Finally, it gave some suggestions on enhancing the competitiveness of Nanjing's high-tech industry [4].

Tsiligiris proposed an adapted Porter Diamond Model as an analytical framework for the strategic evaluation of transnational education host countries in terms of attractiveness for exporting higher education [5]. The study collected data of China and Malaysia, and then used the adopted model to evaluate these 2 countries. The results verified the stability of the model, so it can be used to strengthen the attractiveness for education import or to plan of becoming education hubs. Besides, it provided an effective method to aid decision making at country level [5].

Chobanyan applied Porter Diamond Model to the study in Armenia, a small and land-locked economy [6]. It is found that although there were still some limitations, Porter Diamond Model provided a practical start for studying proper development policy in emerging markets and Porter Diamond Model provided some useful methods for the policymakers in other fields [6].

Jarungkitkul applied Porter Diamond Model to the analysis of competitiveness of the stock Markets in the Stock Exchange of Thailand, the Singapore Exchange etc. [7]. According to the analysis, the Singapore Exchange is the most competitive exchange in the 5 regions. The paper presented the practical implications and social implications of the Porter Diamond Model [7].

Castro-Gonzáles used Double Diamond Model to evaluate the competitiveness of Latin American economies[8]. The model had valuable implications for policymakers to design policies to enhance the economic conditions [8].

With the rapid development of China's automobile industry, the automobile industry has become one of the pillar industries of the national economy, which plays an increasingly crucial role in the rapid growth of the national economy [9]. It's meaningful to establish a model to establish a proper model to evaluate and quantify the core competitiveness of the Chinese automobile industry in different provinces and cities to show the relative advantages of automobile industry in different provinces and cities.

Through consulting the relevant literatures on the Internet, Porter diamond model can be used to find out the four principal components related to industrial competitiveness. Combined with the requirements of this topic, the traditional model has been improved, and finally the production factors, demand conditions, related supporting industries and industrial structure have been determined as four principal components. On this basis, the corresponding eleven secondary indicators, which can specifically reflect the core competitiveness are selected from China automobile industry yearbook [10] and divided into four principal components. To verify the rationality of Porter diamond model classification, principal component analysis (PCA) can be used to test. Finally, to quantify the core competitiveness of the automobile industry in each province, the comprehensive evaluation model of entropy weight method combined with TOPSIS to score and rank the core competitiveness of the automobile industry in each province are introduced. The specific flow chart is presented in Fig. 1.

The rest part of the paper is organized as follows. The Sec. II will introduce the model used in the analysis and test the rationality of index classification by PCA. The Sec. III will solve the model and do the calculations by adopting Entropy method and TOPSIS. Then, the results and explanations will be given. Eventually, a brief summary will be given in the Sec. VI.

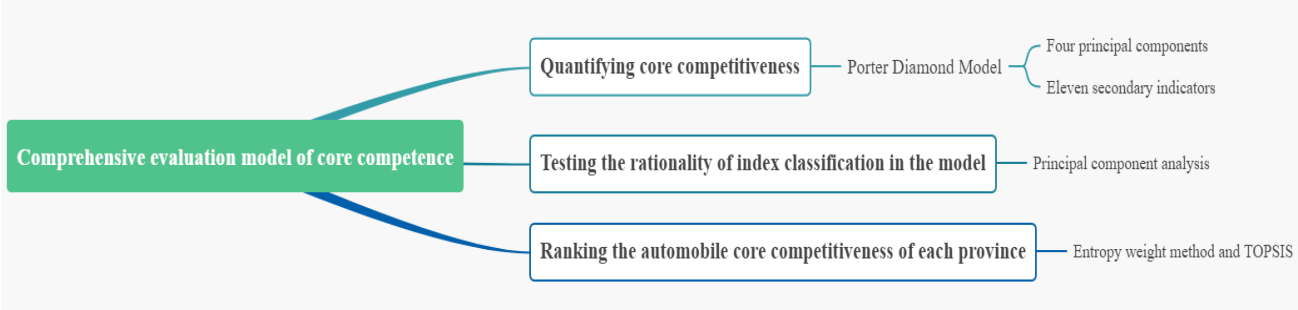

Figure 1. The sketch of framework.

2. Methodology

2.1. Data

From China automobile industry yearbook [10], the data of 11 sub-indexed which reflect the four factors in the Improved Porter Diamond Model in 31 provinces and cities is introduced. Specifically, it includes the total profit, the total profit and tax, the number of employees, the research and development ratio, the main business income, the number of automobile ownerhip, the number of traffic accidents, the road mileage, the total output value of automobile industry, the automobile output, the number of enterprises.

2.2. Improved porter diamond model

According to the characteristics of Chinese automobile industry, Porter diamond model has a certain reference significance for the study of the core competitiveness of automobile industry in various provinces and cities. Therefore, combined with the characteristics of Porter diamond model and the actual characteristics of automobile industry, this paper improves the traditional Porter diamond model, and evaluates the core competitiveness of automobile industry in China from four principal components: production factors, demand conditions, related supporting industries and industrial structure. The specific relationship is shown in the Fig. 2.

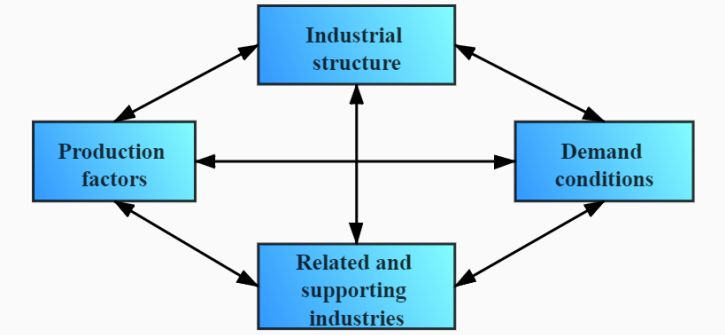

Figure 2. Improved porter diamond model

From China automotive industry yearbook, eleven sub-indexes as secondary evaluation indexes, including the number of enterprises, the number of employees, the main business income, the total profit, the total profit and tax, the research and development investment ratio, the total output value of automobile industry, the number of automobile ownership, the number of traffic accidents, the road mileage, and the automobile output are introduced. Based on Improved porter diamond model, the 11 secondary evaluation indexes are divided into four groups: Industrial structure, Production factors, Demand conditions, Related and supporting industries as listed in Table. I.

Table 1. Core competitiveness index of automobile industry in various provinces and cities

Evaluation criteria	Secondary evaluation index
Production factors	The total profit The total profit and tax The number of employees The research and development ratio The main business income
Demand condition	The number of automobile ownership
Related supporting industries	The number of traffic accidents The road mileage
Industrial structure	The total output value of automobile industry The automobile output The number of enterprises

Through the paper, the following notations are adopted as listed in Table. II. Only the main parameters are defined here while ther parameters are given in the following paper.

2.3. Model testing and determination of principal component coefficient

The classification is based on actual situation and the corresponding economic principles so in order to verify the rationality and validity of the model, principal component analysis (PCA) is used to test it as presented in Table. III. With the help of SPSS software, the coefficient matrix of four principal components is gotten.

Table 2. Parameters' declaration

Symbol	Interpretation
F_1	Production factors
F_2	Demand conditions
F_3	Related supporting industries
F_4	Industrial structure
X_1	The number of enterprises
X_2	The number of employees
X_3	The main business income
X_4	The total profit
X_5	The total profit and tax
X_6	The research and development investment ratio
X_7	The total output value of automobile industry
X_8	The number of automobile ownership
X_9	The number of traffic accidents
X_{10}	The road mileage
X_{11}	The automobile output

Table 3. Principal component coefficient matrix

Secondary indicators	Principal component			
	F_1	F_2	F_3	F_4
X_1	0.218	0.124	-0.341	0.120
X_2	0.204	0.015	0.066	0.134
X_3	-0.114	-0.127	0.161	0.138
X_4	-0.227	-0.187	0.079	0.130
X_5	-0.226	-0.187	0.078	0.130
X_6	0.891	-0.031	0.198	0.068
X_7	-0.079	-0.110	0.085	0.138
X_8	-0.061	0.325	-0.197	0.103
X_9	-0.094	0.331	-0.915	0.088
X_{10}	-0.125	0.509	0.962	0.019
X_{11}	-0.090	-0.043	0.369	0.127

By observing the table, it's clear that the principal component analysis method is basically consistent with the categories according to the actual situation and economic principles, which verifies the accuracy and reliability of the model. Finally, the Comprehensive evaluation model of core competence has been established:

$$F_i = \sum_{j=1}^{11} a_{ij} X_j, j = 1,2,3,4 \quad (1)$$

$$Z_{score} = \sum_{i=1}^{4} w_i F_i \quad (2)$$

where a_{ij} is Principal component coefficient, w_i is the weight of each factor and other parameters are already defined in Table. II.

3. Results & Discussion

3.1. Empirical analysis

Entropy method is an objective weighting method, which uses the idea of information entropy from Ref. [11]. It calculates the information entropy of the index and determines the weight of the index according to the influence of the relative change degree of the index on the whole system. It weights

the index according to the difference degree of the mark value of each index, so as to obtain the corresponding weight of each index. The index with large relative change degree has larger weight. The specific steps are as follows:

- Calculate the proportion p_{ij} of the index value x_{ij} of the evaluation object i under the index j

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, j = 1,2,\cdots n \tag{3}$$

- Calculate the entropy e_j of index j

$$e_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \ln p_{ij}, 0 \le e_j \le 1, j = 1,2,\cdots n \tag{4}$$

- Determine the index weight w_j

$$w_j = \frac{1-e_j}{\sum_{i=1}^{m} 1-e_i}, j = 1,2,\cdots n \tag{5}$$

Table 4. The weight of four principal components

Principal component	w_j
F_1	0.3951
F_2	0.1131
F_3	0.1111
F_4	0.3787

Table 5. Comprehensive scores, fit value and ranking of provinces and cities

Provinces and cities	Scores	Fitting value	Ranking
Guangdong	0.788798101	1	1
Jiangsu	0.782677606	0.992241	2
Shanghai	0.781498725	0.990746	3
Jilin	0.76600737	0.971107	4
Shandong	0.745572331	0.9452	5
Hubei	0.742797367	0.941683	6
Zhejiang	0.619982903	0.785984	7
Beijing	0.517244703	0.655738	8
Anhui	0.484511748	0.614241	9
Chongqing	0.432625259	0.548461	10
Liaoning	0.401968244	0.509596	11
Henan	0.384402546	0.487327	12
Sichuan	0.375396625	0.47591	13
Hebei	0.337018681	0.427256	14
Hunan	0.311787928	0.39527	15
Guangxi	0.307061274	0.389277	16
Tianjin	0.296719442	0.376167	17
Jiangxi	0.271337077	0.343988	18
Shaanxi	0.270765031	0.343263	19
Fujian	0.236006786	0.299198	20
Yunnan	0.222198451	0.281692	21
Shanxi	0.221611667	0.280949	22
Heilongjiang	0.221084575	0.28028	23
Guizhou	0.219716811	0.278546	24
Xinjiang	0.219400103	0.278145	25
Inner Mongolia	0.219337075	0.278065	26
Gansu	0.218910025	0.277524	27
Hainan	0.218462437	0.276956	28
Xizang	0.218450874	0.276941	29
Qinghai	0.218391311	0.276866	30
Ningxia	0.217991084	0.276359	31

With the help of SPSS software, one can get the weight of the four principal components to the target in Table. IV. The comprehensive score of the core competitiveness of the automobile industry in Chinese provinces and cities can be obtained (as given in Table. V). TOPSIS is to find the best scheme and the worst scheme in the limited scheme in the normalized data matrix. Subsequently, one can calculate the distance between the evaluation object and the best scheme and the worst scheme respectively and use this as the basis to evaluate the quality level of the sample [12]. The specific steps are as follows:

- According to the formula, the weighted matrix z_{ij} is obtained, where

$$z_{ij} = w_j * x_{ij}, j = 1,2,\cdots n \tag{6}$$

- Select the maximum and minimum value of the index value from the weighted matrix z_{ij} to represent the positive value ideal solution Z^+ and negative ideal solution Z^-:

$$Z^+ = (z_1^+, z_2^+, \cdots z_n^+), Z^- = (z_1^-, z_2^-, \cdots z_n^-) \tag{7}$$

where

$$z_j^+ = \max(z_{1j}, z_{2j}, \cdots z_{mj}), z_j^- = \min(z_{1j}, z_{2j}, \cdots z_{mj}) \tag{8}$$

- Calculate the distance d_i^+ and d_i^- between the index of each province and positive ideal solution and negative ideal solution respectively:

$$d_i^{\pm} = \sqrt{\sum_{j=1}^{n}(z_{ij} - z_i^{\pm})^2}, i = 1,2,\cdots m \tag{9}$$

- Calculate the similarity C_i

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{10}$$

The larger the *Ci* is, the better the core competitiveness of the province is, and vice versa. Finally, the fitting value of the provinces and cities with the optimal scheme and the ranking of the core competitiveness can be derived as listed in Table. V.

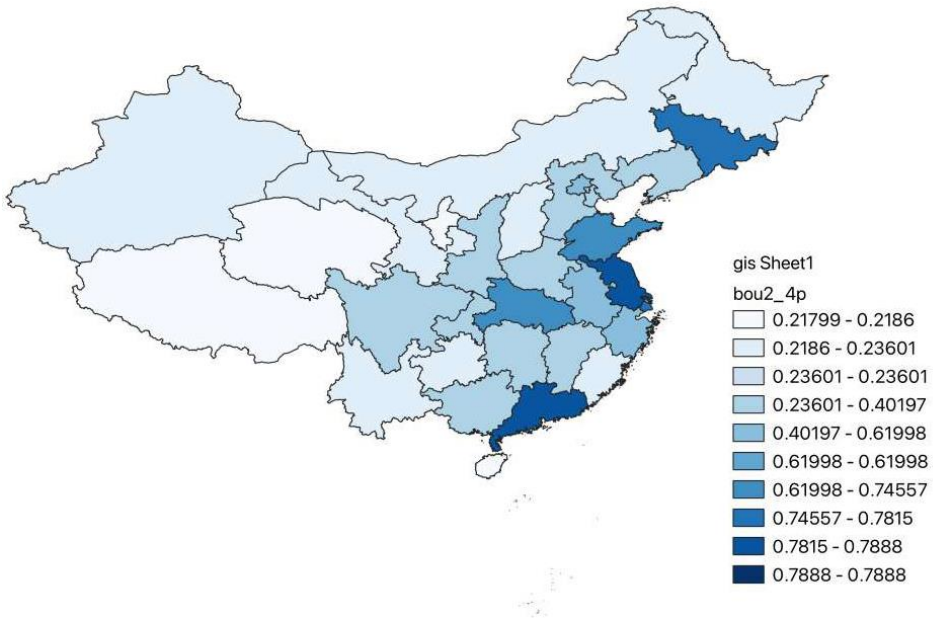

Figure 3. Competitiveness map of automobile industry in various provinces and cities

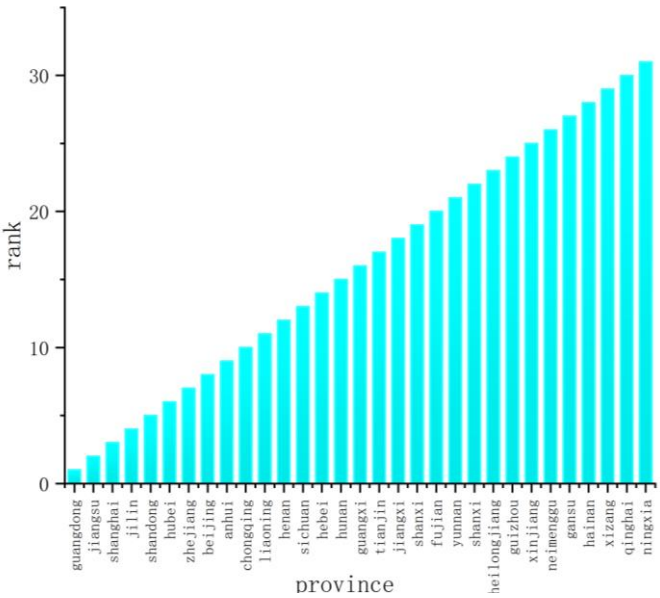

Figure 4. Ranking of core competitiveness of provinces and cities

3.2. Explanition

As this topic requires the competitiveness of the automobile industry in various provinces and cities, the size of the core competitiveness as the range of the color is defined, the darker the color is, the more competitive the province is. To get the map of China sprayed with ink, which can directly reflect the evaluation results of the competitiveness of the automobile industry in various provinces and cities. The specific figure is given in Fig. 3.

To reflect the ranking of the core competitiveness of the automobile more intuitively industry in various provinces and cities, the table is converted into a histogram, as shown in the Fig. 4.

Based on the results, cities in Guangdong, Jiangsu, Shanghai, Jilin, Shandong, Hubei, Zhejiang, and Beijing have higher scores and top ranking, showing strong core competitiveness, which is consistent with the actual situation. According to the data released by GAC in 2019, the total operating revenue of joint ventures and associated companies in 2018 is 363.685 billion yuan, the combined operating revenue is 72.38 billion yuan, and the net profit attributable to the shareholders of the parent company is 10.903 billion yuan, ranking first in China. Hubei, Jilin and Shanghai, as traditional automobile industry bases, have enterprises such as Dongfeng, FAW and SAIC, which also have strong enough core competitiveness. Jiangsu, Zhejiang, and other places have the most potential for the development of the automobile industry. The graphical advantages of the Yangtze River Delta radiate the southern and northern markets, and the eastern coastal market capacity is also large. They can give full play to the advantages of real estate vehicles, hence they also have strong competitiveness. Tibet, Qinghai, and Ningxia ranked last because of their geographical location, which restricted the development of their automobile industry. Therefore, they scored low on the automobile core competitiveness, which is also consistent with the actual situation. To sum up, the evaluation model can truly rank the province's automobile core competitiveness quantitatively, which is consistent with the reality and has high practical application value.

3.3. Strengths and Weakness

The model has a strong generalization and has universal application value in the evaluation of core competitiveness. When the evaluation object or index changes, this model can still be used for comprehensive evaluation. The paper can use the principal component analysis method to verify the classification results, and combined with the improved entropy weight TOPSIS method, objectively give the principal component weight to score, which has excellent accuracy.

Neverthless, it should be noeted that some of the analysis is limited. In the process of selecting the evaluation indexes, only 11 sub-indexes as the secondary indexes have been selected, which means it

has certain subjectivity as it can't list all the indexes related to the four factors in the Improved Porter Diamond Model. Therefore, it can only analyze the evaluation of the core competitiveness of Chinese automobile industry through the selected indexes. In addition, the results and conclusion gained by the model can only hold under such selected indexes.

4. Conclusion

In summary, this paper investigates the competitiveness of Chinese Automobile industry based on Improved Porter Diamond Model. Specifically, Entropy Method and TOPSIS are applied to calculate the weights of each factor and evaluate the quality level of the indexes. According to the analysis, Guangdong, Jiangsu, Shanghai, Jilin, Shandong, Hubei, Zhejiang, and Beijing have higher scores and top ranking, showing strong core competitiveness, which is consistent with the reality. Tibet, Qinghai, and Ningxia ranked last because of their geographical location, which restricted the development of their automobile industry. In the future, the selection process of the secondary evaluation indexes can be optimized to investigate the competitiveness of Chinese automobile industry more accurately. Overall, these results offer a guideline for the government and enterprises to make policy and strategies based on the actual conditions of each province and city to develop the core competitiveness of Chinese automobile industry. Meanwhile, the model has a strong generalization and has universal application value in the evaluation of core competitiveness.

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