Research on the Model of Sports Industry Competitiveness Based on Factor Analysis and Principal Component Analysis

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Abstract

The sports industry competitiveness is systemly analyzed international competitiveness theory. The research on the principal influencing factors as well as evaluation principles of present regional sports industry competitiveness is mainly discussed and the comprehensive evaluation model of regional sports industry competitiveness is set up in this paper. With the combination of logic analysis and empirical analysis, as well as validity analysis and reliability analysis, we selected recent years’ related indicators on economic and social development from eight provinces and municipalities. Then we implemented empirical analysis on these related indicators based on factor analysis and principal component analysis, so as to acquire more realistic and objective indicators and weightiness. The empirical research results show that the methods put forward by us can effectively combine evaluation results of industrial competitiveness and developmental strategies of sports industry and formulate more scientific and rational development strategies according to conditions of the competitive opponents.

Keywords: Sports Industry Competitiveness, Evaluation Indicators, Factor Analysis, Eigenvalues, Rotation Matrix

1. Introduction

Under specific environment, sports industry competitiveness refers that mutual interaction between each component in sports industry and environment appears the reflection of comprehensive competition advantages during the competition in different regions. Since Porter put forth the definition of industrial competitiveness at the industry level, industrial competitiveness has become the research hot topic on economics, management studies, government and business in [1]. Sports industry has become a kind of industry with wide coverage, broad relevancy and deep influence. With further implementation of the reform and opening up policy, sports industry’s status and function on social and economic system have become increasingly obvious. In recent years, many domestic and overseas scholars have performed related research on industrial competitiveness to produce various evaluation models. Meanwhile, as an emerging industry, sports industry has been paid more and more widespread attentions.

Andrew J. Rohm, etc, applied a kind of blended method of data on participation motives separating sports products in [2]. In sports industry, cluster configuration and its structure are defined as market segmentation, some data are collected to perform quantitative analysis and marketing management will greatly play an influencing role in sports communication industry development. Mary A Hums in [3] divided sports industry into professional sports, intercollegiate sports, health, fitness, recreation and facility management in detail and elaborated some factors influencing sports industry competitiveness.

Domestic research on sports industry competitiveness is relatively lagging behind. Lin Xianpeng [4-5] carried out systematic analysis and demonstration on establishing our country’s statistical indicator system of sports industry from economics perspective. Zhang Lin, Min Zhang, etc [6-8] performed description on sports industry from the five perspectives of financial situation, scale and contribution indicator, business activity indicator, foreign economic indicator and supplementary indicator to lay the function for the research of sports industry competitiveness. Luo Jianying and other scholars carried out the research from the perspective of regional sports industry competitiveness [9]. They concluded that the core competitiveness of regional sports industry refers regional sports industry’s acquiring capability under the combined action of tangible or intangible factors, possessing competitive strength differs from other regional sports industry competitiveness and the capabilities which can keep sports industry dynamic development. From the perspective of systematic science, Zhou Chao constructed the
indicator system of sports industry [10]. He considered that sustainable development indicators of
sports industry contained sports population subsystem, sports economy subsystem, sports technology
subsystem and sports culture subsystem and constructed evaluation indicator system with 4 dimensions
and 35 indicators which have great reference value to sports industry competitiveness.

In conclusion, at present, domestic and overseas sports industry competitiveness’ content,
influencing factors and theoretical analysis framework model have not been standardized, the
evaluation of sports industry competitiveness was still short of systematic and scientific evaluation
indicators as well as evaluation methods, empirical research and quantity evaluation on regional sports
industry competitiveness. Thus, in the viewpoint of influencing factors of sports industry
competitiveness, this paper constructed rational evaluation system of sports industry competitiveness
and applied appropriate methods to carry out scientific system evaluation on sports industry. It is
significant to improve our national sports industry competitiveness.

2. Evaluation method

The industry competitiveness evaluation system belongs to the multi-indicator comprehensive
evaluation systems. Most of the scholars use weighting method, analytic hierarchy process or ranking
method to weight, as referred in [11-13]. So the selection and weighting of indicator are decided by
experts. But there exists big difference in the knowledge, experience and individual value orientation of
the experts. So the results are not very objective. Simultaneously, some correlation of indicator is bigger
and tends to cause indicator overlapping, which will lead to deviation of indicator weight the factor
analysis and principal component analysis in [14-15] are used to overcome this defect. The indicator
and weight are decided by SPSS and can supply objective evaluation of the sports industry
competitiveness.

2.1. Factor Analysis Method

The basic idea of Factor Analysis Method (FA) is to find the few random variables controlling
all variables to describe the relations among multiple variables, by study on the correlation
coefficients matrix of variables or the inner structure of covariance matrix. The variables are
grouped according to the correlation. Then the relations of variables in the same group are
higher than that in different groups. Every group of variables stand for a basic structure which is
called public factor or main factor. In economic statistics, finding the fewer main factors from
economic phenomenons that have intricate relationship and catching these these factors are
helpful for us, to analyze and explain complex economic problems. The model of FA method is
described as follows.

(1) \( X = (x_1, x_2, ..., x_p) \) is an observable random vector, mean vector \( E(X) = 0 \), coefficient
matrix \( \text{Cov}(X) = \Sigma \). The coefficient matrix \( \Sigma \) is equal to relation matrix \( R \) (implemented by
variables Standardization).

(2) \( F = (F_1, F_2, ..., F_m) \) is unobservable vector and its mean vector \( E(F) = 0 \).
Coefficient matrix \( \text{Cov}(F) = I \). That means the respective components of vector are independent.

(3) \( e = (e_1, e_2, ..., e_p) \) and \( F \) is independent each other and \( E(e) = 0 \). The coefficient
matrix of \( E \) is a diagonal matrix which means the respective components are independent. So the
model is

\[
\begin{align*}
X_1 &= a_{11} F_1 + a_{12} F_2 + ... + a_{1m} F_m + a_{1} e_1 \\
X_2 &= a_{21} F_1 + a_{22} F_2 + ... + a_{2m} F_m + a_{2} e_2 \\
&\vdots \\
X_p &= a_{p1} F_1 + a_{p2} F_2 + ... + a_{pm} F_m + a_{p} e_m
\end{align*}
\]

The matrix form is \( X = AF + e \). The following conditions are satisfied:

(1) \( m \leq p \)
(2) $\text{Cov}(F, e) = 0$, means $F$ and $e$ is uncorrelated.

(3) $D(F) = 1m$, so $F_1, F_2, \ldots, F_m$ are uncorrelated an the variance value is 1.

(4) $D(e) = m$ means $e_1, e_2, \ldots, e_p$ are uncorrelated and the variance is different.

$F$ is the public factor of $X$, $A$ is the factor loading matrix and $e$ is the special factor of $X$. $A = (a_{ij})$, $a_{ij}$ is the factor loading and it is the correlation coefficients of variable $i$ and factor $j$, which reflects the importance of $i$.

The variance contribution of public factor $F_j$ is defined as the sum of squares of factors in row $j$ of loading matrix $A$. It reflects the ability for the factor to explain the total variance of initial variables.

$$S_j = \sum_{i=1}^{p} a_{ij}^2$$

The general procedures of FA method is:

Step 1: Confirm the initial variables waiting for analysis whether is suitable for FA.

Step 2: Construct factor variables.

Step 3: Make the factor variables more interpretable by rotation method.

Step 4: Calculate the marks of factor variables.

### 2.2. Principal Components Analysis

Principal Components Analysis (PCA) has supplied a data compression technology to reduce dimension form high-dimensional space to low-dimensional feature space. It can simplify the training data variables while keeping the maximum information of original space. Assume the network data source has $P$ attributes $x_1, x_2, \ldots, x_p$, the number of training samples is $n(n > p)$, original data matrix is $X$ and the cumulative contribution rate is $T$. Then the process of algorithm is:

Set training set matrix

$$X = \begin{bmatrix}
x_{11} & x_{12} & \cdots & x_{1p} \\
x_{21} & x_{22} & \cdots & x_{2p} \\
\vdots & \vdots & \ddots & \vdots \\
x_{n1} & x_{n2} & \cdots & x_{np}
\end{bmatrix}$$

After standardization we get

$$A = \begin{bmatrix}
a_{11} & a_{12} & \cdots & a_{1p} \\
a_{21} & a_{22} & \cdots & a_{2p} \\
\vdots & \vdots & \ddots & \vdots \\
a_{n1} & a_{n2} & \cdots & a_{np}
\end{bmatrix}$$

$$a_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}, i=1,2,\ldots,n; j=1,2,\ldots,p.$$ Then the problem has transferred to get the eigenvalues and eigenvectors of relation matrices of the matrix above.
\[ R = \begin{bmatrix}
  r_{11}, & r_{12}, & r_{13}, & \ldots, & r_{1p} \\
r_{21}, & r_{22}, & r_{23}, & \ldots, & r_{2p} \\
\vdots & \ddots & \ddots & \ddots & \vdots \\
r_{n1}, & r_{n2}, & r_{n3}, & \ldots, & r_{np}
\end{bmatrix} \]

\[ R = \begin{pmatrix}
  \frac{1}{m} & i = j \\
  \sqrt{\frac{1}{m} \sum_{i=1}^{m} (s_i - \mu_i)^2} & i \neq j
\end{pmatrix} \]

Sort the eigenvalues according to their value, if \( \lambda_1 > \lambda_2 > \ldots > \lambda_p \) and \( m \) satisfies formula 2. The permutation of eigenvectors \( u_1, u_2, \ldots, u_m \) is the principal components we need.

\[ \sum_{i=1}^{m} \frac{\lambda_i}{\sum_{i=1}^{m} \lambda_j} \geq T \quad (2) \]

3. Empirical study on the evaluation of sports industry competitiveness

3.1. Construction of evaluation indicator system

Our study select the data of eight areas: Beijing, Shanghai, Liaoning, Shandong, Heibei, Sichuan and Inner Mongolia during the year 2005-2010. The research data comes mainly from China Statistical Yearbook and the sports industry development reports of each area. To make comprehensive evaluation, according to the feature and influencing factors of sports industry competitiveness, the public environment, basic conditions, ability to grow and the level of development are considered, which contains a total of seventeen indicators. They are:

- \( X_1 \): Urban population proportion
- \( X_2 \): Students in general colleges
- \( X_3 \): Proportion of recreation and entertainment on resident consumption
- \( X_4 \): CPI in each province (city)
- \( X_5 \): Proportion of tertiary industry on GDP
- \( X_6 \): GDP per-capita
- \( X_7 \): GDP growth rate
- \( X_8 \): Engel's coefficient
- \( X_9 \): Production value of tertiary industry
- \( X_{10} \): Sports lotteries earnings
- \( X_{11} \): Athletes' quantity
- \( X_{12} \): Times of undertaking international and national sports competition
- \( X_{13} \): Total number of medals of acquiring sports competition in international and national levels
- \( X_{14} \): Proportion of local fiscal revenue on GDP
- \( X_{15} \): Proportion of recreation and entertainment expense on financial expenditure
- \( X_{16} \): Operating revenues of tourism industry
- \( X_{17} \): Expenditure of city maintenance on financial expenditure and proportion

Since the indicators units we selected for the sports industry competitiveness evaluation are different. All the data must be standardized first. The standardization in statistics is called “Z Score”. It extracts a variable \( \lambda \) from overall which has average \( \mu \) and standard deviation \( \sigma \). Then z score denotes the standard deviation which is greater or smaller than \( \lambda \). The unit of numerator and denominator in z score is same the it can be used to compare two variables extracted from different units. The calculation formula is
Then some of the anti-indicators are needed to transferred into positive ones, such as the Engel coefficient.

3.2 Evaluation method of sports industry competitiveness based on FA and PCA

First we use KM and Bartlett in SPSS to make statistics checksum for the standardized data and get that: 0.7<KMO=0.754<0.8 meets the required range of factor analysis. The Factor module is used for FA method and the eigenvalue and contribution rate is shown in table 1 (EV=eigenvalue, VC=variance contributes, CVC= cumulative variance contributes).

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Extraction Sums of Squared loadings</th>
<th>Rotation Sums of Squared loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EV</td>
<td>VC</td>
<td>CVC</td>
</tr>
<tr>
<td>1</td>
<td>7.594</td>
<td>45.266</td>
<td>45.266</td>
</tr>
<tr>
<td>2</td>
<td>2.780</td>
<td>16.903</td>
<td>62.169</td>
</tr>
<tr>
<td>3</td>
<td>2.007</td>
<td>11.922</td>
<td>74.091</td>
</tr>
<tr>
<td>4</td>
<td>1.221</td>
<td>7.187</td>
<td>81.278</td>
</tr>
<tr>
<td>5</td>
<td>0.944</td>
<td>5.609</td>
<td>86.887</td>
</tr>
<tr>
<td>6</td>
<td>0.688</td>
<td>4.032</td>
<td>90.918</td>
</tr>
<tr>
<td>7</td>
<td>0.420</td>
<td>2.494</td>
<td>93.412</td>
</tr>
<tr>
<td>8</td>
<td>0.288</td>
<td>1.700</td>
<td>95.112</td>
</tr>
<tr>
<td>9</td>
<td>0.231</td>
<td>1.377</td>
<td>96.489</td>
</tr>
<tr>
<td>10</td>
<td>0.201</td>
<td>1.245</td>
<td>97.731</td>
</tr>
<tr>
<td>11</td>
<td>0.141</td>
<td>0.821</td>
<td>98.553</td>
</tr>
<tr>
<td>12</td>
<td>0.112</td>
<td>0.651</td>
<td>99.205</td>
</tr>
<tr>
<td>13</td>
<td>0.054</td>
<td>0.339</td>
<td>99.524</td>
</tr>
<tr>
<td>14</td>
<td>0.033</td>
<td>0.211</td>
<td>99.730</td>
</tr>
<tr>
<td>15</td>
<td>0.054</td>
<td>0.142</td>
<td>99.875</td>
</tr>
<tr>
<td>16</td>
<td>0.035</td>
<td>0.088</td>
<td>99.962</td>
</tr>
<tr>
<td>17</td>
<td>0.025</td>
<td>0.03</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Table 1. Eigenvalue and its contribution rate

As table 1 shows, four public factors can be extracted from all the seventeen indicators. The cumulative variance contributes rate reach 81.278%, which means that 81.278% of initial variables are kept in the model. Because there are four eigenvalues whose value is greater than 1. According to the results of FA, we can use 4 public factors to replace the 17 original indicators, for indicators simplification.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>I₁</td>
<td>0.831</td>
<td>0.210</td>
<td>0.424</td>
<td>0.189</td>
</tr>
<tr>
<td>I₂</td>
<td>0.132</td>
<td>0.806</td>
<td>-0.148</td>
<td>0.264</td>
</tr>
<tr>
<td>I₃</td>
<td>0.780</td>
<td>-0.152</td>
<td>0.519</td>
<td>0.158</td>
</tr>
<tr>
<td>I₄</td>
<td>0.733</td>
<td>0.343</td>
<td>0.532</td>
<td>0.201</td>
</tr>
<tr>
<td>I₅</td>
<td>0.921</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I₆</td>
<td>0.728</td>
<td>0.313</td>
<td>0.532</td>
<td>0.201</td>
</tr>
<tr>
<td>I₇</td>
<td></td>
<td></td>
<td></td>
<td>0.900</td>
</tr>
<tr>
<td>I₈</td>
<td>0.825</td>
<td></td>
<td></td>
<td>0.249</td>
</tr>
</tbody>
</table>

Table 2. Factor loading matrix after rotation
Based on the varimax method, we rotate the factor loading matrix and get the factor loading matrix as Table 3. It can be seen that, among the indicators related to the first public factor, the value of 7 indicators is greater than 0.70. Considering the correlation coefficient between the indicators and other public factors, the indicator that has the maximum correlation coefficient should be selected. Eliminate the indicators that have a correlation smaller. Then we select 5 indicators, \( X_1, X_3, X_5, X_8, X_{12} \), to replace the first public factor. Similarly, the three remaining public factors’ indicators can be simplified and the evaluation system of sports industry competitiveness is constructed.

**Table 3. Evaluation System of Sports Industry Competitiveness Consisted of 4 Public Factors**

<table>
<thead>
<tr>
<th>Public Factors</th>
<th>Evaluation Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Competitiveness</td>
<td>( a_1: ) Urban population proportion</td>
</tr>
<tr>
<td></td>
<td>( a_2: ) Proportion of recreation and entertainment on resident consumption</td>
</tr>
<tr>
<td></td>
<td>( a_3: ) Proportion of tertiary industry on GDP</td>
</tr>
<tr>
<td></td>
<td>( a_4: ) Engel’s coefficient</td>
</tr>
<tr>
<td></td>
<td>( a_5: ) Total number of medals of acquiring sports competition in international and national levels</td>
</tr>
<tr>
<td>Demand Competitiveness</td>
<td>( b_1: ) Students in general colleges</td>
</tr>
<tr>
<td></td>
<td>( b_2: ) Production value of tertiary industry</td>
</tr>
<tr>
<td></td>
<td>( b_3: ) Sorts lotteries earnings</td>
</tr>
<tr>
<td></td>
<td>( b_4: ) Operating revenues of tourism industry</td>
</tr>
<tr>
<td>Elements Competitiveness</td>
<td>( c_1: ) Proportion of local fiscal revenue on GDP</td>
</tr>
<tr>
<td></td>
<td>( c_2: ) Proportion of recreation and entertainment expense on financial expenditure</td>
</tr>
<tr>
<td>Environmental Competitiveness</td>
<td>( d_1: ) GDP growth rate</td>
</tr>
<tr>
<td></td>
<td>( d_2: ) Total number of medals of acquiring sports competition in international and national levels</td>
</tr>
</tbody>
</table>

As Table 4 describes, the comprehensive value of regional sports industry competitiveness (denoted by \( F \)) includes four public factors: Core competitiveness, Demand competitiveness, Elements competitiveness, and Environmental competitiveness. But the weight of these factors is different. So the contribution rate can be taken as the weight of each factor.

\[
F = f_{\text{demand}} \times 23.002\% + f_{\text{core}} \times 33.812\% + f_{\text{elements}} \times 15.458\% + f_{\text{environment}} \times 8.987\% \quad (4)
\]

\( F \) denotes the score of each public factor, whose value can be calculated by the factor score matrix. Since it denotes the final evaluation model of sports industry competitiveness. To calculate the score of public, we eliminate the unrelated indicators in factor score matrix and transfer them into the score of each factor’s weight.

\[
f_{\text{core}} = 0.122 \times a_1 + 0.199 \times a_2 + 0.210 \times a_3 + 0.179 \times a_4 + 0.154 \times a_5 \quad (5)
\]

\[
f_{\text{demand}} = 0.220 \times b_1 + 0.255 \times b_2 + 0.278 \times b_3 + 0.267 \times b_4 \quad (6)
\]

\[
f_{\text{elements}} = 0.356 \times c_1 + 0.377 \times c_2 \quad (7)
\]

\[
f_{\text{environment}} = 0.698 \times d_1 + 0.385 \times d_2 \quad (8)
\]
### Table 4. Evaluation indicator weight of sports industry competitiveness

<table>
<thead>
<tr>
<th>Core competitiveness</th>
<th>Demand competitiveness</th>
<th>Elements competitiveness</th>
<th>Environmental competitiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>a₁(X₁) 0.122</td>
<td>b₁(X₂) 0.220</td>
<td>c₁(X₁₈) 0.356</td>
<td>d₁(X₇) 0.699</td>
</tr>
<tr>
<td>a₂(X₃) 0.199</td>
<td>b₂(X₉) 0.254</td>
<td>c₂(X₁₅) 0.377</td>
<td>d₂(X₁₃) 0.385</td>
</tr>
<tr>
<td>a₃(X₄) 0.211</td>
<td>b₃(X₁₀) 0.279</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a₄(X₅) 0.179</td>
<td>b₄(X₁₆) 0.257</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a₅(X₁₂) 0.154</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.3 Data analysis

In order to furtherly explain the sports industry competitiveness, the dynamic analysis of regional sports industry competitiveness in the year of 2006-2010 is shown in figure 1. According to the figure, the regional sports industry competitiveness can be divided into 3 regions: strong competitiveness regions (including Shanghai, Guangdong, Beijing), general competitiveness regions (including Liaoning, Shandong, Sichuan) and backward competitiveness regions (including Hebei, Inner Mongolia). In the strong competitiveness regions, up to 2008, the sports industry competitiveness is after that of Shanghai and Guangdong. Shanghai is located in a leading position and Guangdong keeps relatively stable development in 6 years. While in the backward competitiveness regions, Hebei is at the forefront and Inner Mongolia is the weakest. The competitiveness development of these two provinces are slower. From the economic point of view, the sports industry competitiveness depends on external economic development. So economically developed regions usually have stronger competitiveness.

The 29th Olympic Games undertaken by Beijing have influence on the whole. It especially provides a good opportunity for development. So there emerges a momentum of rapid development for Beijing after 2008.

![Figure 1. Dynamic Distribution of regional sports industry competitiveness in 2006-2010](image)
Table 5. Comprehensive value sort of regional sports industry core competitiveness

<table>
<thead>
<tr>
<th>sorting</th>
<th>region</th>
<th>comprehensive value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Beijing</td>
<td>58.21</td>
</tr>
<tr>
<td>2</td>
<td>Guangdong</td>
<td>50.73</td>
</tr>
<tr>
<td>3</td>
<td>Shanghai</td>
<td>43.22</td>
</tr>
<tr>
<td>4</td>
<td>Liaoning</td>
<td>42.10</td>
</tr>
<tr>
<td>5</td>
<td>Shandong</td>
<td>38.66</td>
</tr>
<tr>
<td>6</td>
<td>Sichuan</td>
<td>37.35</td>
</tr>
<tr>
<td>7</td>
<td>Hebei</td>
<td>36.13</td>
</tr>
<tr>
<td>8</td>
<td>Inner Mongolia</td>
<td>33.99</td>
</tr>
</tbody>
</table>

From the sorting results it is known that Beijing ranks first at the core competitiveness contrast and Guangdong ranks the 2nd. According to the comprehensive value in table 5 and combined with the division of regions above, we find the core competitiveness are different in the same the same region whose competitiveness development are of the same level. In the strong competitiveness regions, the values of Beijing, Shanghai, Guangdong is 58.21, 50.73, 43.22. While in the backward competitiveness regions the difference is not so apparent.

4. Conclusion

Sports industry evaluation is a kind of complicated project. Since present statistic indicators of sports industry have not been unified, the existing statistic data have not been directly applied to reflect the practical situation of sports industry competitiveness. Therefore, this paper has not temporarily acquired evaluation results of international comparison on sports industry competitiveness. It has great realistic significance to scientific evaluate industrial competitiveness with applying factor analysis to sports industry, the complex social system, and take full account of each feedback and restraining relationships. Acted as decision-making facility of the combination between quantity and quality, factors analysis and principal component analysis integrate subjective initiative and scientific methods which easily understand self-situation and developing orientations more clearly and objectively. According to evaluation results, the factors which greatly influence self-development can be discovered while subjective arbitrariness and blindness during development can be effectively avoided. Empirical research shows that the methods put forward by this paper can effectively combine the evaluation result of industrial competitiveness and developing strategy of sports industrial development. According to self and opponents’ condition, more scientific and rational developing strategies can be formulated. Evaluation result can integrate with sports industry development so as to provide basis for decision making for improving national sports industry competitiveness.

5. References


