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Evaluation Framework and Model of Oil Industry's International Competitiveness

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Abstract

In the occasion of economic globalization, competitiveness of the pillar industry has become the core of the regional competitiveness. As the largest industry in the world, oil industry's international competitiveness is referred to as the important figure of one country's comprehensive competitiveness. So it may discover a large of information for people by structuring an evaluation framework of oil industry. We need create a set of evaluation index system when structuring an evaluation framework, so it means that the first step for us to do is to find suitable evaluation indexes. In this paper authors created an evaluation index system of oil industry to evaluate its international competitiveness, which was structured from the aspects of current competitiveness, potential competitiveness and environmental factors. Then a fuzzy evaluation model based on two-base-point method was designed to act as the evaluation model. And we can evaluate oil industry's international competitiveness of any country by the model. An empirical analysis was made by several selected well-known oil-producing countries, and it showed a good result of evaluation.

Key words: Well-known Oil-producing Countries; Industry competitiveness; AHP; Evaluation Framework and Model

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INTRODUCTION

Oil industry is one key industry in the world which includes oil exploration, extraction, refining, gathering & transportation (often by oil tankers and pipelines), and marketing petroleum products. The largest volume products of the petroleum industry are fuel oil and gasoline, and it is also the raw material for many chemical products, such as pharmaceuticals, fertilizers, solvents and plastics. Its degree of development has become one of the important symbols of a country's economic strength and scientific & technological level. Evaluating oil industry's competitiveness objectively and accurately is very important for a country's strategic planning & positioning. So it is necessary to structure evaluation framework and model of oil industry's international competitiveness to advance one country's strategic planning. When we do this work, there is something which we have to do including to design evaluation index system, structure model and compare the rank of each country. And now, let solve this problem step by step in the following context.

1. DESIGN OF EVALUATION FRAMEWORK FOR OIL INDUSTRY'S INTERNATIONAL COMPETITIVENESS

Evaluation index is the carrier of evaluation content and the basis for evaluation activities. In order to make a comprehensive evaluation, we need to select and design evaluation index from multi-levels and multi-angles, and all these evaluation indexes constitute an evaluation index system. The construction of evaluation index system should follow certain design principles to ensure that the evaluation is objective and accurate.

1.1 Design Principles of Evaluation Framework

In this article, the design of the oil industry's international competitiveness evaluation index system is guided by

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the following principles: (1) Scientific principle. The scientific and reasonable level of index system is directly related to the quality of evaluation. Scientific principle requests the index system must be in accordance with the meaning of the international competitiveness. Indexes must be typical, integral and systematic to secure that the evaluation result is objective and true, and also must be easy for vertical and horizontal comparison. Human interference should be minimized in order to reduce error. (2) Comprehensive principle. This principle requests the design of the index system should try to reflect the oil industry's international competitiveness from all aspects: not only the present status of production and operation activities, but also the long-term trend of development; not only the inner conditions but also the outside affecting factors. (3) Importance principle. The importance of impact on international competitiveness, or the degree of contribution to competitiveness, must be considered when selecting indexes to secure the indexes selected are appropriate and prominent for reflecting the oil industry's international competitiveness. (4) Comparability principle. In the design of statistical indexes and index system, index's caliber and calculation method should be consistent in order to realize the comparability in different areas and nations and at different time points, and to find out gaps and improve the oil industry's international competitiveness. (5) Highlighting oil industry's nature principle. The evaluation index system will be used to compare the international competitiveness in different areas and nations for the oil extractive & refining industry. So the indexes should not only reflect the common character of competitiveness evaluation, but also highlight the special nature of the oil industry. In addition the indictors should be consistent or little change with the present work of oil industry to make evaluation easier.

1.2 Selection of Evaluation Index

According to the above principles, this article selected eighteen evaluation indexes in total from three aspects: current competitiveness, potential competitiveness and environmental factors to form the international competitiveness evaluation index system of oil industry, as shown in Table 1. Among them, the current competitiveness indexes reflect the oil industry's integral competitiveness level of a country at a specific period, such as the exports for a certain year and so on; potential competitiveness indexes reflect the oil industry's staying power of a country, such as the available resources (rich oil & gas resources, cheap labor, etc.); environmental indexes reflect the external environment in which the oil industry survives and develops, such as the Government's policies & measures, economy & trade conditions and so on. In this article, current competitiveness indexes include oil & gas export capacity, oil & gas production & refining capacity and operating profitability; potential competitiveness indexes include oil & gas reserves, oil & gas self-sufficiency rate and the average annual growth rate of oil & gas exports; environmental indexes include governmental regulation & support, economic environment, social & cultural environment and technological support & innovation environment based on the popular method of environmental analysis - PEST analysis.

Table 1
International Competitiveness Evaluation Index System of Oil Industry

Target Hierarchy	Criteria Hierarchy	Index Hierarchy
Oil industry's international competitiveness	Current competitiveness	Crude oil & refined product exports
		Natural gas exports
		Crude oil production capacity
		Natural gas production capacity
		Refinery capacity
		Return on total assets
		Sales margin
		Labor productivity
	Potential competitiveness	Crude oil reserves
		Natural gas reserves
		Crude oil self-sufficiency rate
		Natural gas self-sufficiency rate
		Average annual growth rate of crude oil & refined product exports
		Average annual growth rate of natural gas exports
	Environmental factors	governmental regulation & support capabilities
		Economic environment
		Social and cultural environment
		technological support capabilities and innovation environment

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According to the evaluation index system in Table 1, the index data of oil-producing countries included in evaluation will form a 18 × n order evaluation matrix B .

$$B = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{181} & b_{182} & \cdots & b_{18n} \end{bmatrix} = (b_{ik})$$

Here b_{ik} is k country's index value of index i.

2. ESTABLISHMENT OF EVALUATION MODEL FOR OIL INDUSTRY'S INTERNATIONAL COMPETITIVENESS

2.1 Determination of Evaluation Index's Weight Using AHP

For multi-indexes evaluation system, it is necessary to take into account the significance of each evaluation indicator in the entire evaluation system, that is, it is necessary to consider the indicator's weight. This article used Analytic Hierarchy Process (AHP) to determine each evaluation indicator's weight. The procedure for using the AHP can be summarized as:

Step one: constructing the judgment matrix.

Judgment matrix can indicate the relative significance of each element in a certain hierarchy, as shown in Table 2.

Table 2
Judgment Matrix

X	X_1	X_2	…	X_i
X_1	a_{11}	a_{12}	…	a_{1i}
X_2	a_{21}	a_{22}	…	a_{2i}
⋮	⋮	⋮	⋮	⋮
X_i	a_{i1}	a_{i2}	…	a_{ii}

Where a_{ij} indicates that, as for the indicator X , the relative importance judgment value of X_i compared to X_j ,which is usually given the number from 1 to 9. Each judgment matrix is required to meet the condition as follows:

$$\begin{cases} a_{ii} = 1 \\ a_{ij} = \dfrac{1}{a_{ji}} \end{cases} \quad (i,j = 1, 2, 3, \cdots, n) \tag{1}$$

Step two: calculating single-sort weights and test the consistency.

The step is to determine the weight value of each element that shows the importance rank of each element in a certain hierarchy.

(1) Calculating the maximum characteristic root marked by λ_{max} and the corresponding characteristic vector marked by W (square root method).

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$$

Where λ_{max} is A's maximum characteristic root; W is the regular characteristic vector corresponding to λ_{max}; the subvector w_i of w is the weight of corresponding element in single-level sorting.

(2) Checking the consistency of judgment matrix

There may be inconsistency in importance judgments in the judgment matrix constructed with experts' judgment scores, thus consistency check is necessary. Generally speaking, if the order of matrix is 1 or 2, the matrix is in consistency completely. As to judgment matrix with order greater than 2, the ratio of its consistency indicator marked by CI to the average random consistency indicator with the same order is noted as CI . CI and CI are calculated as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

$$CR = \frac{CI}{RI} \tag{4}$$

Generally speaking, if $CR < 0.1$, the judgment matrix is regarded as in satisfying consistency; if $CR < 0.1$, we need to revise the judgment matrix until $CR < 0.1$

Step three: calculating total-sort weights and test the consistency.

The upper-level elements can be used as the criteria for ranking the lower-level elements in order to get the combined weights. Consistency check is also needed in hierarchy total ranking.

$$CR = \sum_{j=1}^{n} w_j CI_j \Big/ \left[\sum_{j=1}^{n} w_j RI_j \right] \tag{5}$$

Where w_j is the total-sort weight of index j in the index hierarchy, If $CR < 0.1$, the judgment matrix passes the consistency check; if not, we need to revise the judgment matrix until $CR < 0.1$.

2.2 Normalization of Evaluation Matrix B

In this article, the following relative membership functions are used to normalize evaluation matrix B .

$$r_{ik} = \begin{cases} 1 \ , \ x_{ik} \geq s_{i1} \\ \dfrac{x_{ik} - s_{ic}}{s_{i1} - s_{ic}} \ , \ s_{i1} \succ x_{ik} \succ s_{ic} \\ 0 \ , \ x_{ik} \leq s_{ic} \end{cases} \tag{6}$$

Where r_{ik} is the membership degree of country k to

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index i; x_{ik} is the evaluation value of index i of country k; s_{ic} is minimum value of index i; s_{il} is maximum value of index i. We can easily get a normalized evaluation matrix R using the above functions.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ r_{181} & r_{182} & \cdots & r_{18n} \end{bmatrix} = (r_{ik})$$

2.3 Application of the Two-Base-Point Method to Make Fuzzy Comprehensive Decision

Using weights to weight the normalized evaluation matrix R, we can get a new matrix D.

$$D = \begin{bmatrix} \omega_1 r_{11} & \omega_1 r_{12} & \cdots & \omega_1 r_{1n} \\ \omega_2 r_{21} & \omega_2 r_{22} & \cdots & \omega_2 r_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \omega_{18} r_{181} & \omega_{18} r_{182} & \cdots & \omega_{18} r_{18n} \end{bmatrix} = \begin{bmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ d_{181} & d_{182} & \cdots & d_{18n} \end{bmatrix}$$

Assume that P^* is the ideal point and P_* is the negative ideal point of the matrix, then

$$P^* = (p_1^*, p_2^*, \cdots, p_{18}^*)^T$$

Where $P_i^* = \max\{d_{ij} \,|\, j = 1, 2, \cdots, n; i = 1, 2, \cdots, 18\}$ is the approximate the ideal point of index i; $P_* = (0,0,\cdots,0)^T$.

Assume that $D_j = (D_{1j}, D_{2j}, \cdots, D_{18j})^T$, $j = 1,2,\cdots,n$, then the close-degree of the evaluated object to the ideal point.

$$T_j = \frac{(P^* - D_j)^T (P^* - P_*)}{\| P^* - P_* \|^2} = \frac{(P^* - D_j)^T P^*}{\| P^* \|^2} \qquad (7)$$

$$= 1 - \frac{D_j^T P^*}{\| P^* \|^2} = 1 - \frac{\sum_{i=1}^{18} d_{ij} p_i^*}{\sum_{i=1}^{18} (p_i^*)^2} \qquad j = 1,2,\cdots,n$$

According to the values of T_j, we can rank the evaluated objects, and the smaller of T_j, the better of the evaluated object in terms of international competitiveness of oil industry.

3. APPLICATION OF EVALUATION FRAMEWORK AND MODEL

Based on evaluation framework and model for oil industry 's international competitiveness, this article selected seven oil-producing countries as empirical study objects including China, the United States, Canada, United Kingdom, Russia, Saudi Arabia and Nigeria to evaluate its oil industry's international competitiveness. According to data accessibility and timeliness, this article collected the related data of these countries for 2010, as shown in Table 3 to Table 4. these data mainly come from *Petroleum Intelligence Weekly*(2011),*BP Statistical Review of World Energy*(2011), as well as some from Energy Information Administration (EIA) and Central Intelligence Agency (CIA).Considering that the environmental indicators are comprehensive and hard to quantify, we used the expert grading method to get data. We get a summary of seven oil-producing countries' international competitiveness evaluation index values of oil industry through calculation and arrangement based on the statistical data for 2010 as shown in Table 5.

3.2 Empirical Analysis

Phase one:We disseminated Judgment matrix questionnaires to five experts studying in the field of oil & gas and five spot experts working in the well-known oil companies, used the Delphi method through systematic process to gather common opinions and processed data with analytic hierarchy process method. Finally we got single-sort

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Table 3
Seven Countries' Main Production Indexes (2010)

Index / Country	Crude oil production capacity (million tons)	Natural gas production capacity (billion cubic meters)	Refinery capacity (1000b/d)	Crude oil reserves ending December 31,2010 (billion tons)	Natural gas reserves ending December 31,2010 (trillion cubic meters)	Crude oil consumption (million tons)	Natural gas consumption (billion cubic meters)
China	203.0	96.8	10121	2.0	2.8	428.6	109.0
United States	339.1	611.0	17594	3.7	7.7	850.0	683.4
Canada	162.8	159.8	1914	5.0	1.7	87.4	93.8
United Kingdom	63.0	57.1	1757	0.4	0.3	73.7	93.8
Russia	505.1	588.9	5555	10.6	44.8	147.6	414.1
Saudi Arabia	467.8	83.9	2100	36.3	8.0	125.5	83.9
Nigeria	115.2	33.6	505	5.0	5.3	3.9	12.9

Note:*All the other figures are from BP Statistical Review of World Energy,June 2011* .We use Refinery capacity, crude oil consumption, natural gas consumption figures of Nigeria (2008) instead.

Table 4
Seven Countries' Oil Industry Exports (2007-2010)

Index / Country	Crude oil exports(1000b/d)				Refined product exports(1000b/cd)				Natural gas exports(million standard cu m)			
	2007	2008	2009	2010	2007	2008	2009	2010	2007	2008	2009	2010
China	389.3	562.7	627.0	623.3	6246.0	6246.0	6246.0	6806.0	2790	2690	3320	3320
United States	1250.7	1680.1	1833.3	2106.6	17447.2	17379.7	17763.5	17869.2	22530	27290	30320	30480
Canada	1844.3	1970.2	1922.2	1798.6	1969.5	2029.5	2039.3	1902.0	107300	103200	92240	92200
United Kingdom	1544.3	1400.6	1296.8	1284.1	1857.7	1857.7	1857.7	1766.2	10400	11500	12170	15650
Russia	6993.8	6173.2	6828.8	7852.2	5339.0	5428.5	5428.5	5430.9	231830	237300	207660	223300
Saudi Arabia	8100.9	8380.0	7275.9	7594.9	2130.0	2135.0	2109.0	2109.0	0	0	0	0
Nigeria	2197.5	2117.2	2172.5	2487.3	445.0	445.0	445.0	445.0	21900	20550	15990	20004

Note:All the other figures are from *OPEC Annual Statistical Bulletin 2011*.

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weights and total-sort weights, as shown in Table 6.

Table 5
Seven Countries' International Competitiveness Evaluation Index of Oil Industry (2010)

	China	United States	Canada	United King-dom	Russia	Saudi Arabia	Nigeria
Crude oil & refined product exports(1000b/d)	7429.3	19975.8	3700.6	3050.3	13283.1	9703.9	2932.3
Natural gas exports(million standard cu m)	3320	30480	92200	15650	223300	0	20004
Crude oil production capacity (million tons)	203.0	339.1	162.8	63.0	505.1	467.8	115.2
Natural gas production capacity (billion cubic meters)	96.8	611.0	159.8	57.1	588.9	83.9	33.6
Refinery capacity (1000b/d)	10121	17594	1914	1757	5555	2100	505
Return on total assets (%)[2]	5.18	8.83	12.91	9.75	13.18	13^	11^
Sales margin (%)[2]	5.02	5.97	24.37	6.31	16.61	22^	19^
Labor productivity (ten thousand dollars each person)[2]	20.6	450.50	430.69	422.46	43.3	600.37	195.33
Crude oil reserves (billion tons)	2.0	3.7	5.0	0.4	10.6	36.3	5.0
Natural gas reserves(trillion cubic meters)	2.8	7.7	1.7	0.3	44.8	8.0	5.3
Crude oil self-sufficiency rate	47.36%	39.89%	186.27%	85.48%	342.21%	372.75%	2953.85%
Natural gas self-sufficiency rate	88.81%	89.41%	170.36%	60.87%	142.21%	100.00%	260.47%
Average annual growth rate of crude oil & refined product exports	2.97%	2.23%	0.96%	-3.72%	0.21%	-1.78%	1.15%
Average annual growth rate of natural gas exports	5.53%	13.84%	-5.52%	12.02%	-1.98%	0%	-7.31%
governmental regulation & support	85	85	75	75	85	95	95
Economic environment	90	95	90	90	80	80	70
Social and cultural environment	70	90	90	90	70	75	75
technological support & innovation	80	95	90	91	85	80	75

Note: Figures with ^ is estimated figures; Average annual growth rate is calculated by cumulative method; Return on total assets, Sales margin and Labor productivity are the average levels of oil companies from the seven countries which are ranked top 50 oil companies in the world.

The data of return on total assets, sales margin and labor productivity come from reference 2.

Table 6
Single-Sort Weights and Total-Sort Weights

First-class Indexes	Second-class Indexes	Sing-sort Weights	Total-sort Weights
current competitiveness 40%	Crude oil & refined product exports	19.82%	7.93%
	Natural gas exports	19.82%	7.93%
	Crude oil production capacity	6.15%	2.46%
	Natural gas production capacity	6.15%	2.46%
	Refinery capacity	6.15%	2.46%
	Return on total assets	11.04%	4.42%
	Sales margin	11.04%	4.42%
	Labor productivity	19.82%	7.93%
potential competitiveness 40%	Crude oil reserves	25.00%	10.00%
	Natural gas reserves	25.00%	10.00%
	Crude oil self-sufficiency rate	12.50%	5.00%
	Natural gas self-sufficiency rate	12.50%	5.00%
	Average annual growth rate of crude oil & refined product exports	12.50%	5.00%
	Average annual growth rate of natural gas exports	12.50%	5.00%
potential competitiveness 20%	governmental regulation & support	35.12%	7.02%
	Economic environment	18.87%	3.77%
	Social and cultural environment	10.89%	2.18%
	technological support & innovation	35.12%	7.02%

$CR_0=0<0.1$ $CR_1=0.00236<0.1$ $CR_2=0<0.1$ $CR_3=0.00384<0.1$ $CR_t=0.00163<0.1$,all weights passed consistency check

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Phase two: We normalized the evaluation matrix using membership functions. The result is shown as follows.

$$R = \begin{bmatrix} 0.2639 & 1.0000 & 0.0451 & 0.0069 & 0.6073 & 0.3973 & 0.0000 \\ 0.0149 & 0.1365 & 0.4129 & 0.0701 & 1.0000 & 0.0000 & 0.0896 \\ 0.3167 & 0.6245 & 0.2257 & 0.0000 & 1.0000 & 0.9156 & 0.1181 \\ 0.1095 & 1.0000 & 0.2186 & 0.0407 & 0.9617 & 0.0871 & 0.0000 \\ 0.5627 & 1.0000 & 0.0825 & 0.0733 & 0.2955 & 0.0933 & 0.0000 \\ 0.0000 & 0.4563 & 0.9663 & 0.5713 & 1.0000 & 1.0000 & 1.0000 \\ 0.0000 & 0.0491 & 1.0000 & 0.0667 & 0.5990 & 1.0000 & 1.0000 \\ 0.0000 & 0.7415 & 0.7073 & 0.6931 & 0.0392 & 1.0000 & 0.3014 \\ 0.0446 & 0.0919 & 0.1281 & 0.0000 & 0.2841 & 1.0000 & 0.1281 \\ 0.0562 & 0.1663 & 0.0315 & 0.0000 & 1.0000 & 0.1730 & 0.1124 \\ 0.0026 & 0.0000 & 0.0502 & 0.0156 & 0.1037 & 0.1142 & 1.0000 \\ 0.1400 & 0.1430 & 0.5485 & 0.0000 & 0.4075 & 0.1960 & 1.0000 \\ 1.0000 & 0.8894 & 0.6996 & 0.0000 & 0.5874 & 0.2900 & 0.7280 \\ 0.6071 & 1.0000 & 0.0846 & 0.9139 & 0.2520 & 0.3456 & 0.0000 \\ 0.5000 & 0.5000 & 0.0000 & 0.0000 & 0.5000 & 1.0000 & 1.0000 \\ 0.8000 & 1.0000 & 0.8000 & 0.8000 & 0.4000 & 0.4000 & 0.0000 \\ 0.0000 & 1.0000 & 1.0000 & 1.0000 & 0.0000 & 0.2500 & 0.2500 \\ 0.2500 & 1.0000 & 0.7500 & 0.8000 & 0.5000 & 0.2500 & 0.0000 \end{bmatrix}$$

Phase three: We used the two-base-point method to make fuzzy comprehensive decision. The result is shown in Table 7.

Table 7
Result of Fuzzy Comprehensive Decision

	China	United States	Canada	United Kingdom	Russia	Saudi Arabia	Nigeria
Close-degree	0.8105	0.5276	0.6707	0.7884	0.4490	0.4830	0.6879

CONCLUSION

It is a complicated system to comprehensively evaluate international competitiveness of oil industry. The method designed in this paper do us a favor by translating complex and fuzzy problems into accurate indexes which can be measured by experts. And then two-base-point method was used to structure the evaluation model on the basis of the evaluation framework. We can safely draw some conclusions as follows.

(1) Crude oil reserves and natural gas reserves got 10% weight in the total-sort weight, and played an important role in the evaluation of oil industry's international competitiveness. So we'd better pay more attention to advance our country's oil exploration ability.

(2) Index system structured from current competitiveness, potential competitiveness and environmental factors could clearly discover the international competitiveness of oil industry. The evaluation result we got by the framework suited the traditional view, which means the evaluation framework is credible.

(3) Joint application of AHP and two-base-point methods enhanced the evaluation operability, and they could be regarded as a practical approach. To simplify the calculation process, computer programming can be used in practice.

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