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Sustainability Assessment Based on Weighing Method of Combined Subjective-objective ——Case of Shaanxi Province in Northwestern China

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Abstract: Based on the principle of the triple bottom line (economy, society and environment), considering about energy export region of Shaanxi actual situation, this paper constructed a comprehensive assessment for sustainability of industrial ecosystem (SIE) by weighing method of combined subjective-objective (CSO) and based on the data from 2008 to 2018. The research results indicated that the sustainable development of industrial ecosystem continues to improve and the policy guidance plays a significant role in this process. Many policy measures had characteristic of Shaanxi, such as the strategies of energy industry-- stable production and quality improvement, structural optimization of non-energy industry and the leading role of major project.

1 INTRODUCTION

After 40 years of rapid economic growth and sufficient accumulation, the contradiction between economic development and the environment has exposed obviously, and policy makers are aware and intend to resolve this crucial contradiction--- pursuing economic growth efficiency to meet the needs of all social members of the society, and maintain the stable and benign evolution of the society within the limits ecological environment permits. The sustainable development has become the value orientation of China's current economic development. As a country with a vast territory, China has uneven economic development and the distribution of natural resources. The ecological environment in the northwest region is particularly fragile, which has a more significant restricting effect on the economy. Therefore, the northwest region of China must treat the environmental restricting effect in a more important position than the eastern region. This paper discussed how to comprehensively and objectively evaluate SIE in a typical area of northwest China, and to apply the concept of sustainable development to the operation and structural adjustment of the industrial system by referring to the evaluation results.

2 LITERATURE REVIEW

Industrial ecosystem theory has become a multidisciplinary cross-application research field, involving economics, management, society, network, biological evolution and other disciplines after 30 years of deepening and extension on concept and connotation. Many scholars conducted abundant researches on industrial ecosystem based on different theories and methods. The study mainly about the evaluation and assessment of the industrial ecosystem, such as assessing the sustainability or efficiency of region1 using case study2, constituting comprehensive evaluation index3, Ecological performance evaluation, vector autoregression model4 and so on. At present, the evaluation of industrial ecosystem focuses on the triple bottom line (social, economic and environment) approach to sustainability15. Based on the principle of case by case, regions with different resource endowments maybe have different emphases on aspects of sustainable development. For resource-dependent regions, energy sustainability is worthy of attention. Therefore, energy sustainability was included in the scope of investigation of industrial ecosystem sustainability of Shaanxi in this paper.

The evaluation of SIE in previous studies mostly employed the analytic hierarchy process (AHP) method6 or the maximum entropy method(MEM)7. Subjective weighting methods(such as AHP) can clearly express the value judgment of the evaluation subject to the evaluation object, but the results are subjective distinctly, without of considering the difference of the information capacity of the data sample; Objective weighting method(such as MEM) selects the combination of factors with greater entropy based on the information entropy of the sample, but the stability of the results is poor due to the excessive dependence on the sample data8.It can be seen that subjective and objective valuation methods have their own advantages and disadvantages in practical application. Therefore, this paper adopts the weighing method of combined subjective-objective (CSO) in order to organically integrates the results of subjective and objective weighting. By doing so, it can gain an advantage from the both two, evaluation weight sequence can reflect both the value orientation of the evaluator and the heterogeneity of sample entropy9.

3 METHODS

3.1 Indicator system

the United Nations Conference on Sustainable Development proposed change in green economy paradigm——emphasizing the undiminished development of the earth's key natural capital, based on the idea of strong sustainable development, it means that human economic and social development must be limited to the boundaries and natural limits of the earth. Sustainability science is a solution-oriented discipline that studies the complex relationship between nature and humankind, conciliating the scientific and social reference paradigms which are mutually influenced, and covering multi temporal and spatial scales. The discipline implies a holistic approach, able to capitalise and integrate sectorial knowledge as well as a variety of epistemic and normative stances and methodologies towards the definition of solutions10.

Sustainable development became a cross-cutting concept including three dimensions – social, economic and environment11. In accordance with the concept, sustainability assessment should be one of the most complex types of appraisal activity, as it is multi-disciplinary in nature and based on cultural and value-based elements10.In order to evaluate SIE, it is important to seek the evaluation subject and the stakeholders of the industrial ecosystem, and to clarify their needs and expectations. Only in this way, is it possible to define the connotation involved of the assessment of industrial ecosystem objectively and comprehensively10. The goal of the industrial ecosystem is to coordinate the contradiction between the expansion of the industrial system and the deterioration of the ecological environment, so as to ensure the industrial system in optimum and sustainable status within the reasonable space of environmental constraints. As an energy exchange link between human society and nature, industrial system's operation mode and efficiency will inevitably affect the society, environment and economic system itself, which are the stakeholders of industrial ecosystem system.

Table 1 the assessment system of SIE

destination	**Subsystems**	**Secondary subsystems**	**Indicator (unit)**	**Attribute**	MEM weight	AHP weight	CSO weight
SIE	Energy sustainability	energy consumption	Energy consumption per unit output value (10000 Tons of standard coal / 100 million yuan)	Negative	0.033	0.019	0.019
			Water consumption per unit output value (100 million cubic meters / 100 million yuan)	Positive	0.027	0.019	0.019
		Energy efficiency	Unit energy processing and conversion efficiency (%)	Positive	0.039	0.038	0.039
	Environment sustainability	Environment quality	The proportion of days with air quality above grade 2 (%)	Positive	0.055	0.118	0.055
			Total effluent discharge (10000 tons)	Negative	0.044	0.039	0.043
			Emissions of industrial sulphur dioxide (Ten million tons)	Negative	0.081	0.039	0.081
		pollution abatement	Total investment in pollution control (100 million yuan)	Positive	0.050	0.049	0.050
			Investment in the treatment of industrial pollution sources (10 thousand yuan)	Positive	0.043	0.016	0.016
	Economic sustainability	Economic efficiency	GDP (100 million yuan)	Positive	0.045	0.173	0.087
			Added value of secondary industry (100 million yuan)	Positive	0.041	0.058	0.047
			Added value of tertiary industry (100 million yuan)	Positive	0.052	0.058	0.058
		innovative development	Internal expenditure of R&D funds (10 thousand yuan)	Positive	0.034	0.082	0.034
			Patent for invention + patent for utility model（item）	Positive	0.050	0.041	0.044
			Technology market turnover（100 million）	Positive	0.063	0.020	0.063
		industrial transformation	The ratio of coal, oil and natural gas exploitation to GDP (%)	Negative	0.047	0.018	0.018
			GDP contribution rate of high-tech industry（%）	Positive	0.070	0.053	0.070
	society sustainability	social benefit	GDP per capita（ten thousand yuan/person）	Positive	0.044	0.060	0.060
			Urbanization rate (%)	Positive	0.051	0.020	0.051
		social stability	Engel coefficient	Negative	0.087	0.020	0.087
			unemployment rate (%)	Negative	0.044	0.060	0.060

3.2 Data and method

The process is as follows:

1) standardize the data using the range standardization method.

The positive indicator standardization formula:

$$X_{ij} = \frac{x_{ij}-minX_j}{maxX_j-minX_j} \tag{1}$$

The negative indicator standardization formula:

$$X_{ij} = \frac{maxX_j-X_{ij}}{maxX_j-minX_j} \tag{2}$$

Then, the sample matrix composed of n indexes and k evaluation objects is

$$X = (x_1, x_2, \cdots, x_k) = \begin{bmatrix} x_{11} & \cdots & x_{1k} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nk} \end{bmatrix}_{n\times k} \tag{3}$$

2) calculate the weight with AHP as β_1 column and with MEM as β_2 column to form the weight *matr:*

$$x\,\theta = [\beta_1, \beta_2] = \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \\ \vdots & \vdots \\ \beta_{k1} & \beta_{k2} \end{bmatrix} \tag{4}$$

3) Determine reasonable range of the ith index weight:

$$\theta_i^{-} = min\{\beta_{i1}, \beta_{i2}\},\ \theta_i^{+} = \ max\{\beta_{i1}, \beta_{i2}\}; \tag{5}$$

Take r values from the interval of $(\theta_i^{-},\ \theta_i^{+})$ equably (including upper and lower boundary values) to form the prepared weight interval matrix W:

$$\forall \alpha_{ij} \in (\theta_i^{-},\ \theta_i^{+}),\ (j = 1, \cdots, r) \tag{6}$$

$$W = (w_1, w_2, \ \dots, \ w_r) = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1r} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2r} \\ \vdots & \vdots & \cdots & \vdots \\ \alpha_{n1} & \alpha_{n2} & \cdots & \alpha_{nr} \end{bmatrix} \tag{7}$$

4) comprehensive evaluation result vector $Z\ is$:

$$Z = W^T \cdot X = \begin{bmatrix} w_1{}^T \\ \vdots \\ w_r{}^T \end{bmatrix} \cdot (x_1, x_2, \cdots, x_k) = \begin{bmatrix} w_1{}^T \cdot x_1 & w_1{}^T \cdot x_2 & \dots & w_1{}^T \cdot x_k \\ w_2{}^T \cdot x_1 & w_2{}^T \cdot x_2 & & w_2{}^T \cdot x_k \\ \vdots & \vdots & & \vdots \\ w_r{}^T \cdot x_1 & w_r{}^T \cdot x_2 & \dots & w_r{}^T \cdot x_k \end{bmatrix} = \begin{bmatrix} z_1 \\ \vdots \\ z_r \end{bmatrix} =$$

$$\begin{bmatrix} \sum_{t=1}^{n}(\alpha_{t1} \cdot x_{t1}) & \sum_{t=1}^{n}(\alpha_{t1} \cdot x_{t2}) & \dots & \sum_{t=1}^{n}(\alpha_{t1} \cdot x_{tk}) \\ \sum_{t=1}^{n}(\alpha_{t2} \cdot x_{t1}) & \sum_{t=1}^{n}(\alpha_{t2} \cdot x_{t2}) & \dots & \sum_{t=1}^{n}(\alpha_{t2} \cdot x_{tk}) \\ \vdots & \vdots & \vdots & \vdots \\ \sum_{t=1}^{n}(\alpha_{tr} \cdot x_{t1}) & \sum_{i=1}^{n}(\alpha_{tr} \cdot x_{t2}) & \dots & \sum_{t=1}^{n}(\alpha_{tr} \cdot x_{tk}) \end{bmatrix} \tag{8}$$

z_i is the weight sequence of the index under the ith weight option in the total r weight sequence options, then its mean value

$$\overline{z_i} = \frac{1}{k}\sum_{j=1}^{k} z_{ij} = \frac{1}{k}\sum_{j=1}^{k}\sum_{t=1}^{n}(\alpha_{ti} \cdot x_{tj}) \tag{9}$$

5) Get the weight sequence with the largest variance:

$$\underbrace{max}_{i=1,\dots,r}\left\{\frac{1}{k-1}\sum_{j=1}^{k}\left(z_{ij} - \overline{z_i}\right)^2\right\}$$
$$s.t.\begin{cases} \sum_{i=1}^{k} \alpha_{ij} = 1 \quad (j = 1, \dots r\,) \\ \forall \alpha_{ij} \in (\theta_i^{-},\ \theta_i^{+}),\ (j = 1, \cdots, r) \end{cases} \tag{10}$$

The weights of the indicators can be calculated by following the steps above, not tired in words here. The associated weights were shown in Table1. As can be seen from the above table, CSO weight adjusts and gains the weight sequence with the largest variance in weight sequence of AHP and MEM, the weight result can present the evaluator's tendency to value with consideration to the difference in information entropy, so the results were more stable and reliable.

4 RESULTS AND FINDINGS

All of data used in this study are collected from the following sources: Shaanxi Statistical yearbook (2008-2018), China industry statistical yearbook (2008-2018), China statistical yearbook on environment (2008-2018), China statistical yearbook on high technology industry (2008-2018) and China statistical yearbook on science and technology (2008-2018). Putting the normalized indicator values and the associated weights (shown in Table 2) into Equation process, we obtain the sustainability performances of Shaanxi.

Table 2 The sustainability degrees of subsystem and in the year 2008–2018

	Energy sustainability	Environment sustainability	Economic sustainability	Social sustainability	Composite Indexes
2008	0.0001	0.0601	0.0377	0.0049	0.1028
2009	0.0104	0.0797	0.0411	0.0052	0.1363
2010	0.0216	0.1073	0.0919	0.0268	0.2476
2011	0.0383	0.0803	0.0921	0.0648	0.2755
2012	0.0521	0.1192	0.1285	0.1035	0.4034
2013	0.0586	0.0916	0.1744	0.1785	0.5031
2014	0.0610	0.1079	0.2057	0.1842	0.5588
2015	0.0657	0.1169	0.2317	0.2027	0.6170
2016	0.0705	0.1876	0.3057	0.2135	0.7773
2017	0.0742	0.1797	0.3517	0.2305	0.8360
2018	0.0736	0.1838	0.3951	0.2578	0.9103

Showed in Table 2, the sustainability of the industrial ecosystem in Shaanxi presents four-stage climbing trend from 2008 to 2018, with the overall trend of gradual migration from a low level to a high level. GDP growth rate has slowed down gradually, whereas SIE has shown a good and steady improvement trend. It indicates that the improvement and implementation of long-term policies in Shaanxi is effective, such as promoting new industrialization, ensuring industrial growth, energy conservation and emission reduction, returning farmland to forests, deepening the coordinated development of three regions and urban-rural areas, etc.

From 2008 to 2009, Shaanxi was indirectly affected by both the Wenchuan earthquake and the international financial crisis, resulting in the following problems emerged: The external market demand shrinking, the export volume declining, the internal earthquake relief, the enterprise capital chain tight, etc. Faced with many unfavorable factors, Shaanxi has implemented the driving strategy with the goal of maintaining growth. Urging banks to lend more credit to enterprises, promoting large-scale and infrastructure projects, adopting a number of measures and allocating special funds to help enterprises alleviate their financial difficulties. From 2010 to 2011, the SIE grade of Shaanxi entered a small plateau. Benefiting from the early accumulation of infrastructure construction and economy, development bottlenecks have been eased temporarily, Shaanxi adjusts the policy guidance to the direction of Structural adjustment with consideration of investment expansion. From 2012 to 2015, the level of SIE showed a relatively stable trend of improvement. Shaanxi has experienced a slowdown in industrial growth after golden decade of resource-driven economic growth, and continues to implement the industry-oriented policy placing equal emphasis on restructuring and expand investment and consumption, to increase investment in infrastructure and major projects, and to improve energy conservation and emissions reduction in some key area. From 2016 to 2018, the SIE in Shaanxi has steadily improved from a medium level to comparatively high level. After entering the 13th five-year plan period, the development strategy of Shaanxi focuses on sustainable development with supply-side structural reform, and the emphasis of industrial development shifts from "investment-driven" to "improving quality and efficiency".

5 CONCLUSIONS AND SUGGESTION

The sustainability of Shaanxi industrial ecosystem was assessed from both the aspects of economic, social, environmental and energy subsystems and the coupling coordinated development. In the assessment process, a collection of 20 indicators was selected from the four subsystems, according to aforementioned principles of the triple bottom line. The indicator weight was determined by weighting method of CSO. The scientific contributions of the paper are mainly represented in the following two aspects. Firstly, the method of CSO was employed to embody subjectivity with consideration of objectivity, and Coupling coordination degree method was employed to investigate coupling state between the four subsystems. Secondly, the paper conducted SIE of Shaanxi--typical resource exporting region in northwest China, from economic, social, environmental and energy subsystems. The rich evaluation conclusions and policy suggestions can provide beneficial references for SIE of Shaanxi and other energy-dependent regions.

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