An Evaluation System of Sustainable Development Based on the Analytic Hierarchy Process(AHP) and Entropy Weight Method

Qizhe Zhang

North China Electric Power University, Baoding, China

sxjczqz@163.com

Keywords: sustainable development, entropy weight method, Analytic Hierarchy Process

Abstract. A sustainable development country was defined as “a country or a region has a capacity of the health continuous growth, against the undue consumption of resource, based on the existing conditions without considering the emerging technical breakthroughs”. A country's sustainable development capacity was evaluated from four aspects, including economy, resources, population and environment. Large amounts of economic data of different counties were collected through extensive resource such as World Bank etc. was introduced to appraise and compare the sustainable development capacities of different countries. To analyze more fully, the entropy weight method was applied to amend the Analytic Hierarchy Process (AHP).

Introduction

The natural environment and resources that we depend on to survive not only inherit from our parents, but also borrow from future generations. The sustainable development has a widely accepted definition as “Humanity has the ability to make development sustainable-to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs”. Some countries, such as the Middle East oil exporters, rely on exporting non-renewable energy as the main resource of the national income, it is clear that they do not belong to the sustainable development country according to our definition, even though they are quite rich. A least developed country (LDC) is a country that, according to the United Nations, exhibits the lowest indicators of socioeconomic development, with the lowest Human Development Index ratings of all countries in the world.

Select the Indicators of Sustainable Development

We evaluate the sustainable development of a country from four aspects which are economy, resources, population and environment. For each aspect, we have selected a large quantity of indicators and implementing R cluster analysis thus we can select representative indicators for further analysis among indicators from each category.

Evaluation of sustainable indicator based on AHP and entropy weight method

We decompose the problem to three hierarchies, namely, overall goal, criteria hierarchy and the alternatives hierarchy. The overall goal is to define the sustainable development indicator to evaluate a country’s level of sustainable development. The criterions include economy, resources, population and environment. The last hierarchy is the alternatives of the problem. Hierarchical structure of the problem is showed in **Figure 1**.

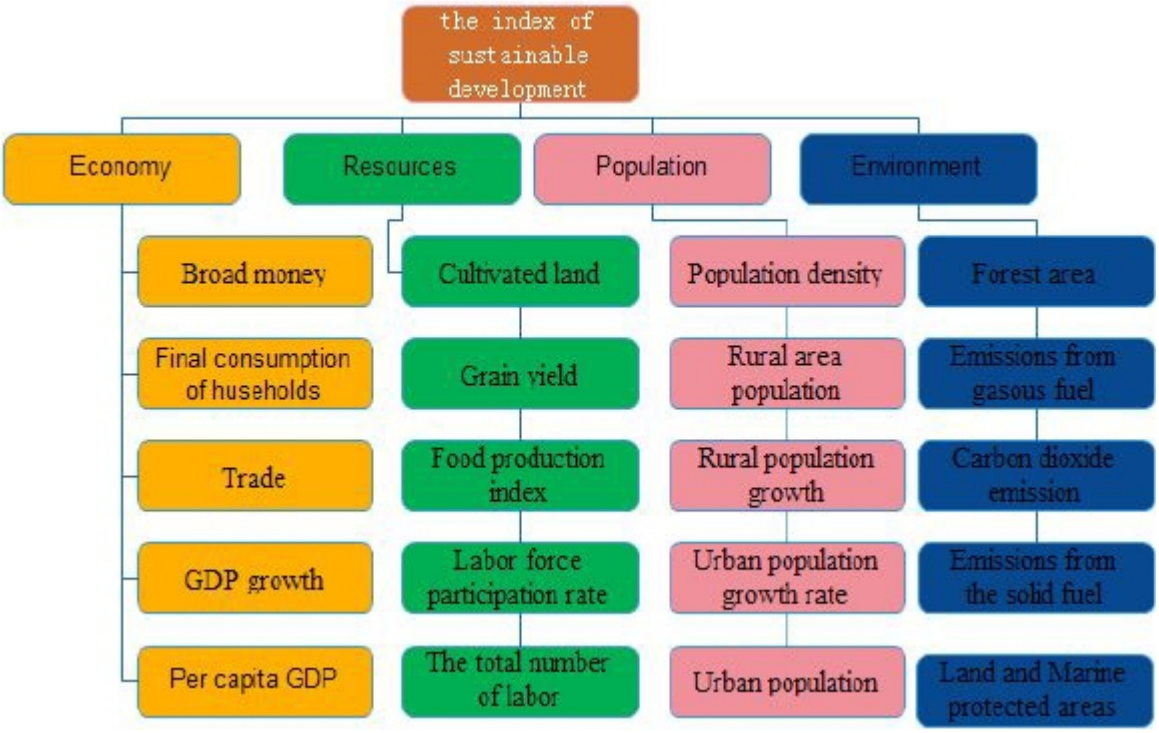

Figure 1

M countries and N indicators constitute the original matrix.
Standardization

$$r_{ij} = \frac{\max\{x_{ij}\} - x_{ij}}{\max\{x_{ij}\} - \min\{x_{ij}\}}$$

Definition of entropy
Entropy of the jth indicator:

$$H_j = -k\sum_{i=1}^{m} f_{ij} \ln f_{ij} (j = 1,2,3...n,\ f_{ij} = r_{ij} / \sum_{j=1}^{n} r_{ij}, k = 1/\ln n)$$

Definition of entropy weight

$$\omega_j = \frac{1 - H_j}{n - \sum_{j=1}^{n} H_j} (0 \le \omega_j \le 1, \sum_{j=1}^{n} \omega_j = 1)$$

Through the above steps, The result is shown in **Table 1**.

Table 1. the Weight of Alternative Hierarchy Based on Entropy Weight Method

Economy	Broad money	0.191
	Final consumption of households	0.195
	Trade	0.209
	GDP growth	0.206
	Per capita GDP	0.199
Resources	Cultivated land	0.200
	Grain yield	0.200
	Food production index	0.202
	Labor force participation rate	0.204
	The total number of labor	0.194
Population	Population density	0.198
	Rural area population	0.191

	Rural population growth	0.211
	Urban population growth rate	0.206
	Urban population	0.193
Environment	Forest area	0.183
	Natural gas fuel consumption of carbon dioxide emissions	0.212
	Carbon dioxide emission	0.205
	The solid fuel consumption of carbon dioxide emissions	0.210
	Land and Marine protected areas	0.190

Unify judgment Matrix to determine the weight of criteria hierarchy

We unify the usage in the judgment matrix of quality: when we get number 1 to 9,that means the quality in horizontal row is more important. Our judgment matrix is as followed:

$$A=\begin{bmatrix} 1 & 3 & 7 & 5 \\ 1/3 & 1 & 3 & 3 \\ 1/7 & 1/3 & 1 & 1/3 \\ 1/5 & 1/3 & 3 & 1 \end{bmatrix}$$

Calculate the eigenvalue and eigenvector

$$Ax=\lambda_{\max} x$$

Then we can get the eigenvector x from the equation so that we can obtain the weight of criteria hierarchy by normalizing x.

Eigenvectors: [0.5710, 0.2406, 0.0647, 0.1237].

Check consistency:

Judgment matrix is not a consistent matrix, so we have to make sure the extent of inconsistency within limits.

$$CI=\frac{\lambda_{\max}-n}{n-1} \qquad CR=\frac{CI}{RI}$$

The result is shown in **Table 2**.

Table 2. Random Index(RI)

N	1	2	3	4	5	6	7	8	9	0	11
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51

CR=0.0518.

CR should be less than 0.1.

Therefore, consistency check meets the demand.

We find five countries which get higher scores according to our evaluation system and five countries which get lower scores. The result is shown in **Table 3**.

Table 3.

Country	Score	country	score
Swizerland	30.911	SouthSultan	16.264
Norway	27.809	Somalia	16.486
Denmark	24.903	Chad	17.352
Poland	23.371	Zimbabwe	17.748
New Zealand	23.261	Ethiopia	17.935

Conclusion

The results indicated that the maximum weighting coefficient of sustainable development are the ratio of trade to GDP in economy, the cultivated land in resources, the rural population growth in population and natural gas fuel consumption of carbon dioxide in environment, respectively. The GSR and AHP combined with the entropy weight method were then joined to achieve a national sustainable development index. The top 5 countries are Switzerland, Norway, New Zealand, Denmark and Poland, while the bottom 3 South Sudan, Somalia and Chad, respectively.

References

[1]http://data.worldbank.org/country

[2]Saaty T.L. What is the Analytic Hierarchy Process? Mathematical Models for Decision Support.NATO ASI Series Volume 48,1998, pp109-121

[3]ZOU Zhi-hong, YUN Yi, SUN Jing-nan. Entropy method for determination of weight of evaluating indicators in fuzzy synthetic evaluation for water quality assessment, Journal of Environmental Sciences, 2006-Elsevier

