Comprehensive Evaluation of Energy-Economy-Environment Harmonious Rate in Chang-Zhu-Tan

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Abstract - Energy is material foundation of economic development and social sustainable development, economic growth relies heavily on energy consumption, green energy is necessary to reduce environment pollution. Finding energy-economy-environment harmonious rate in Chang-Zhu-Tan has important practical significance. The paper constructs an energy-economy-environment evaluation indicator system and uses analytic hierarchy process to adjust indicator weight coefficient, comprehensive evaluation method was taken to measure the energy-economy-environment harmonious rate and finally an objective evaluation result was obtained.

Index Terms - Energy-Economy-Environment, Comprehensive Evaluation, Analytic Hierarchy Process, Harmonious Rate

1. Introduction

Energy-economy-environment is called 3E system and its core content is sustainable development. Sustainable development refers to a mode of social development in which energy use aims to meet human economic needs while ensuring the sustainability of natural systems and the environment, so that these needs can be met not only in the present, but also for generations to come.

Environmental sustainability is the process of making sure current processes of interaction with the environment are pursued with the idea of keeping the environment as pristine as naturally possible based on ideal-seeking behavior. Thus, environmental sustainability demands that society designs activities to meet human economic needs while indefinitely preserving the life support systems of the planet[1]. The Venn diagram of sustainable development has many versions[2], but was first used by economist Edward Barbier (1987) [3]. However, Pearce, Barbier and Markandya (1989)[4] criticized the Venn approach due to the intractability of operationalizing separate indices of economic, environmental, and social sustainability and somehow combining them. They also noted that the Venn approach was inconsistent with the Brundtland Commission Report, which emphasized the interlinkages between economic development, environmental degradation, and population pressure instead of three objectives. Economists have since focused on viewing the economy and the environment as a single interlinked system with a unified valuation methodology (Hamilton 1999,[5] Dasgupta 2007) [6]. Intergenerational equity can be incorporated into this approach, as has become common in economic valuations of climate change economics (Heal 2009) [7]. Ruling out discrimination against future generations and allowing for the possibility of renewable alternatives to petro-chemicals and other non-renewable energy, efficient policies are compatible with increasing human welfare, eventually reaching a golden-rule steady state (Ayong le Kama 2001[8] and Endress et al. 2005) [9]. Thus the three pillars of sustainable development are interlinkages, intergenerational equity, and dynamic efficiency (Stavins et al. 2003) [10]. Economic development has traditionally required a growth in the gross domestic product. This model of unlimited personal and GDP growth may be over[11]. Sustainable development may involve improvements in the quality of life for many but, particularly for the affluent, may necessitate a decrease in energy consumption [12].

As shown in Fig. 1 the relationship between energy, economy and environment and there are harmonious rate at the confluence of three constituent parts.

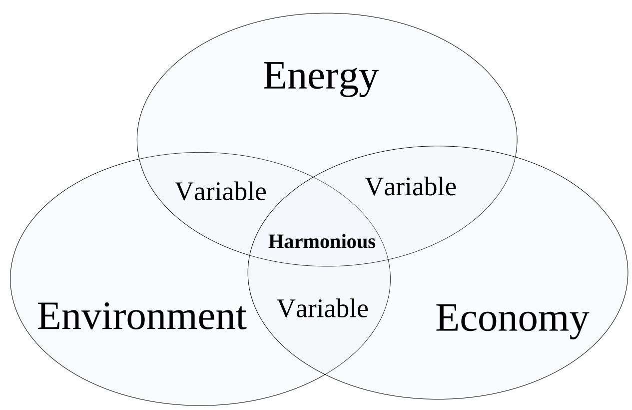

Fig. 1 Relationship between energy, economy and environment

2. Energy-Economy-Environment Evaluation Indicator System Construct

Based on the other researcher’s results and considering Chang-Zhu-Tan’s situation, obey principle of scientificalness, systematicness, hierarchy,etc. Establish the evaluation indicator system as shown in table I:

TABLE I Chang-Zhu-Tan's Energy-Economy-Environment Evaluation Indicator System

Target Layer	Index Layer	Element Layer
Energy-Economy-Environment Harmonious Rate	Energy Level (B1)	Total energy production(million tons standard coal) (C1)
		Total energy consumption(million tons standard coal) (C2)
		Energy consumption per capita(kilogram standard coal) (C3)
	Economy Level (B2)	GDP(ten thousand yuan) (C4)
		GDP per capita(ten thousand yuan) (C5)
		Tertiary industrial proportion(%)(C6)
	Environment Level (B3)	Sulfur dioxide emission(ten thousand tons) (C7)
		Nitrogen oxide emissions(ten thousand tons) (C8)
		Total suspended particulate emissions(ten thousand tons) (C9)

3. Theoretical Framework

A. *Comprehensive Evaluation Model*

Comprehensive evaluation is the process of evaluating an objective utilizing the fuzzy set theory. When evaluating an objective, multiple related factors must be considered comprehensively in order to give an appropriate, non-contradicting and logically consistent judgment. The specific steps which establish comprehensive evaluation model are as follows:

1) Determine the evaluation object and factor set

P is the evaluation object，evaluation factor set is

$$u=\{u_1,u_2,\cdots\cdots,u_p\} \tag{1}$$

2) Determine appraisal set of evaluation factor

$$v=\{v_1,v_2,\cdots\cdots,v_p\} \tag{2}$$

3) Establish judgment matrix

After construct hierarchical fuzzy subset, should be quantified evaluation object from each factor $u_i\left(i=1,2,\cdots\cdots,p\right)$, determine membership degree $\left(R\,|\,u_i\right)$ of grade fuzzy subsets, and then get the fuzzy relation matrix:

$$R=\begin{bmatrix} R\,| & u_1 \\ R\,| & u_2 \\ \multicolumn{2}{c}{\cdots} \\ R\,| & u_p \end{bmatrix}=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{p1} & r_{p2} & \cdots & r_{pm} \end{bmatrix}_{p.m} \tag{3}$$

4) Determine weight vector of evaluation factors

$$W=\left(w_1,w_2,\cdots\cdots,w_p\right) \tag{4}$$

Element w_i in The weight vector A is membership degree on u_i.

$$\sum_{i=1}^{p} w_i=1,\ w_i\geq 0,\ i=1,2,\cdots\cdots,n$$

5) Combine evaluation result vector

$$S=W*R=\left(s_1,s_2,\cdots\cdots,s_m\right)$$

$$W*R=\left(w_1,w_2,\cdots\cdots,w_p\right)\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{p1} & r_{p2} & \cdots & r_{pm} \end{bmatrix} \tag{5}$$

If there is more than one competitive objective to be appraised, all the objectives should be evaluated separately and finally the objective with the maximum membership degree should be taken as the optimal decision.

B. *Analytic Hierarchy Process*

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It has particular application in group decision making [13], and is used around the world in a wide variety of decision situations. Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

The specific steps which establish comprehensive evaluation model are as follows:

1) Establish hierarchy structure model

Decompose decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well- or poorly-understood—anything at all that applies to the decision at hand.

2) Construct judgment matrix

Use 1-9 scale method to produce judgment matrix

$$A=\left(u_{ij}\right)_{p\times p} \tag{6}$$

3) Calculate judgment matrix

Calculate characteristic root and characteristic vector which satisfy the eq. (7)

$$AW = \lambda_{max} W \tag{7}$$

4) Consistency check

$$C.I. = \frac{\lambda_{max} - n}{n-1}$$

Query the average random consistency index R.I.
Calculating the consistency ratio C.R.

$$C.R. = \frac{C.I.}{R.I.} \tag{8}$$

When $C.R. < 0.1$,the consistence check is passed,but when $C.R. > 0.1$, the judgment matrix do not meet the consistency check requirement and need to revise the judgment matrix A.

4. A Case Study of Chang-Zhu-Tan

1) Use 1-9 scale method to produce matrix A

$$A = \begin{bmatrix} 0.2001 & 0.2143 & 0.2647 \\ 0.3333 & 0.2857 & 0.2941 \\ 0.4666 & 0.5000 & 0.4412 \end{bmatrix} \tag{9}$$

2) Calculate matrix A

$$W = \begin{pmatrix} 0.2264 & 0.3044 & 0.4692 \end{pmatrix} \tag{10}$$

Calculate $\lambda = \frac{1}{n} / \sum_{i=1}^{n} \frac{(Aw)_i}{w_i}$ as approximate solution of characteristic root, λ_{max} =3.1152

3) Consistency check

$$C.I. = \frac{\lambda_{max} - n}{n-1} = \frac{3.1152 - 3}{3-1} = 0.0576$$

R.I.=0.9

$$C.R. = \frac{C.I.}{R.I.} = \frac{0.0576}{0.9} = 0.064$$

C.R.<0.1, matrix A is acceptable.

4) Establish judgment matrix R

According to the requirement of evaluation, the Evaluation classify standard is follows:

TABLE II Evaluation Classify Standard

Evaluation interval	Evaluation level
[3.5,5.0]	excellent
[2.5,3.5)	better
[1.5,2.5)	common
[0.0,1.5)	bad

$$R_1 = \begin{pmatrix} 0.3 & 0.4 & 0.2 & 0.1 \\ 0.2 & 0.3 & 0.3 & 0.2 \\ 0.4 & 0.2 & 0.4 & 0 \end{pmatrix} \tag{11}$$

$$R_2 = \begin{pmatrix} 0.2 & 0.3 & 0.3 & 0.2 \\ 0.3 & 0.3 & 0.2 & 0.2 \\ 0.4 & 0.1 & 0.3 & 0.2 \end{pmatrix} \tag{12}$$

$$R_3 = \begin{pmatrix} 0.5 & 0.3 & 0.2 & 0 \\ 0.4 & 0.3 & 0.1 & 0.2 \\ 0.1 & 0.5 & 0.4 & 0 \end{pmatrix} \tag{13}$$

According to $B_i = W_i * R_i$ is calculated as follows:

$$B_1 = [0.3890，0.3521，0.2235，0.0354] \tag{14}$$

$$B_2 = [0.3089，0.3467，0.2623，0.0821] \tag{15}$$

$$B_3 = [0.3637，0.2722，0.2363，0.1278] \tag{16}$$

Accordint to the result of B_1,B_2,B_3,B_4, the judgment matrix R can be obtained:

$$R = \begin{pmatrix} 0.3286 & 0.3849 & 0.2404 & 0.0461 \\ 0.3890 & 0.3521 & 0.2235 & 0.0354 \\ 0.3089 & 0.3467 & 0.2623 & 0.0821 \end{pmatrix} \tag{17}$$

5) Combine evaluation result vector

$$S = [0.3459, 0.2987, 0.2533, 0.1021] \tag{18}$$

6) Analyze final result

The weighted average principle was measured in analyze the comprehensive evaluation vector , hypothesis evaluation rating α = (4,3,2,1), according to eq.(19),

$$F = \sum_{i=1}^{n} \alpha_i s_i \tag{19}$$

F=4*0.3459+3*0.2987+2*0.2533+1*0.1021 and calculate final result F=2.8884.

Compare evaluation interval and evaluation level in table II, F belong to [2.5,3.5) and evaluation level is better, it mean Chang-Zhu-Tan's energy-economy-environment harmonious rate is better.

5. Conclusions

The paper presents Chang-Zhu-Tan's energy-economy-environment evaluation indicator system, use AHP method that is a mathematical decision-making method and comprehensive evaluation method to measure the harmonious rate of Chang-Zhu-Tan's energy-economy-environment. Comprehensive evaluation of Chang-Zhu-Tan's energy-economy-environment system reveals that the comprehensive level is significantly improved, and energy-economy-environment system is direct to harmonious and stabilize, but the difference between Changsha, Zhuzhou and Xiangtan is obvious.

The evaluation for energy efficiency should be based on economic efficiency, environment efficiency and ecological efficiency. Chang-Zhu-Tan's the medium and long-term energy development strategy should take into account the above aspects, but should also take into account the harmonious development of energy, economy and environment as well as the objective differences among regions.

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References

[1] http://en.wikipedia.org/wiki/Sustainable_development
[2] Visualising Sustainability. Posted by Samuel Mann under Computing for Sustainability.
[3] Barbier, E. (1987). "The Concept of Sustainable Economic Development". Environmental Conservation 14(2): 101–110.
[4] Pearce, D.; Markandya, A.; Barbier, E. (1989).Blueprint for a green economy. London: Earthscan.
[5] Hamilton, K.; Clemens, M. (1999). "Genuine savings rates in developing countries". World Bank Econ Review13 (2): 333–356.
[6] Dasgupta, P. (2007). "The idea of sustainable development". Sustainability Science 2 (1): 5–11.
[7] Heal, G. (2009). "Climate Economics: A Meta-Review and Some Suggestions for Future Research". Review of Environmental Economics and Policy 3 (1): 4–21.
[8] Ayong Le Kama, A. D. (2001). "Sustainable growth renewable resources, and pollution". Journal of Economic Dynamics and Control 25 (12): 1911–1918.
[9] Endress, L.; Roumasset, J.; Zhou, T. (2005). "Sustainable Growth with Environmental Spillovers". Journal of Economic Behavior and Organization 58 (4): 527–547.
[10] Stavins, R.; Wagner, A.; Wagner, G. "Interpreting Sustainability in Economic Terms: Dynamic Efficiency Plus Intergenerational Equity". Economic Letters 79(3): 339–343.
[11] Korowitz, David (2012), Ignorance by Consensus, Foundation for the Economics of Sustainability
[12] Brown, L. R. (2011). World on the Edge. Earth Policy Institute. Norton.
[13] Saaty, Thomas L.; Peniwati, Kirti (2008). Group Decision Making: Drawing out and Reconciling Differences. Pittsburgh, Pennsylvania: RWS Publications.