

The Modeling in the Coordination Analysis and Evaluation of the 3E System in China

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Abstract: As shown in previous studies, energy-economy-environment (3E) system has become more and more complicated in the evolution of the development in human society. Although there have been plenty of researches on the system, there are still scarcity in the problem of coordination evaluation. How to evaluate the status or operating efficiency is very important for the energy planning. In this paper, the definition of the coordination development of system is given and a coordination development evaluation model on the 3E system is developed. Finally, China is chosen as an example to do an empirical study. The research results indicate that the environment subsystem is seriously deteriorated due to the heavy energy consumption and fast economy development in recent years. The 3E system is far away from the coordination development. It gives us an important warning for the sustainable development.

Keywords: energy-economy-environment system; coordination development; evaluation model; China

1 Introduction

At present, the global climatic change has attracted unprecedented attention from all around the world. Due to the limitation of environmental capacity, it has become not only the restrictive factor for the thermal power generation, but great challenge to the sustainable utilization of energy. How to maintain the sustainable development of the energy-economy-environment (3E) system has become an important question for many nations. In China's long-development plan, the energy supply and consumption is an important part. Few scholars disagree that the coordinating development of 3E system is important for the sustainable development in the future. Therefore, it is significant to study the coordination degree of the 3E system. In this paper, it will give the definition of the coordination development, and construct a model to quantitatively study the coordinating degree of the three subsystems and the entire system.

2 Literature Review

In order to provide decision-makers with a comprehensive model which allows to assess environmental burdens

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(global warming potential and acidification potential) with respect to changes in economic activities consistent with distinct policy measures, Carla Oliveira(2004) constructed an multiple objective linear programming model including sustainable energy strategies, economic growth, social welfare and environmental friendliness based on the linear structure of inter-industry production linkages^[1]. Li zhi-dong (2003) divided the 3E model into macroeconomic, energy and environment three sub-models and developed an econometric model to perform a long-term simulation study for China^[2]. Lazzaretto(2004) discussed a thermal system design that optimized the energy, economy and environment as separate objectives and developed an evolutionary algorithm^[3]. In order to estimate the long-term energy, economy and environment interactions for Turkey, Tiris(1994) gave a linear optimization model and a multi-attribute value model^[4]. Hawdon(1995) investigated the complex interrelationships between energy, environment and economic welfare with the aid of a 10-sector input-output (I-O) model of the UK, with pollution emission coefficients and a European sulphur deposition vector^[5].

In addition to the 3E system, there are many studies on the system on four sub-models adding people, i.e. people-resource-economy-environment complex system.

Meng(1999) argued that the system coordination is the harmoniously and mutually operating of inter-element or intersystem in the evolution of system^[6]. Wang (1997) defined the system coordination as a set of the interrelated, interactive relationship, and descript it as coordination degree. Niu Wenyan (1999) regards the total process of sustainable development as a compromising results^[7]. Besides, Li Yan(2003) puts forward the systematic index system of economy-environment and mathematical model^[8]. Although there are many qualitative analysis in the system coordination studies, it is rare in the quantitatively analysis. In this paper, the author will discuss this problem from a quite broad perspectives and study the time series of coordination degree.

3 Model Description

3.1 Energy-Economy-Environment System

As shown in Fig.1, there are complicated interactions between the three subsystems in the EEE model (3E). Energy subsystem and economy interact directly through supply and demand, prices and capital investments. The energy marketplace is a result of the population, investment capital, government policies, technology, energy sources, and energy demand. The marketplace balances all of these factors and yields equilibrium of supply and demand by means of prices and controls. As the world's energy marketplace changes, a redistribution of economic wealth occurs.

3.2 Coordination Degree Evaluation Method

Definition I: The coordinated development of 3E is defined as a state in which not only the energy consumption is satisfied, but the pollution in environment is reduced by the interaction among the elements in the system in the energy consumption and production. The final goal of the coordinated development of the 3E is to reach the sustainable development.

The systematic coordinated development index of the 3E system is related not only respectively its development level, but to their mutually interaction. Let D_d, D_j denote the development level of energy subsystem and the economic development. Meanwhile, let the

D_h represent the environmental tolerance level. C_{dj} is the coordination level of the energy subsystem and economy subsystem. The variable C_{dh} Expresses the coordination degree between energy and environment subsystem. The variable C is the total coordination level of the 3E system. By collecting some evaluation index of the three subsystems, we can calculate the system coordination degree.

Supposed that the D_d evaluation indexes is (d_1, d_2, \dots, d_d) , economy subsystem D_j evaluation indexes is (j_1, j_2, \dots, j_k) , correspondingly, the environment subsystem tolerance degree indexes is (h_1, h_2, \dots, h_m) .

Then,

$$D_d = \sum_{i=1}^d f(d_i)w_{d_i} \quad (1)$$

$$D_j = \sum_{i=1}^k f(j_i)w_{j_i} \quad (2)$$

$$D_h = \sum_{i=1}^m f(h_i)w_{h_i} \quad (3)$$

Among the Eq. (1)~(3) $\sum w_{d_i} = 1 \quad 0 \leq f(d_i) \leq 1$,

$$\sum w_{j_i} = 1 \quad 0 \leq f(j_i) \leq 1 \quad (4)$$

$$\sum w_{h_i} = 1 \quad 0 \leq f(h_i) \leq 1 \quad (5)$$

Eq. $f(h_i), f(j_i), f(d_i)$ are respectively the standardized measurement of each subsystem. It's got by the following formulas.

(1) When the index is a positive, i.e. benefit target

$$f(x) = \begin{cases} 1 & x \geq B \\ x/B & x < B \end{cases} \quad (6)$$

(2) The index is a negative, i.e. a cost index, the least, the better

$$f(x) = \begin{cases} 1 & x \leq B \\ B/x & x > B \end{cases} \quad (7)$$

Figure 1. Energy-Environment-Economy system (3) As for medium index,

$$f(x) = \begin{cases} x/B & x < B \\ 1 & x = B \\ B/x & x > B \end{cases} \quad (8)$$

B is the referencing index or coordinating data set by expert consultation, w is confirmed by AHP.

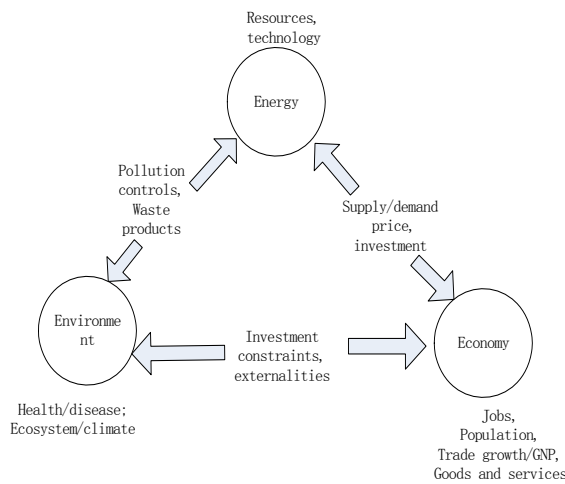


Figure 1. The internal relationship of Energy-Environment-Economy system

The internal relationship of

$$D_d = \begin{cases} = \exp\left(\frac{dD_d}{dt} - \frac{dE}{dt}\right) & \frac{dD_d}{dt} < \frac{dE}{dt} \\ = 1 & \frac{dD_d}{dt} = \frac{dE}{dt} \\ = \exp\left(\frac{dE}{dt} - \frac{dD_d}{dt}\right) & \frac{dD_d}{dt} > \frac{dE}{dt} \end{cases} \quad (9)$$

Where, E is the development level of the 3E system. The other two subsystem, economy and environment is to take the same expression as (9). Thus,

$$C_i = \sqrt[3]{D_d \cdot D_j \cdot D_h} \quad i = 1, 2, \dots, n \quad (10)$$

In Eq.(9) $dD_d/dt < dE/dt$ shows that the subsystem of energy is lower than the 3E system in the growth rate. Where, $dD_d/dt = dE/dt$ is the energy subsystem hav-

ing the same growth rate with the 3E system. According to the Eq. (10), in term i , the coordination degree of the 3E system,

$$C_i \in [0, 1] \quad (11)$$

Only when $dD_i/dt = dE/dt (i = d, j, h)$, it reach the maximum.

There are many advantages in the definitions of the coordination degree evaluation methods. Firstly, it can scientifically shed light on the real connotation of the coordination degree by defining the deviation of development level of every subsystem and the whole 3E system. Thus, it is scientific and accurate for the analysis of the 3E system. Secondly, according to description above to coordinate degrees of definition, no matter it is the single system coordinate degree or the whole system coordinated degree, they are all the functions of the subsystem development levels and the whole development level of 3E system. Therefore, the whole development level of 3E system can be turned into the function of the actual development level of every subsystem, and the single system coordinates degree and coordinates degree of functions that can be turned with the system into every subsystem development level wholly. Finally, the model above can portray the state of development of coordination of every subsystem and can describe out the state of development of coordination of the whole system based on this. In this way, we can reflect relevant systems coordinate all information of the state of development and avoid the loss of valuable information in the analytic process of systematic harmony.

4 Empirical study in China

China has experienced great changes in the 3E system in the recent three decades. It has become a typical example in many aspects. In order to study the energy consumption, economy growth and environment protection, we can employ the model and definition of the coordination degree of the system to study the variables in recent years which can reflect the trend in future. We collect the historical data from China statistical yearbook and the energy statistical yearbook. Then calculate the standard-

ized data as shown in Table 1.

TABLE I. THE ORIGINAL DATA IN THE 3E SYSTEM IN CHINA IN RECENT YEARS

	Energy Equipme nt	Energy Producti on	Coal Consumptio n	GDP	Investme nt in Fixed Asset
2002	1.0743	1.054	1.0063	1.0932	1.0885
2003	1.0873	1.061	1.0065	1.0954	1.0884
2004	1.0755	1.0652	1.0153	1.051	0.9855
2005	1.0688	1.1098	1.0179	1.0902	1.1026
2006	1.06	1.0843	1.0219	1.0879	1.123
2007	1.0429	1.1052	1.0157	1.0768	1.1689

Then, according to Eq.(1)~(3), we calculate the development level of the three subsystems.

TABLE II. THE DEVELOPMENT LEVEL OF THE 3E SYSTEM IN CHINA

	Energy subsystem	Economy subsystem	Environment subsystem	The 3E system
2002	0.0198	0.094	0.712	0.325
2003	0.228	0.143	0.756	0.367
2004	0.319	0.285	0.812	0.482
2005	0.495	0.505	0.697	0.564
2006	0.543	0.564	0.739	0.632
2007	0.712	0.743	0.572	0.601

According to Eq.(6)~(9), we can get the growth rate of the subsystem, as shown in table 3.

TABLE III. THE RELATIVE GROWTH RATE OF THE SUBSYSTEMS

	dD_a/dt	dD_j/dt	dD_h/dt	dE/dt
2002				
2003	1.089	0.537	0.288	1.299
2004	0.498	0.678	0.356	0.158
2005	0.522	0.769	-0.172	-0.354
2006	0.415	0.476	-0.505	-0.723
2007	0.412	0.131	-0.513	-1.732

Based on the definition of the coordination degree of the system, we can get the 3E system coordination level in recent years in China. The following table 4 is the coordination level of the 3E system.

TABLE IV. COORDINATION DEGREE OF THE 3E SYSTEM IN CHINA

	Energy(D_a)	Economy(D_j)	Environment(D_h)	3E(C)
2002	0.9665	0.9783	0.9708	0.9727
2003	0.9583	0.9637	0.9344	0.9538
2004	0.9753	0.9382	0.9238	0.9461
2005	0.9939	0.9786	0.9262	0.9688
2006	0.9791	0.9842	0.8478	0.9758
2007	0.9844	0.9871	0.9053	0.9876

According to table 4, we plot the graph as the following indicated. According to Fig.2, the time series of the subsystem of energy, economy and environment is varied fluctuated in the recent year in China. From 2002 to 2006, the environment subsystem is deteriorated seriously due to the ineffective environment protection in the 3E system. As the macro-economy grew very fast since 2002, the energy demand mount was also larger than expected. Many aspects of economy indicated that China has entered the middle and latter phase in the industrialization. The attributes of development stage is consisted with the developed countries. Therefore, in order to realize the harmony development of the 3E system, it is necessary for the system to strength the environment protection, reduce the waste emission, and develop the environment-protection industries.

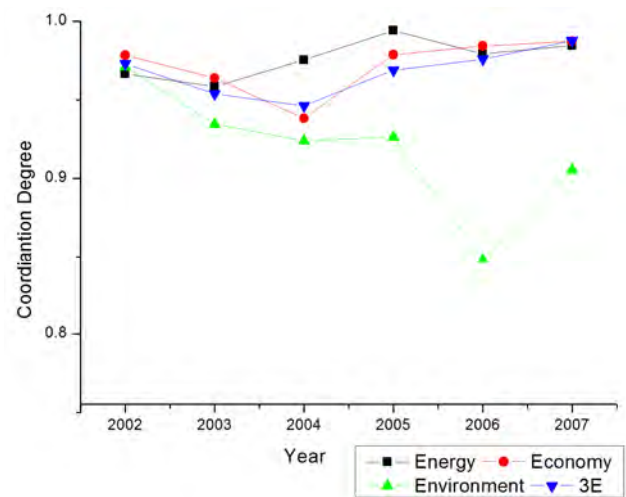


Figure 2. The coordination degree of the 3E system in recent years.

5 Conclusions

The empirical study indicated that the coordination degree evaluation model 3E system in this paper is consistent with the practice in China. It can be effectively identified that the coordinating degree of the complicated system in its development process. It can be used in many regions and help the local governments made proper policies for their energy consumption, economy growth and environment protection.

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