

A Method of Forecasting Sustainability and Development Based on Entropy-GE Matrix

Liwen Liang

North China Electric Power University, Baoding, Hebei 071000, China
1325578456@qq.com

Keywords: Sustainability, Development, Entropy-GE Matrix, Lanchester's Equation, OAT/OFAT method

Abstract. Sustainability is a comprehensive concept to describe a pattern of development without losing coordination or over consuming resources. Our research is divided into three steps: assessing and forecasting sustainability, formulating development plan, and involving external factors.

1 Introduction

The concept of Sustainable Development (SD) was derived from forest management in early 12th to 16th centuries^[1]. In recent decades, with the continuous development of modern society, the concept of SD evolved and was broadened. It was not until 1987 had this concept been defined by the United Nations World Commission on Environment and Development in its report Our Common Future defines sustainable development. The report defines: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"^[2]. While this is the most commonly used definition, it is not the only one. A pragmatic version with economic nuances was formulated by the OECD Environment Committee which considers that sustainable development means "maximizing the net benefit of the economic development, while maintaining the dimensions of quality and production at the level of the resources over time"^[3]. To measure the progress of sustainability, sets of Sustainable Development Indicators (SDI) have been created by many organizations include World Bank, World Resource Institute, Worldwatch Institute etc^[4]. At present, problems like over increased population, poverty, shortage of energy resources, and environmental pollution remain to be crucial global issues. Without effective ways to solve these problems, they will finally cause disasters to earth environment and lead to human society collapse. Hence, SD has its unprecedented significance in today's world.

2 A Model for Sustainability

2.1 Sustainable Development Indicators (SDI)

In order to give a well-rounded description of Sustainable development, a series of indicators is used, which are called Sustainable Development Indicators (SDI). Since there is no global consensus of how SDI should be selected, we therefore choose the indicators based on 3 principles:

- The indicators should be as comprehensive as possible to include most parts which are effective to sustainability.
- The indicators had better be easy to be controlled and regulated through government policies and feasible plans.
- The indicators which have already been tested reasonable in existent researches have apriority.

2.2 A Measurement of Sustainability

We provide a complete way to measure sustainability. To start with, data normalization ways are introduced. Then the Entropy Method is adopted to determine weight of indicators and calculate comprehensive performances on environmental, social, and economic aspects. Consequently, we defined Development Index and Coordination Index to describe sustainable development of a country. Finally, a GE-Matrix is used to score sustainability.

Table 1: Indicator system for sustainable development

Level1	Level2	Level3
Environment	Population	Population growth
		Population density
	Resources Pollution	The aging rate
		Forest rents in GDP
Social	Health	Energy use per capita
		CO2 emission per capita
	Education	Life expectancy
		Mortality rate
	Livelihood	Health expenditure per capita
		Tertiary school enrollment rate
Economic	Per Capita GDP Inflation	Education spend in GDP
		Depth of the food deficit
	Tertiary industry rate	Improved water source with access
		Household expenditure per capita

2.3 The Comprehensive Performance

The Entropy Method is derived from thermodynamics and is later introduced to telecommunication, energy, finance and other disciplines. Previous studies have successfully used this method to determine the weight of a group of indicators which are used for evaluation.

The Entropy Method suits for our study because our original data of indicators are trivial therefore hard to analyze. By adopting a Entropy Method, we can process the data (after normalization) into three main variables, representing environmental, social, and economic aspects; hence the analysis on data can be easier to approach and clearer to understand.

To start with, the entropy value H_i of indicator i is obtained by Equation (3.2.2)

$$H_i = -k \sum_{j=1}^m f_{ij} \cdot \ln f_{ij}$$

$$\text{where } i = 1, 2, 3, \dots, n; \quad k = \frac{1}{\ln m}$$

Accordingly, we determine the weight w_i of indicator i by Equation (3.2.2)

$$w_i = \frac{1 - H_i}{\sum_{i=1}^n (1 - H_i)}$$

Hence, the comprehensive performance of sample j by considering indicators 1 to n can be defined as

$$F_j = \sum_{i=1}^n w_i \cdot f_{ij}$$

Since our SDI system set up in Section 2.1 has three main aspects, we accordingly get three F_s to describe the comprehensive performance of a country (j omitted in the equation) on environmental (en), social (so), and economic (ec) aspects. Descriptions are shown in Equation.

$$F_{en} = \sum_{i=1}^{n_{en}} w_{i(en)} \cdot f_{ij(en)} \quad i = 1, 2, \dots, n_{en}$$

$$F_{so} = \sum_{i=1}^{n_{so}} w_{i(so)} \cdot f_{ij(so)} \quad i = 1, 2, \dots, n_{so}$$

$$F_{ec} = \sum_{i=1}^{n_{ec}} w_{i(ec)} \cdot f_{ij(ec)} \quad i = 1, 2, \dots, n_{ec}$$

2.4 Development Index and Coordination Index

Sustainable development is a concept which requires both development and coordination. To be coordinated requires a country to improve itself not only in one aspect but in all aspects at the same time. In our model, we use a Development Index (DI) to depict a overall development status and a Coordination Index (CI) to depict the consistency and coordination of development among environmental (en), social (so), and economic (ec) aspects. Both index are based on comprehensive performance on aspects (en, so, ec). It is only when DI and CI are both high can we consider a country to be a sustainable one.

Here we define Development Index (DI) to be

$$DI = CF$$

The parameters γ_1 , γ_2 , and γ_3 in C show weight of F_{en} , F_{so} , F_{ec} when composing DI.

The Coordination Index (CI) is defined as:

$$CI = 1 - \frac{S}{\bar{F}}$$

$$\text{where } S = \sqrt{\frac{1}{3}[(F_{en} - \bar{F})^2 + (F_{so} - \bar{F})^2 + (F_{ec} - \bar{F})^2]}$$

$$\bar{F} = \frac{1}{3}(F_{en} + F_{so} + F_{ec})$$

S is the standard deviation of the three performance values, and \bar{F} is the arithmetic mean value of the three.

2.5 A GE-Matrix to Score Sustainability

The GE-Matrix (McKinsey Matrix) is originally used in evaluating competitiveness and attractiveness of a company in a two-dimensional frame. The matrix can provide company with management and development strategies. Here we consider to use GE-Matrix to depict sustainability of countries.

3 A Forecast on Sustainability

3.1 Mechanism of Lanchester's Equation

Lanchester's Equation is originally used in combat to assess loss of soldiers from both sides. It is a nonlinear first order differential equation which can obtain dynamic changes of the system under different war strategies. The equation is described as

$$\begin{cases} \frac{dx}{dt} = -ay - \alpha x + u(t) \\ \frac{dy}{dt} = -bx - \beta y + v(t) \end{cases}$$

where a and b are attack strength from one side to the other; α and β are loss of soldiers due to reasons other than attacks; $u(t)$ and $v(t)$ represent supplement of soldiers.

3.2 State Equation

We know that Lanchester's Equation provides a model for war, but we "buy" it a new coat of peace in our model. We use it to obtain the dynamic process of sustainability and forecast sustainability changes. This new coat fits well since Lanchester's Equation can provide an equation to characterize not only effect on self aspect, but also effects of interaction among all aspects and effects from outside of the system.

$$\begin{cases} \frac{dF_{en}(t)}{dt} = \alpha_{11}F_{en}(t) + \alpha_{12}F_{so}(t) + \alpha_{13}F_{ec}(t) + \beta_1 \hat{U}_1(t) \\ \frac{dF_{so}(t)}{dt} = \alpha_{21}F_{en}(t) + \alpha_{22}F_{so}(t) + \alpha_{23}F_{ec}(t) + \beta_2 \hat{U}_2(t) \\ \frac{dF_{ec}(t)}{dt} = \alpha_{31}F_{en}(t) + \alpha_{32}F_{so}(t) + \alpha_{33}F_{ec}(t) + \beta_3 \hat{U}_3(t) \end{cases}$$

4 Results

4.1 Country Rankings

We acquired original data from World Bank Database. The data cover all 17 indicators in our SDI system. Ten sample countries are selected from 5 different continents and covers both developed countries and developing countries. Based on our model in Section 2.2, sustainability scores of sample countries in year 2013 are calculated. The rankings are shown in Table 3.

Table 2. 2013 Sustainability rankings of 10 countries

Rank	Country	Fen	Fso	Fec	DI	CI	Score
1	U.S.	0.378	0.343	0.439	0.876	0.897	0.161
2	U.K.	0.164	0.277	0.386	0.625	0.672	0.499
3	Brazil	0.085	0.050	0.056	0.144	0.761	0.889
4	China	0.122	0.213	0.035	0.279	0.408	0.932
5	South Africa	0.147	0.053	0.057	0.195	0.494	0.951
6	Bangladesh	0.015	0.012	0.006	0.025	0.635	1.041
7	Central Africa	0.020	0.015	0.005	0.030	0.521	1.082
8	Cambodia	0.022	0.010	0.007	0.030	0.517	1.084
9	Nepal	0.023	0.016	0.004	0.032	0.478	1.100
10	Congo	0.023	0.014	0.003	0.031	0.396	1.142

4.2 A 20-Year Forecast

We use data from 2009-2013 to forecast the comprehensive performances on environmental, social, and economic aspects for different countries based on the model introduced in section 2.3.

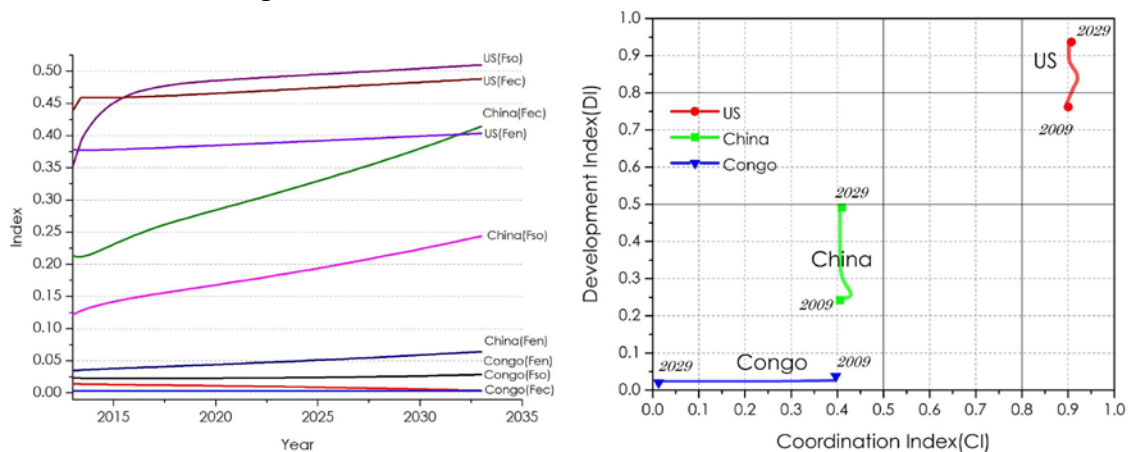


Figure 1. Forecast on comprehensive performances of three countries

References

- [1] Ina Ehnert: Sustainable Human Resource Management: A Conceptual and Exploratory Analysis from a Paradox Perspective; Springer, 2009; pp. 35-36
- [2] Brundtland Commission (1987). "Report of the World Commission on Environment and Development". United Nations.
- [3] Danut Mosteanu, Elisabeta-Emilia HALMAGHI. The Sustainable Development-Human Development. Management and Economics, 2014, 73(1):106-113.
- [4] Paula Bocarova, Stanislav Kolosta. Assessment of sustainable development in the EU 27 using aggregated SD index. Ecological Indicators, 2015, 73(48):699-705.