Type the National Vulnerability Evaluation System Research Based on Fuzzy Comprehensive Evaluation

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Type the National Vulnerability Evaluation System Research Based on Fuzzy Comprehensive Evaluation

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Abstract. At the beginning, the report filter six main influential factors which has seriously affect toward the fragile of a country by Grey Correlation Grade model. Second, based on Fuzzy Comprehensive Evaluation, we introduce the idea of Entropy Method into our model and build an evaluation model in valuing the national vulnerability. Finally, select twenty countries around the world evenly to substitute their data into our model and compare our results with the published results of Peace Foundation. The comparison shows that the error in rating is limited in 20%. Therefore, the view that our model has high credibility.

1. Background

In recent ten years, the huge climate change had caused severe impacts on the environment in some areas. For example, Eastern Africa encountered the most severe drought in the past sixty years which caused serious food crisis and tens of millions of people were starving. The most drought-hit areas were Kenya, Ethiopia, Somalia and Djibouti. In these areas, more than two million children were malnutrition and their lives were facing challenges. About 500,000 children were in extremely hard situation. Drought had hit especially hard in Somalia where is in war and anarchy for the past 20 years. Farmers and herdsmen of Somali pushed to migrate domestically and even outside the country. They moved to Kenya, Ethiopia, Djibouti, Yemen and Sudan which caused a colossal immigration rush. There is also another example showed that the current forest covered area of Kenya is only 2% as its acreage in 1995 according to the statistic of Food and Agriculture Organization (FAO). The reduction of forest area causes the shrinking of lake, lower river level and reducing rainfall. In this situation, once an extreme climate happened in these areas, the life of residents would fall into trouble and the country may collapse evenly.

Climate change makes some countries become even more fragile. It is our responsibility to prevent these countries fall into irreversible fragile situation. However, there is no common definition of vulnerability. Through literature review, we define vulnerability as the sensitivity, resilience and stability a system reflects when it faces external changes.

Until now, international society pays great attention to the problem of vulnerable countries. What kind of areas could be considered as fragile area and what can we do for them? These questions are becoming research hotspot of public welfare organizations and academic institutions. Accordingly, we are interested in this topic and hoping to do a contribution for the development of human beings. Following, we will discuss ways to identify the vulnerable countries.

2. Evaluation Model Foundation

2.1. Model Ideas

In order to establish a "fragile country" assessment system, showing what kind of country is "fragile country", we will adopt the following ideas:

First, sort influential factors based on Grey Correlation Grade model.

Then, decide the weight of every influential factor through the Analytic Hierarchy Process (AHP).

At last, apply the Fuzzy Comprehensive Evaluation method to evaluate the vulnerability.

The logic diagram is as follows：

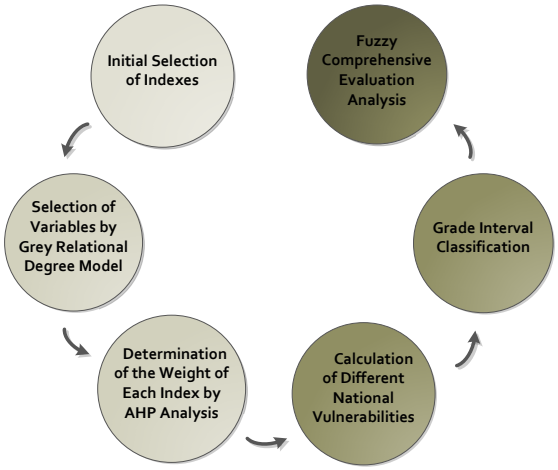

Figure 1. The logic diagram of Fuzzy comprehensive evaluation model

Through literature review, there are five main influential aspects that have seriously influential on the fragile of a country, which are external influence, health, climate change, education and resources allocation [1][5][6]. Based on these researches, we select some important indexes from every influential aspect to value the vulnerability. The indexes are listed below:

Table 1. Three Scheme comparing.

Impact Factor		
Indexes	Implication	
x1	external influence	
x2	health	per capita expenditure
x3		mortality rates of children under 5 years
x4		crude mortality rate
x5		population mutation
x6	education	total enrollment rate
x7		adult general literacy rate
x8		higher education population immigration rate
x9	resources	per capita GDP
x10		per capita cultivated land
x11		per capita available domestic water
x12		water shortage rate
x13	climate	precipitation
x14		mean annual temperature
x15		per capita CO2

2.2. Model Building

Set a reference sequence [2]:

$$x_i = \left(x_i(1), x_i(2), ..., x_i(k), ..., x_i(n) \right), i = 1, 2, 3..., q \tag{1}$$

And another sequence to compare:

$$x_i = \left(x_i(1), x_i(2), ..., x_i(k), ..., x_i(n) \right), i = 1, 2, 3..., q \tag{2}$$

Then define the correlation coefficient as:

$$\varepsilon_{ij}(k) = \frac{\min \min \left| x_j(k) - x_i(k) \right| + \rho_{\max} \max \left| x_j(k) - x_i(k) \right|}{\left| x_j(k) - x_i(k) \right| - \rho_{\max} \max \left| x_j(k) - x_i(k) \right|} \tag{3}$$

And correlation degree as:

$$r_{ji} = \frac{\sum_{k=1}^{n} \varepsilon_{ji}(k)}{n} \tag{4}$$

Sorting all a from big to small and select the indexes which are used in modelling based on following principle [3]:

(1) Select the indexes with larger value of preferentially.

(2) Satisfy comprehensiveness. In other words, contain as many areas as possible.

(3) Satisfy comparability. It represents that the influence degree of indexes can be obtained easily for different method.

(4) Avoid repeatability. If there are several indexes are highly related, then choose one of them.

Therefore, we could obtain the sorting of indexes which is represented by U .

Then, weighing the selected indexes through AHP Method. There are more discussions about AHP , we do not repeat them here. Set positive reciprocal matrix:

$$A = (a_{ij})_{n \times n}, a_{ij} > 0 \tag{5}$$

Matrix A could be obtained through literature review [4] and certain weight could be calculated through programming.

Based on the results of AHP Method, start the math model building through Fuzzy Comprehensive Evaluation.

First, we need to do further research on Evaluation Matrix B . Evaluation Matrix B is based on the rating of experts. However, the subjectivity of this method is too strong and weakens the robustness of the model. We consider using a more objective method. In this case, we use Entropy method to build Evaluation Matrix B .

Suppose:

$$b_{ij} = \begin{cases} \dfrac{v_{ij} - \min \left\{ v_{1j}, \ldots v_{nj} \right\}}{\max \left\{ v_{1j}, \ldots v_{nj} \right\} - \min \left\{ v_{1j}, \ldots v_{nj} \right\}}, & \text{Positive Index} \\ \dfrac{\max \left\{ v_{1j}, \ldots v_{nj} \right\} - v_{ij}}{\max \left\{ v_{1j}, \ldots v_{nj} \right\} - \min \left\{ v_{1j}, \ldots v_{nj} \right\}}, & \text{Negative Index} \end{cases} \tag{6}$$

Hence, fuzzy assessment vector is:

$$S = T \circ B \tag{7}$$

Here, weighted mean type operator is used in evaluating S .

Suppose the set of rating level is:

$$M = \{dangerous,\ waring,\ stable,\ sustainable\} \tag{8}$$

And assign values to different levels, then we get a set:

$$\mu = \{4,3,2,1\} \tag{9}$$

Accordingly, the scores of a country's vulnerability is:

$$\mu^* = \frac{\sum_{i=1}^{4} \mu_i \cdot S_i}{\sum_{i=1}^{4} S_i} \tag{10}$$

3. Empirical Analysis And Conclusion Of The Model

3.1. Solution of grey relational degree

Based on our model, we evenly select twenty countries around the world. The locations of these countries are listed as below:

Figure 2. The locations of selected countries

Then substitute their data into the model, deal with these data through MATLAB 2017b and filter several indexes. To simplify our model, we compare different result and the counts of similar result. We filter six Vulnerability impact indexes:

Table 2. Impact Indexes Of Vulnerability

Indexes	Explanations
v1	External intervention
v2	CO2 emissions (metric tons per capita)
v3	Arable land (hectares per capita)
v4	GNI (dollars per capita)
v5	Population density
v6	Positive feedback of national vulnerability to v1-v6

3.2. Solving weight matrix T and evaluation matrix B

Through literature review, we get a suitable positive reciprocal matrix A which is:

$$A = \begin{bmatrix} 1 & 3/2 & 2 & 3 & 6 & 12 \\ 2/3 & 1 & 4/3 & 2 & 4 & 8 \\ 1/2 & 3/4 & 1 & 3/2 & 3 & 6 \\ 1/3 & 1/2 & 2/3 & 1 & 2 & 4 \\ 1/6 & 1/4 & 1/3 & 1/2 & 1 & 2 \\ 1/12 & 1/8 & 1/6 & 1/4 & 1/2 & 1 \end{bmatrix} \tag{11}$$

Then we get Matrix T through MATLAB:

$$T = [0.3636,\ 0.2424, 0.1818, 0.1212, 0.0606, 0.0303] \tag{12}$$

3.3. Solving the evaluation matrix B and vulnerability score based on entropy information

We classify countries with complete data into three groups: undeveloped countries, developing countries and developed countries. Substituting the data of these countries into (3)(4)(6)(7).

And get various results through MATLAB.

There is a view that the Fragile Country Index published by Peace Foundation is reliable in the past twelve years. Accordingly, we compare our results with the Fragile Country Index. The situation of accuracy is showed below:

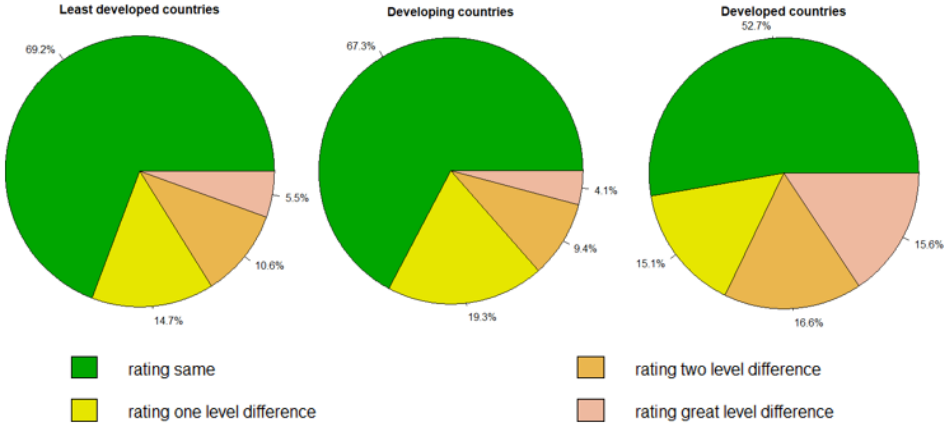

Figure 3. The situation of accuracy

It is obvious that, the results of two evaluation systems have high level of similarity. Therefore, we hold the view that our model in evaluating fragile is confidential.

Additionally, the figure shows that the credibility in evaluating undeveloped countries and developing countries are higher than the credibility in evaluating developed countries.

4. The Advantage And Defect Of The Model

As we all know, there is not perfect model. In the process of building our model, we found the following shortcomings and advantages.

(1) A bit indexes with strong representative which improve the adaptive of our model are selected.

(2) Applying Entropy method creatively and reduce the interference of active composition.

(3) Have a high request of the data structure continuity of the data set used. As a result, applying interpolation in dealing with some lost data which may reduce the accuracy of model.

5. Future Work

The definition of vulnerability lets us think of Hook's Law. According to this idea, we do some further research work (The equation of Hook's Law is $F = k \bullet \Delta x$). It is well agreed that there are many influential factors that will affect the vulnerability of a country. Among these factors. Among these influential factors, there exists an interaction which will influence vulnerability, we define the synergy of these influence as F. The vulnerability is reflected in two ways: First, with the same F, the huger the change of environment, which is represented by the increasing Δx, the higher the vulnerability. Second, with a similar change of environment, which means is same, the smaller the system's resilience, the more vulnerable the environment is. Moreover, it is easy to happen poverty, population, environment circle (PPE circle). It means that the bad changes increase vulnerability and the increasing vulnerability makes the situation even worse. Therefore, there is a negative relationship between influential factors and vulnerability.

There is an idea come to us after we finishing the building of vulnerability assessment system. We divide vulnerability into two parts and evaluate the sensitivity and adaptability of the spring. For the

reason that it is difficult to value sensitivity (because of the loss of data), we hold the view that we are able to find the situation of critical point through analyzing the adaptability of a system which means the ability to recover after influenced.

Based on these ideas, we are able to explore the impact mechanism of different influential factors (especially climate change) towards the vulnerability of a country and propose targeted measures to deal with the vulnerability of a country.

References

[1] Zhu, J. and Hao, Q. Y. "Failed states" and civilized mission: Revaluation of national vulnerability index." Exploration, 2017, NV(5): 157-164.
[2] Jiang, Q. Y. MATLAB in Mathematical Modeling (2nd ed.). Beijing University of Aeronautics and Astronautics Press, 2014.
[3] Zhou, X. C. Application of Fuzzy Analytical Hierarchy Process and Gray Correlation in the decision-making of railway construction schemes. Southwest Jiaotong University, 2011, 1-80.
[4] Jiang, J. Climate change vulnerability on agriculture in poor areas. Chinese Academy of Agricultural Sciences, 2012, 1-57.
[5] G.L. Munck, J. Verkuilen. Conceptualizing and measuring democracy evaluating Alternative Indices. Comparative Political Studies, Vol. 35 No. 1, February 2002 , 5-34.
[6] F.G. Sanín. Evaluating State Performance: A Critical View of State Failure and Fragility Indexes. European Journal of Development Research, Vol.23 No.1, 2011, 20-42.