Fragility Assessment Model Based on Principal Component Analysis

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Abstract. In recent years, the global impact of climate change has increasingly become a serious problem humankind facing in the world. In this paper, a fragility assessment model has been established by using principal component analysis in response to how climate change affects regional instability. In the study we found that exposure degree, sensitivity and strain capacity are important components of fragility. Because of the impact of climate change on the comprehensive development in country, we have created 12 indicators from the aspects of social, economic and human-induced to make a concrete analysis of the national fragility, the risks posed by these 12 indicators also affect exposure degree, sensitivity and strain capacity, which in turn affect the fragility of a country.

Background

There is sufficient evidence show that significant global warming will occur in the 21st century because of natural and human activities. Climate change poses new challenges to all countries in the world. Climate change will change the way people live and affect the use of food, water and energy, and many of these effects will alter the way humans live, and may have the potential to cause the weakening and breakdown of social and governmental structures. Consequently, destabilized governments could result in fragile states. In addition, due to rapid climate change, famine, disease, and frequent weather disasters, many countries' needs more than their bearing capacity, which may lead to offensive invasion to restore balance. Therefore, it is an inevitable requirement of the contemporary world to take intervention measures to mitigate the risks of climate change.

Assumptions

- Data collected from online database is accurate and reliable.
- The degree of coping between the various factors is small.
- The model emphasizes that although climate and environmental factors affect political stability and lead to violent conflicts, the impact of political, economic and cultural variables is also important
- The model mainly analyzes the impact of a series of chain reactions caused by climate change on the national fragilities.

Model: Comprehensive Evaluation Based on Principal Component Analysis

Model Overview. First of all, select 12 index variables for principal component analysis, using MATLAB software to calculate the eigenvalues of the correlation coefficient matrix and its contribution rate. Select the first three principal components, they are exposure degree, sensitivity, strain capacity for comprehensive evaluation, to build a fragility assessment model. By studying 175 countries' fragility Assessment (FMD) scores and ranking results, we found that when the national rankings were at 41 and FMD = 1.8, the fragility changed most rapidly.
Then, select the Central African Republic, one of the 10 fragile countries , as the research object and it can be find that climate increase the contribution of that exposure, sensitivity, strain capacity, thus exacerbating the country's fragility. By comparing the FMD obtained from reducing the

contribution of one of the principal components to the unmodified FMD, we find that without these effects, the fragility of the country will slow down.

Symbols and Definitions

Table 1 Symbol Definition

Variables	Definitions
FRD	Fragility
CMC	Climate Change
ED	Exposure Degree
SD	Sensitivity
SC	Strain Capacity

Table 2 Symbol Description

Variables	Symbol Representation
Provisionment	X_1
Health and Disease	X_2
Public Service	X_3
Business and Trade	X_4
Human flight and brain drain	X_5
State legitimacy	X_6
Human right	X_7
Demographic pressures	X_8
Refugees and internally displaced persons	X_9
The Emergence of Extreme Weather	X_{10}
Fiscal policy	X_{11}
External intervention	X_{12}

Construction. Because of the impact of climate change on the comprehensive development in country, we have created 12 indicators from the aspects of social, economic and human-induced to make a concrete analysis of the national fragility, the risks posed by these 12 indicators also affect exposure degree, sensitivity and strain capacity, which in turn affect the fragility of a country. We optimize the model later in our analysis and forecasting of non-fragile states.

In this task, we focus mainly on the connection between climate change and national fragility. We use Principal Component Analysis to establish fragility assessment model from the perspective of measuring climate change and establish a bridge between climate change and fragility. We select the relevant indicators of the smaller coupling: Exposure Degree, Sensitivity, Strain Capacity, and Bearing Capacity to explain the impact of climate change on 12 indicators, and ultimately determine the fragility of a country. First of all, we define 12 indicators in the economic, social and cultural aspects under the influence of climate change: Provisionment, Health and Disease, Equal Access to Public Resources, Business and Trade, Human Flight and Brain Drain, State Legitimacy, Human Right, Demographic Pressures, Refugees and Internally Displaced persons, labor and Social Security, Fiscal policy, External Intervention.

Qualitatively examining these 12 evaluation indicators, we can see that there may be strong correlations between some of the indicators. The direct use of these indicators for comprehensive evaluation will result in the overlapping of information and affect the objectivity of the evaluation results. Therefore, we converted the 12 indicators into three indicators which is less relevant (exposure, sensitivity and resilience) by using principal component analysis. Therefore, we convert the 12 indicators into five indicators （Exposure, sensitivity and adaptability, resilience）which have low correlation by using principal component analysis. By analyzing the literature and data, we obtain 12 index values of 178 national under climate change conditions with the same statistical time in the same year, and conduct principal component analysis on 12 indicators in different years, In order to verify the correlation, we calculated the correlation coefficient between the 12 indicators and the eigenvalues and contribution rates of each set of data, and next obtained the cumulative contribution rate. According to the regulations, when the cumulative contribution rate reaches more than 98%, it can be defined as the main component. From the data given, it can be clearly concluded that three of the five defined indicators are the main components, namely, exposure degree, sensitivity and strain capacity. We conduct a more systematic analysis of the links between the 12 indicators and the three principal components, the link between three principal components and the fragilities.

Principal Component Analysis.

- Standardized processing original data

Assuming there are m index variables for principal component analysis, they are $x_1, x_2, \dots, x_m$.And there are n evaluation objects, the j-th index's value of the i-th evaluation object is a_{ij}

Then Turn it into a standardized index value $\overline{a}_{ij}$:

$$Z = 72.5670$$

$$\tilde{a}_{ij} = \frac{a_{ij} - \mu_j}{s_j}, i = 1,2, \dots, n; j = 1,2, \dots, m$$

where: $\mu_j = \frac{1}{n}\sum_{i=1}^{n} a_{ij}, s_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(a_{ij} - \mu_j\right)^2}, j = 1,2, \dots, m$

where: μ_j is the sample mean of the j-th index. s_j is the sample standard deviation of the j-th index ,correspondingly:

$\tilde{x}_j = \frac{x_j - \mu_j}{s_j}$,j=1,2,...,m

is called Standardization indicator variables.

- Calculate the correlation coefficient matrix R:

correlation coefficient matrix $\boldsymbol{R} = \left(r_{ij}\right)_{\boldsymbol{m}\times\boldsymbol{n}}$:

$$r_{ij} = \frac{\sum_{k=1}^{n} \tilde{a}_{ki} \cdot \tilde{a}_{kj}}{n-1}, i, j = 1,2, \dots, m$$

Where: $r_{ii} = 1, r_{ij} = r_{ji}$,$r_{ij}$is the correlation coefficient between the i-th index and the j-th index.

- Calculate the eigenvalues and eigenvectors.

Calculate the eigenvalues of the correlation coefficient matrix R:$\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_m \geq 0$ and the corresponding eigenvectors $\mu_1, \mu_2, \dots, \mu_m$and where $\mu_j = [\mu_{1j}, \mu_{2j}, \dots, \mu_{mj}]^T$. M new index variables composed of eigenvectors:

$$y_1 = u_{11}\,\tilde{x}_1 + u_{21}\,\tilde{x}_2 + \cdots + u_{m1}\,\tilde{x}_m$$
$$y_1 = u_{12}\,\tilde{x}_1 + u_{22}\,\tilde{x}_2 + \cdots + u_{m2}\,\tilde{x}_m$$
$$y_1 = u_{13}\,\tilde{x}_1 + u_{23}\,\tilde{x}_2 + \cdots + u_{m3}\,\tilde{x}_m$$
$$y_1 = u_{1m}\,\tilde{x}_1 + u_{2m}\,\tilde{x}_2 + \cdots + u_{mm}\,\tilde{x}_m$$

Where: y_1 is the first principal component, y_2 is the second principal component, ...y_m is the m-th principal component.

- Choose P (P<=M) Principal components, calculate the comprehensive evaluation value.
  - Calculate the information contribution rate and cumulative contribution rate of eigenvalue λ_j（j=1，2，...，m）.

Where: $b_j = \frac{\lambda_j}{\sum_{k=1}^{m}\lambda_k}$,j=1,2,...,

m is the information contribution rate of the principal component y_j.At the same time:

$$\alpha_p = \frac{\sum_{k=1}^{p}\lambda_k}{\sum_{k=1}^{m}\lambda_k}$$

is the cumulative contribution of the principal components $y_1, y_2, \dots, y_p$

When α_p is close to 1, the first p index variables $y_1, y_2, \dots, y_p$ are selected as the principal components to replace the original m index variables so that the p principal components can be comprehensively analyzed.

- Calculate Composite Score:

$$Z = \sum_{J=1}^{P} b_j y_j$$

Where ： b_j is the information contribution rate of the j-th principal component, and is evaluated according to the Composite Score.

Based on this algorithm:

we first use matlab software for principal component analysis of 12 indicators , the first few characteristic roots of the correlation coefficient matrix and their contribution rate are shown in the following table

Table 3 Principal component analysis results

Number	Characteristic Root	Contribution Rate	Accumulative Contribution Rate
1	8.708	72.567	72.567
2	2.1183	17.6524	90.2194
3	0.9669	8.0582	98.2776
4	0.1623	1.3523	99.6299
5	0.0444	0.3702	100

It can be seen that the cumulative contribution rate of the first two eigenvalues reaches more than 90% and the principal component analysis works well. Next, we select the first three principal components (the cumulative contribution rate of 98%) for comprehensive evaluation, the first three eigenvectors corresponding to the eigenvector in the table below.

Table 4 Eigenvectors to which principal components correspond

	$\tilde{x}_1$	$\tilde{x}_2$	$\tilde{x}_3$	$\tilde{x}_4$	$\tilde{x}_5$	$\tilde{x}_6$	$\tilde{x}_7$	$\tilde{x}_8$	$\tilde{x}_9$	$\tilde{x}_{10}$	$\tilde{x}_{11}$	$\tilde{x}_{12}$
1	0.3091	0.1488	-0.0550	-0.0343	0.2115	-0.0306	0.6944	0.4022	-0.4051	-0.0157	-0.1154	0.1039
2	0.3001	0.2821	-0.1029	0.2210	0.0652	0.1243	-0.4980	0.0974	-0.4213	0.4968	-0.1807	0.1918
3	0.2381	0.5263	0.2985	-0.2856	0.4378	0.3619	0.0010	-0.1891	0.3469	-0.0114	0.1255	-0.0326

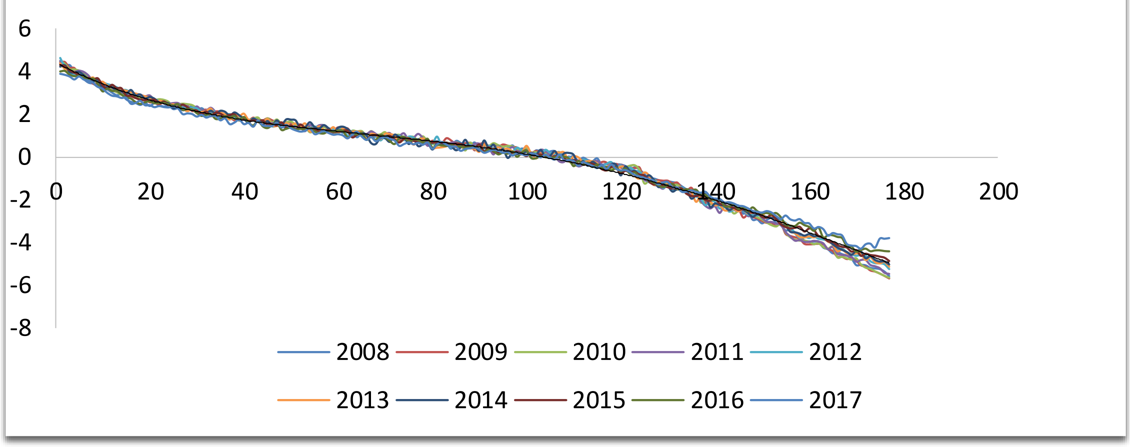
The three main components are respectively:

$$y_1 = 0.3091\tilde{x}_1 + 0.1488\tilde{x}_2 + \cdots + 0.1039\tilde{x}_{12}$$
$$y_2 = 0.3001\tilde{x}_1 + 0.2821\tilde{x}_2 + \cdots + 0.1918\tilde{x}_{12}$$
$$y_3 = 0.2381\tilde{x}_1 + 0.5263\tilde{x}_2 + \cdots - 0.0326\tilde{x}_{12}$$

Taking the contribution rate of 3 principal components as the weight respectively, construct a comprehensive evaluation model of the principal components

$$Z=0.7256y_1 + 0.1765y_2 + 0.0806y_3$$

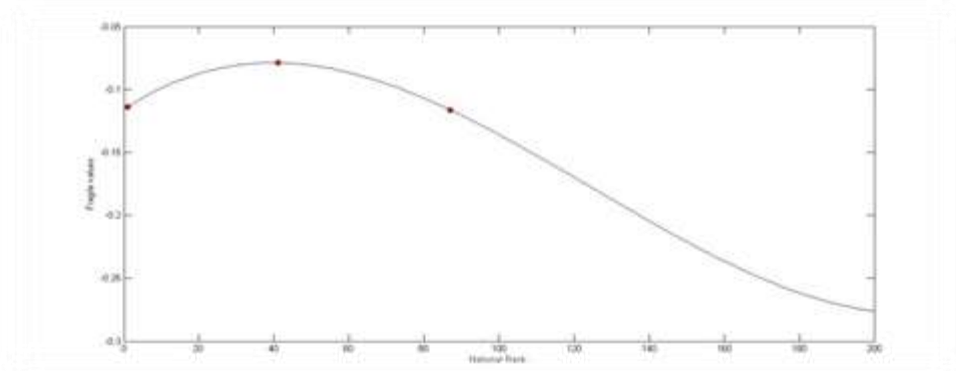
Figure 1. Ratings of 175 Countries in ten years



Conclusion： Division of National Fragility LevelsConclusion part is mainly how to define the criteria that classify 220 countries in the world as fragile, vulnerable and stable. We take the contribution rate of the three main components as the weight, construct the comprehensive evaluation model of the principal components, and get the comprehensive evaluation value of each country.

From Figure 1, it can be very straightforward to conclude that national fragility is positively related to the comprehensive evaluation value. But we can not precisely get the definition of the conditions among fragile countries, vulnerable countries and stable countries

Fig. 2 the relationship between national rank and fragility value



Further analyze the model, from Fig.1 and Fig. 2 we find that when the country ranked 41, the degree of fragility changes most rapidly. By observing the changes in the fragility values of Fig.2 and Fig.2 we define the boundary indicators that distinguish fragile countries, vulnerable countries and stable ones.

Table5 Fragility Assessment Standards

Grade	Value	Fragility Assessment
I	-6—0.5	Stable
II	0.5—1.8	Vulnerable
III	1.8—5	Fragile

Reference

[1]Fragile States Index: http://fundforpeace.org/fsi/
[2]The World Bank: http://www.worldbank.org/en/topic/fragilityconflictviolence/brief/harmonized-list-of-f ragile-situations

[3]Krakowka, A.R., Heimel, N., and Galgano, F. ―Modeling Environmenal Security in Sub-Sharan Africa – ProQuest.‖ The Geographical Bulletin, 2012, 53 (1): 21-38.
[4]Schwartz, P. and Randall, D. ―An Abrupt Climate Change Scenario and Its Implications for United States National Security‖, October 2003.
http://eesc.columbia.edu/courses/v1003/readings/Pentagon.pdf