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The impact of climate change on regional instability

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ABSTRACT. *The main purpose of this paper is to establish a regional vulnerability index evaluation model to describe a country's vulnerability and how climate change affects national vulnerability. In this paper, gray relational analysis is used to quantitatively describe the degree of development of similar or different degrees of development among factors. The selected indexes are normalized and the gray correlation coefficient and national vulnerability index are calculated. In this paper, the regression model of national vulnerability index is established, and the factors affecting national vulnerability are analyzed by using the method of control variables. Finally, we can know that the national vulnerability index is positively correlated with the climate index value, and find out the national vulnerability index. A turning point in the number.*

KEYWORDS: *gray relational analysis, regression model, data standardization, climate, instability*

1. Introduction

The effects of climate change, including increased droughts, shrinking glaciers, changes in the range of animals and plants, and sea-level rise, vary from region to region. These influences will change human lifestyles and may lead to the breakdown and collapse of social and governmental structures. An unstable government system may lead to increased vulnerability and crisis in the country. Unstable and persistent environmental measures, relocation and scarce resources are likely to further aggravate the instability of government governance in some countries. It can be said that the drought in Syria and Yemen further aggravated the conflicts between the already fragile countries. Environmental pressure by itself does not necessarily trigger violent conflict, but there is evidence that it can trigger violent conflicts when it is combined with weak governance and social divisions.

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An unstable country means that the government of a particular country can not or willfully not supply sufficient necessities of life. We also call it "fragile country."In the broadest sense, a social community is entangled in various forms of violent conflict and is politically, socially or economically unstable. The vulnerability thus understood is defined as "the vulnerability of the social situation." At present, most publications in the west use the term "fragile state" mostly in the broad sense.

2. Methodology

2.1 Our works

Through the World Bank(WB), this article has obtained fifteen sets of data such as precipitation, forest area and GDP from various countries in the world in the past two decades. And ranked by the Peace Foundation(TPF) the Vulnerability Index for each country in 2006-2017.

The far-reaching implications and implications of climate change may lead to the breakdown and collapse of social and government structures and may even directly or indirectly result in increased national vulnerabilities. Therefore, on the issue of how climate change affects regional instability, the problems to be solved are:

Develop models to characterize a country's vulnerabilities and describe how climate change affects national vulnerabilities. The model should identify whether the state of a country is very fragile, fragile or stable.

Select the top 10 most vulnerable countries and then find out how climate change has actually added to the vulnerability of a country.

2.2 Basic assumption and Symbol description

In order to simplify the issue, we have the following basic assumptions, which are rightly justified.

The data we collect is sufficient, accurate, quantitative, and correctly.

It is assumed that the national vulnerability index relates only to 15 indicators in five dimensions: social, economic, climate, security and social. And ignore the impact of other indicators.

The following is the symbolic description of this article:

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Symbols	Definition
FSI	Indicate the fragile state index
SI_i	Indicate a level indicator $(i=1,2,...,5)$
IM_j	Indicate secondary indicators ($j=1,2,...,15$)
Δ	Indicates the magnitude of the change in vulnerability index
β_i	Indicates the regression coefficient

2.3 Analysis of Problems

The creation of a national vulnerability index model that takes into account the effects of climate requires three steps: the definition of national vulnerability, the selection and processing of vulnerability indicators, and the composite calculation of the national vulnerability index.

□ For the definition of national vulnerability: The definition needs to evaluate the bad performance of government governance in many developing countries based on the assumption of "short-board theory." In order to quantify the size of the national vulnerability index, several more specific dimensions and core features are used to refine the meaning of fragile states based on the fragile consensus of the concept of fragile states. Considering the influencing factors of national vulnerability, we choose five dimensions of safety, economy, climate, society and politics.

For the selection and management of vulnerability indicators:Specific indicators are selected under each of the macro-dimensions that form the concept of national vulnerability in order to quantify the vulnerability. The choice of specific measurement indicators generally follow three principles: the diagnostic utility of the problem, the availability of data and time continuity. In the five dimensions analyzed above, the total stock of external debt, GDP per capita, official exchange rate, commodity trade, international crime rate, global stock index, enrollment rate of secondary school students, electricity rate, gap between the rich and poor, military expenditures, public expenditure on education, number of immigrants , Emissions, precipitation, forest area and other 15 indicators.

□ For the synthetic calculation of the national vulnerability index: A gray relational analysis model is established, and the size of a country's vulnerability is measured by the difference between the national measurement index and the ideal country. Finally, through the analysis of the national vulnerability index, the environmental impact is obtained.

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Table 1 Indicators in FSI metric system.

	Indicators	Notation	Indicators	Notation	Target
FSI	economic	SI1	Total foreign debt stock	IM1	↓
			GDP per capita	IM2	↓
			Official exchange rate	IM3	↓
	Safety	SI2	Commodity trade	IM4	↓
			International crime rate	IM5	↑
			Global stock index	IM6	↓
	society	SI3	Secondary school enrollment ratio	IM7	↓
			Electricity rate	IM8	↓
			Income gap	IM9	↑
	political	SI4	Military spending	IM10	↓
			Public expenditure on education	IM11	↓
			Immigrant population	IM12	↑
	climate	SI5	Carbon dioxide emissions	IM13	↑
			Precipitation	IM14	↓
			Forests area	IM15	↓

The target ↑ (↓) indicates that the increase (decrease) of the value will help promote the extent to success of economical prosperity in smart growth. In all, the metric of FSI can be finally expressed by the function of SI1, SI2 , SI3 , SI4 and SI5 as .The diversity can be calculated by Shannon diversity index.

2.4 National Vulnerability Index Evaluation Model

Due to the complex and uncertain correlation between the measurement indicators and the first-level indicators, it is difficult to analyze their explicit impact on the NIF if we consider methods to improve the information. Gray relational analysis (GRA) is a quantitative comparison method of similar or dissimilar degree of development between quantitative description factors in gray system theory.

Step1: Data normalized

Because of these four types of evaluation index with different orders of magnitude, and may have different dimensions, so it is necessary to transform the

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different types of indicators for the unification, the standardization of dimensionless index.

(1) The international crime rate, the gap between the rich and the poor, and the number of immigrants are extremely large indicators, and their data indicators are minimized. Is to make the countdown transform, that is $IM'_{ij} = 1/IM_{ij}$. This will be the evaluation of the target into $\{x'_{ij}\}$, $\{x'_{ij}\}$ is a very small indicator, and then make the effect of data standardization, the formula is shown below.:

$$IM''_{ij} = \frac{IM'_{ij} - \min}{max - \min}$$

$$\min = \min_{1 \le j \le 178} \{IM_{ij}\} \qquad \max = \max_{1 \le j \le 178} \{IM_{ij}\}$$

Then the corresponding index value is $IM''_{Ij} \in [0,1]$, that is, the dimensionless standardization index.

(2) GDP, Power Rate and other indicators are very small, and then make the effect of data standardization directly，the formula is shown below:

$$IM'_{ij} = \frac{IM_{ij} - \min}{max - \min}$$

$$\min = \min_{1 \le j \le 178} \{IM_{ij}\} \qquad \max = \max_{1 \le j \le 178} \{IM_{ij}\}$$

Then the corresponding index value is $IM'_{Ij} \in [0,1]$, that is, the dimensionless standardization index.

Step2: Calculate the gray correlation coefficient

Taking the optimal index of all indicators as the reference series, we select the factors that affect the country's vulnerability: Economic dimension (Total foreign debt stock, GDP per capita, Official exchange rate), Security dimension (Commodity trade, International crime rate, Global stock index), Social dimension (Secondary school enrollment ratio, Electricity rate, The gap between rich and poor), Political dimensions (Military expenditures, Public expenditure on education, Immigrant population), Climate dimensions (Carbon dioxide emissions, Precipitation, Forest area) and so on. Where the reference sequence is $x_0(k)$ and the comparison sequence is $x_i(k)$.

Take the reference sequence as $y(k) = (y(1), y(2), ..., y(n))$ $x_0 = y$

The fifteen comparison numbers are $x_i(k)$ $x_i(k) = (x_i(1), x_i(2), ..., x_i(n))(i = 1, 2, ..., 15)$

k represents 178 countries.

$$\eta_i(k) = \frac{\min_i \min_k |x_i(k) - x_0(k)| + \rho \max_i \max_k |x_i(k) - x_0(k)|}{|x_i(k) - x_0(k)| + \rho \max_i \max_k |x_i(k) - x_0(k)|}$$

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$\left|x_i(k)-x_0(k)\right|$ is the absolute error of the k th point of $x_0(k)$ and $x_i(k)$; $\min_i \min_k \left|x_i(k)-x_0(k)\right|$ is the minimum difference between the two levels; ρ is the resolution, $0<\rho<1$,the bigger the ρ is, the smaller the resolution is; the smaller ρ is, the larger the resolution is.

Step3: Calculate national vulnerability index

Calculate the national vulnerability index FSI_i, x_i that the degree of correlation of x_0 , the formula is:

$$FSI_i = \frac{1}{n}\sum_{k=1}^{n}\eta_i(k)$$

Among them: FSI_i is the i th evaluation object's ideal target's national vulnerability index

2.5 Regression model of national vulnerability index

Synthesis of a target

Since the first-level index is obtained through the measurement data and takes into account the uncertainties between the first-level indexes, the second-level index is quantified by calculating the arithmetic average of the measurement indexes, that is:

$$SI_k = \sum_{j=1}^{n} IM_{kj} \Big/ n \qquad \left(j=1,\cdots,n\right)$$

Where n represents the number of measures in the k -first dimension. IM_{kj} denotes the j th measurement index under the k th first-level indicator dimension.

Least-squares regression

Using the least-squares method, five first-level indicators of safety, climate and economy are returned as independent variables and national vulnerability index as dependent variables:

$$FSI = \hat{\beta}_0 + \hat{\beta}_1 * SI_1 + \cdots + \hat{\beta}_i * SI_i \qquad \left(i=1,\cdots 5\right)$$

Where FSI is the national vulnerability index and SI_i is the i th level indicator.

Where $\beta_0, \beta_1, \cdots \beta_5$ is the regression coefficient. According to n independent observation data $FSI, SI_i (i=1,2,3,4,5)$, find the regression coefficient, the regression coefficient $\hat{\beta}_j \left(j=0,1,\cdots,5\right)$ in the regression model can be estimated by least square method, that is, the estimation value $\hat{\beta}_j$ should be selected. Then:

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$$X = \begin{bmatrix} 1 & x_{11} & \cdots & x_{1j} \\ 1 & x_{21} & \cdots & x_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & x_{i1} & \cdots & x_{ij} \end{bmatrix}$$

And $Y = [y_1, y_2, ..., y_i]^T$, $\beta = [\beta_0, \beta_1, ..., \beta_j]^T$. Then the linear regression equation can be expressed as:

$$Y = X\beta$$

When the matrix X column full rank, $X^T X$ is an invertible matrix, then $X^T X \beta = X^T Y$ can be $\hat{\beta}_j$ solution, the solution is:

$$\hat{\beta} = (X^T X)^{-1} X^T Y$$

By substituting $\hat{\beta}$ into the original regression model, an estimate of y can be obtained to obtain the functional relationship between the national vulnerability index and the first-level index SI_i that affects the national vulnerability:

$$FSI = \hat{\beta}_0 + \hat{\beta}_1 * SI_1 + \cdots + \hat{\beta}_i * SI_i \qquad (i = 1, \cdots 5)$$

3. Results and discussion

3.1 Solve the model of problems

According to the normalization of fifteen indicators in five dimensions of security, climate and economy, we get the comprehensive vulnerability assessment value of each country in 2016, namely the national vulnerability index. The results obtained are shown in the following table, showing only the top ten countries with the highest vulnerability index.

Table 2 Vulnerability index rankings

Country	South Sudan	Central African Republic	Chad	Somalia	Sudan
Vulnerability index	0.712	0.694	0.672	0.504	0.490
Ranking	1	2	3	4	5
Country	Republic of Yemen	Syria	Democratic Republic of the Congo	Afghanistan	Haiti
Vulnerability index	0.485	0.481	0.472	0.467	0.463
Ranking	6	7	8	9	10

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According to the magnitude of the Vulnerability Index and the actual situation in each country, we divide the National Vulnerability Index into three sections that are very fragile, fragile and stable. The country is stable when the vulnerability index is between 0-0.2, the country is vulnerable when the vulnerability index is between 0.2-0.4, and the country is very vulnerable when the vulnerability index is greater than 0.4.

The effect of climate change on the national vulnerability index is expressed as a function of the functional relationship between the national vulnerability index and the second-level indicator of national vulnerability. The regression coefficients of the five second-level indicators obtained from the regression model are shown in the following table:

Table 3 The regression coefficient of the second-level index

β_0	β_1	β_2	β_3	β_4	β_5
0.004	0.366	0.141	0.312	0.261	0.047

The functional relationship between the national vulnerability index and the first-level indicator SI_i that affects national vulnerability is:

$$FSI = 0.004 + 0.366 * SI_1 + \cdots + 0.047 * SI_5$$

Regression test: the coefficient of determination $R^2 = 0.993$, the fitting degree of the regression model is very high, the regression equation is more significant.

3.2 Climate Change Impact Analysis

(1) Using the functional relationship between the national vulnerability index and the first-level index SI_i affecting the national vulnerability, the control variable method is used to analyze the impact of the first-level index on the national vulnerability index. Using Syrian 2016 data, calculate the change in the Syrian Vulnerability Index and the Variance in Vulnerability Index Δ for each of the five normalized first-level indicators by 10% alone.

$$\Delta = \frac{FSI' - FSI}{FSI} \times 100\%$$

It represents the size of the national vulnerability index after the single index changes.

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Table 4 The impact of a single indicator on the national vulnerability index alone

	Safety	Society	Economic	Climate	Political
Vulnerability index changes	0.1487	0.1215	0.1344	0.1398	0.1227
Vulnerability index changes in magnitude	30.91%	25.26%	27.94%	29.06%	25.51%
Ranking	1	5	3	2	4

According to the impact of the five first-level indicators on the national vulnerability index alone, it is clear that security and climate have the greatest impact on the vulnerability of a country, and the five indicators have a more obvious impact on them. Therefore, in order to maintain the stability of a country. Focus on these five aspects in order to develop in harmony.

(2) In order to get a clearer picture of the impact of climatic factors on national vulnerabilities, sensitivity analysis is a way to learn and analyze the sensitivity of a model's state to ambient conditions. The use of sensitivity analysis to study raw data helps to understand the impact of climate change on national vulnerability.

According to the calculation of national vulnerability, by changing the value of the first-level indicator climate, the other first-level indicators will change according to the actual situation, which is conducive to adjusting according to the actual situation so as to realize the actual control of the national vulnerability by adjusting the environment the size of.

Only when the indicators of climate in the first grade of Syria in 2016 are taken as 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 respectively, the corresponding national vulnerability indices are obtained as follows:

Table 5 Climate - National Vulnerability Index Sensitivity Analysis

Climate	0.2	0.3	0.4	0.5	0.6	0.7
National Vulnerability Index	0.2391	0.2756	0.3254	0.4359	0.5698	0.6854

Now further analysis of the data in the above table, make the following line chart:

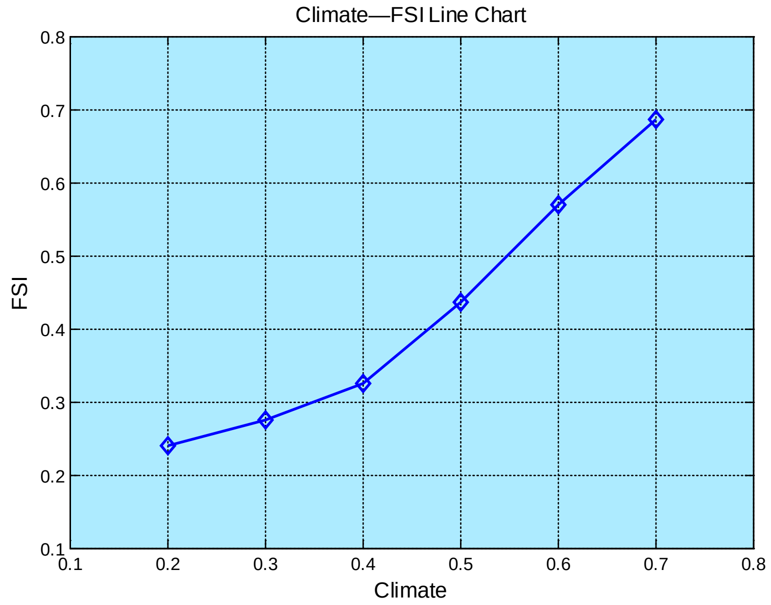

Figure. 1 Climate - National Vulnerability Index Line Chart

The conclusions that can be drawn from the figure above are: Firstly, the national vulnerability index is positively correlated with the climate index value. Secondly, when the value of the climate indicator varies from 0.2 to 0.4, the national vulnerability index shows an upward trend but changes very much.Thirdly, when the climate index value varies from 0.4 to 0.7, the change trend of the national vulnerability index suddenly increases. Therefore, we can see from the analysis that the climatic value of 0.4 is the critical point for Syria from vulnerable to very vulnerable.

4. Conclusion

In this paper, the gray prediction model is used to discuss the influence of climate change on regional instability, which provides a clear idea and reference for other prediction problems. In addition, the gray forecasting model can also be used for sales forecasting, urban road traffic accidents forecasting, China population growth forecast, and the prediction of virus transmission.

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