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Study on the Impact of Climate Change on Regional Instability

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ABSTRACT

In this paper we will discuss the problem on how the regional instability of a country can be affected by the climate change. Based on the data collected about the national vulnerabilities, we select fifteen indicators by the principal component analysis. A new three-level indicator system is then established to assess the country's vulnerability. To obtain and optimize the weight for each indicator used at different levels, the Analytic Hierarchy Process (AHP) and Gray Relational Analysis (GRA) are used. Based on this work, a measurement system including the climate, economic, security, politics and human development is set up to measure the vulnerability of the country.

Keywords: Climate change; Regional instability; Three-level indicator system

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1. Introduction

Since the beginning of 21st century, the theory of the fragile state has been gradually rising in the west. The study of the national fragility has become a basic core issue for the western academia to discuss the issue of world development. As to the nature of vulnerability, many scholars have some disagreements. Some scholars believe that vulnerability is an important attribute of the coupling system (social-ecosystem, human-environment coupling system) while Mitchell J. Erte and Bohle H. G [1] believes that vulnerability includes response ability and exposure to external disturbances and shocks of the system. On the contrary, GallopinG.G believes that exposure is not a component of vulnerability, which is combined with the sensitivity and coping ability to disturbance from the outside world, etc. Based on the understanding of different concepts of vulnerability proposed by different scholars [2], vulnerability is defined as a property of the structure and function of the system that is susceptible to changes due to the sensitivity of the system to disturbances both from inside and outside of the system as well as the lack of coping ability. Only when the system is disturbed does this property show that the internal characteristics of the system is the direct and main reason that leads to the fragility of the system, while the interaction between the disturbance leading to the system enlarges or reduces the fragility of the system is the indirect and forcing reason for the change of the system vulnerability. The indirect and forcing reason works by influencing the internal characteristics of the system so that changes take place, which ultimately reflects external sensitivities and coping skills. Therefore, the vulnerability of a country can be defined as: "Those governments are unwilling or unable to exercise their core functions for the majority of their people." Countries can be classified into three states of stable, vulnerable and very vulnerable.

As is well known, climate change [3] may have some impact on the region, including glacier shrinkage, increased droughts, sea level rise, and the scope of flora and fauna changes. These changes vary region by region. The Intergovernmental Panel on Climate Change claimed climate change [4] is likely to be far-reaching and influential, and that those changes will change the way humans live and may lead to the breakdown and collapse of social and government structures [5]. An unstable government system, on the other hand, may increase national vulnerability and put the country in crisis. Therefore, the relationship between vulnerable countries under climate change is worth studying.

Climate change may not only directly lead to the change of national vulnerability, but also indirectly affect the national vulnerability through economic, war, political and other factors. Solomon M. Hsiang [6] studied the global non-linear effect of temperature on economic production and found that economic productivity would rise with the annual average temperature and peaks at 13 degrees Celsius. When the average annual temperature exceeds 13 degrees Celsius, economic productivity will decline. Marshall B. Burke et al. [7] found that there was a strong historical link between the civil war and the temperature in Africa. Climate warming makes the possibility of war greatly increased, see, for example, Mark A [8]. Cane and the others predicted the future war on the history of the temperature. It is estimated that by 2030, the incidence of armed conflicts in Africa will increase by about 54%, resulting in 393,000 deaths. Climate change will cause turmoil in the country and the stability of the country will face a severe test. The government climate change special committee (IPCC) [9] stressed that the melting of ice will affect the stability of the country. Climate warming will lead to the Arctic ice melting, and then have a global impact. More and more evidence shows that climate change can affect various social factors, which directly and indirectly affects the country's vulnerability. Therefore, it is necessary to establish a reasonable

and effective system to quantify the impact of climate change on national vulnerability.

2. The main indicator system

There are many factors that affect a country's vulnerability [10]. In order to "describe the concepts with as few constitutional elements as possible, determine the conceptual logic, and avoid unnecessary or mixed concepts," we carry out a general analysis of the different indicators of vulnerability and score the selected indicators. The following three steps are mainly taken: systematization of the concept of vulnerability, selection of the index of vulnerability and calculation of the final score.

The initial choice of the third-level indicators: With reference to the country external vulnerability indicator description, considering the need to take climate change into consideration [8], climate and environmental relevance, and the merger of population and human development, the concept of vulnerability can be systematized into five categories of indicators, namely, security and crime, economics, politics, human development and climate [11]. We will select fifteen major third-level indicators, which are specified as follows:

Indicator Name	Indicator Description	Indicator Source	Types
Conflict intensity	Annual sum for INT (intensity) variable	UCDP/PRIO Armed Conflict Dataset	Security and crime（SAC）
Human Rights – Empowerment	Empowerment Rights Index	CIRI Human Rights Index	Security and crime（SAC）
Political Stability	Political stability/no violence, point estimate	World Governance Indicators	Security and crime（SAC）
GDP per capita	GDP per capita (constant 2005 US $)	World Development Indicators	Economic（EN）
Percentage of GDP	GDP Growth %	World Development Indicators	Economic（EN）
Inflation	Inflation, consumer prices (annual %)	World Development Indicators	Economic（EN）
Government Effectiveness	Government effectiveness, point estimate	World Governance Indicators	Politics（PT）
Level of Corruption	（CPI）Corruption Perceptions Index (CPI)	Transparency International	Politics（PT）
Level of Democracy	POLITY2 – Net Democracy/Autocracy score	IV Polity IV	Politics（PT）
Gender Inequality	Gender Inequality Index	HDR UNDP HDR	Human Development（HDP）
Human Development Index	Human Development Index	HDR UNDP HDR	Human Development（HDP）
Population Density	Population density (people per sq. km)	World Development Indicators	Human Development（HDP）
Temperature	Average annual temperature	Climate Change Knowledge Portal	Climate（CA）
Rainfall	The average annual rainfall	Climate Change Knowledge Portal	Climate（CA）
Extreme natural disaster	Annual natural disasters sum	Climate Change Knowledge Portal	Climate（CA）

3. Weight analysis

3.1 De-dimensional data

As the dimensions of the indicators are not unified, firstly we process all the indicators based on dimension 10, the absolute value of each indicator is then transformed into a relative value, finally, the standardized processing for COSTTYPE indicators, efficiency indicators and moderate indicators of data is applied. We introduce the following three indexes:

Benefit-type index

$$X_{ik}(j)=\left[(X_{ik}^{'}(j)-X_{ik}^{'}(j)_{\min}/(X^{'}(j)_{\max}-X^{'}(j)_{\min})\right]\times 10$$

Cost-type index

$$X_{ik}(j)=\left[(X_{ik}^{'}(j)_{\max}-X_{ik}^{'}(j))/(X^{'}(j)_{\max}-X^{'}(j)_{\min})\right]\times 10$$

Moderate-type index

$$X_{ik}(j)=\begin{cases}1-\left(s_1-X_{ik}^{'}(j)\right)\Big/\left[\max\left\{s_1-X^{'}(j)_{\min},X^{'}(j)_{\max}-s_2\right\}\right] & X_{ik}^{'}(j)<s_1\\ 0 & X_{ik}^{'}(j)=s_1\\ 1-\left(X_{ik}^{'}(j)-s_1\right)\Big/\left[\max\left\{s_1-X^{'}(j)_{\min},X^{'}(j)_{\max}-s_1\right\}\right] & X_{ik}^{'}(j)>s_1\end{cases}$$

where subscript i indicates the national ordinal numbers, j indicates the ordinal of the metric, k indicates the number of time series, $X^{'}(j)_{\max}$ indicates item j maximum value of the metric, $X^{'}(j)_{\min}$ indicates item j minimum value of the metric, and $X_{ik}(j)$ indicates in k year the value of the item i j after normalized metric.

3.2 The weight of AHP analysis

In order to streamline and optimize the indicators in a better way, AHP selected 1-9 scales to construct a judgment matrix for the above hierarchy. The weight of each indicator is as follows:

Index	Security and crime	Economic	Political	Human Development	Climate
Weight	0.172	0.243	0.324	0.136	0.125

In order to scientifically and comprehensively assess the national vulnerability and select different vulnerability indicators according to different countries, we consider the correlation between the metrics and the complexity of the data. Applying the standard processing of index data, we can obtain the modified weight of each indicator using the gray relational analysis, and then implement the comparable computation of the vulnerability of different countries.

3.3 Gray correlation assessment weight

Due to the complexity and certain mutual influence of each indicator on the overall evaluation, it is considered to establish a gray relational assessment model to analyze and evaluate the vulnerability of each country. Gray relational assessment is a branch of gray system theory, which is widely used in the comprehensive evaluation of things and phenomena influenced by many interrelated factors. The steps of using gray relational analysis to make a comprehensive evaluation are as follows:

$Step1$: Determining the reference data column as the ideal comparison standard, it is possible to construct the reference data column based on the optimal value (or the worst value) of each metric, or to select other reference values according to the purpose of the evaluation, referred to as

$$X_0=(x_0(1),x_0(2),\cdots,x_0(m)).$$

Choose the worst value as the reference series, that is, $X_0=(10,10,\cdots,10)$.

$Step2$: Calculate the absolute difference between the index of each target object (comparison sequence) and the corresponding element of the reference sequence, that is,

$$\Delta_{ik}(j)=\left|x_i(j)-x_0(j)\right|.$$

$Step3$: Determine $a=\min\limits_{1\le i\le n}\min\limits_{1\le j\le m}\min\limits_{1\le k\le u}\{\Delta_{ik}(j)\}$ and $b=\max\limits_{1\le i\le n}\max\limits_{1\le j\le m}\max\limits_{1\le k\le u}\{\Delta_{ik}(j)\}$.

$Step4$: Calculate the absolute difference between the index sequence (comparison sequence) of each target object and the corresponding element of the reference sequence, that is,

$$y_{ik}(j)=\frac{(a+b\rho)}{(\Delta_i(j)+b\rho)}\quad j=1,2,\cdots,m,$$

where ρ means resolution factor, $\rho\in(0,1)$, the smaller ρ,the greater the difference between the correlation coefficients, and the stronger the ability to distinguish. It usually takes 0.5.

$Step5$: Calculate the degree of association, and the average of each correlation coefficient between each metric and the corresponding element of each evaluation object (comparison sequence) to reflect the relationship between each evaluation object and the reference sequence and call it the degree of association, which is denoted by:

$$r_j = \frac{1}{n \times u} \sum_{i=1}^{n} \sum_{k=1}^{u} y_{ik}(j).$$

$Step6$: Calculate the weight of each metric

$$r_j^{'} = \frac{r_j}{r_1 + r_2 + \cdots + r_m} \quad j = 1, 2, \cdots, m.$$

4. Comprehensive evaluation index

4.1 Determine the second-level indicators

Determining the second level of indicators is the selection of a series of comprehensive and effective five major indicators, namely, safety and crime, economics, politics, human development and climate, and to determine a reasonable weight. These five second-level indicators will be used to assess the five dimensions of country vulnerability.

- **Security and Crime:** National security is the fundamental interest of the country. It is an unsuspecting objective state in which the state has no external threats and aggressions as well as internal chaos. National security, to a certain extent, has made the country more stable.
- **Economics:** The national economy refers to the autonomy of a country's domestic economy in supporting the country's economy. The weak economy and the lack of economic independence will increase the country's vulnerability.
- **Politics:** The political instability and lack of ability of handling, coping and adaptability to the political crisis will make the country politically vulnerable and more politically active, which in turn will increase the country's vulnerability.
- **Human development:** The human development perspective inherently includes the need for sustainable development, comprehensive attention to health, education, equality and the decent life of mankind. The enhancement of human development also contributes to the realization of sustainable development. The improvement of the sustainable development level will help the country's stability.
- **Climate:** The impact of climate change on the country is multi-scale, multi-faceted, and multi-level. Climate change will also lead to the stability of the country and affect its vulnerability.

The final establishment of the index system and weight are shown in the Table 1:

Table 1：the weight of indicators

Second indicators	Weight	Third indicators	Weight
Security and crime(SAC)	0.172	Conflict intensity	0.041
		Human Rights –Empowerment	0.062
		Political Stability	0.069
Economic（ EN ）	0.243	GDP per capita	0.12
		Percentage of GDP	0.06
		Inflation	0.081
Political（ PT ）	0.324	Government Effectiveness	0.133
		Level of Corruption	0.09
		Level of Democracy	0.11
Human development（ HDP ）	0.136	Gender Inequality	0.036
		Human Development Index	0.057
		Population Density	0.043
climate（ CA ）	0.125	Temperature	0.045
		Rainfall	0.044
		Extreme natural disaster	0.036

4.2 Determine the first-level of indicators

Based on the above-mentioned index system to determine the third-level indicators and weight of the second-level indicators, a comprehensive assessment can be established that identifies the country's vulnerability. The country's vulnerability Z_i can be expressed as：

$$Z_i = w_1 \bullet SAC + w_2 \bullet EN + w_3 \bullet PT + w_4 \bullet HDP + w_5 \bullet CA$$

Among them： w_i indicates the weight corresponding to the second level indicator and can be vectored as：

$$w = [0.172 \;\; 0.243 \;\; 0.324 \;\; 0.136 \;\; 0.125]$$

Through the above analysis, the three-level comprehensive evaluation system is finally established. The relationship between the evaluation indicators of these three levels is shown in the Fig.1.

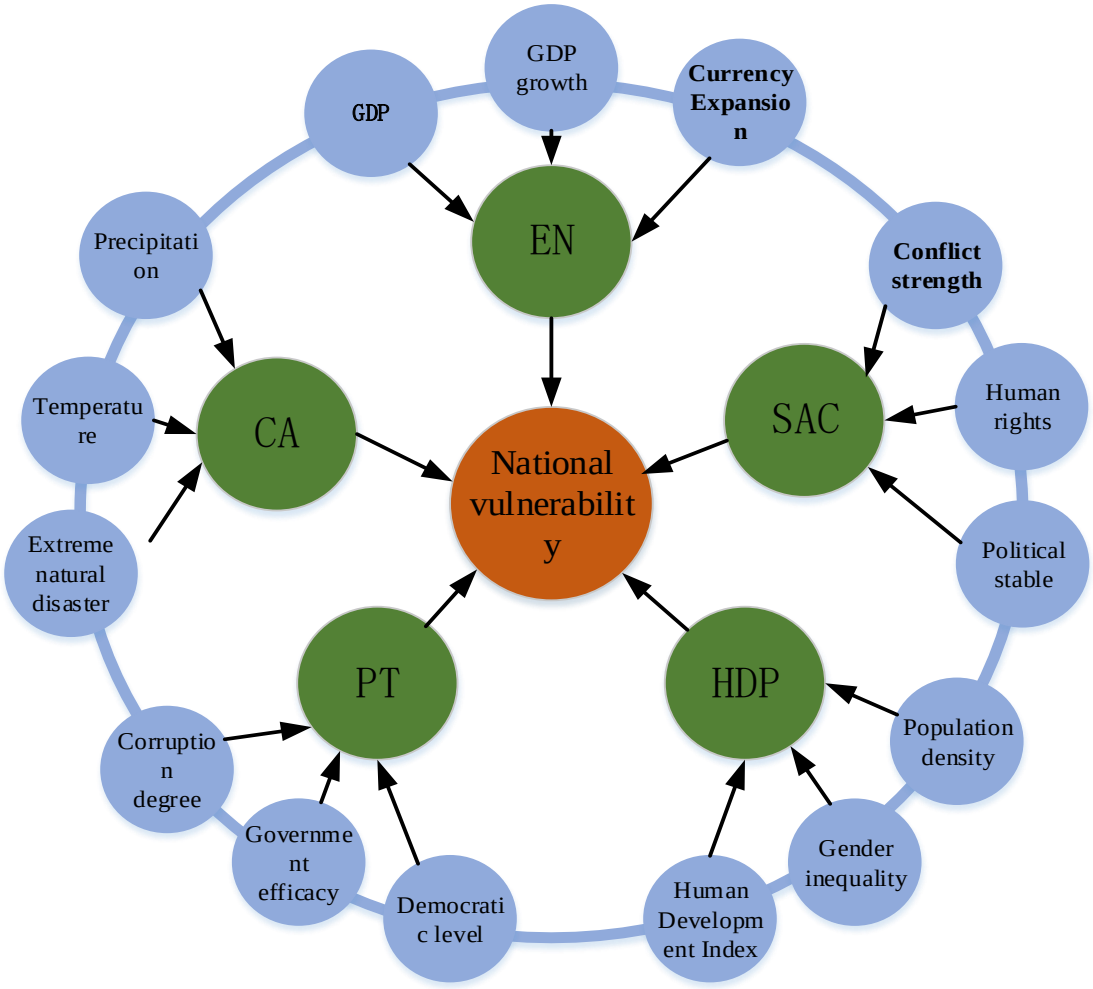

Figure 1: The relationship between the evaluation indicators of these three levels.

5. Conclusion

Through principal component analysis, 20 indicators that affect regional vulnerability were identified. The weights are analyzed by the gray correlation algorithm, and the weights of these indicators affecting regional vulnerability are determined. Among them, safety and crime, economics, politics, human development and climate are the main factors affecting regional vulnerability, especially politics is the most critical, and climate has less impact. By analyzing these factors, the vulnerability of a country or region can be assessed. This has a very important role in predicting regional vulnerability.

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