For office use only	Team Control Number	For office use only
T1 ________________	**77314**	F1 ________________
T2 ________________		F2 ________________
T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**E**	F4 ________________

2018

MCM/ICM

Summary Sheet

Summary

In this paper, we mainly do the following three work. Firstly, look up the relevant data of climate-related data and state's fragile index to quantitatively assess the impact of climate change on state's fragility. secondly, for a specific country, determine which national interventions are effective for reducing climate risk and explain how intervention affects climate risk. Thirdly,discuss the applicability of the model to smaller states and larger states and find out specific improvement directions.

For task 1, we first take a data matrix consisted of climate factors such as *dts*, *frs*, and others of each country from 1901 to 2014 as the basis. Then we take the mean series of climate factors for a quarter of its 114 years as reference climate series.Adopting gray correlation analysis to the annual climate data series and the corresponding reference climate series .Then we get the climate index of a year (sum of every quarter).

Based on the data from the the Peace for Fund, we adopt principal component analysis to improve the original index evaluation method in order to avoid the significant shortcomings

We found that taking three principal components each year the cumulative contribution rate still reaches more than 88%.Utilizing three principal components each year we get the principal component regression equation of a specific country .Substituting the data of indicators in each country in a given year into the equation and then transforming the results to reasonably obtain a state's fragile index for each country in the world . Finally , adopt K-means cluster analysis and clarify countries by fragile,vulnerable and stable. Then, in order to measure the impact of climate change on the state's fragility, we adopt a single linear regression between each year's climate indicators of a specific country and its historical principal component data. The climate will affect the state's fragility by affecting the three main components.The degree of influence on each principal component is measured by the coefficients of three linear regression equations, so the significance of the influence is determined. **For Task 2,** we take Chad into our model to quantify the impact of climate change on the country's vulnerability index and describe the impact of climate change in tabular form. **For Task 3,** we take Gabon into our model to get the state's fragility index of the past years and analyse the impact of climate change on the national fragility. We use the quadratic exponential smoothing method to predict when the fragility may reach its tipping point. **For task 4**, analyzed the climate data of a country over the years with its 12 indicators by gray relational analysis, and obtained 12 correlations, which classified the correlations according to different levels. The higher the correlation value and the higher the grade are, the greater the impact of climate change on this factor. Correspondingly, the nationally formulated intervention policy should be tilted in this direction, and its intervention cost also increases as the rank increases. **For task 5,** due to some of 12 indicators can not be used directly to measure a state, and , the greater vulnerability of states is greatly supported by the state, so the original model can not Used directly in the vulnerability of small states. As for the continents, since the indicators of different countries in the continent have large differences, it is not straightforward to find the average of the indicators and apply the original model to solve them. So, in measuring the continents and cities, we have improved the original model in these directions.

Assessment of the Impact of Climate Change on National Vulnerability

Contents

1 Introduction

1.1 Background

During the past decade,academia used several quantitative fragile indices to evaluate the turbulence of a state and thus produced the Fragile State Index(FSI) published by the United States think tank and Fund for Peace. The index aims to assess states' vulnerability to conflict ,violence or collapse, ranking all sovereign states with membership in the United Nations.It contains twelve different indicators grouped by catagory:social (Demographic pressures, Refugees and internally displaced persons (IDPs),Group grievance,Human flight and brain drain), economic (Uneven economic development,Poverty and economic decline) and political (State legitimacy,Public services,Human rights and rule of law,Security apparatus,Factionalized elites,External intervention).[1]These twelve indicators are related to various factors including infant mortality, ethnic violence environmental hazards and climate change,etc.

Climate shocks such as natural disasters, decreasing arable land, unpredictable weather, and increasing temperatures happen frequently around the world over years.Several cases following suggest that climate change is related to FSI and simultaneously leads to fragile states.

- Somalia has suffered drought for decades due to the La Nina phenomenon.The Norwegian Refugee Council (NRC) said its latest data shows that 438,000 people in Somalia have been displaced since November 2016, by the worst drought the country has experienced in 20 years.Over 3,000 people a day are being forced to abandon their homes in search of water and food.Severe drought render dwellers and refugees thirsty and homeless .
- On March 2nd,2017,officials of Zimbabwe declared that numerous regions suffering the flood in the country caused about 2000 people homeless and 246 deaths.Extreme flood gave great shock to the national economy of Zimbabwe and its governmental structures.

1.2 Restatement of the problem

To illustrate the exact relation between climate change and a country's fragility,we need to do as follows:

Task 1:Develop a model that determines a country's fragility and simultaneously measures the impact of climate change. Identify when a state is fragile, vulnerable, or stable. It should also identify how climate change increases fragility through direct means or indirectly as it influences other factors and indicators.

Task 2:Select one of the top 10 most fragile states as determined by the Fragile State

Index and determine how climate change may have increased fragility of that country. Show in what way(s) the state may be less fragile without these effects.
Task 3:Use the model on another state not in the top 10 list to measure its fragility, and see in what way and when climate change may push it to become more fragile. Identify any definitive indicators. Explain how to define a tipping point and predict when a country may reach it.
Task 4:Use model to show which state driven interventions could mitigate the risk of climate change and prevent a country from becoming a fragile state. Explain the effect of human intervention and predict the total cost of intervention for this country.
Task 5:Clarify and modify our model .

2 Variable Description

$Notations$	$Definitions$
Cld	$Cloud\ Cover$
Frs	$Ground\ Frost\ Frequency$
Pet	$Potential\ Evapotranspiration$
Pre	$precipitation$
Tmn	$Minimum\ Temperature$
Tmp	$Mean\ Temperature$
Tmx	$Maximum\ Temperature$
Vap	$Vapour\ Pressure$
Wet	$Rain\ Days$
$X_0^r(j)$	$Ideal\ Comparison\ Standard\ Value\ of\ Different\ Climate\ Parameters$
r	$Season$
j	$Different\ Climate\ Parameters$
$X_i^r(j)$	$Climate\ Index\ in\ Arbitrary\ Year\ and\ Season$
$\Delta_i^r(j)$	$Absolute\ Difference\ Value$
λ_i	$coefficient$
r_j	$Correlation\ Degree$
r'_j	$the\ Weight\ of\ Each\ Measure\ Stadard$
r_i	$Regression\ Coefficient$
Z_i	$Climate\ Index\ of\ One\ Season$
C	$Climate\ Index\ of\ One\ Year$
Q	$Fragile\ State\ Index\ of\ Our\ Model$
t_i	$Intercept$
C_{chad}	$Climate\ Index\ in\ One\ Year\ of\ Chad$
b_i	$Contribution\ Rate$
LSI	$Linear\ Smoothing\ Analysis$
QSI	$Quadratic\ Smoothing\ Analysis$

3 General Assumption

- The evaluation model of state's fragility indicators only deals with the fragile data from the Peace for Fund during limited period. That is to say, the principal component analysis does not establish an independent evaluation model, although it has some rationality.
- As for the impact of climate change on vulnerability indicators, we use linear regression between the three main components of the national climate indicator and the national vulnerability indicator for that year. However, we only found the data from 2006 to 2017 Of state's fragility index data, the data is too few for linear regression and results in effect greatly reduced.
- Without enough supported data , the total cost of intervention in Task 4 is not quantified, only the level of intervention cost under the same climate is divided.

4 Calculating and Simplifying the Model

4.1 Climate assessment grey relation grade analysis

Because of the complex interaction between these parameters,we simplify the number of parameters and finally choose Grey Relation Grade Analysis to determine the index of climate change(Z_i).

step 1: Determine the ideal comparison standard sequence of climate.In our model,the average value of each parameter respectively constitutes the reference sequence.

$$X_0^r = (X_0^r(1), X_0^r(2), \cdots, X_0^r(9)), r = 1, 2, 3, 4 \tag{4.1}$$

here

$$X_0^r(j) = \frac{1}{114}\sum_{i=1}^{114} X_i^r(j) \tag{4.2}$$

step 2: Calculate the absolute difference value of each parameter and the reference sequence of the corresponding elements

$$\Delta_i^r(j) = |X_i^r(j) - X_0^r(j)| \tag{4.3}$$

In the formula, different i represents different year .j denotes to different parameter of climate.And r refers to different season in a year.

step 3: Confirm

$$a = \underset{1\le i\le 114}{min}\ \underset{1\le i\le 9}{min}\{\Delta_i^r(j)\}, b = \underset{1\le i\le 114}{max}\ \underset{1\le i\le 9}{max}\{\Delta_i^r(j)\} \tag{4.4}$$

step 4: Calculate the correlation coefficient as:

$$f_i(j) = \frac{a + b\lambda}{\Delta_i^r(j) + b\lambda} \tag{4.5}$$

where resolution coefficient $\lambda \in (0, 1)$,commonly using 0.5.
step 5: Calculate the correlation degree.

$$r_j = \frac{1}{n}\sum_{i=1}^{n} f_i(j) \tag{4.6}$$

step 6: Calculate the weight of each measure standard.

$$r'_j = \frac{r_j}{r_1 + r_2 + \cdots + r_m} \tag{4.7}$$

step 7: Build the evaluation model.

$$Z_i^r = \sum_{j=1}^{9} r'_j |X_i^r(j) - X_0^r(j)| \tag{4.8}$$

Based on the data we have calculated above,we can solve the model and obtain the following results(Figure 1). On the other hand,we can add up all Z_i and then get Climate

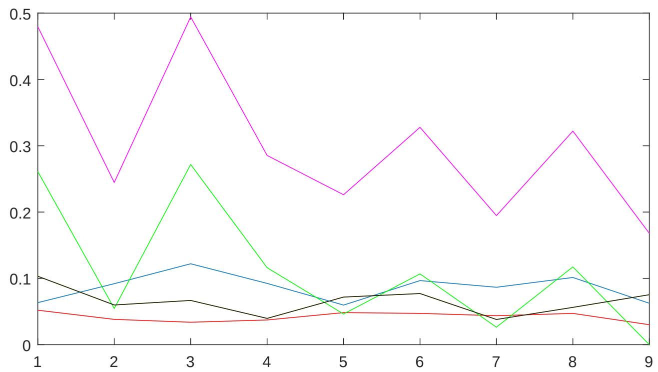

Figure 1: Results of Grey Relation Grade Analysis

Index of One Year(C).In our model,we define Q as the Fragile State Index.Then,

$$Q = \sum_{i=1}^{3} b_i y_i = \sum_{i=1}^{3} b_i(r_i C + t_i)$$
$$\text{here} \quad b_i = \frac{\lambda_i}{\sum \lambda_i} \tag{4.9}$$

4.2 Optimized model of fragile state index

The main methodology used in fragile states research is quantitative approach, as a result, series evaluation criteria are initiated to measure the fragility in the developing countries and thus Fragile State Indices are created.Researchers classify these parameters in three dimensions but there still exist overlap among them.The twelve indicators are not independent to each other completely.[2] Due to the complexity and implicit relevance between these twelve indicators,we determined to adopt Principal Component Analysis to filter factors and obtain other variables as succinct as possible.Take 2017 for example,we collected data of all sovereign states with membership in the United Nations and made Principal Component Analysis.After data processing we obtain the following two sheets.

Eigenvalue	Contributionrate	Total Contribution rate
9.2696	0.7725	0.7725
0.9797	0.0816	0.8541
0.4039	0.0337	0.8878
0.39	0.0325	0.9203
0.2565	0.0214	0.9416
0.1978	0.0165	0.9581
0.1346	0.0112	0.9693
0.1102	0.0092	0.9785
0.1007	0.0084	0.9869
0.0669	0.0056	0.9925
0.0529	0.0044	0.9969
0.0373	0.0031	1

Table 1: DS

0.3044	0.2264	-0.0541
0.2959	0.4833	0.212
0.2745	-0.3568	-0.2671
0.291	-0.1477	0.3553
0.2666	-0.4083	-0.2707
0.3002	0.1900	-0.3291
0.3002	-0.271	0.3093
0.2902	0.3145	-0.0885
0.2972	-0.2355	0.3914
0.2899	0.0806	0.3445
0.2921	-0.1875	-0.3717

Table 2: PV 2017

Finally,we obtain three principle components.Thus,they can be expressed as:

$$F_i = a_{1i}Z_{X1} + a_{1i}Z_{X1} + \cdots + a_{pi}Z_{Xp}$$

substitute a_{pi} with processed data(Table 2),we have

$$\begin{aligned} F_1 &= 0.3044Z_{X1} + 0.2959Z_{X2} + \cdots + 0.2921Z_{X12} \\ F_2 &= 0.2264Z_{X1} + 0.4833Z_{X2} + \cdots + (-0.1875)Z_{X12} \\ F_3 &= (-0.0541)Z_{X1} + 0.212Z_{X2} + \cdots + (-0.3717)Z_{X12} \end{aligned} \tag{4.10}$$

Then we use the data of climate change(Z_i) and three principle components to simulate the regression equation.Through the scatter diagram and a series matching steps,we got two almost parallel straight lines (Figure 2). Conclusion comes out that different in-

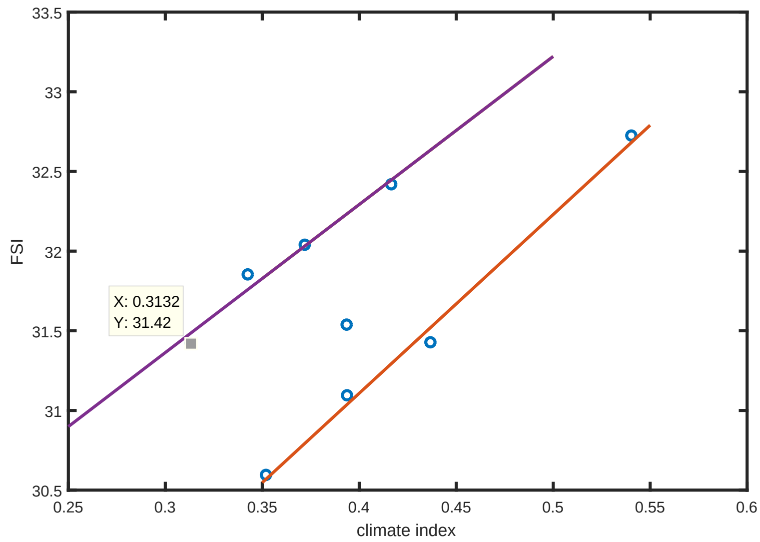

Figure 2: Two simulated straight line

tercepts result from other factors excluding climate change. Then we did some numerical analysis of micro-variation,the result can be seen in the following table.

$climate\ index$	-3%	-1%	0	-1%	-3%
FSI	-0.9398%	-0.3132%	0	0.3132%	0.9398%

According to distribution of the data,we got the regression equation:

$$y = 0.6922x + 5.5413$$

4.2.1 Relation between climate change and state's fragility

Regression equation tells us:

a'_{1i}	a'_{2i}	a'_{3i}	a'_{4i}	a'_{5i}	a'_{6i}
0.2518	0.2454	0.2458	0.1739	0.2247	0.1635
a'_{7i}	a'_{8i}	a'_{9i}	a'_{10i}	a'_{11i}	a'_{12i}
0.2363	0.2202	0.2469	0.2236	0.2421	0.1978

- Climate change truly has relation with state's fragility.Climate index(Z_i) can fit three principle components in some degree.Experience tells us the result satisfies our logical knowledge.
- Larger Z_i means more fragile for a certain state.When Z_i turns into a larger one,climate changes more frequently compared to the usual. Meanwhile,state becomes more fragile than usual time.
- Climate change holds about 30% among all other factors.It has significant influence compared to other factors.

4.2.2 Regression coefficient r_i

When simulating the the regression equation,each state has its individual coefficient r_i.It represents the relativity between climate change and state's fragility.Different countries and in different year have different values.But once the state and the year are determined,$r_i$only depends on the principle component we chose.Meanwhile,relativity between climate change and state's fragility grows as r_i grows.

4.3 Cluster Analysis of Q

Q has the significant instruction of assessing a state's fragility but it lacks of classification reasonably.In order to identify different extent of a state's fragility,we determined to do K-means cluster analysis to Q.The initial cluster center concentrate on $8, 5, 3$.Then we calculated out three final cluster centers,which are $2.9117, 5.8869, 8.1369$ .The cluster center determines the boundary of a cluster.It means Q can be divided into three parts independently.

4.3.1 Identification of a state's fragility

According to the work done above,we can conclude that a state's fragility can be divided into three categories.Group standard shows in Table 3.

Steadiness	fragile	vulnerable	stable
Initial clusterc enter	8	5	3
Final cluster center	>7.0509	[7.059,4.5995]	<4.5995
Boundary condition(rank)	0∼52	53∼117	118-

Table 3: results of K-means cluster analysis

5 Taking Chad for Example

5.1 How climate change may have increased fragility of Chad

Chad is one of the top 10 most fragile states as determined by the Fragile State Index.Chad got 109.4 points FSI in 2017 and ranked 8th compared to other countries.To analyse the relation between climate change and fragility of Chad,we can use our model to have a detailed analysis.
step 1: Find out $C_{chad} = (C(1), C(2), \cdots, C(9))$.
step 2: Do principal component analysis to state's fragility data from all the countries in UN during $2006 - 2014$.We obtained three principle components:

$$\begin{aligned} F_1 &= a_{11}Z_{X1} + a_{21}Z_{X2} + \cdots + a_{91}Z_{X9} \\ F_2 &= a_{12}Z_{X1} + a_{22}Z_{X2} + \cdots + a_{92}Z_{X9} \\ F_3 &= a_{13}Z_{X1} + a_{23}Z_{X2} + \cdots + a_{93}Z_{X9} \end{aligned} \tag{5.1}$$

step 3: Through linear regression between climate index C and F_1, F_2, F_3,we have

	r_i	t_i
1	11.2144	26.6221
2	2.3226	0.1104
3	7.1336	-2.0338

Table 4: Data analysis

step 4: According to fragile state index of our model,we have

$$Q = \sum_{i=1}^{3} b_i y_i = \sum b_i(r_i C + t_i) \tag{5.2}$$

step 5: Conspicuousness analysis

$climate\ index$	-3%	-1%	0	-1%	-3%
FSI	-0.9398%	-0.3132%	0	0.3132%	0.9398%

Finally,we concluded that climate change probably influence the fragility of Chad.As C grows up,Q grows up simultaneously. Judging from our model,the value Q is better than FSI to evaluate the fragility of a country.Larger Q means more fragile.

5.2 In what ways the state may be less fragile

In our model,the Regression Coefficient r_i is a significant index to assess the relativity between C and Q.The larger r_i is,the more relation they would have.As for Chad,in a certain year r_i is fixed.Then Q will have some internal relation with C.According to Table

4,r_1 is much greater than r_2 and r_3.We can conclude that climate change hold the vast majority of influence to the fragility of Chad through the first component.

6 Taking Gabon for Example

6.1 Using our model to evaluate Gabon's fragility

Gabon got 73.8 points ranking 91^{st} in 2017 FSI.We determined to use our model to analysis its fragility and do some prediction.Through Principle Component Analysis,we have the following table(Table 5):

Filtering extreme data ,our analysis shows Q of Gabon various between 4.7699 and

	Q_{Gabon}	1st component	b_1	2nd component	b_2	3rd component	b_3
2006	6.1764	21.34322	0.7707	-1.02407	0.054	-1.0056	0.0402
2007	4.7699	21.2038	0.7645	-0.78292	0.0602	0.07872	0.0384
2008	5.9186	21.69736	0.7768	0.92889	0.059	-0.56649	0.0346
2009	5.8824	21.55069	0.7906	1.30292	0.0603	-0.63719	0.0321
2010	5.7805	21.80901	0.7925	1.39472	0.0632	-1.01073	0.0314
2011	5.6277	21.82383	0.7874	-0.86814	0.069	1.00265	0.0317
2012	3.9446	21.63726	0.7765	-0.89943	0.0707	-1.50159	0.0341
2013	4.8747	21.18028	0.7752	-0.88247	0.0769	-0.71984	0.0328
2014	5.256	20.94937	0.7725	-0.58744	0.0816	0.06317	0.0337

Table 5: Principle Component Analysis of Gabon

6.1764.Ultilizing table 3,since

$$4.5995 \leq Q_{Gabon} \leq 7.059 \tag{6.1}$$

we can conclude that Gabon is a vulnerable state relatively.

6.2 Climate change may push Gabon to become more fragile

Although the fragility indicators of various countries over the years have changed slightly, such changes have not caused obvious changes in the distribution of vulnerability indicators in more than 170 countries. Therefore, we still use the cluster boundary condition in task one as the tipping point for Gabon.Using our model to analysis the data of Gabon,we have:

$$C_{Gabon} = (C(1), C(2), \cdots, C(9)) \tag{6.2}$$

substitute variables with calculated data,

$$C_{chad} = (0.029325, 0.03885, 0.022275, 0.0327, 0.0272, 0.032725, 0.045675, 0.029275, 0.03595) \tag{6.3}$$

Linear regression analysis result shows in Table 6. The result tells us:

	r_i	t_i
1	69.7507	18.462
2	5.9048	-1.0492
3	105.0956	-3.9245

Table 6: Linear regression analysis result

- r_1 and r_3 is much greater than r_2.It means climate change influences a state's fragility mainly in the first principle component and the third principle component.
- The value of C is extremely small indicates that cluster boundary changes slightly and thus we can define the tipping point under the boundary condition.

6.3 Tipping point and prediction

In order to predict the future condition of Gabon,we adopted time series quadratic smoothing analysis to predict its future tendency.The result shows in the following table.

Table 7 tells us :In 2021, Gabon's fragility index will reach the tipping point, which means that Gabon will change from a vulnerable state to an fragile state according to table 3.

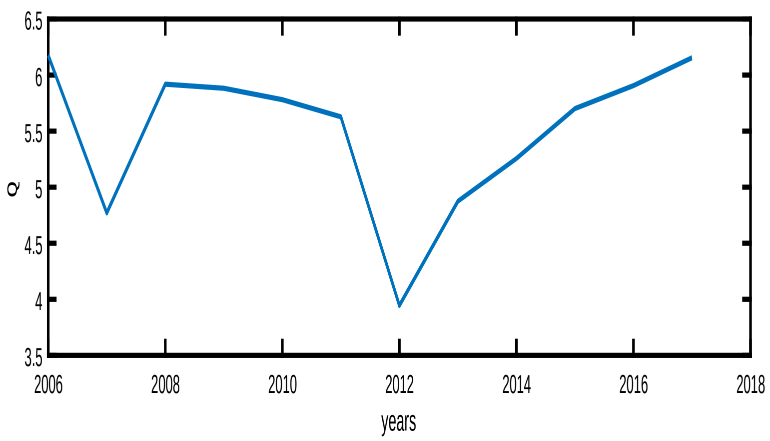

Figure 3: The tendency of Q of Gabon

	practical Q	linear prediction	practical Q	lSI	QSI	predicted Q
2006	6.1764	6.1764	6.1764	6.1764	0	
2007	4.7699	21.6174	4.7699	5.3325	3.1995	21.6174
2008	5.9186	10.665	5.9186	5.68416	4.69029	10.665
2009	5.8824	8.16882	5.8824	5.80310	5.35798	8.16882
2010	5.7805	6.91591	5.7805	5.78954	5.61691	6.915912
2011	5.6277	6.22110	5.6277	5.69243	5.66222	6.22110
2012	3.9446	5.76795	3.9446	4.64373	5.05113	5.76795
2013	4.8747	3.62524	4.8747	4.78231	4.88984	3.62524
2014	5.256	4.51349	5.256	5.06652	4.99585	4.51349
2015	5.7011	5.24320	5.7011	5.44727	5.26670	5.24320
2016	5.906	5.89868	5.906	5.72250	5.54018	5.89868
2017	6.1544	6.17831	6.1544	5.98164	5.80506	6.17831
2018		6.42310	6.42310	6.24651	6.06993	6.42310
2019		6.68797	6.68797	6.51139	6.33480	6.68797
2020						6.95284
2021						7.21772

Table 7: Q prediction of Gabon

7 The State-driven Intervention Theory

7.1 The state-driven intervention

In order to establish an effective state-driven intervention theory to mitigate climate risks (where we consider climate risk as a measure of the possibility that changes in climate will increase national vulnerability), giving countries policy guidance when the climate deteriorate sharply , we take the data of a country's historical fragility indicators and its calendar year's climate indicators into account.

- First,according to our model,utilize a country's climate data to find its climate index in n years.

$$C(x) = (C(1), C(2), \cdots, C(9)) \tag{7.1}$$

- Then adopt gray relational analysis to the 12 indicators (population pressure, refugee and IDPs, group dissatisfaction, labor force and brain drain, economic development imbalances, poverty and economic decline, Legitimacy, public services, human rights and the rule of law, security agencies, the socialization of the elite, and external interference) and $C(x)$, obtaining the coefficient $r_1, r_2, \cdots, r_{12}$.This index represents the shock degree of extreme climate change to twelve indicators.

- Finally, observe the characteristics of the tables analysed and give attention to the factors that have a high correlation with some indicators.They are strongly influenced by climate change and will have catastrophic consequences in those areas once the climate is abruptly worsened ,and then have a crucial impact on the fragility of the whole country. Therefore, the national illnesses determined by the factors that have a high degree of correlation with climate indicators need to be improved. This is also the direction for the state to formulate an intervention policy. However, what kind of intervention policy should be improved,yet making which kind of policies on which areas is obviously not unified in conclusion.
  We still take Gabon for example, applying the above state-driven intervention theory.

In task 3 we have the climate index of Gabon in past nine years. The gray relational

	2006	2007	2008	2009	2010	2011	2012	2013	2014
$C(x)$	0.0293	0.0388	0.0222	0.0327	0.0272	0.0327	0.0456	0.0292	0.0359

analysis of the 12 indicators of the country is given below: The top three factors that

r1	r2	r3	r4	r5	r6
0.4512	0.2723	0.4401	0.4114	0.6997	0.257
r7	r8	r9	r10	r11	r12
0.2877	0.7108	0.3049	0.2953	0.8122	0.2858

Table 8: Gray relational analysis of the 12 indicators

rank the r values âĂŃâĂŃare the situation of refugees and internally displaced persons, the imbalance of public services and economic development. Therefore, the Gabon government should vigorously develop the economic conditions in impoverished areas, improve domestic public service facilities and improve domestic refugees' living condition to reduce the climate risk.

7.2 The cost of intervention

In order to measure the intervention cost of a country in response to climate risks, referring to the relevant data we think it is reasonable to use the correlation degree r_k as the basis for the sub-assessment under the premise of consistency of climate. Still taking Gabon as the example, the Refugees and IDPs intervention cost is 1, the cost of intervention is extremely high. The cost of intervention of Economic Inequality and Public Services is 2 and the cost of intervention is pretty much. However, Factionalized Elites, Human Flight and Brain Drain factors such as intervention cost of 4, intervention costs are small. The above analysis results are consistent with our common sense, further illustrating the rationality of the state-driven intervention theory we have established.

rank	r_k	characteristic description
1	0.8∼1.0	influenced extremely by climate change,cost greatly much
2	0.5∼0.8	influenced greatly by climate change,cost much
3	0.3∼0.5	influenced slightly by climate change,cost few
4	0∼0.3	hardly influenced by climate change,nearly cost nothing

8 Limitation of Our model

The model to identify national fragility and measure the impact of climate change on national fragility **can not** be used in smaller states. Our model of identifying national fragility is determined by three principal components, and the three principle components result from twelve indicators given by the Peace for Fund.Legitimacy of States, public services, human rights,the rule of law, the security agencies,factionalized elites and external interference are not obvious to a state.They are determined by the overall national conditions of a country, simultaneously the state government can not intervene.Therefore, it is inevitable to measure the state's fragility with our model. In addition, the flow of population, labor force, etc. between the various states in the country are very frequent. If the population is over-stressed, it will naturally migrate to other states. Therefore, it is inappropriate for these factors to directly measure the state's fragility. Moreover, for a relatively more fragile state in a country, the national government will inevitably introduce corresponding policies to give priority to support it so as to effectively reduce its fragility. Therefore, macro-control in a country is an important factor to be considered in a state's fragility analysis .So the original model can not be used directly in smaller states. As for the analysis of the fragility of the smaller states, the factors that should be considered are the unemployment rate of the state, the unbalanced economic development, the decline of the economic status, the dissatisfaction of the group,etc. Adopting principal component analysis of the above factors to obtain the principal component and the initial fragility, and then add the relevant state regulation on the fragility to obtain the final fragility.

On the other hand, these models **can not** be used on a continent. For a continent, these 12 factors are difficult to measure. Factors such as national legitimacy, human rights and the rule of law, mass discontent and population pressure are different for each country and it is impossible to get these factors from a continent. Averaging the various factors and then using the original model from the twelve values can lead to very large errors of fragility. For example, if one country has a very small population and the other country has a large population, its actual fragility is very large, while the fragility calculated by average factor will not be large. Therefore, the improvement for calculating the fragility of a continent is not to directly calculate the fragile index of a continent, but to calculate the fragility indicators of each country of a continent by using our model, and then take the proportion of each country in the continent. The weighted average of the fragile index in each country is the fragile index of the continent. The impact of climate change on the vulnerability of the continent should also look at its impact on the countries it corresponds to. And then seek its impact on the overall fragility of the continent as climate change may affect limited countries and does not affect all of the states. Therefore,instead of analyzing the whole continent directly, focus on the impact on the state's fragility is better.

9 Strengths and weaknesses

9.1 Strengths

- Using gray correlation analysis in the description of climate indicators and state-driven state intervention question skillfully solve the problem of quantitative assessment of climate. Establish the indirect relationship between climate change and state's intervention.
- In the description of climate indicators, we consider the influence of nine climate factors such as dtr and frs. The evaluation is comprehensive and accurate.
- Explore the practical significance of multiple parallel linear intercepts obtained by regression analysis. (That is, on the issue of state's fragility, the impact of climate is still small, while the impact of other factors is revealed in the intercepts of parallel lines)

9.2 Weaknesses

- The evaluation model of state's fragility indicators only deals with the fragile data from the Peace for Fund during limited period. That is to say, the principal component analysis does not establish an independent evaluation model, although it has some rationality.
- As for the impact of climate change on vulnerability indicators, we use linear regression between the three main components of the national climate indicator and the national vulnerability indicator for that year. However, we only found the data from 2006 to 2017 of state's fragility index data, the data is too few for linear regression and results in effect greatly reduced.
- Without enough supported data , the total cost of intervention in Task 4 is not quantified, only the level of intervention cost under the same climate is divided.

10 Future work

Due to the time limitation, our model needs to be further optimized and improved.

- In the future, we must look for more climate data such as temperature, rainfall and extreme weather, simultaneously consider more reasonable ways to quantify climate change so that climate change can be quantified more scientifically and accurately. Make the gray correlation analysis get a more accurate correlation.Measure the impact of climate change on the national vulnerability index, and make the stateâĂŹs fragility result predicted by the time series more corresponding to the future reality.

- We can learn more about the existing mature climate assessment standards and compare our climate change indicators with the corresponding indicators of other assessment criteria to guide us in constantly updating the assessment criteria.

- Look for the appropriate data (unemployment, economic decline, etc.) needed to evaluate the fragility of small states and continents and climate change indicators, and train and refine the model to measure vulnerability on the small and large continents.

- Find out the actual data of national human intervention to mitigate the impact of climate change, quantify the total cost of state intervention, and use the characteristics of the model to find ways to reduce the total cost of intervention.

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Appendices

Laos				
season	1st	2nd	3rd	4th
cld	60.19912281	84.4	63.78333333	46.43185841
frs	0	0	0	0.065486726
pet	3.707017544	2.964912281	2.807017544	72.727668572
pre	316.1578947	875.8912281	521.0017544	90.31196648
tmn	19.01140351	21.92631579	18.89561404	13.47852612
tmp	24.2254386	25.44473684	23.03684211	19.04727073
tmx	29.49210526	29.01140351	27.22631579	24.66423369
vap	22.63157895	26.56140351	22.74736842	16.2651578
wet	36.59385965	71.60087719	38.36754386	17.16857232

Eritrea				
season	1st	2nd	3rd	4th
cld	27.35087719	48.05964912	26.04035088	24.85975409
frs	0	0	0.000877193	0.125890829
pet	5.316666667	5.020175439	4.510526316	3.890179341
pre	40.42631579	266.9017544	53.79736842	21.51041585
tmn	19.56842105	21.52192982	19.15701754	15.81785574
tmp	26.40964912	27.54649123	25.59298246	22.76072519
tmx	33.30350877	33.62368421	32.08333333	29.75894745
vap	19.6754386	22.25877193	20.96578947	17.34285379
wet	8.539473684	18.1122807	8.739473684	3.930362597

Gabon				
season	1st	2nd	3rd	4th
cld	84.34912281	93.27017544	91.41929825	84.116078
frs	0	0	0	0
pet	27.2754386	23.84561404	25.93333333	26.84013627
pre	608.2157895	75.98684211	671.3359649	466.5237842
tmn	21.62894737	19.91491228	21.08245614	21.57765683
tmp	26.14298246	23.66140351	25.10263158	25.72229619
tmx	30.70526316	27.42105263	29.17894737	29.93836636
vap	27.2754386	23.84561404	25.93333333	26.84013627
wet	43.44824561	11.14035088	49.41754386	35.38297439

Greece				
season	1st	2nd	3rd	4th
cld	50.73771930	21.11228000	41.15964912	61.34289294
frs	7.621052632	0.001754386	2.951754386	25.24398935
pet	2.802631579	5.106140351	2.192982456	1.001793406
pre	138.0535088	45.17543860	186.3736842	289.6704675
tmn	8.710526316	18.02631579	12.10175439	4.044764664
tmp	13.69561404	23.86140351	16.90175439	7.696554155
tmx	18.72631579	29.74385965	21.75526316	11.40101809
vap	10.62105263	16.58245614	13.31929825	7.957201034
wet	24.41754386	12.07368421	20.69385965	33.43965855

New Zealand				
season	1st	2nd	3rd	4th
cld	60.5122807	63.34210526	65.66754386	65.12768424
frs	14.12631579	38.80087719	18.20087719	3.764319837
pet	1.592105263	0.79122807	2.289473684	3.238382019
pre	146.9210526	211.8973684	215.0885965	184.6073224
tmn	6.575438596	1.887719298	5.329824561	9.535680163
tmp	11.03245614	5.821929825	9.950877193	14.60798026
tmx	15.54824561	9.802631579	14.61491228	19.73295481
vap	10.72105263	7.789473684	9.533333333	12.48122014
wet	39.10964912	44.61403509	43.20526316	35.54829666

Poland				
season	1st	2nd	3rd	4th
cld	63.24385965	58.01491228	67.46140351	78.72044796
frs	31.52719298	0.035087719	22.27807018	70.97472003
pet	2.166666667	3.430701754	1.138596491	0.383052706
pre	127.4114035	228.6394737	137.9675439	103.6849009
tmn	3.168421053	12.14736842	4.769298246	-4.174030856
tmp	7.781578947	17.28070175	8.454385965	-1.42669747
tmx	12.44210526	22.47192982	12.17017544	1.32242149
vap	7.959649123	14.68333333	9.470175439	4.905348892
wet	38.97807018	40.63421053	41.74035088	48.85687211

Nepal				
season	1st	2nd	3rd	4th
cld	45.1754386	72.99561404	48.86754386	41.68396116
frs	42.31491228	20.61929825	39.34912281	61.49183178
pet	3.457894737	3.240350877	2.185087719	1.441968831
pre	187.0324561	825.5640351	252.845614	69.16717832
tmn	1.664035088	9.948245614	2.597368421	-7.038350693
tmp	8.839473684	14.93070175	8.964035088	0.569684392
tmx	16.0377193	19.95701754	15.36578947	8.18040567
vap	5.965789474	12.69385965	8.610526316	4.331858407
wet	15.82105263	51.29824561	18.29298246	8.432743363

Dominican Republic				
season	1st	2nd	3rd	4th
cld	56.06842105	59.13421053	61.8754386	48.91068212
frs	0	0	0	0
pet	4.098245614	4.264035088	3.236842105	3.329461978
pre	361.7710526	388.6324561	444.4166667	262.4375597
tmn	19.25	21	20.57192982	17.76873678
tmp	23.9877193	25.59736842	25.06842105	22.58212076
tmx	28.77894737	30.25263158	29.61754386	27.4374814
vap	22.44210526	24.95	25.30175439	20.56693555
wet	30.75350877	40.72631579	43.81842105	33.10949957

Chad				
season	1st	2nd	3rd	4th
cld	25.74736842	36.61754386	21.41315789	13.93931396
frs	0.054385965	0	0.088596491	1.85446002
pet	6.784210526	6.021052632	5.412280702	4.954867257
pre	29.62807018	232.2429825	66.52631579	1.870538022
tmn	20.63157895	22.82368421	18.9622807	12.77699115
tmp	29.10614035	29.52631579	26.61842105	21.73481087
tmx	37.63596491	36.2745614	34.3254386	30.7374814
vap	11.34561404	19.24385965	14.74385965	7.374101339
wet	5.125438596	26.98947368	7.574561404	0.204463936

China				
season	1st	2nd	3rd	4th
cld	58.52807018	63.31403509	48.47894737	45.43893805
frs	42	10.98508772	41.02807018	72.44690265
pet	2.934210526	3.900877193	2.050877193	0.978761062
pre	141.7333333	317.3114035	121.0403509	41.93982301
tmn	1.304385965	13.12807018	1.706140351	-12.10088496
tmp	7.660526316	18.83684211	7.751754386	-5.916814159
tmx	14.03508772	24.59035088	13.8254386	0.247787611
vap	6.740350877	14.68596491	7.872807018	3.120353982
wet	25.37719298	40.17280702	24.23157895	14.82654867