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2018
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Summary Sheet

In the past two decades, regional instability caused by some fragile state(s) has become more and more concerned by the whole world. Among the various factors, climate changes usually lead to high frequency of extreme weather events, which significantly exacerbate the fragility of a certain state. How to mitigate the impact of climate changes and prevent a state from becoming a fragile one has been widely recognized as a very important and urgent issue.

As a response, in order to predict a state's fragility accurately, we develop a novel model called **PSA** (Pressure Sensitivity Adaptability), which is significantly extended from the well-known **PSR** (Pressure State Response) model. Specifically, our model contains three dimensions whose weights are obtained by combining **AHP** (Analytic Hierarchy Process) and **EWM** (Entropy Weight Method). Notice that **FI** (Fragile Index) is a weighted sum of the three dimensions denoting the fragility of a certain state. In our empirical studies, we verify the effectiveness of our model via the ground truth of the public fragile state index. Meanwhile, we use a **regression analysis** method to get functional relationship between non-climatic indicators and climatic indicators. We choose DRC (Democratic Republic of the Congo) and BD (Bangladesh) in our case studies. Specifically, we use the values of the indicators of a decade as the input data fed to our model, and obtain the FI curve. For DRC, the FI curve without the effect of climate changes is modeled by keep the values of the corresponding climate indicators constant. For BD, we use **GM (1,1)** to draw the prediction curve of FI and find that the time that BD is likely to become a stable state is around 2076.

Furthermore, we study six major intervention policies of BD for climate changes. We find that natural disasters in BD are serious and suggest investing more fiscal expenditure in intervention2 (intervention2: Comprehensive Disaster Management). It is estimated that this expenditure will increase by 35% every 5 years. We can then get other policies' fiscal expenditures through GM (1, 1), and finally get the total expenditure in 5 years, 10 years and even 20 years.

We select Asia, Europe and Africa so as to study the portability of our proposed model. For continents, the fragile indexes of several representative countries are selected and averaged in order to estimate the continent fragile index. The results are very promising, which clearly showcases the effectiveness of our model on continents.

Finally, we conduct a sensitivity analysis in order to gain some deep understanding of our model, and conclude the report via discussing the strengths and weaknesses of our proposed model.

Keywords: Fragile State, Climate Change, PSA, GM (1,1)

Contents

1 Introduction

1.1 Background

In the past 20 years, there have been local wars and conflicts in the world and the fragile states have been a threat to the world security. Therefore, fragile states become a major issue for the world's development. OECD (Organization for Economic Co-operation and Development) defines "States are fragile when state structures lack political will and/or capacity to provide the basic functions needed for poverty reduction, development and to safeguard the security and human rights of their populations."[1] Many universities and research institutes start to research centers to specialize in problems of fragile states. To measure fragility of a state, many evaluation indexes have been put forward, such as World Bank's Country Policy and Institutional Assessment (CPIA) [2], Carton University's Country Indicators for Foreign Policy Fragility Index (CIFP)[3]and The Fund for Peace's Fragile States Index (FSI)[4]. Nowadays, due to the rapid development of industries and the rapid increase of population, large amount of energy consumption and greenhouse gases emission like carbon dioxide cause global warming, then the frequent extreme weather and even the more extreme phenomena like a colder winter and a hotter summer. The climate change leads to more frequent and more serious drought, flood, storm, coldness and hotness, and leads to decline of water, food and energy[5], and then even leads to the wide spread of famine and diseases. If the government is unable to solve the problem of famine and diseases for people, there will be local violent conflicts. If the foreign government interferes in internal affairs, there will be wars and regional instability. Without effective measures to solve these problems, there will be disasters which bring threats to the world's peace and development. Hence, reducing the fragility of a state has its unprecedented significance in today's world.

1.2 Restatement of Problems

To create a more stable world, fragile state should be studied first and the following tasks are to be accomplished:

- An evaluation index system to evaluate a state's fragility and measure the influences of climate change on fragility is needed. By considering various factors like economy, society, politics and local climate, the model should clearly extinguish the state is fragile, vulnerable or stable. Meanwhile the model can identify how climate change increases fragility through direct means or indirectly as it influences other indicators. (Refer to Task1)

- The influence of climate change on state should be evaluated, which help find out some definitive indicators. (Refer to Task2 and Task 3)

- The risks of current national policies about reducing climate change, the effect of protecting the state from being fragile as well as the total cost should be evaluated. (Refer to Task4)

- Adjust the model and make it adaptable to cities and continents.(Refer to Task5)

1.3 Our Work

First we build our basic model PSA(Pressure Sensitivity Adaptability) based on PSR Model. Then we utilize its FI(Fragility Index)to measure a state's fragility. Afterwards, we compare the result with the FSI's ranking and discover that our model is rational. Moreover, we show the relations between indexes through regression analysis.

We choose Democratic Republic of the Congo in our case study, and analyze how climate change influences its fragility in details. By adjusting the model appropriately, we simulate the state without fragility. Next we analyze Bangladesh through several aspects: fragility, influences of climate change on fragility and related indicators. According to range in task 1, we define a tipping point 0.6 and forecast the time taken for Bangladesh's fragility to reach that point using GM (1, 1).

In task 4, we continue to discuss about Bangladesh further. We collect Bangladesh policies about climate change and fiscal expenditure data in recent years. Through analysis of the data and events about climate change, we can show the influences of these human interventions on this state's fragility. Finally, the fiscal expenditure in 5 years will be estimated based on the current one.

Then we expend the PSA and analyze other regions. After respective analysis on cities and continents, we find that our model is portable.

Finally we do sensitivity analysis on related parameters of our model, and discuss strengths and weaknesses.

2 Assumptions and Symbol Table

2.1 Assumptions

- **We assume the countries we studied are regular.**
  Almost every country' development conforms to certain regular patterns, which is based on facts.

- **We assume the countries we studied are stable.**
  Though countries' political stabilities are different, we focus more on climate change. Thus, this assumption is reasonable and helps avoid unnecessary troubles when building the model.

- **We assume that indicators except those we have studied have few influences on the system.**
  In the model, we consider several crucial indicators. However, there are large numbers of indicators. Thus, we assume that other indicators except those mentioned above are uninfluential.

- **We assume that the statistics we captured from websites are precise and reliable.**

The statistics we collected are from different websites which are authoritative. Therefore, this assumption is reasonable.

2.2 Symbol Table

Symbol that we use in the model are shown in the following table :

Table 1: Symbol table

Symbol	Description
FI	Fragile Index
P	Pressure
S	Sensitivity
A	Adaptability
DRC	Democratic Republic of the Congo
BD	Bangladesh
x_i	The i-th indicator

Note:P_i means the i-th indicator, e.g.temperature anomalies is the first indicator. Hence, it can be denoted as x_1.

3 Model PSA

According to previous work, we are going to build our model base on the PSR model.

3.1 PSR

Currently the PSR model (Pressure State Response) are frequently applied among research on fragility. In PSR, '***P***' represents the pressure dimension, which indicates the pressure that are brought to the system. Here, we suppose that climate change and human activites are the 'pressure'. Moreover, '***S***' represents the state dimension, which shows the states that are influenced by the pressure. '***R***' represents the Response dimension, which reflects the response of the system.

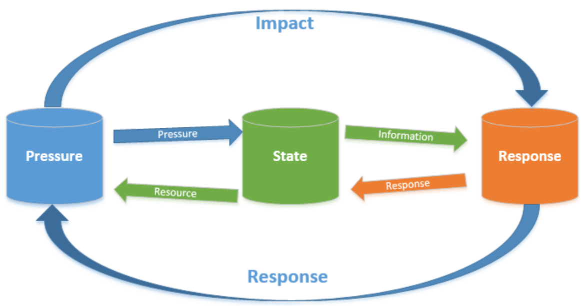

Figure 1: PSR Model

3.2 PSA

We will do the following steps to build our PSA model.

3.2.1 Identify indicators

After carefully analyzing the relevant information, we determine the indicators shown in the figure below:

Target Layer	Dimension Layer	Theme Layer	Indicator Layer	
Fragility Index	Pressure	Nature	temperature anomalies	*
			average elevation	+
			natural disaster risk index	-
		Human	population density	-
			CO_2 emission	-
			energy consumption per capita	-
	Sensitivity	Nature	forest cover rate	+
			crop production index	+
			percentage of people using basic drinking water services	+
		Social	health index	+
			GDP unit energy consumption	-
	Adaptability	Economic	GDP per capita	+
		Social	Gini coefficient	-
			public service	+
		Political	democracy index	+
			human right	+

Figure 2: Indicators

In line with the characteristics of PSR, we first divide fragility into three aspects: ***Pressure, Sensitivity, Adaptation***. Then as for Pressure, we assume that there are pressure from the climate and the one from human activities. As for Sensitivity, we determine indicators according to Xu's work[16]. Finally, we choose indicators for Adaptation referring to Fragile State Index(FSI).

- **Pressure**
  - **Temperature departure value**: it reflects the difference between the temperature this year and the usual average temperature.
  - **Average altitude**: the higher the average altitude is, the less influences by rise of sea level.
  - **Natural disaster risk index**: it is to measure the degree of being endangered of a state confronted earthquake, rainstorm, flood, drought and other natural disasters. (Refer to Wikipedia's natural disaster risk index: as a result of vulnerability and natural hazards such as earthquakes, volcanic eruptions, storms, floods, droughts and sea level)
  - **Population density**: the higher the population density, the heavier the burden to different kinds of national resources like water, food and energy, and to national public infrastructures.
  - CO_2 **emissions**: it reflects the pollution. The larger it is, the more serious the pollution and the more powerful the pressure to environment.

  - **Energy consumption per capita**: it indirectly reflects the abundance of a state's energy.

- **Sensitivity**
  - **Forest cover rate**: the larger the forest cover rate is, the less sensitive to climate change.
  - **Crop production index**: the more the food production and store, and people will not starve, and in some way avoid unrests, the less sensitive to deal with foreign interference and domestic conflicts.
  - **Percentage of people using basic drinking water services**: many conflicts in the world result from water shortage.
  - **Health index**: the healthier the people are, the less the diseases are, the less sensitive to influences of climate change.
  - **GDP unit energy consumption**: it reflects the economic efficiency of a state. The higher the efficiency is, the more prosperous the economy is.

- **Adaptability**
  - **GDP per capita**: economy can reflect the degree of prosperity of a state economy. The more prosperous the economy is, the better the infrastructure is, the stronger the ability to deal with climate change is.
  - **Gini coefficient**: Gini coefficient reflects the status of a state's gap between the rich and the poor. The larger the gap is, the greater the conflicts, the weaker the ability to adapt to the external threats.
  - **Public service**: it means public financing and community service, and the basic guarantee to public health. The better the public welfare is, the better the adaptability is.
  - **Democracy index**: being undemocratic will leads to social unrest and regional instability.
  - **Human right**: Guarantee the human right and make humans' basic right guaranteed to make people happier and society more stable.

3.2.2 Data Pre-processing

We searched some websites like WorldBank,The Economist and Fragile State Index and find 16 indicators of 20 countries firstly. Some statistics of indicators are missing for not all statistics can be searched on Internet. We utilize **SPSS's multiple imputation to fill the missing values** to ensure smooth data processing and analysis.

3.2.3 Data Normalization

While analyzing all the indicators, we find that they can be divided into three types. Symbol '+' means that for the indicator, bigger is better. Similarly, symbol '-' means smaller is better and symbol '*' means that the value is better when it is closer to the specific value.

Therefore, for those bigger is better, the equation should be

$$r_i = \frac{r_i - r_{min}}{r_{max} - r_{min}} \tag{1}$$

As for the smaller is better, the equation should be

$$r_i = \frac{r_{max} - r_i}{r_{max} - r_{min}} \tag{2}$$

As for the special type, such as the temperature anomalies here, we define the equation as follow:

$$r_{ta} = 1 - \frac{|ta|}{|ta|_{max}} \tag{3}$$

where $|ta|$ means the original absolute value of temperature anomalies, and $|ta|_{max}$ means the maximum absolute value.

3.2.4 Calculate weight by AHP

To calculate weights of indicators of PSA, we intend to use ***AHP***. Firstly, we define the expressions as follow:

$$FI = \omega_1 P + \omega_2 S + \omega_3 A \tag{4}$$

$$P = \sum_{i=1}^{n} \alpha_i P_i \tag{5}$$

where n means the number of indicators and P_i represents the indicators of Pressure.

Similarly, we have

$$S = \sum_{i=1}^{n} \beta_i S_i \tag{6}$$

$$A = \sum_{i=1}^{n} \gamma_i A_i \tag{7}$$

where S_i and A_i represents indicators of Sensitivity and Adaptability respectively.

Afterwards, we construct the score matrices and calculate the weight of each indicator.

3.2.5 Calculate weight by EWM

As we all know, AHP has some subjectivity due to the score matrices. Hence, we calculate the weights using ***Entropy Weight Method(EWM)***[15]

Firstly, we calculate the proportion of the j^{th} indicator of the i^{th} country.

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \tag{8}$$

where r_{ij} means the value of the corresponding indicator, and m represents the number of the countries.

Then we get the entropy value of the j^{th} indicator:

$$E_j = -k \sum_{i=1}^{m} (p_{ij} * ln\, p_{ij}) \tag{9}$$

where $k = ln\, m$
Finally, we get the weight of the j^{th} indicator:

$$q_j = \frac{1 - E_j}{\sum_{j=1}^{n}(1 - E_j)}, \quad \sum_{j=1}^{n} q_j = 1, \quad q_j \in [0, 1] \tag{10}$$

3.2.6 Weighted average

Since we want to reduce the subjectivity of AHP, which can be supplemented by EWM, we get the final weight by calculating the weighted average of the results calculated above.

We define the equation as follows,

$$W_i = \theta_1 W_{ai} + \theta_2 W_{ei} \tag{11}$$

where W_{ai} represents the weight of the i^{th} indicator calculated by AHP and W_{ei} represents the one calculated be EWM. Here we suppose $\boldsymbol{\theta_1 = 0.8}$ and $\boldsymbol{\theta_2 = 0.2}$

Finally we get the weights of all the indicators.

3.3 Analyze direct and indirect impacts of climate change

In task 1, we are required to identify how climate change increases fragility directly and indirectly.

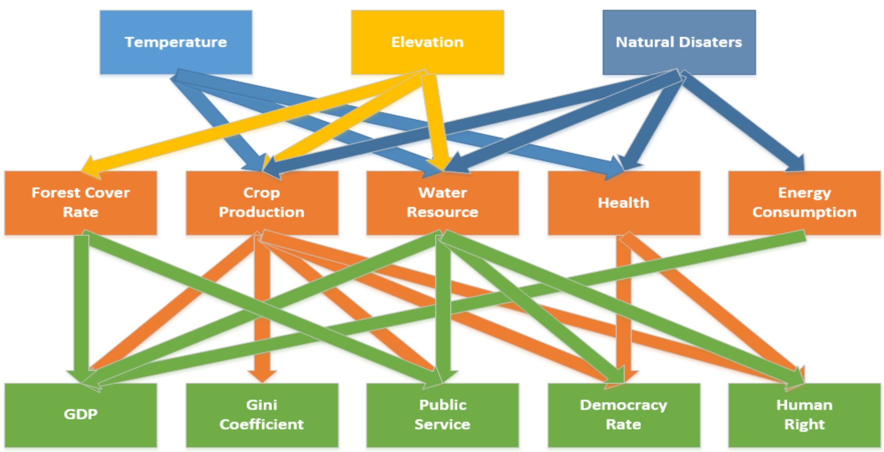

Figure 3: Relationship between indicators

Through regression analysis, we can give a more specific relationship among the indicators.Some examples are listed in Table 2:

Climate Indicators	**Relationship**
Temperature t	$Water = -1.099 \times t + 42.15$
	$Crop\ Production = -3.551 \times t + 114$
Elevation e	$Human\ Right = 30.25 \times e - 17.29$
	$Democracy\ Rate = -20.12 \times e + 19.97$

Table 2: Examples of Relationship

- **Through direct means**
  - **Temperature anomalies**: the characteristic of significant climate change is influences of temperature. Temperature of current year is different from usual like the rise or drop of temperature. The most direct influence index is to increase the absolute value of temperature anomalies, which directly makes a state more fragile.
  - **Average elevation**: the global warming causes the sea level rise. For some low-lying countries, they will be confronted with being submerged, which directly makes a state more fragile.
  - **Natural disaster risk index**: climate change is likely to bring hot weather and then the hurricane, rainstorm, flood, drought and other natural disasters.
- **Through indirect means**
  - **Forest cover rate**: climate change probably causes rainstorm and mountain torrents which erode soil and destroy the forests and villages, and probably causes drought which makes trees wither. Therefore, it indirectly causes the decrease of forest cover rate.
  - **Crop production index**: climate change is likely to cause more intense rainfall, longer dry periods or increased temperature. More intense rainfall will result in crop stopping growing due to water shortage and decline of production. The increased temperature will result in reduction of output for some crops' inadaptability, insects calamity or some viral pathogens which will infect crops and livestock and then cause death in batches. What's worse, there will be no harvest at all. The increased temperature will also influence the output of fishery. The increased temperature helps phycophyta grow up rapidly, then dissolved oxygen declines, and the nutrition necessary for fish upwells, which is bad for survival of fish. Finally the output of fish declines.
  - **Percentage of people using basic drinking water service**: increased temperature will lead to more evaporation of the open shallow groundwater

sources. Flood and rainstorm will cause death of livestock, breeding of bacteria, water infection of virus, then water pollution, degradation of water quality, and reduction of clear drinking water.

– **Health Index**:

1. Climate change influences the supply of food nutrition. Some research reports show that, global warming and increasing concentration of carbon dioxide will cause the decrease of protein synthetized by crops. Higher carbon dioxide concentrations will drain the protein contents of barely(14.6 percent), rice(7.6 percent), wheat(7.8 percent), and potatoes(6.4 percent).[6] other key nutrition like zinc and iron are threated for the same reasons. This is more serious than the influence on human health of lack of protein.

2. Climate change will make diseases spread more easily and as a result, people are easier to get sick. Climate change induces some new infectious diseases, such as HIV, SARS and Ebola disease.[7]Rainstorm and flood create a humid and warm environment which is suitable for breeding for mosquitoes pathogens, which causes the wide spread of infectious diseases. Through touching or drink the polluted water, people will suffer from water-borne diseases like diarrhea and so on, which greatly undermines human health.

– **GDP per capita**: for tropical countries, increased temperature will reduce workers' productivity. In contrary, for northern countries in cold areas, increased temperature probably increase productivity and then the average GDP.

– **Human right**: the negative influences of climate change result in high frequency of extreme weather and natural disasters, which directly or indirectly brings threats to human's basic rights including water drinking and hygiene, food, health, housing, culture and development , and influences fragility.

3.4 Test PSA

After building the basic model PSA, we are going to test it. By analyzing the ranking of **FSI**, we select 20 countries from different level. We compare the FI calculated by PSA and the ranking of FSI, and then analyze the result.

Furthermore, we set up thresholds according to the relevant report.

$$Status = \begin{cases} Stable & if \quad FI \geq 0.6 \\ Vulnerable & if \quad 0.4 \leq FI < 0.6 \\ Fragile & if \quad 0 \leq FI < 0.4 \end{cases} \tag{12}$$

We can see the results on the figure below, which makes comparison easily.

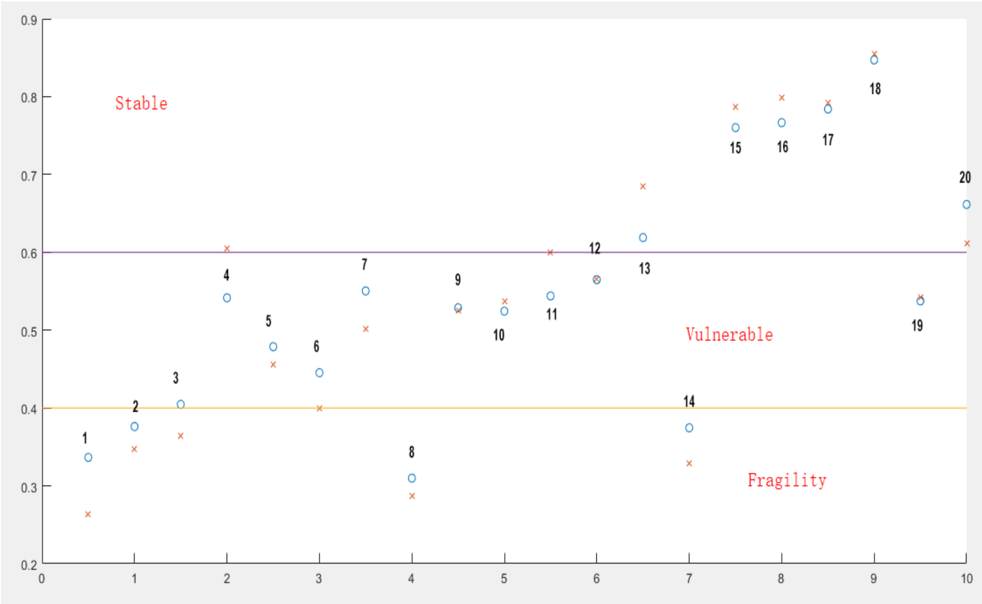

Figure 4: Fragility Index:Blue circles represent the results of PSA, and red crosses represent the results of FSI

The corresponding contries are listed in the Appendix A.
From Figure 4, we can clearly see that the result is relatively consistent with the trend of the ranking. For this reason, we believe that PSA is **resonable**.

For task 1, we are required to identify when a state is fragile,vulnerable, or stable. In PSA we can identify a state by Equation 12. For example, when the FI of a state satisfy the inequality $\boldsymbol{FI \geq 0.6}$, we can draw a conclusion that the state is **stable**.

Table 3: Classification of 20 states

PSA	Country Code
Fragile	DRC,EG,BD,HT,KE
Vulnerable	JM,TR,PH,IN,CN,ZA,MY,BR,MX
Stable	AR,US,UK,FR,NZ,GR
FSI	Country Code
Fragile	DRC,EG,BD,PH,HT,KE
Vulnerable	JM,TR,IN,CN,ZA,BR,NZ,MY,BR
Stable	AR,US,UK,FR,MX

From Table 3,Our model's classification results are mostly consistent with FSI, which proves that our model is valid.

4 Case Study

4.1 Study 1: Democratic Republic Of the Congo

We choose the Democratic Republic Of the Congo as our research object. The reason is that this country is top10 in Fragile State Index, with distinct climate change, clear dry and rainy seasons. Climate change has great influences on this state's fragility.

4.1.1 Climate change effects of Congo

We collect ten years data of Congo and draw the curve as follow:

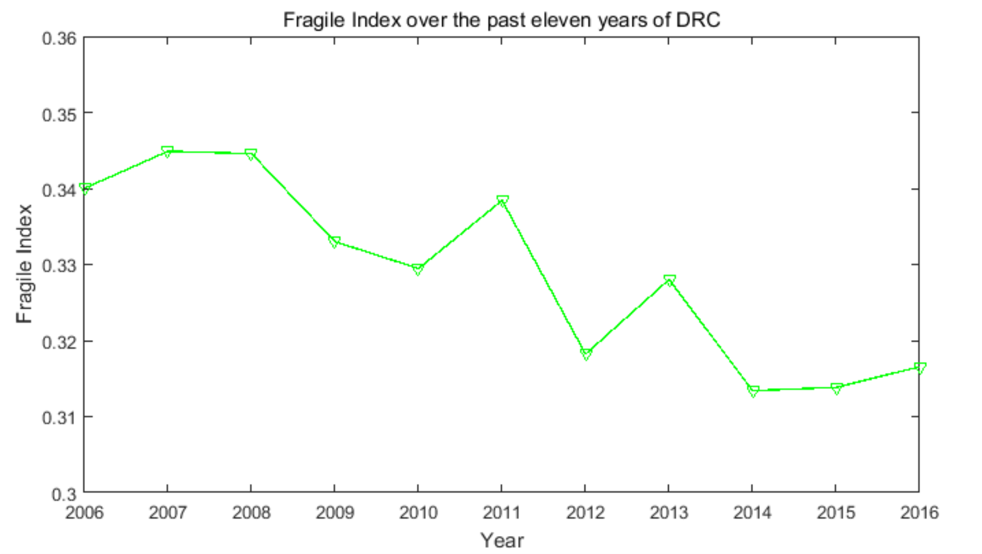

Figure 5: FI of Congo

The reason for the decrease of its fragile index during 2009 to 2010 is the cholera at the end of 2008, which causes 1million people at risk for water-borne diseases.[9] The reason for occurrence of cholera is that the heavy rainstorm created an environment of high temperature and high humidity, and water was polluted by stools.

Then the Bacillus comma bred rapidly and people drank the polluted water without any sanitization. At last, cholera broke out and further caught local riots and wars and the state became more fragile. In 2012, Congo suffered the severe drought in 60 years.[10] In some regions, not only rivers, grass dried up but also some basic food like cassava and vegetables were in shortage.[11] **It destroyed public service and human right and hence the state became more fragile.**

4.1.2 The FI without climate change effects

According to Task 2, we are required to analyze the situation without considering climate change.

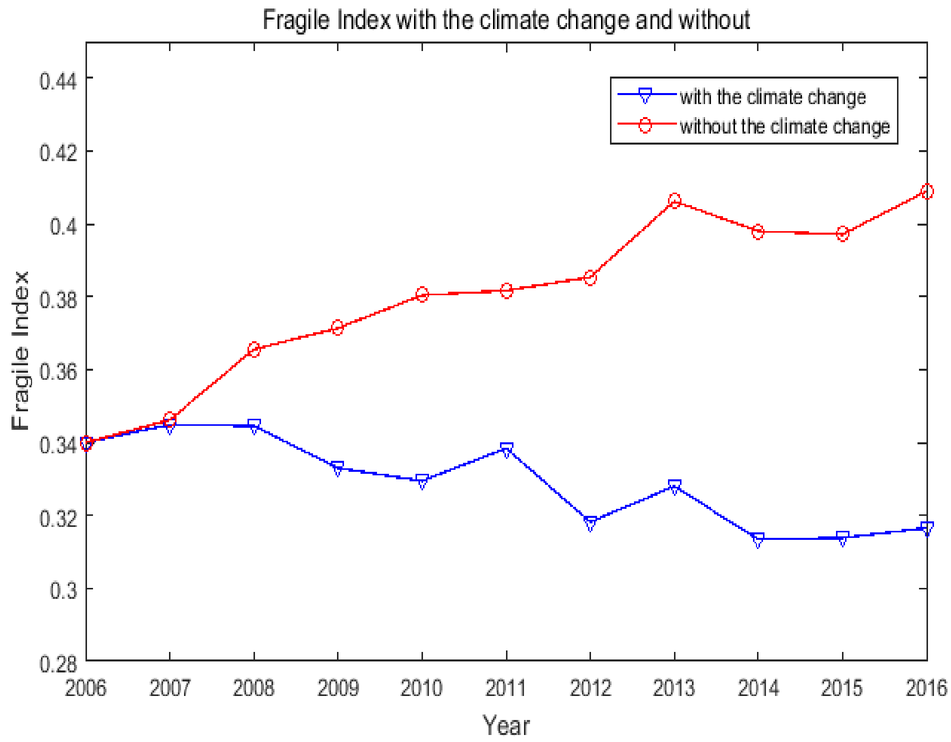

Figure 6: Comparison of Congo's FI with and without climate change's effect

According to Task 2, we are required to analyze DRC's situation without considering climate change. Details are as followed:

In the Figure 6, the red curve represents the FI curve without effects of climate change and is denoted as FI-1; the blue curve represents the FI curve with effects of climate change and is denoted as FI-2.

We adjust the climate indicator value (temperature anomalies and average elevation) to be **consistent** to that in 2006, then calculate the values of other non-climatic indicators without effects of climate change through regression equation, and finally gain the FI-1 curve through PSR model. The FI-1 curve shows a slow uptrend, which suggest that DRC will be less fragile without effects of climate change. However, without considering the heavy rainstorm during 2008 to 2010, fragile index still rises slowly and even stagnates. It is possible that DRC is affected by other factors like earthquake and refugees.

4.2 Study 2: People's Republic of Bangladesh

4.2.1 Climate change effects of Bangladesh

As for Task 3, we select Bangladesh as our study state. Reasons are as followed: BD is a fragile state. Occasional climate change in some years makes it more fragile. Nonetheless, with political stability and government's interventions to deal with threats of climate change, BD is gradually becoming stable for development.

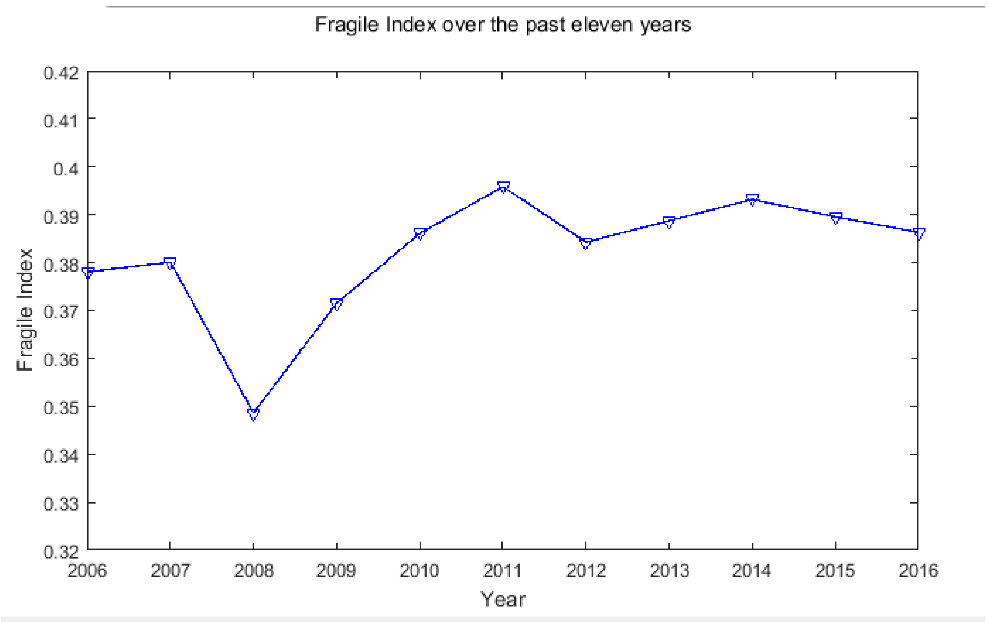

Figure 7: FI of Bangladesh

As the chart above shows, the general trend of BD is upward. It is mainly the privatization policy that BD's government actively promotes that helps infrastructure construction, investment environment's improvement and economic development. However, the sharp decline of fragile index in 2008 is mainly caused by the Cyclone Sidr in November, 2007, which attacked the southeast coast of BD and badly affected about 1 million families' life. It was estimated 3406 deaths, 1001 missing and over 55,000 injuries.[12]

Gale and flood destroyed housing and infrastructure including roads and bridges. Tide water made water polluted by salt sea water and sanitary fixture was destroyed, which directly gave rise to the soar of natural disaster risk index and sharp decline of public service. In the following years the government took active measures of disaster recovery and reconstruction. It is not until 2010 that the country recovered from the hit of Cyclone Sidr in 2007.

In June, 2012, rainstorm gave rise to flood and landslide, caught deaths and destruction, and seriously influenced ten regions in norther and southeastern BD.[13]In December, a cold wave once in 40 years hit the northern BD. Hospital reports in affected areas showed larger numbers of people suffered from the relative diseases. The weather also caught loss of crops and other natural resources. [14]Climate change in these regions makes BD more fragile.

As the BD fragile index curve show, there is obvious decline from 2007 to 2009 and from 2011 to 2012. According to the original statistics, the increases of temperature anomalies and natural disaster risk index suggest that both of them (**temperature anomalies and natural disaster risk index**) are key identify definitive indicators that influence BD's fragility.

4.2.2 Prediction

We referred to FSI's ranking and define the three c: stable, vulnerable, fragile, when validating our model in Section 3. BD is in the interval of Frafile.

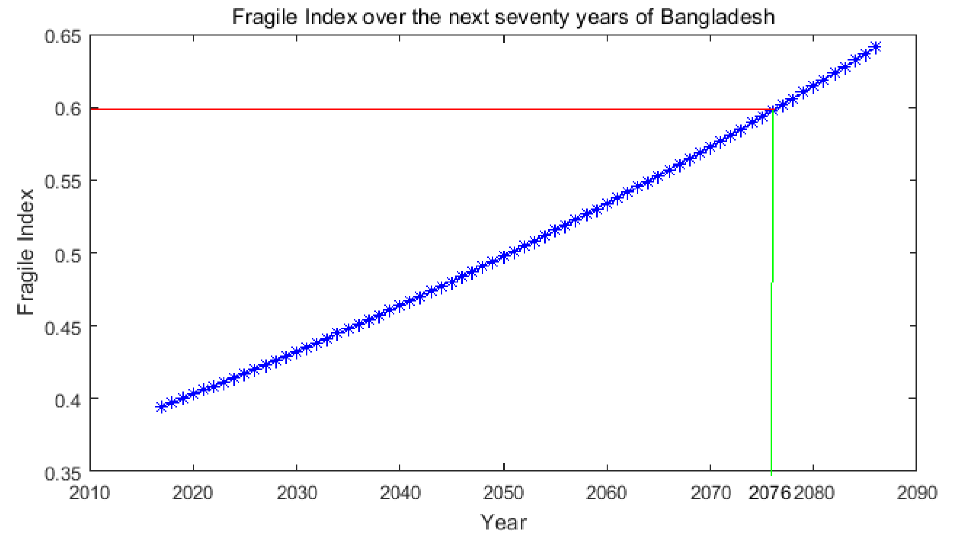

Figure 8: Prediction of Bangladesh

According to definition of intervals of fragility in Task 1, BD's FI is 0.38, meaning it is fragile. Based on the trend of BD's FI in recent years, we predict its FI predict curve in 80 years through Gray Prediction Model (GM(1,1),Gray Prediction Model). As Figure 8 shows, BD will be stable in **60** years, namely **2076**.

4.2.3 Effect of Human Intervention

We continue to take Bangladesh as our research target. According to the report of the Bangladesh government on climate security and development over the past few years[], they have made some countermeasures against climate change and can be broadly classified into six categories:

- Intervention1:Food Security Social Protection and Health
- Intervention2:Comprehensive Disaster Management
- Intervention3:Climate Resilient Infrastructure
- Intervention4:Research and Knowledge Management
- Intervention5:Mitigation and Low Carbon Development
- Intervention6:Capacity Building and Institutional Strengthening

We analyzed the impact of these interventions on our model, as shown in the following table:

Intervention	Impact indicators
Intervention1	health index,Gini coefficient
Intervention2	natural disaster risk index crop production index, percentage of people using basic drinking water services forest cover rate
Intervention3	public service,Gini coefficient
Intervention4	GDP per capita,Gini coefficient
Intervention5	CO_2 emission
Intervention6	population density,democracy index,human right

4.2.4 Total cost

To predict the total cost of intervention in climate change, first of all we look up the budget allocation for expenditure and total coast of six interventions from 2014 to 2017.

From 2014 to 2017, with budgets of other intervention except Intervention2 Comprehensive Disaster Management increasing relatively steadily, budgets in Intervention2 Comprehensive Disaster Management decreases, which results in the decline of fragility index and better fragility.

Therefore, we set up constraint conditions when predicting total cost of BD government's interventions:

- Over the next few years, BD government's total cost of interventions in climate change will only increase at the growth rate of those in recent years rather than increasing unlimitedly
- Except Intervention2 Comprehensive Disaster Management, other budgets for expenditure will be predicted according to status quo through Gray Prediction Model
- The fiscal expenditure of Intervention2: Comprehensive Disaster Management will increase by 35% every five years

Total expenditure and budget allocations for expenditure estimated in 5 years, 10 years and 20 years are as followed:

program	Current	in 5 years	in 10 years	in 20years
Intervention1	1735.9	2076.4	2487.5	3570
Intervention2	3467.2	4680.72	6318.972	8530.6122
Intervention3	2474.39	2890.4	3378.4	4615.2
Intervention4	365.87	522.7	786.9	1783.2
Intervention5	169.92	185.95	205.58	251.3
Intervention6	6420.84	8230	10443	16813
Total	14633.61	18586.17	23620.352	35563.3122

5 Further Exploration

According to Task 5, we are required to extend our model to a wider range. First of all, we use PSA to analyze the fragility of the continents. We choose Asia, Europe and Africa. Since continent is made up of countries, we are going to take an average of statistics of all the counties. Here, we select several typical countries of every continent and do the analysis.

Results calculated by PSA are shown in the table below:

Continents	Europe	Asia	Africa
FI	0.8176	0.3218	0.2849

Table 4: FI of different continents

Frome Table 4, we can clearly see that Europe get the highest score and Africa get the lowest one. By analyzing the FSI map, we can see that our result is reasonable. Almost all the European countries are stable while most of those in Africa are fragile. As a result, we can draw a conclusion that **our model works well on continents.**

Next, we apply our model to analyze the cities. We find that several indicators, such as CO_2 emission and crop production index, are hard to be obtained for a specific city. Therefore, we need to modify PSA to make it work on cities.

The solution is to replace those indicators that are not suitable for the cities with the similar ones.

For example,it is difficult to evaluate the forest cover rate of many cities, we can use greenland rate instead. Besides, crop production index may be another barrier, we can replace it with the local food safety index.

6 Sensitivity Analysis

While we combine the results of AHP and EWM to get the final weight of each indicator, we set $\theta_1 = 0.8$ and $\theta_2 = 0.2$. Here, we will analyze the sensitivity of θ_1 and θ_2.

We set $\theta_1 = 0.2, 0.3, 0.5, 0.7, 0.8$ respectively and get the results as follows:

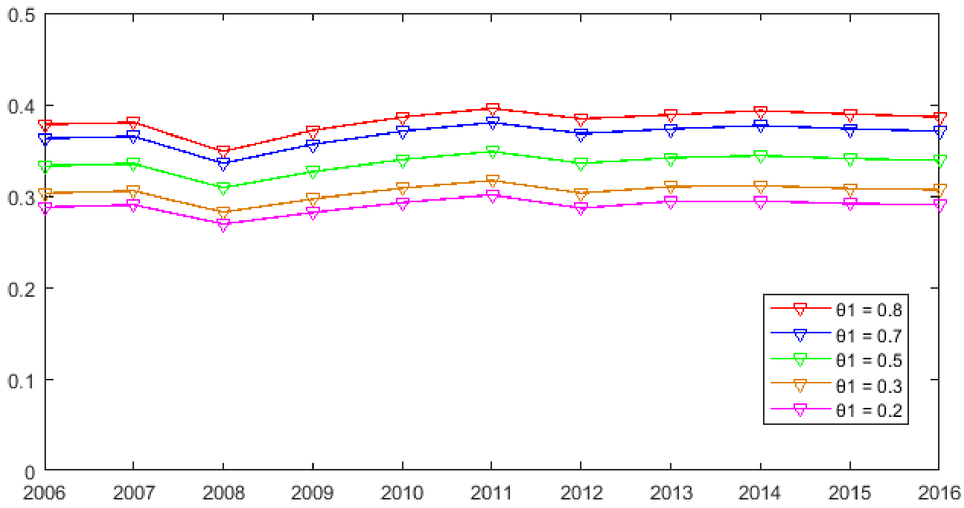

Figure 9: Analysis of θ_1

Figure 9 indicates that when the value of θ_1 is changing, the trend does not change a lot, which means that PSA is stable.

7 Strengths and Weaknesses

7.1 Strengths

- **Our model inherits the advantages of AHP (AHP, Analytic Hierarchy Process) and EWM (EWM, Entropy Weight Method).**

  When weighing the indicators, we utilize weight average method combining the AHP (AHP, Analytic Hierarchy Process) with (EWM, Entropy Weight Mothed). To some extent, this method not only provides a supplement of indicators' horizontal comparison with EWM, but also covers the shortages that indicator weight under EWM vary with samples and is even overwhelmingly dependent on samples. Moreover, this method reduces subjectivity of AHP.

- **Our model is effective through validation.**

  Fragile State Index's result serves as a benchmark to verify our model. We find the results of our model are close to the truth no matter the classification of state fragility or state ranking, which shows that our model is rational.

- **The model we build has good adapability.**

  Experienced studies show that, our model can be adapted to larger states (continents) for effective analysis on fragility.

7.2 Weaknesses

- In our model, due to time constraints, we just choose the average fragile index of some states to represent the continent's fragile index during calculation of continent index. Thus, there will be some deviation.
- In our model, regional instability and violent conflicts are excluded. We don't take riots and wars into consideration. Therefore, our model is not reliable when facing states with large-scale wars.

8 Conclusions

By building up an indicator system, we select a leading indicator FI to measure a region's fragility. Our PSA model is reasonable after validation. We analyze Congo and Bangladesh respectively combining climate change. According to our model, we estimate a state's fiscal expenditure on climate change interference. Afterwards, we expend the application of PSA model to analyze cities and continents our model is testified to be extensible.Finally, by sensitivity analysis, we can see that our model is stable.

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Appendices

Appendix A FI of Country

No.	Country	FI	FSI Ranking
1	Congo, Dem. Rep.	0.3366	7
2	Egypt	0.3762	36
3	Bangladesh	0.4047	39
4	Jamaica	0.5416	117
5	Turkey	0.4788	64
6	Philippines	0.4454	54
7	India	0.5504	72
8	Haiti	0.3099	11
9	China	0.5288	85
10	South Africa	0.5244	96
11	Malaysia	0.544	116
12	Brazil	0.5649	110
13	Argentina	0.619	140
14	Kenya	0.3746	22
15	United States	0.7602	158
16	United Kingdom	0.7666	160
17	France	0.7842	159
18	New Zealand	0.8472	170
19	Mexico	0.5376	88
20	Greece	0.6615	127

Country Code	DRC	EG	BD	JM	TR	PH	IN	HT	CN	ZA
PSA	0.337	0.376	0.396	0.542	0.479	0.445	0.550	0.310	0.529	0.524
Rank	19	17	16	10	14	15	8	20	12	13
FSI	0.1839	0.348	0.365	0.594	0.456	0.399	0.501	0.207	0.525	0.537
Rank	20	17	16	7	14	15	13	19	12	11
Country Code	MY	BR	AR	KE	US	UK	FR	NZ	MX	GR
PSA	0.544	0.565	0.619	0.375	0.760	0.767	0.784	0.847	0.538	0.662
Rank	9	7	6	18	4	3	2	1	11	5
FSI	0.590	0.566	0.685	0.269	0.787	0.798	0.793	0.855	0.542	0.612
Rank	8	9	5	18	4	2	3	1	10	6

Appendix B Climate expenditure of Bangladesh

Table 2.6: Climate Expenditure by Thematic Areas

(Crore taka/BDT 10 million)

Thematic Area	Climate ADP Expenditure				Non-Development Climate Expenditure				Total Climate Expenditure			
	Revised 2010/11	Revised 2011/12	Revised 2012/13	Budget 2013/14	Revised 2010/11	Revised 2011/12	Revised 2012/13	Budget 2013/14	Revised 2010/11	Revised 2011/12	Revised 2012/13	Budget 2013/14
Theme 1	926.42	869.12	2,276.12	2,439.63	1,292.86	1,312.06	1,921.69	1,801.38	2,219.28	2,181.18	4,197.81	4,241.02
Theme 2	891.08	964.60	1,459.97	1,403.56	650.07	670.34	978.19	873.81	1,541.15	1,634.94	2,438.17	2,277.37
Theme 3	1,492.62	1,396.09	2,111.95	2,167.66	94.24	87.53	76.95	98.69	1,586.85	1,483.62	2,188.89	2,266.35
Theme 4	351.73	271.65	555.88	636.68	381.05	407.32	567.35	416.23	732.78	678.97	1,123.24	1,052.91
Theme 5	178.84	68.14	609.76	682.38	144.57	142.09	77.67	38.50	323.40	210.23	687.43	720.89
Theme 6	1,350.98	1,277.47	2,077.528	2,154.81	1,102.11	1,088.754	1,479.19	1,443.2	2,453.09	2,366.22	3,556.72	3,597.99
Total	5,191.66	4,847.08	9,091.20	9,484.73	3,664.90	3,708.09	5,101.05	4,671.79	8,856.56	8,555.17	14,192.26	14,156.51

Sources: iBAS, ADP, BCCSAP-2009 and CPEIR, 2012

Figure 10: Climate Expenditure: 2011-2014

Table 2: Allocation in BCCSAP Thematic Areas in Selected Ministry Budget

BCCSAP Themes	CC relevant Allocation *(amount in thousand taka)*			
	2017-18	2016-17	2015-16	2014-15
Food Security Social Protection and Health	17,353,924	16,678,265	16,146,944	13,304,421
% of total CC relevant allocation	11.86	12.11	13.04	14.15
% of Ministry budget	2.28	2.19	2.12	1.75
Comprehensive Disaster Management	34,671,966	29,434,227	30,318,387	20,687,257
% of total CC relevant allocation	23.69	21.37	24.49	22.00
% Ministry budget	4.55	3.86	3.98	2.71
Climate Resilient Infrastructure	24,743,940	23,947,171	13,248,641	6,559,625
% of total CC relevant allocation	16.91	17.39	10.70	6.97
% of Ministry budget	3.25	3.14	1.74	0.86
Research and Knowledge Management	3,658,676	2,804,454	4,165,926	2,631,410
% of total CC relevant allocation	2.50	2.04	3.37	2.80
% of Ministry budget	0.48	0.37	0.55	0.35
Mitigation and Low Carbon Development	1,699,220	1,613,205	1,653,730	1,639,602
% of total CC relevant allocation	1.16	1.17	1.34	1.74
% of Ministry budget	0.22	0.21	0.22	0.22
Capacity Building and Institutional Strengthening	64,208,380	63,261,544	58,246,322	49,226,953
% of total CC relevant allocation	43.88	45.93	47.06	52.34
% of Ministry budget	8.43	8.30	7.64	6.46
Total CC Relevance (Tk)	**146,336,106**	**137,738,867**	**123,779,950**	**94,049,267**
% of Total Budget - 6 Ministries	**19.20**	**20.88**	**20.71**	**17.95**

Source: Finance Division, Ministry of Finance

Figure 11: Climate Expenditure: 2015-2017