A Changing Process-from climate change to country’s fragility

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Abstract—We analyze the impact of climate change to different extent of country’s fragility, using Central African Republic and Mexico as an example of top ten most fragile country and a moderate fragile country respectively. Through our dynamic model, a strong intervention of government is proved to have a significant effect on alleviating the fragility of country. The strengths and weaknesses of our models are discussed and we also propose solution for the fragility of the country. In this paper, we conclude the relationship between climate change and country’s fragility together with the effect of interventions based on our models, which may also give an inspiration for the later dynamic prediction.

1. INTRODUCTION

1.1 Background
Climate change has always been a main focus for researchers because of its wide range of impacts to the whole world. In recent decades, great attention has been addressed on its impact on countries, a’r fragility which can be divided into two aspects. First and foremost, such as a direct reduction in the area of arable land or a shortage of water resources; the other is indirect effects like weakening government administration and so on. The more vulnerable a country is, the greater impact it suffers from the climate change. The extend of countries fragility has a severe affect on standard of living of its citizens and even lead to violence which poses a great threat to the peace of mankind both at a domestic and international level. Therefore, it is of great significance to study the relationship between climate change and countries, a’r fragility.

1.2 Literature Review
To explore the relationship between climate change and countries fragility, researchers made many related attempts. Some of them apply theoretical explanations, such as spatially disaggregated data and empirical literature to try to give a theoretical mechanism, and some others analyze the plausible correlation between climate change and fragility by seeking channels linking these two phenomena, like adverse economic condition, resource scarcity and migration, these are three widely recognized route giving rise to how climate change results in a fragile country. Whats more, there are also some researchers try to model this linking through Analytic Hierarchy Process and Multiple Linear Regression. However, the existing methods are not flawless. First, the indicators of either climate change or country fragility is limited, as most researches only use precipitation and temperature as factors for climate change and the frequency of conflict to measure the fragility of a country while ignoring the influence of other factors. Second, the connection between these two phenomena is often indirect and narrow with the lack of robust causal effects. In other words, the connection is not a precise
mechanism or quantitative. The last, the existing models are static only summarize the current situation. Here we expect to build up a dynamic model concerning more comprehensive indicators of both phenomena and could achieve the goal to predict future trends.

2. OUR WORK

• Construct a model to determine the degree of country are fragility with measurement of the impact of climate change through direct means or indirectly as it influences other factors and indicators.
  • Analyze the impact of climate change to one of the most fragile country and the way to be less fragile.
  • Analyze the impact of climate change to less fragile country and find out a tipping point for it to reach fragility.
  • Explain the human and state driven interventions to mitigate the risk of climate change and calculate the total cost.
  • The application of our model and modification according to country sizes.

3. THE MODEL

3.1 The Static Model: AHP Model

• Introduction
  The AHP Model we have constructed is aimed to predict the country’s fragility using the relevant data provided by the World Bank. From the perspective of regional representation and data integrity, we selected 46 countries with the data spanning from 1990 to 2014. We select 6 first-level indicators and 14 second-level indicators to assess the country’s fragility and determine the corresponding weights of each indicator through Analytic Hierarchy Process (AHP). We standardize the data of each indicator according to the formula 1 while the data of Population Density is standardized according to formula 2 in order to score on the country’s fragility.

First-level indicators are:
  • Climate: Climate change has an impact on many aspects of a state, such as agriculture, economy and policy.
  • Population Density: Population density should be maintained at a certain level, too high or too low will lead to the country’s fragility.
  • Household: the facility of a state, including infrastructure, education, health etc.
  • Government Management Capabilities: the ability of government management directly affects the stability of a country.
  • Size: Bigger countries are kind of less vulnerable to the outside world.
  • Wealth: Wealthier countries tend to be more stable.

In the process of AHP, we constructed a 6 × 6 comparison matrix according to the importance of each indicator to country’s fragility and passed the consistency test. The CI value is 0.1087 and the CR value is 0.0862.

• Results
  We calculated the corresponding scores of 46 countries in 2014 using six first-level indicators. Based on the scores, we draw the map of each country and hoped to have a brief understanding of the global situation. It can be seen from the map that the global climate level is evenly distributed, with higher scores in Europe and the Mediterranean region, reflecting the better local environmental conditions. In terms of population density scores, India has a lower score because of its higher population density. In the household category, North America, Oceania and Europe have better infrastructure, while Africa and Asia are limited. In attracting foreign investment, the United States scored far more than any other country. In addition, China and Japan also have a better performance which may due to the more open market in Asia in recent years. At the size level, China, the United States, Canada and Australia all have good performance, and these countries own exactly a greater GDP
and territorial powers. In terms of the rate of GDP growth, some Asian countries performed better, which is in line with the recent literature.

In order to understand the changes in each country on a time scale, we cluster and draw the heat map for each country’s total fragility score. The lower score is bluer in the heat map which means the country is more fragile.

As can be seen from the clustering results, in time scale, the scores are mainly divided into two parts, before 2000 and after 2000. All countries in the world are more fragile in years before 2000 than after. Kenya and Bangladesh scored the lowest, probably due to their geographical location and economic status. In addition, Bangladesh has a very high population density with a population of 160 million, which has greatly increased its fragility. The United States, Canada, Japan, France and other developed countries generally have a high score in a long-term. It is noteworthy that China also has a high score among developing countries, which may be related to China’s rapid economic development in recent years and the implementation of its one-child policy. Based on the clustering results, we divided the 46 countries into four categories. Stable: country code: 44 —— 17; Vulnerable: country code: 6 —— 36; Fragile: country code: 38 —— 37; Crash: country code: 5 —— 26; (the country code order is shown in the vertical axis) The ratio of the four types of countries is Stable: Vulnerable: Fragile: Crash=2: 8: 26: 10. After averaging the 25-year fragility scores of 46 countries and combining the clustering results, we result in a mathematical model that divides the country categories according to the country fragility scores:

$$\text{Score} = \begin{cases} 
\text{crash,} & \text{Score} < 0.26 \\
\text{fragile,} & 0.33 > \text{Score} \geq 0.26 \\
\text{vulnerable,} & 0.41 > \text{Score} \geq 0.33 \\
\text{stable} & \text{Score} > 0.41 
\end{cases}$$

The Score point are: 0.26, 0.33, 0.41.

3.2 Dynamic model: Markov probability process

- Assumptions
  - According to the static model, we divide the countries in the world into four categories: stable, vulnerable, fragile and crash. The state of the country in the next phase is only related to the state of the current phase and the probability of transition. The probability of transition is calculated by a combined effect of changes in the future environment, climate, national policies, demographics, etc., and has nothing to do with the past. However, in our model, in order to quantitatively evaluate the transition probability, a time-based forecasting method and a comprehensive analysis method based on literature data are used.
  - Stable, vulnerable, and fragile countries are interchangeable, and countries in all three states can crash, but the countries that have already crashed will not reenter into other three states.
  - In this model, we do not consider the birth of a new country.
  - Assuming that time is discretized, the time period is divided into 10-year periods. The following models are analyzed in 10-year units.

- Introduction

Based on the AHP model, the 46 countries with more complete data are divided into four groups through the fragility indicators as we constructed. They are stable, vulnerable, fragile and crashing respectively. However, the AHP model can not show the dynamic process from one current state to another future state as time changing. Therefore, our dynamic model will show the process of change.

At this time point, past and present information is known and the future is in an unknown state. In this subject, we consider that the state of the next stage of a country depends only on the current state and the probability, which is in line with the Markov process. Therefore, we construct a Markov probability model to study this problem.

At each time point, there are four states for a country: stable, vulnerable, fragile and crashing. The first three states can be converted to each other, and both of them can also be converted into the fourth
state. However, the fourth state cannot be transformed into the first three states. Based on this, we construct transition probability matrix:

\[
P = \begin{bmatrix}
P_{11} & P_{12} & P_{13} & P_{14} \\
P_{21} & P_{22} & P_{23} & P_{24} \\
P_{31} & P_{32} & P_{33} & P_{34}
\end{bmatrix}
\]

Model
The two key variables of the model are the current state and transition probability matrix.

First, we should build transfer equation:

\[
f = \begin{cases}
2, & \text{if } x = w = 0 \\
\frac{x-w}{x-w(1)}, & \text{if } x = w > 0 \\
\frac{x-w}{x-w(1)}, & \text{if } x = w < 0
\end{cases}
\]

X: current state. x = 1, stable; x = 2, vulnerable; x = 3, fragile. W: the next phase state. w = 1, stable; w = 2, vulnerable; w = 3, fragile; w = 4, crashing. Y: Climate Change Index. Z: National Status Index.

Z = 0, the government of a country has not promised to take measures in response to climate changes in the coming period. Then, we should normalize. For each current state (x), the sum of its transition probabilities equals 1.

The transfer equation is normalized according to the following formula to get the transfer probability matrix:

\[
P_{ij} = \frac{f_{ij}}{\sum f_i}
\]

P = \((p_{ij})_{3x4}\)

Third, we should determine the climate change index y. The Y indicator reflects changes in the climate conditions in the coming period relative to the current state. Here, we use four indicators to build a composite indicator. The method for constructing the y indicator is:

\[
y = \frac{1}{2} \Delta \text{access-to-water} + \frac{1}{6}(\Delta \text{forest-area} + \Delta \text{Renewable-energy-consumption} + \Delta \text{CO}_2)
\]

At the 46th IPCC meeting, the second group proposed seven indicators:

- Terrestrial and freshwater ecosystems and their services.
- Ocean and coastal ecosystems and their services.
- Water.
- Food, fibre, and other ecosystem products.
- Cities, settlements and key infrastructure.
- Health, wellbeing and the changing structure of communities.
- Poverty, livelihoods and sustainable development.

Based on these seven aspects, we have selected water sources (2/3/4/6), the proportion of sustainable energy sources (7), forest area (1) and carbon dioxide emissions (5), of which the water source for a country’s development is crucial, thus we give the indicator of water resource a weight of 1/2 and a weight of 1/6 for each of the other three. For each weight indicator, we use its relative rate of change. In predicting future values, we use a time series model that is specific to a particular set of indicators and data, and we choose the method based on how the data fit. We use the methods are: AR model, linear regression, moving average method.

After the initial value of y is calculated, y is adjusted and normalized to obtain the value in the range of [0,1] to better explain the model.

Y is explained as follows: when y = 0.5, the change of climatic environment in the next time period has not changed obviously compared with the current one. 1 > y > 0.5, the climate environment will improve relative to the current one in the next time frame. 0.5 > y > 0, the climate environment deteriorates relative to the current one in the next time period. Y = 0, the next time period extreme deterioration of climate and environment. Y = 1, extreme improvement of climatic environment occurs in the next time period.
Model Test

Before applying it to real-world data, it tests the scope of the model and the application effect. Assuming that country A, country B and country C are currently in a stable, vulnerable and fragile state respectively, none of the three governments has made any commitment to take measures to cope with environmental changes in the next decade, ie $z = 0$.

$$f = \begin{cases} e^{(x-w)/y}, & x - w < 0 \\ 2, & x - w = 0 \\ \ln(e+y), & x - w > 0 \end{cases}$$

Scenario one: $y = 0.6$. In the next decade, the climate change in ABC countries will have a significant improvement. Calculate the transfer function and transfer probability matrix of ABC by formula. Scenario two: $y = 0.4$. In the next decade, the climate change in ABC has a more pronounced deterioration.

In conclusion:

- Inertial Theorem: Each country has the property of keeping its own state unchanged. Unless the impact of extreme climate change is affected, the probability of the state transition remains the highest among all probability transitions.

- Stable countries have the lowest probability of collapse, vulnerable countries followed, fragile countries the largest.

- The probability of a collapse in a vulnerable country increased by 4 percentage points (0.09 -> 0.13) when the condition of the environment worsened by 2 percentage points, the probability of a stable country collapse by 3 percentage points (0.06 -> 0.09), fragile The country increased by 5 percentage points (0.16 -> 0.21). This means that as the environment deteriorates, fragile countries have changed more, followed by vulnerable countries and at least stable ones. That fragile countries are more vulnerable to the impact of climate change.

- When climate change moves in the bad direction, all countries have a lower probability of conversion to a more stable state and a higher probability of conversion to an unstable state.

A simple case was established through the model analysis. The four conclusions obtained are consistent with our understanding of the real world, indicating that the model is effective.

Explanation

According to the dynamic model, there are two ways in which climate change can have an impact on national vulnerability: direct and indirect.

In a direct way, $y$ as a transfer equation variables, directly involved in the composition of the transfer equation. According to the model test of 3.3, when $y$ decreases, that is, when the future climate condition is relatively deteriorated, the probability of improving the state will decrease and the probability of worsening will increase.

In a indirect way, the state state index $z$ is also one of the variables of the transfer equation besides $y$. And $z$ is a multidimensional variable. The composition and value of $z$ can be decided by the researcher according to the specific country and the specific situation of the study.

$$z = \sum w_i z_i$$

There are some variables in $z_i$ that are highly correlated with $y$, such as the level of economic growth and the proportion of immigrants. The economic growth in a country is highly vulnerable to the effects of climate change, especially in countries with the primary industry as its mainstay. For example, the greenhouse effect, drought and soil degradation have a greater impact on agricultural countries, causing economic stagnation or even recession. Economic stagnation can easily lead to social problems such as unemployment, causing conflicts and state civil strife, which are all important factors that lead to changes in the country’s vulnerability. At the same time, climate change will make some countries emigrate, while others will not emigrate, thus driving immigration. The conflicts between immigrants and the economic and cultural exchanges are inevitable and also an important measure of vulnerability.
4. MODIFIED MODEL

4.1 Central African Republic: an example of top ten most fragile country

- Overview
  The impact of extreme weather conditions on countries around the world is different, with vulnerable countries hit first and hit even harder. We selected the global refugee and total population figures for 2016 and 2011 from the World Development Indicators (WDI) as the ratio of refugees to the total population.

  As can be seen from this table, the share of refugees in East Africa has risen significantly compared to West Africa.

  Therefore, we have chosen a country in East Africa, the Central African Republic, as the most vulnerable country representative to analyze the impact of environmental change. The Central African Republic is a landlocked country in the Central African continent with many hills in Central Africa. China and Africa are located in the tropics, the annual temperature difference is small, but the temperature difference between day and night is bigger. Annual dry season and rainy season. Its rich mineral resources and forest resources, water mainly Wu Bangui River, is the largest river in the country.

- Solution
  According to the FSI, the Central African Republic has a very high ranking of fragility and its government’s role in facing the crisis is rather weak. Climate change will increase the fragility of countries through direct and indirect impacts. When the climate gets worse, on the one hand, climate change directly reduces major river flows by reducing precipitation and increasing temperature, which in the short term can lead to a rapid reduction in access to safe water for people. In addition, this scarcity of water and high temperatures will also lead to drought on the land, drastically reducing crop production and affecting the economy of the country.

  Climate change will also directly reduce the area of forests and renewable energy, causing a serious reduction in the country’s natural resources and making it vulnerable to the shortage of available energy. On the other hand, climate change can affect country fragility through indirect ways such as reducing economic growth, increasing population migration and increasing violence. Climate change will reduce the output of resources, thus affecting the export trade, thus endangering the country’s economic conditions. Countries with poor economic conditions will increase violence because of lower costs of violence and weakened government controls. Finally, shortages due to climate change will also make the population begin to migrate to find new resources. This migration into the territory of other people for resources will come to conflict. Conflicts of riots further weaken the government’s management capacity and make the country more vulnerable. That is the case in Central Africa, where civil strife in 2012 further reduced the stability of the country.

- Analysis
  If you do not consider the impact of the environment, that is, in the dynamic model, so that \( y = 1 \). This means that climate change is to a good trend that does not increase the country’s fragility trend, thus ignoring the impact of climate change premise. Consider that \( z \) is the management of the national government. The range of \( z \) is \((0, 1)\) where \( z = 0 \) means the government does not act, \( z = 1 \) means the government responds quickly and effectively. The value of \( z \) is based on the values of \( z \), such as Government Responsiveness, Government Response Capacity, Openness to External Assistance, Political Stability and Political Violence. When \( y = 1 \), \( z \) changes from \((0, 1)\), we can get the probability \( p_1 \) (from fragile to crashing), showing the state’s deterioration from the fragile state, and \( p_2 \) (the sum of the probabilities of fragile to vulnerable and stable), showing the state of country’s fragility is getting better, and \( p_3 \) (from fragile to fragile), showing the possibility of remaining the same. The results are as follows:

  As can be seen from the figure, as \( z \) increases, \( p_1 \), \( p_3 \) significantly reduced, \( p_2 \) significantly increased. This shows that without considering the impact of the environment, a fragile country can make its state significantly improved through the following aspects: Government Responsiveness,
Government Response Capacity, Openness to External Assistance, Political Stability and Political Violence.

Figure 1: relationship between P1, P2 and P3 with Z

5. CONCLUSION
Based on the global climate change impact on country fragility, this paper establishes two models, AHP (static model) and Markov probability model (dynamic model). Through AHP, we select 6 first-level indicators and 14 second-level indicators and establish a country fragility index, and divide the countries in the world into four categories: stable, vulnerable, fragile and crash. In the dynamic model, we establish the link between the current state of a country and the state of the next time period, and in turn explore the issue of changes in countries in Central Africa, Mexico and the world. Based on the above two models, we have analyzed that the global climate and environment are deteriorating at present, and if no measures are taken, many vulnerable countries will face the threat of collapse. However, if the government can take effective measures, the effect is very significant. I hereby remind all countries in the world to be prepared for the challenges of the upcoming climate change.

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