For office use only	Team Control Number	For office use only
T1 ________	**87211**	F1 ________
T2 ________		F2 ________
T3 ________	Problem Chosen	F3 ________
T4 ________	**E**	F4 ________

2018 Mathematical Contest in Modeling (MCM) Summary Sheet

Abstract

We have proposed a composite judging method considering the change of climate.First of all, we are going to measure the direct influence of climate change. We are required to build a model to quantify climate change. The climate is mainly composed of precipitation and temperature. An objective index is determined by using nonlinear weighted product method through temperature and precipitation. It is called the climate index.

Considering the indirect effects of climate change, we find 12 indicators related to the climate index and build a function model of approximately positive correlation. The climate index affects the state fragility by affecting some of these 12 factors.Climate index and the original 12 indicators together determine the state fragility. In order to facilitate the processing of large amounts of data, linear model is a good and convenient choice. At the same time, we normalize all the data using deviation type method.

Using the analogy method to divide the fragility, states in the original data that are at critical values (such as those in a boundary between stable and vulnerable) still play a critical role in our model and their norms are calculated as an indicator to distinguish the state fragility.Find a country that is fragile and use our model to find the relationship between climate index and its other indicators and calculate the current year's state fragile index. Suppose there is no climate change influence and the climate index is zero. Use the model to calculate the fragility at this time to illustrate that no climate change will not make the country so fragile.

Choose a country not in the top ten to use our model to analyze the relationship between the climate index and the state fragile index and make a prediction. When the climate index arrives at some value, the country will be more fragile and use the model in task one to define the critical point.

Find a country under state intervention and establish a function of the relationship between the climate index and other indicators is not in line with our expectation. So we infer the state policy and estimate the cost of the intervention.

Finally, we will analyze the impact of smaller and larger states on the thirteen indicators to modify the model.

*Keywords:***climate index, state fragile index, deviation type method, linear model,analogy method**

A Research on how Climate Change Affects Regional Stabilty

87211

February 13, 2018

Contents

1 Introduction

Changes in climate may bring many implications, including sea levels rising, arable land declining and erratic temperature changes, which can have adverse impacts on agriculture and so on including production declining, which reflects the indirect impact of climate change on a state's economy. At the same time, natural disasters such as floods and tsunamis caused by climate change will directly undermine the state's economy. This shows the direct impact climate change has on a country. Fragility reflects a state's level of stability, which means that a fragile country in the face of climate change may deteriorate further, while a stable state may be little affected by the climate change. Some agencies stablish a set of scoring criteria to indicate the degree of vulnerability of a particular factor in a state based on the 12 indicators. The higher the fragile index is, the more unstable the country is. We now include the impacts of climate change, including indirect impacts and direct impacts, and build a model to research the indirect impacts of climate change, which is the impacts climate change makes on 12 factors. This affect a state fragility indirectly. At the same time, we analyze the impact of climate change in different states to indicate the degree of state intervention which means related policy.

2 Analysis of the Problem

Task1:
The first step is to build a model, according to the data on fundforpeace.org, we have 12 different indicators which influence the states fragile index (SFI).[2] In the same time, we have a new indicator, climate change, which influence SFI directly, so we have to consider building a new model. While the 12 indicators are range from 0 to 10, we thought the value was based on longitudinal comparison, where the worst is 10 and the best is 0. However, we find that not every indicator in each year has 0 and 10. So, we can believe that the value is an objective number based on specific regulation. In fact, the data we find can illustrate this conclusion. Therefore, we can determine the climate index by taking an objective method. The climate includes temperature and precipitation, the problem is how to get an objective index through them. Obviously, it's not correct to calculate the index only base on the annual average temperature and the annual average precipitation since regions of different location could differ from each other to a large extend. Therefore, we make the difference between the annual average temperature and the perennial temperature be the standard to judge the region, it's the same with the precipitation. When we find the precipitation difference is large, we can believe that floods or droughts occurred. As to the large temperature difference, El Nino or La Nina occurred. Since there is no linear relationship between precipitation and temperature, we decide to take nonlinear weighted product method.[1] However, temperature and precipitation are different in unit and value size while they influence the climate to different extend. Under different weights, we make a comparison and we define the weight of temperature 0.8 and the weight of precipitation 0.2. We calculate the new climate index and we use neural network function and make a change to form an objective index ranging from 0 to 10. What's more, climate change could have influence on other indicators that larger climate index which indicates a worse climate corresponds with related indicators, and it's similar to positive correlation. We could measure that climate index has an impact on the five indicators. Because of abundance of indicators, we only take climate change and related indicators change into consideration. If the result is different from prediction of model, which means not similar to positive correlation, there might be a deviation caused by human intervention. We will build graphics through MATLAB to illustrate it's indeed similar to positive correlation. As to the judge of SFI, the material given describes that SFI is divided into four levels, set 0 - 30, 30 - 60, 60 - 90, 90 - 120 as four levels. While the task asks us to divide them into three levels, we could set 0 - 40,40 - 80 and 80 - 120

as the dividing standard according to the formal one. We will select one year and find the SFI whose value is 40 or 80 in order to build a new model which includes climate index. Since the objective and reasonable indicators are all ranged between 0 and 10, we will regulate them and find the sum of them according to deviation type. The larger the sum is, the more stable the state is. Therefore, 40 corresponds to the boundary between 'stable' and 'vulnerable', at the same time, 80 corresponds to the boundary between 'vulnerable' and 'fragile'.

Task 2:
We select a state (Sudan) and calculate the climate index through the model built in task 1 according to the material and related weather data,[3] and we build connection between the five indicators and climate index, which tends to be positive correlated. It means that the state will get more fragile with the deterioration of climate. A larger value of climate index means a larger value of related indicators, so we can search for related data in order to find that climate change brings natural disasters to the state, including floods, droughts and other natural disasters, which will affect the economic development of the state. Without the influence of these indicators, which means we let the climate index be 0, we will find the SFI will get lower making the state not so fragile.

Task 3:
Based on the model built on task1, we predict the seven indicators variety which are not related with climate change so tightly. As to the five indicators, we establish the relationship between them and climate index, and we predict the climate index using our model. We calculate SFI based on our model and we find that SFI corresponds with climate index. When SFI reaches the boundary, we record the climate index and set it as the turning point and predict this point according to our model.

Task 4:
We find that the related indicators increase with the increase of climate index based on our model. While some states are not in line with our model, we guess that it might be caused by human intervention, and we search the state intervention policy for the previous cost and based on which we predict the total cost in the future.

Task 5:
Based on our model, we ignore the difference of various regions of one state in climate change and economics. However, a larger state means the difference will become more significant. So, we will divide the larger state into smaller parts based on climate type. Then we analyze these parts dividedly and integrate them at last. As to a smaller state, it's more frequent for population to exchange and easier for the state to be intervened, based on which we modify our model.

3 Calculating and Simplifying the Model

3.1 Assumption

- Assuming that all data sources are reliable
- Assuming that various indicators are only related to climate change without human intervention
- Assuming that states in model are ideal, and there are no regional differences.

3.2 Definition and symbolic description

- A: Annual average temperature
- B: Annual average precipitation
- C: Temperature in normal year
- D: Precipitation in normal year
- E: Decision Matrix
- f: The intermediate variable of the climate indicator
- W: Climate Index(defining that the lower the index is, the more stable the state is)
- w: weight (w = [w1, w2])
- p_i 1: The i-th national security apparatus fragility index (defining that the lower the index is, the more stable the indicator is)
- p_i 2: The i-th national Factionalized Elites fragility index.
- p_i 3: The i-th national Group Grievance fragility index.
- p_i 4: The i-th national Economy fragility index.
- p_i 5: The i-th national Economic Inequality fragility index.
- p_i 6: The i-th national Human Flight and Brain Drain fragility index.
- p_i 7: The i-th national State Legitimacy fragility index.
- p_i 8: The i-th national Public Services fragility index.
- p_i 9: The i-th national Human Rights fragility index.
- p_i 10: The i-th national Demographic Pressures fragility index.
- p_i 11: The i-th national Refugees and IDPs fragility index.
- p_i 12: The i-th national External Intervention fragility index.
- C1: Security Apparatus
- C2: Factionalized Elites
- C3: Group Grievance
- E1: Economy
- E2: Economic Inequality
- E3: Human Flight and Brain Drain
- P1: State Legitimacy
- P2: Public Services
- P3: Human Rights
- S1: Demographic Pressures

- S2: Refugees and IDPs
- X1: External Intervention
- CI: Climate Index
- P: Country's Fragility Indicator (defining the larger and more stable the indicator)
- R: Canonical matrix
- H: Result matrix

3.3 Specific proof

3.3.1 The establishment of climate index model

Use nonlinear weighted product method:

$$f = |A - C|^{w_1} \times |B - D|^{w_2}$$

Among the formula :$w1 = 0.8, w2 = 0.2$

Neural network function (sigmoid function)[4]

$$W = \left(\frac{1}{1 + e^{-f}} - \frac{1}{2} \right) \times 20$$

We make a deformation on the function, which means subtracting $\frac{1}{2}$ from the formula and then multiplying the formula with 20.

3.3.2 Establishment of State Fragile Index Function

Construct a decision matrix

$$E = (a_{ij})_{n \times m}$$

, among which n means the number of rows which is the number of all states and m is 13 which means 13 indicators. $R = (r_{ij})_{n \times m}$ is a normalized matrix, and we use deviation type method. Let

$$r_{ij} = \frac{|a_{ij} - \beta| - \min_i |a_{ij} - \beta|}{\max_i |a_{ij} - \beta| - \min_i |a_{ij} - \beta|}, i = 1, 2, ..., n. \ \beta = 10$$

Among which a_{ij} is the fragility of a certain indicator of a country in that year, where i denotes the country and j denotes the jth indicator (j = 1 corresponds to the safety apparatus, ... j = 13 corresponds to the climatic index), β is 10, this formula shows that the larger the difference between 10 is, the better the indicator is(From definition, the larger the value ,the less stable and the upper limit is 10), max represents that the current column that all countries, the maximum difference between index of the indicator and 10. It's the same with min. $w = [w1, w2, w3, w4, w5, w6, w7, w8, w9, w10, w11, w12, w13]$ represents the weight, we can know that each weight is equal from the analysis of the problem. The last product of them is the SFI(P),and

$$P = R \times w^T$$

, we finally get the result matrix

$$H = (h_{i1})_{n \times 1}$$

,where i represents state and h_i represents the state fragility.

3.3.3 Simplifying the Model

Since that the number of countries is too large, we should select one of the representative countries, which should have been a matrix of 176×13. However, it is required that a single state only need to know the data of this one and the maximum and minimum values of all the indicators of the country in that year .Since the first 12 indicators have clear data, and the number of states is large, and the amount of data is too large to calculate the national climate indicators one by one, but that we set the climate index a maximum of 10, a minimum of 1 is reasonable. In summary, considering a single country does not need to consider the value of i, so we no longer write i value.

3.3.4 Solution to Task1

State Fragility Index division. Taking 2012 as an example, the country with index 40 in the data given is Uruguay. Therefore, in that year we used the Uruguayan data as the criterion for the classification between stable and vulnerable, and we collect the data from 2012 and its temperature and precipitation in normal year and the annual average temperature and the precipitation of that year.

Table1:The all indicators of Uruguay in 2012

State	C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1
Uruaguay	4.0	2.7	2.7	3.8	4.6	5.0	2.2	3.4	2.6	4.1	1.8	3.7

Average temperature in 2012: 18.3 Average Precipitation in 2012: 1487.2
Temperature in normal year: 17.4 Precipitation in normal year :1209.2
Calculate the difference, $|A-C| = 0.9, |B-D| = 278$, and according to $f = |A-C|^{w_1} \times |B-D|^{w_2}$ and then generate the result into neural network function

$$W = \left(\frac{1}{1+e^{-f}} - \frac{1}{2}\right) \times 20$$

,the calculated result is W = 8.8855
Find the maximum and minimum of the various indicators in the original data as follows (where the estimated minimum of climate index is 1, the maximum value is 10).

data(year of 2012)

Table2:The maximum and minimum of the various indicators in all states

	C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1	CI
max	10	10	10	9.7	9.1	9	9.9	9.8	9.9	9.9	10	10	10
min	1.3	1	1	1.6	1.3	1.3	0.8	1.6	1.3	1.9	0.9	0.8	1

According to the fragility indicator function,calculate each p_i and W,which shown as below:

Table3:Each indicator of Uruguay in 2012(including climate index)

	C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1	CI
value	0.6897	0.8111	0.8111	0.7284	0.5769	0.5195	0.8462	0.7805	0.8488	0.725	0.9011	0.6848	0.1222

According to $P = R \times w^T$,we calculate that $P = 9.0453$.

Through our model, state fragility index is larger than the state which is stable. The state in original data whose index is 80 is Ecuador ,and we search for the related data again.

Table4:Each indicator of Ecuador in 2012

C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1
6.5	8.2	6.9	5.9	7.7	7.1	7.5	7.2	5.2	5.6	6.0	6.3

Average temperature in 2012: 21.4 Average Precipitation in 2012: 2117
Temperature in normal year: 16.3 Precipitation in normal year :1554.30
Calculate the difference, $|A - C| = 0.9, |B - D| = 278$, and according to $f = |A - C|^{w_1} \times |B - D|^{w_2}$ and then generate the result into neural network function

$$W = \left(\frac{1}{1 + e^{-f}} - \frac{1}{2} \right) \times 20$$

,the calculated result is W = 10
Find the maximum and minimum of the various indicators in the original data as follows (where the estimated minimum of climate index is 1, the maximum value is 10),which is the same as Uruguay's.
Calculate each indicator index

Table5:Norm of each indicator of Ecuadorin 2012 (including climate inex)

	C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1	CI
value	0.4023	0.2	0.3444	0.4691	0.1795	0.2468	0.2637	0.3171	0.5465	0.5375	0.4396	0.4022	0

According to $P = R \times w^T$,we calculate that $P = 4.3487$.

From our model, the state whose SFI larger than 4.3487 and smaller than 9.0453 is a vulnerable state, and the state whose SFI smaller than 4.3487 is a fragile state, and the state whose SFI larger than 9.0453 is stable.So, climate index influences SFI directly.

3.3.5 Validating the Model built in Task1

Brazil:5.8772 (4.3487<5.8772<9.0453)
China:4.9431 (4.3487<4.9431<9.0453)
Sudan:1.0934 (1.0934<4.3487)
Australia: 11.2785 (11.2785>9.0453)
The results fit the criterion of our model.Let's take Brazil as an example to research the impact of climate change on five indicators, then find climate data from Brazil in recent years.

Table6: Temperature and precipitation of Brazil in recent years

Country	Year	Temperature(°C)	Precipitation(mm)	GDP Growth(%)
Brazil	2006	25.55	1848.4323	3.961
Brazil	2007	25.64	1688.4919	6.072
Brazil	2008	25.3	1902.7998	5.094
Brazil	2009	25.57	1930.591	-0.126
Brazil	2010	25.82	1758.5119	7.529
Brazil	2011	25.53	1832.3801	3.974
Brazil	2012	25.72	1652.7	1.853
Brazil	2013	25.73	1764.9588	3.015
Brazil	2014	25.83	1746.2925	0.504
Brazil	2015	26.21	1599.5889	-3.8

Precipitation in normal year: 1747.1mm Temperature in normal year: 24.94 °C

Table7:The values of the five indicators of Brazil in recent years

year	Group Grievance	Economy	Human Flight and Brain Drain	Demographic Pressures	Refugees and IDPs
2006	5.7	2.7	5.0	6.5	3.6
2007	6.1	3.2	5.0	6.6	3.4
2008	6.1	3.7	5.0	6.3	3.3
2009	6.4	4.1	5.0	6.4	3.9
2010	6.2	4.0	4.8	6.3	3.7
2011	6.5	3.9	4.5	6.1	3.5
2012	6.2	3.6	4.2	7.0	3.9
2013	5.9	3.3	3.9	7.0	3.6
2014	5.6	3.6	3.8	6.7	3.6
2015	5.9	3.9	4. 1	7.6	3.1

Set the climate index as an independent variable, the indicator index as dependent variable to draw function image.

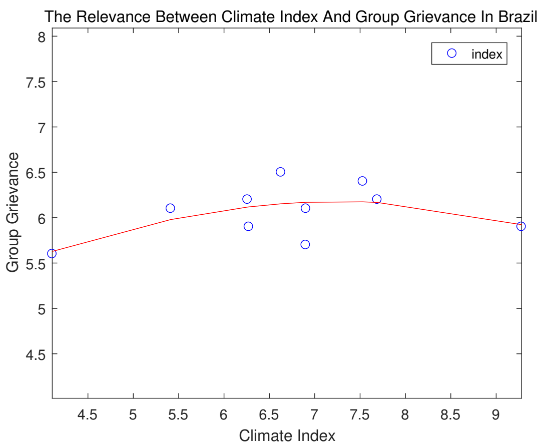

Figure 1: Brazil Group Grievance

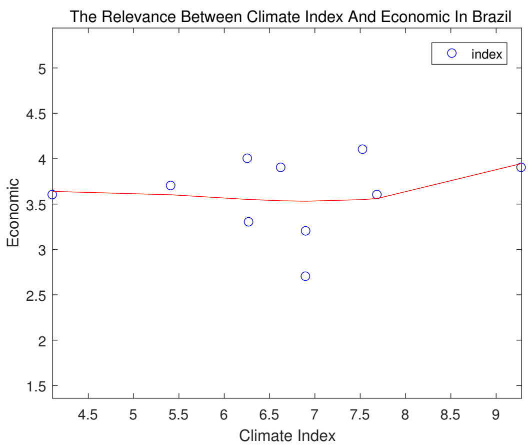

Figure 2: Brazil Economic

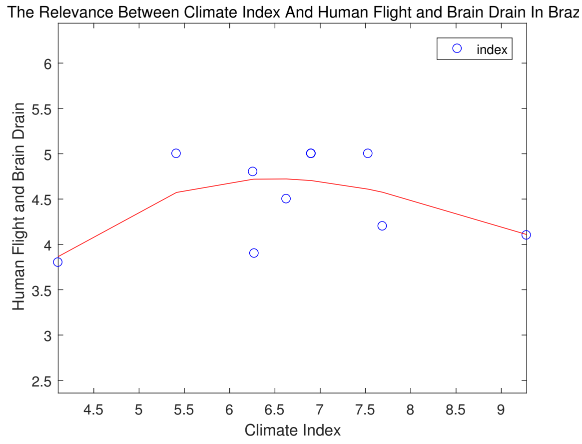

Figure 3: Brazil Human Flight and Brain Drain

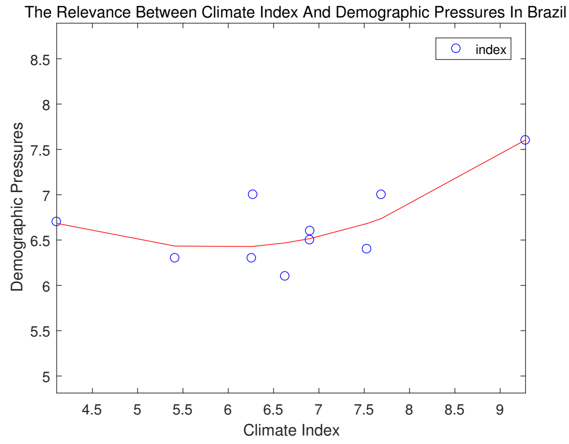

Figure 4: Brazil Demographic Pressures

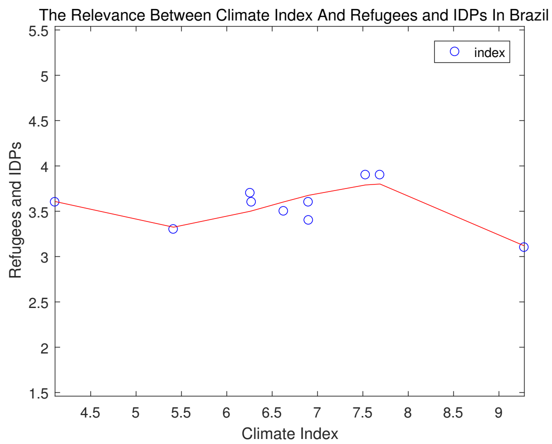

Figure 5: Brazil Refugees and IDPs

We found that in the years before year of 2015, the fact that the indicators are in the basic correlation with the climate index is in line with our prediction model, which shows that the climate index changes other factors directly.
Figure1:$p3 = -0.0018x^3 - 0.0208x^2 + 0.5907x + 3.6787$
Figure2:$p4 = 0.0124x^3 - 0.211x^2 + 1.1302x + 1.6961$
Figure3:$p6 = 0.0145x^3 - 0.4003x^2 + 3.3615x - 4.1922$
Figure4:$p10 = 0.003x^3 + 0.0392x^2 - 0.7704x + 8.9793$
Figure5:$p11 = -00549x^3 + 1.0638x^2 - 6.5894x + 16.5294$
However, in 2015, the climate index has reached to the maximum value, and some indicators have declined and we have reason to believe that in 2015 Brazil intervened in the population. In fact, Brazil's economy was threatened in 2015 and indeed intervened population. Therefore, our model is still in place to illustrate the impact of climate change on state fragility.

3.3.6 Solution to Task2

Task2:

We select Sudan and search for related data:

Table8:Temperature and precipitation of Sudan in recent years

Year	Precipitation(mm)	Temperature(°C)
2006	465.20411	27.99
2007	507.10588	28.15
2008	450.99619	28.29
2009	354.68484	28.65
2010	472.1597	28.95
2011	411.17231	25.30
2012	475.9236982	28.44
2013	453.82584	25.97
2014	470.61622	26.77
2015	405.98522	28.31

Precipitation in normal year: 439.9 mm Temperature in normal year: 26.85 °C

Accoring to

$$f = |A - C|^{w_1} \times |B - D|^{w_2}$$

and neural network function (sigmoid function)

$$W = \left(\frac{1}{1 + e^{-f}} - \frac{1}{2} \right) \times 20$$

,calculate W.

Table 9:The climate index calculated by the formulas above

Year	Climate Index
2006	7.855
2007	8.9185
2008	7.9437
2009	9.6006
2010	9.4817
2011	8.8309
2012	9.022
2013	6.4366
2014	1.3074
2015	8.7856

The climate index in 2012 is 9.022. In our model,the maximum of state fragile index is 10 and the minimum is 1.Using

$$r_{ij} = \frac{|a_{ij} - \beta| - \min_i |a_{ij} - \beta|}{\max_i |a_{ij} - \beta| - \min_i |a_{ij} - \beta|}, i = 1, 2, ..., n. \ \beta = 10$$

.The calculated norm is 0.1087

Table10:value of each indicator in 2012

Country	Year	Rank	C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1
Sudan	2012	3rd	9.7	9.9	10.0	7.3	8.8	8.3	9.5	8.5	9.4	8.4	9.9	9.5

Then we use

$$r_{ij} = \frac{|a_{ij} - \beta| - \min_i |a_{ij} - \beta|}{\max_i |a_{ij} - \beta| - \min_i |a_{ij} - \beta|}, i = 1, 2, ..., n. \ \ \beta = 10$$

,after normalizing we calculate value of each indicator $p_1, p_2, \dots, W$.Here is the table:

Table 11:Norms of each indicator including climate index of Sudan in 2012

	C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1	CI
value	0.0345	0.0111	0	0.2963	0.0385	0.0909	0.044	0.1585	0.0581	0.1875	0.011	0.0543	0.1087

According to $P = R \times w^T$, we calculate that $P = 1.0934$

Based on

$$r_{ij} = \frac{|a_{ij} - \beta| - \min_i |a_{ij} - \beta|}{\max_i |a_{ij} - \beta| - \min_i |a_{ij} - \beta|}, i = 1, 2, ..., n. \ \ \beta = 10$$

,we calculate the state fragile index of Sudan in 2012 is 1.0934.In order to ignore the influence of climate change, we let climate index be 0. According to $r_{ij} = \frac{|a_{ij} - \beta| - \min_i |a_{ij} - \beta|}{\max_i |a_{ij} - \beta| - \min_i |a_{ij} - \beta|}, i = 1, 2, ..., n. \ \ \beta = 10$,the norm of the value of climate index is 1.1111.
At the same time we construct the relation between climate index and the five indicators:

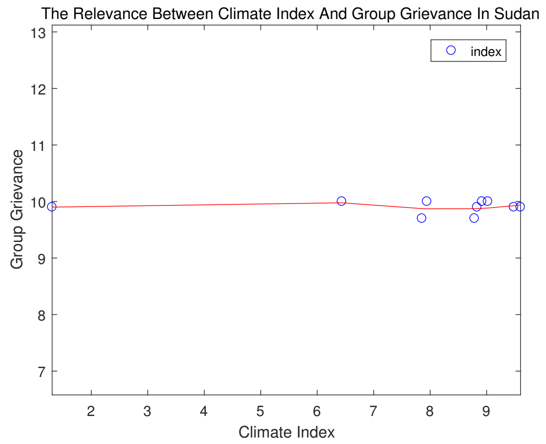

Figure 6: Sudan Group Grievance

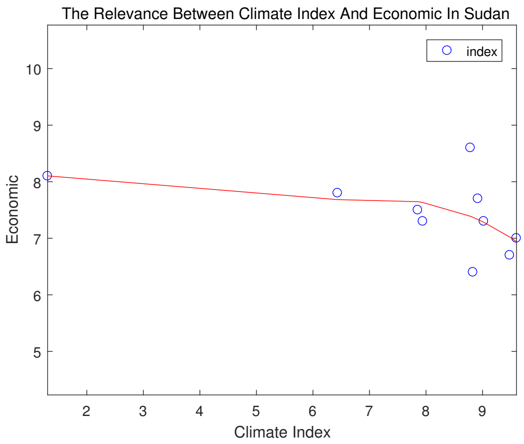

Figure 7: Sudan Economic

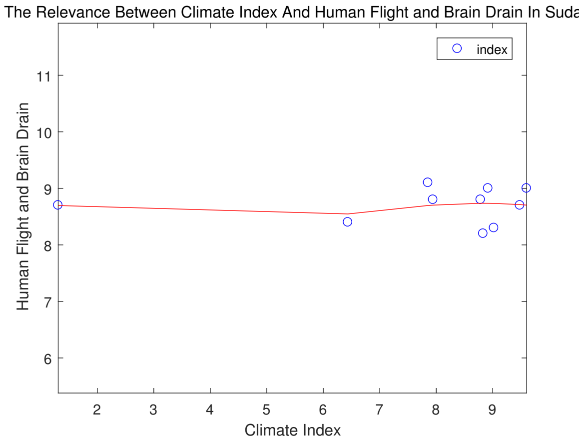

Figure 8: Sudan Human Flight and Brain Drain

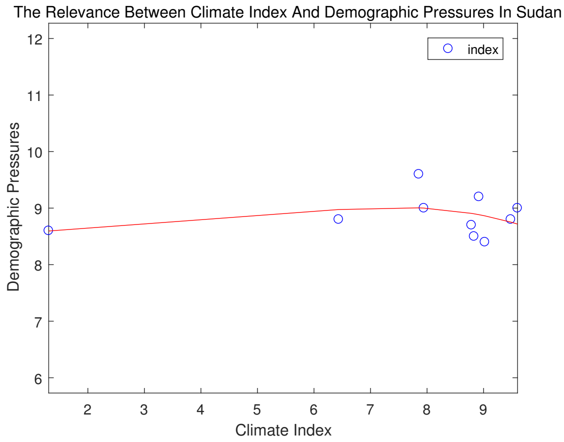

Figure 9: Sudan Demographic Pressures

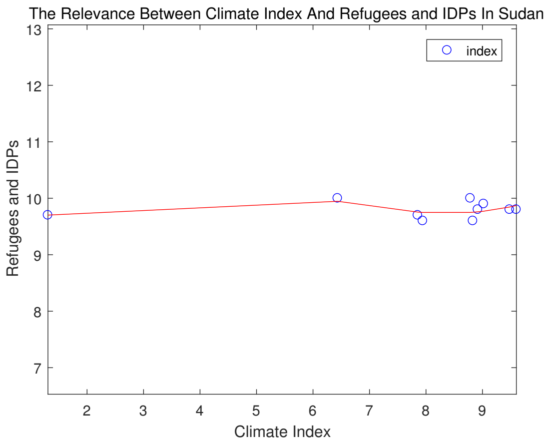

Figure 10: Sudan Refugees and IDPs

The figures above is the model which includes the relations between Group Grivence,Economy,Human Flight and Brain Drain,Demographic Pressures,Refugees and IDPs and climate index.We use polynomial to fit function.

- Figure6:$p3 = 0.0058x^3 - 0.1039x^2 + 0.5205x + 9.3848$
- Figure7:$p4 = -0.0155x^3 + 0.2502x^2 - 1.2206x + 9.3059$
- Figure8:$p6 = -0.0063x^3 + 0.1194x^2 - 0.6268x^2 + 9.3256$
- Figure9:$p10 = -0.0061x^3 + 0.0871x^2 - 0.2861x + 8.8341$
- Figure10:$p11 = 0.0111x^3 - 0.2003x^2 + 1.0291x + 8.6738$

When there is no impact of climate, x is squal to 0 ,the five indicators value is 9.3848,9.3059,9.3256,8.8341,F8.673 will replace the five indicators in original table with these ones and recalculate the fragile index and the new table is:

Table12:The value of each indicator of Sudan ignoring climate change (including climate index)

State	C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1	CI
Sudan	9.7	9.9	9.3848	9.3059	8.8	9.3256	9.5	8.5	8.8341	8.6738	9.9	9.5	0

According to $r_{ij} = \dfrac{|a_{ij}-\beta| - \min_i |a_{ij}-\beta|}{\max_i |a_{ij}-\beta| - \min_i |a_{ij}-\beta|}, i = 1, 2, ..., n.\ \ \beta = 10$,we calculate the following values:

Table13:The norm of value of each indicator of Sudan ignoring climate change (including climate index)

C1	C2	C3	E1	E2	E3	P1	P2	P3	S1	S2	X1	CI
0.0345	0.0111	0.0684	0.0494	0.0385	0	0.44	0.1585	0.1239	0.1533	0.0549	0.0543	1.1111

By calculating the sum of norms we get the state fragile index of Sudan is 2.2979.Although it doesn't make Sudan become a vulnerable state, the index mutiplies itself,which illustrates that without the influence of Climate change,Sudan will not become so fragile.

3.3.7 Solution to Task3

Task3: The divided basis is that the state which is at the boundary between vulnerable and stable and the state between stable and vulnerable.When climate index reached to a value,vulnerable state will get fragile and stable state will get vulnerable.We set the points where state fragility changed as the turning point.Once the climate index is larger than the threshold, a vulnerable state will become a fragile state and a stable state will become a vulnerable state. We take the date in 2012 as an example, and we select the state,Thailand, which is at the threshold of 'vulnerable'. Seven of the indicators are the data of the year of 2012.As to the other five indicators, we list the relation between them and climate change,and we write down the function model.

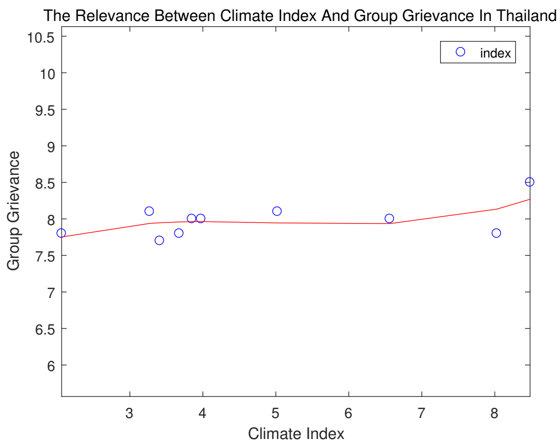

Figure 11: Thailand Group Grievance

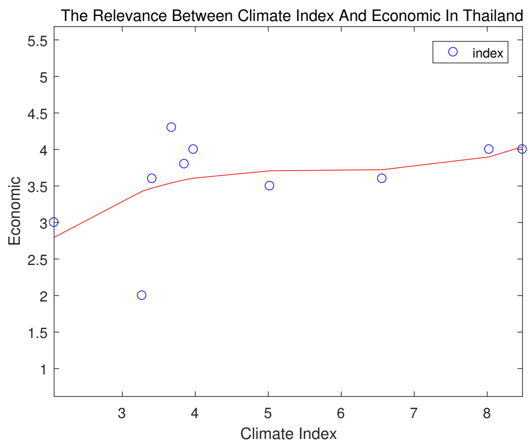

Figure 12: Thailand Economic

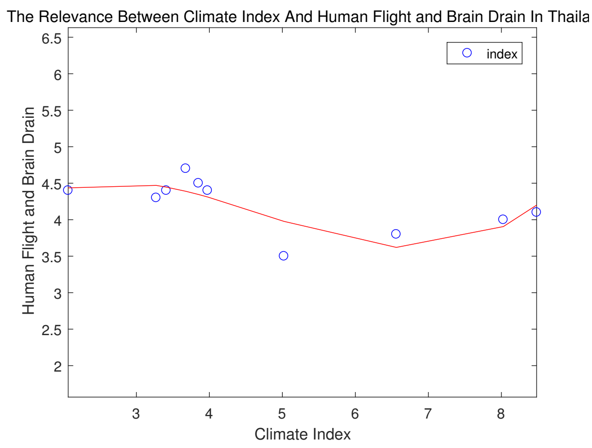

Figure 13: Thailand Human Flight and Brain Drain

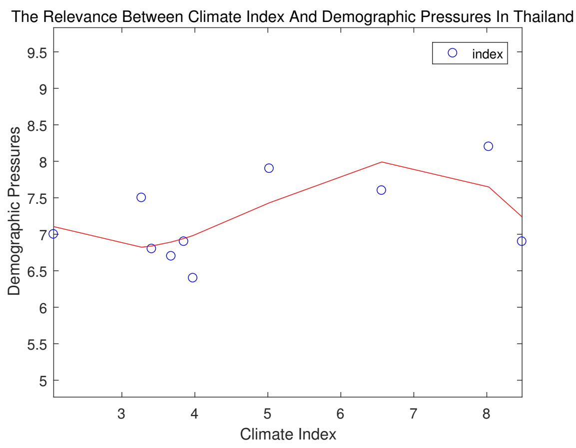

Figure 14: Thailand Demographic Pressures

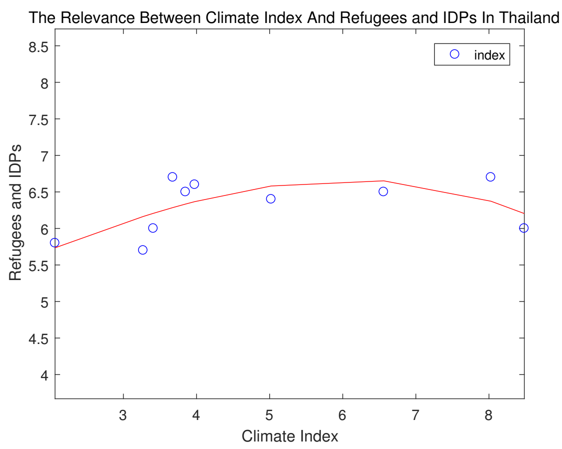

Figure 15: Thailand Refugees and IDPs

The figures above is the function model image which includes the relations between Group Grivence,Economy, Human Flight and Brain Drain,Demographic Pressures,Refugees and IDPs and climate index.We know climate index affects these five indicators and affects SFI directly. So we build a function between the other twelve indicators and the climate index. We use polynomial to fit function, here are the functions:

- Figure11:$p3 = 0.011x^3 - 0.1618x^2 + 0.7755x + 6.7763$
- Figure12:$p4 = 0.0173x^3 - 0.3018x^2 + 1.7595x + 0.2981$
- Figure13:$p6 = 0.0267x^3 - 0.3808x^2 + 1.481x + 2.7665$
- Figure14:$p10 = -0.0019x^3 + 0.0225x^2 - 0.0388x + 7.9812$
- Figure15:$p11 = 0.0096x^3 - 0.1825x^2 + 1.1831x + 3.9476$

p1=7.3,p2=8.8,p5=6.9,p7=6.5,p8=4.7,p9=7.2,p12=4.9,W=x,p3,p4,p6,p10,p11 function is above and each generates into $r_{ij} = \dfrac{|a_{ij} - \beta| - \min_i |a_{ij} - \beta|}{\max_i |a_{ij} - \beta| - \min_i |a_{ij} - \beta|}, i = 1, 2, ..., n.$ $\beta = 10$.(we ignore i

here)And we get r_1,r_2,...,r_{13},13 morms. r_1+r_2+...+$r_{13} \leq 4.3487$,then

$$-0.0055 \times x^3 + 0.0759 \times x^2 - 0.3954 \times x + 6.0118 \leq 4.348$$

,the answer is $x >= 9.5931$.So, when climate change is larger than 9.5931,Thailand will change from vulnerable to fragile.The index 9.5931 is the threshold.

3.3.8 Solution to Task4

Task4:
Here we build a model using China and we observe that there is no obvious positive correlation between Group Grivence,Economy, Human Flight and Brain Drain,Demographic Pressures,Refugees and IDPs and climate index.We can associate that it might have its root in that state human intervention lightened the risk of climate change.In fact, most data illustrates that the relation between the five factors which have relation with climate of most developed states and climate index is not obvious positive correlation.That the lightning of the threats of climate chage is caused by human intervention and state policies.

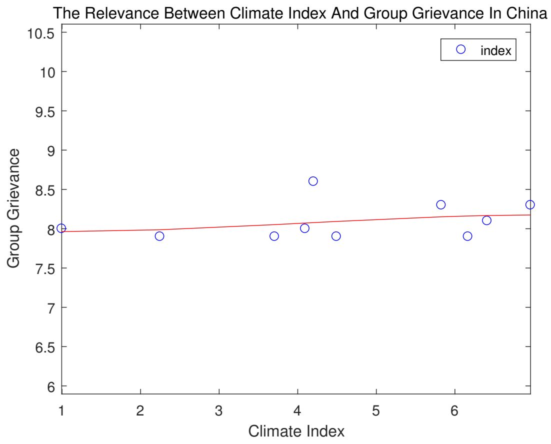

Figure 16: China Group Grievance

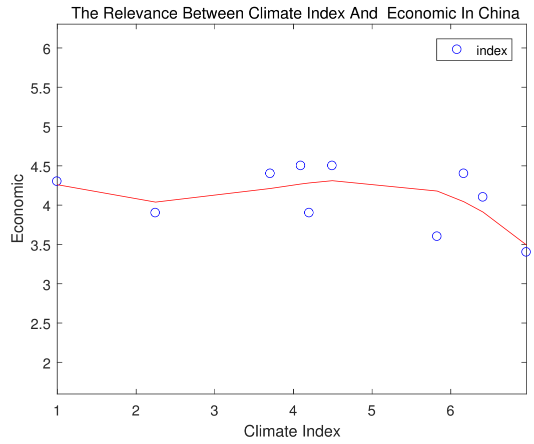

Figure 17: China Economic

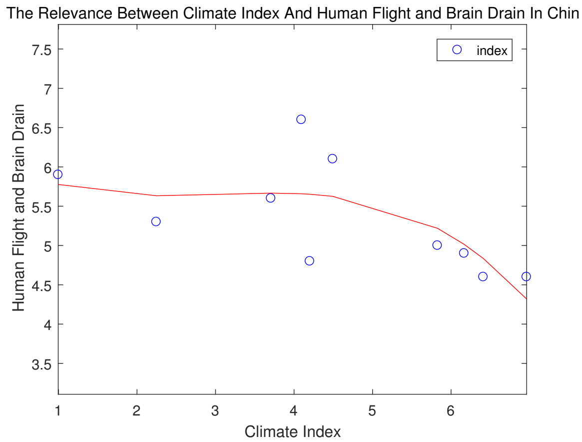

Figure 18: China Human Flight and Brain Drain

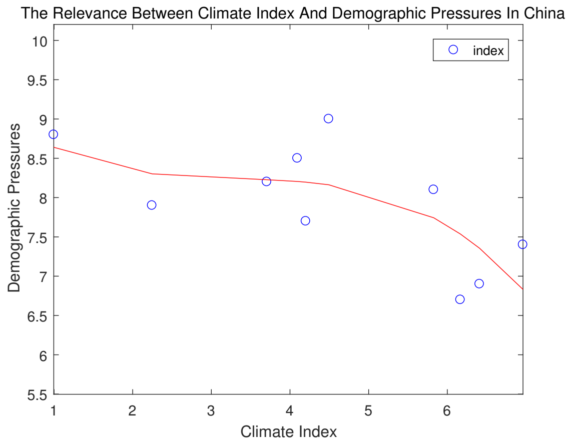

Figure 19: China Demographic Pressures

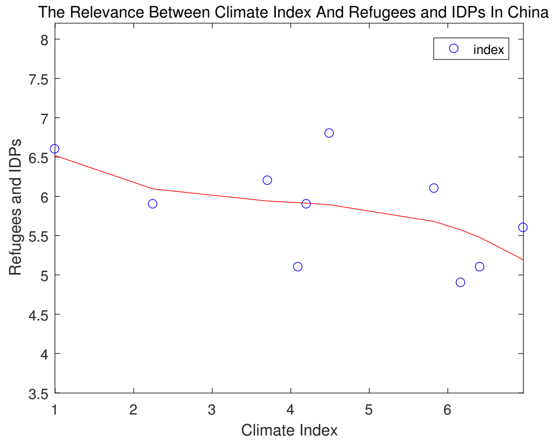

Figure 20: China Refugees and IDPs

The figures above is the model which includes the relations between Group Grivence,Economy,Human Flight and Brain Drain,Demographic Pressures,Refugees and IDPs and climate index.And we find the result is not positive correlation.On the contary, it tends to decline and it doesn't become more fragile with the climate index getting larger.This is the result of state intervention.Analyse each image and we can guess some state intervention measures.From the demographic pressures,we can believe that it's rooted in family planning policy.We search for the investment in family planning policy in China in recent years.

Table14:The investment of China in family planning policy

Year	Investment(hundred million)
1997	43.64
1998	50.4
1999	58.99
2000	64.51
2001	82.96
2002	114.71
2003	141.89
2004	183.67
2005	255.37
2006	244.76
2007	303.24
2008	364.01
2009	442.79
2010	587.94
2011	694.38
2012	812.85
2013	907.53

Tips:We are sorry that we can not find the data in year of 2014,2015,2016,2017 almost anywhere we look.
From the table we can find that the state strengthens the investment every year. We use the data from the year of 1997 to the year of 2010 to predict the data a few years later through MATLAB. We use a gray prediction model:We predict the data from 2011 to 2018.

Table14:The investment of China in family planning policy

Year	Investment(hundred million)
2011	700.2
2012	854.1
2013	1041.9
2014	1271
2015	1550.4
2016	1891.3
2017	2307.1
2018	2814.3

We use the data from 1997 to 2010 to predict the data from 2011 to 2018,and we compare the prediction from 2011 to 2013 with the actual data.
We predict the data from 2011 to 2018 using polynomial fitting through MATLAB

Table15:The predicted data from 2011 to 2018 using polynomial fitting through MATLAB

Year	Investment(hundred million yuan)
2011	671.926
2012	799.6029
2013	945.2734
2014	1110.3
2015	1295.9
2016	1503.4
2017	1734.3
2018	1989.7

We use the data from 1997 to 2010 to predict the data from 2011 to 2018,and we compare the prediction from 2011 to 2013 with the actual data.
Combining the two tables, the prediction accuracy of the polynomial fitting is larger, and it is predicted that in 2018, the state will invest 1989.7 hundred million yuan. For refugees and IDPs, with the increase of climate index, the function also shows a downward trend. We speculate that the reason is the improvement of the national social security system.We find the investment of national social security.

Table16:National social security investment over the years

Year	Investment(hundred million yuan)
2017	24812
2016	21548
2015	19001
2014	15913
2013	14490
2012	12585
2011	11109
2010	9130.62
2009	7606.68
2008	6684.83

From the table above, we can see that the annual investment in social security funds are increasing.We make a prediction on this.

Table17:The predicted data using polynomial fitting through MATLAB

Year	Investment(hundred million yuan)
2016	21434.8
2017	24451
2018	27861.2

We use the data from 2008 to 2015 to predict the data from 2016 to 2018,and we compare the prediction from 2016 to 2017 with the actual data.

Table18:The predicted data using gray prediction.

Year	Investment(hundred million yuan)
2016	21784
2017	25123
2018	28973

We use the data from 2008 to 2015 to predict the data from 2016 to 2018,and we compare the prediction from 2016 to 2017 with the actual data.
We find that the error value made through MATLAB is smaller.So we adopt the data predicted by MATLAB and the investigation will reach to 27861.2 hundred million yuan.

3.3.9 Solution to Task5

Task5: For smaller states, such as cities, considering the legitimacy of the country where the city is located in. The calculation of the fragility is still modeled and because of the frequent population movements among the smaller states, the climate index has a significant impact on brain drain and demographic pressures. With more pressure, smaller areas and more convenient external interventions, climate index has an impact on external interventions. Therefore, our model needs to enhance the impact of climate index on the population and its impact on external interventions. For larger states, such as continents, because of the different types of climates in different regions, the development of each region is very different. It would be very inaccurate to compute the economic index directly by calculating the climate index without considering the regional differences. Therefore, according to the different types of climates in the state, we divide different regions and construct each model for each region to calculate the fragility of different regions. However, there are still some indicators that we do not need in the all factors, and the economic inequality is a comparison. If a region covers several countries and the development level of a country is different, then this indicator will be unusually large. Therefore, we don't think about it.It's the same with state legitimacy. We only consider the remaining 11 factors, which divide the index for each indicator in each region.These indicators are weighted into this indicator index for the entire large state, specifically using population density weights (for example, a state is divided into three blocks with a population density ratio of 1: 2: 3, and the index of one indicator is 6,7 and 8. So the indicator index of the larger state is $\frac{1\times 6+2\times 7+8\times 3}{1+2+3}=7.333$ because these indicators are based on people, and the population in a region is very small, and even if the safety apparatus is not enough, it will not have a huge impact on the entire state. From the above-mentioned 11 indicators in this state, examine the economic inequality of the entire state, and calculate the national legitimacy of each country included in this state. Then we calculate the average of the 13 factors and apply it to our model. As for the seven factors other than the five factors influenced by climate index directly will not be influenced by climate index so great.

4 A Summary

We find that climate index can affect a country's fragility index directly and indirectly, but national interventions can mitigate the risks of such changes, and our model can guess what measures countries are taking. We can calculate the annual climate fragility index of each country by our model and classify it as one of stable, vulnerable and fragile. We can use models to illustrate the impact of climate index on a country and predict future impacts. A slight modification of our model can be applied to larger or smaller states.

5 Strengths and weaknesses

5.1 Strengths

Our model is a simple and practical one, so it is easy to deal with a huge amount of data. It has some rationality, and certain accuracy in the short term. Model construction method is not complicated and easy to work around in special cases.

5.2 Weaknesses

The situation is different every year and the number of countries and data is too large, and only some of the representative countries in a given year can be set as a representative model. When selecting some special countries in different years, it may not be consistent with the model and we need specific analysis.

Appendices

Appendix A First

References

[1] Baodong Liu ; Jie Su ; Jianliang Chen Mathematical Modeling Fundamentals ,Higher Education Press, 2015.

[2] http://fundforpeace.org/fsi/

[3] http://sdwebx.worldbank.org/climateportal/

[4] Han, Jun; Morag, Claudio The influence of the sigmoid function parameters on the speed of backpropagation learning:From Natural to Artificial Neural Computation., 1995: 195-201

Appendix B Second

Here are simulation programmes we used in our model as follow.

Input matlab source:

```
clc,clear;
syms a b;
c=[a b]';
A=[6684.83,7606.68,9130.62,11109,12585,14490,15913,19001];
B=cumsum(A);
n=length(A);
for i=1:(n-1)
    C(i)=(B(i)+B(i+1))/2;
end
D=A;D(1)=[];
D=D';
E=[-C;ones(1,n-1)];
c=inv(E*E')*E*D;
c=c';
a=c(1);b=c(2);
F=[];F(1)=A(1);
for i=2:(n+3)
    F(i)=(A(1)-b/a)/exp(a*(i-1))+b/a;
end
G=[];G(1)=A(1);
for i=2:(n+3)
    G(i)=F(i)-F(i-1);
end
t1=2008:2015;
t2=2008:2018;
G
h=plot(t1,A,'o',t2,G,'-');
set(h,'LineWidth',1.5);
```

```
yg=[8.1,7.8,7.9,8.0,7.8,8.0,8.1,8.1,8.0,8.5];
yh=[2.0,3.0,3.6,3.8,4.3,4.0,4.0,3.5,3.6,4.0];
yj=[4.3,4.4,4.4,4.5,4.7,4.4,4.0,3.5,3.8,4.1];
```

```
yn=[7.5,7.0,6.8,6.9,6.7,6.4,8.2,7.9,7.6,8.0];
yo=[5.7,5.8,6.0,6.5,6.7,6.6,6.7,6.4,6.5,6.7];

x=[3.2708,2.0654,3.4096,3.8503,3.6763,3.9755,8.0269,5.0215,6.5606,8.4832];

[x1,k]=sort(x,'ascend');
for i=1:length(x)
     yg1(i)=yo(k(i));
end
A=polyfit(x1,yg1,3)
z=polyval(A,x1);
plot(x1,yg1,'bo',x1,z,'r')
axis equal
```