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| Problem Chosen F | **2020 MCM/ICM Summary Sheet** | **Team Control Number** 2010652 |

Where to go next

As global warming is increasingly severe, many coastal countries are in danger of disappearing due to rising sea levels. In the face of the international problem of the resettlement of environmentally displaced persons, we establish models to help the UN address the multifaceted issue and propose policies concerning that how they should meet the challenge. We focused on the resettlement of climate refugees caused by global sea level rise and the protection of human rights and culture in the process.

In the first question, we use quadratic function to fit global mean sea level data from 1993 to 2017 to predict sea level rise in the 21st century. Based on the data provided by the World Bank on the global submerged area and the affected population corresponding to the rise in sea level, we obtain the growth curve of the number of EDPs in the 21st century. According to the ranking of the total greenhouse gas emissions of the countries in the world since 1990, we conclude that China, the United States and other major countries should shoulder the main responsibility for hosting climate refugees.

In the process of assessing cultural loss and analyzing factors affecting the protection of human rights, we quantify culture and use fuzzy algorithm to evaluate the cultural similarity of different countries. We also use analytic hierarchy process to measure the weight of each cultural element. In addition, we use human rights index to quantify human rights and Riemann closeness degree to calculate national similarity.

When analyzing the impact of policies, we use the four dimensions of effectiveness, rate of return, fairness and responsiveness to depict the impact of policies. We also analyze the impact of policies on national decision-making through game theory, and draw a conclusion that a sufficient punishment and reward is conducive to the country taking the responsibility of accepting refugees, and the implementation of human rights and cultural protection policies.

Finally, based on the established models and the results of analysis, we suggest that climate refugees should choose a country with high similarity as a resettlement country, which is beneficial to their cultural protection and human rights protection.

**Key words:** Climate refugees; Fuzzy algorithm; Analytic hierarchy process; Game theory

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# Introduction

## Background

With carbon dioxide emissions rising, global warming is increasingly serious. Recent decades have seen sea level rising. Several island nations, such as The Maldives, Tuvalu, Kiribati, and The Marshall Islands are facing a series of impacts of climate change, for instance, the reduction of the territory area, flood disaster and land salinization, etc. They are not only in danger of sinking but also face the challenges about cultural differences and human rights. Therefore, these environmentally displaced persons (EDPs) need to relocate as their homeland becomes uninhabitable. In fact, the term “climate refugees” is not legally valid as the 1951 Refugee Convention does not recognize environmental factors as criteria to define a refugee.

Recently, a UN ruling has opened the door to the theoretical recognition of EDPs as refugees. As the IPCC report says, if greenhouse gas emissions continue to rise, sea-level will rise at 1.1m by 2100 and low-lying coastal countries will be at risk of disappearing. It is necessary to design a reasonable model and analyze this complex issue of when, why, and how the UN should take action to address the problem on the increasing number of EDPs. In particular, the response system guidance should include the desire of protections of cultural heritage.

## Restatement of the Problem

Considering the background, it is essential to establish an appropriate model to solve out the problem including three core aspects, which are the relocation decisions, resettlement and cultural preservation, and time factors. At the same time, make accurate predictions about the size of it. Under the circumstance, we are consulted to help address the complex issue of the migration of climate refugees. our main work is as follows:

* Define the scope of the issue of EDPs. Based on the data we collected, we use time series to predict the time and number of climate refugees.
* Propose policies to address EDPs. We are supposed to take human rights and cultural preservation into account. The risk of loss of culture is characterized by the retention rate of national cultures. Considering the cultural differences, we establish a cultural optimization model to integrate the immigrant cultures and native cultures better.
* Describe the development of a model used to measure the potential impact of proposed policies. Explain how to design our models and how they do good to proposed policies.
* State the importance of proposed policies in light of our analyzation and results. Give advice on the migration of EDPs. Let most countries pay attention to the issue of EDPs. Explain who should shoulder more responsibility for assisting climate refugees and what other aspects should we capture to develop our models.

# Analysis of the Problem

Developing the response system for EDPs can be divided into four sub-problems.

**Problem 1:** We need to analyze the number of people at the risk of becoming EDPs. which requires us to know sea level rise. We first fit the collected data of global mean sea level to predict the sea level growth curve in the 21st century. By comparing the sea level data with the global elevation data, we can know the area of land to be submerged. And then we combine the data of global population density with the range of submerged land area to get the affected population. Considering the level of submerged different in different countries, not all affected people will become refugees seeking new homes in a foreign country, and some will find new homes through internal migration. We take the countries whose land will be seriously submerged, especially low-altitude island countries, as the key research object. And then we can predict the number of EDP based on their population.

**Problem 2:** We are expected to develop a model that is conducive to human rights protection and culture preservation. We need to develop a model that is conducive to human rights protection and cultural protection. We first need to quantify human rights and culture, which we characterize by human rights indices and cultural retention rates, respectively. The problem is simplified by analyzing the composition of the two indices and considering them as the weighted sum of many factors. When analyzing the factors affecting human rights index and cultural retention rate, we consider the country similarity and cultural similarity, and use fuzzy algorithm and analytic hierarchy process to give their quantitative model. We simplify the problem by analyzing the composition of the two indices and considering them as the weighted sum of many factors. When analyzing the factors affecting human rights index and cultural retention rate, we consider the country similarity and cultural similarity. Finally, we use fuzzy algorithm and analytic hierarchy process to build their quantitative model.

**Problem 3:** When evaluating the impact of policies, we analyze the effects of policies from four aspects: effectiveness, rate of return, fairness and responsiveness. In order to analyze the impact of policies on state behavior, we use game theory models to analyze state decisions and discuss the role of rewards and punishments in motivating states to fulfill their obligations.

**Problem 4:** Based on the principle of responsibility sharing, our policy advises EDPs on the selection of suitable countries for settlement, human rights protection and cultural protection. The aim is to address the following four issues: settlement, human rights protection, cultural protection and conflict of interest, which is the significance of our proposed policy.

# Symbols

Table 1 Symbols and Definitions

|  |  |
| --- | --- |
| Symbols | Definitions |
|  | The acceptability of country  receiving country |
|  | A country and region *i* |
|  | The population density of country *i* |
|  | A country’s respective greenhouse gas emissions |
|  | The number of people in country *i* who need to migrate to another country |
|  | T The country similarity between country  and country  The average distance between country  and country  The migration dispersion of country  The amount of EDPs that the country  is obliged to receive  The retention rate of culture |
|  | The willingness of people in country  to go to country |
|  | The retention rate of a certain item *i* in culture |
|  | The importance of a cultural category |
|  | The cultural value weight of a certain behavior *i* |
|  | The consistency index |
|  | The random index |
| *CR* | The consistency ratio |

# Simplifying Assumptions

1. It is assumed that coastal countries are unable to achieve internal migration to help EDPs, so the victims of rising sea levels are all climate refugees.
2. It is assumed that coastal countries don’t build dams to prevent flooding. If the sea rises, it will flood the country's land directly.
3. Assuming that the elevation of the land in this country increases gradually from the sea level to the middle of the land, the extent to which the land is submerged by the sea changes gradually with the height of the sea.
4. Sea levels are rising at a steady rate.
5. We suppose that the birth rate is equal to the death rate, and there are no people moving in and out for a long time.
6. The amount of cultural value that exists on the land of unit area is equal

# Model Design

## Model I: Growth model of EDPs

Our task is to explore the number of EDPs due to the sinking land. In order to solve this problem, we need to know how much land is flooded, because the earth's crust is not going to rise or fall dramatically in the short term, so we think that flooding is entirely due to sea level rise. We fitted historical sea level data from NASA.

### Sea Level Rise

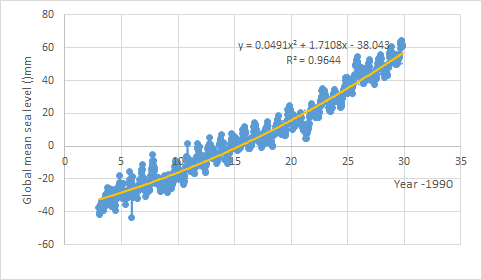


Figure 1 quadratic model

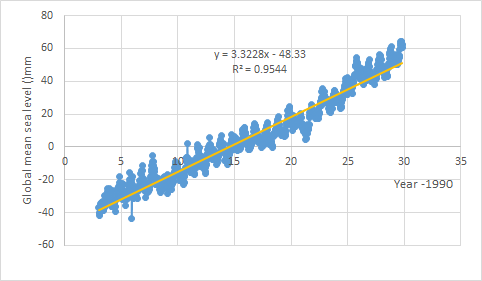


Figure 2 linear model

Obviously, the fitting effect of the quadratic model is better than that of the linear model. And the quadratic coefficient of the quadratic model is much smaller than the coefficient of first order. However, this small difference will lead to a big difference in the predicted future sea level rise. Given the dramatic rise in carbon dioxide emissions in recent decades in many developing countries, notably China, and the melting of glaciers as a result of global warming, we would prefer to use secondary models to fit the global sea-level rise data.

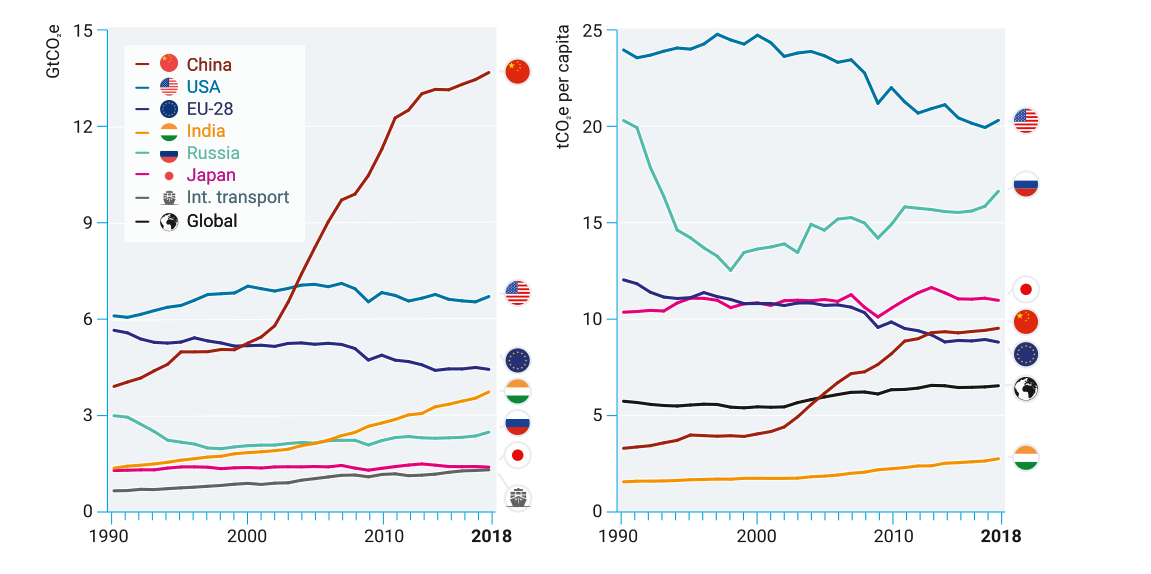


Figure 3 Emissions Gap report 2019 from UN[5]

IPCC pointed out that the global sea-level rise rate has been  mm/a since 1961, and since 1993 it has increased by mm/a. This confirms our suspicions, so we have reason to use quadratic model to fitting the data of global sea level rise.

The figure below sets the average sea level height in 2020 to zero as a reference plane to study future sea level rise relative to today. It shows the projected future mean sea level, which will rise by 0.728 m by 2100.

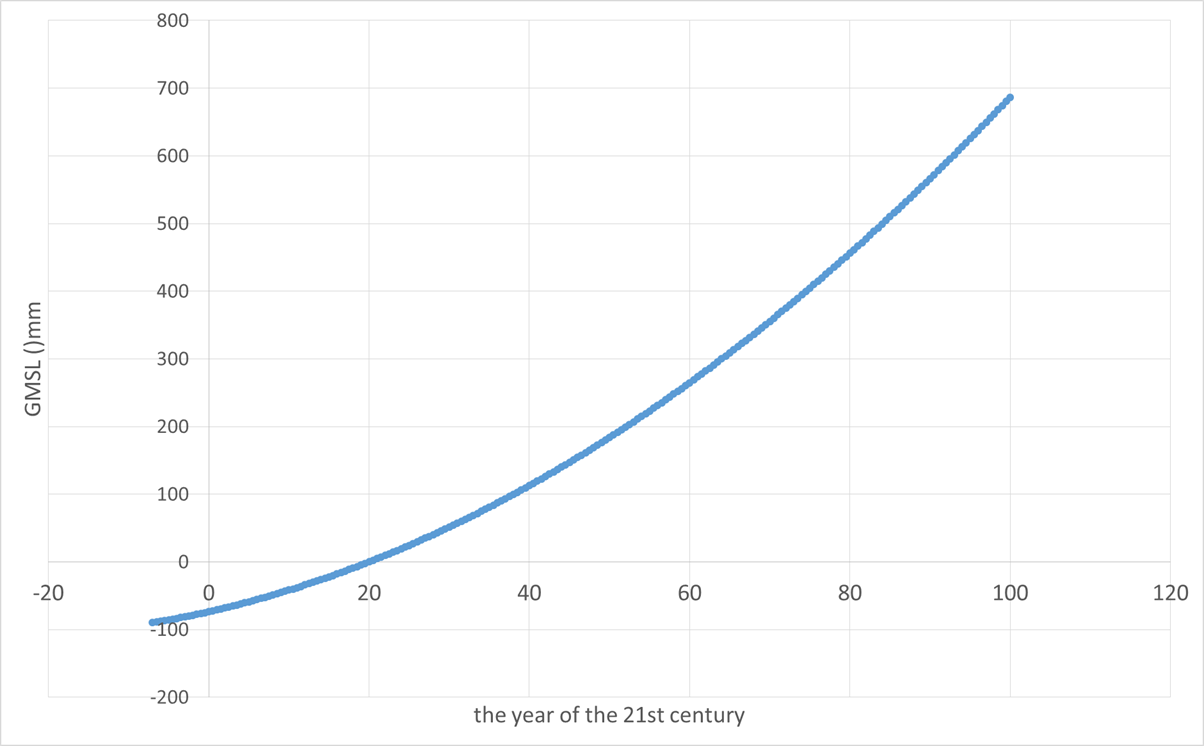


Figure 4 prediction of future mean sea level height

Although 0.728 m is a high figure, it is still an underestimate of the risk to rely solely on the comparison of this figure with land elevation data to calculate the submerged area. As we can see, the sea level data itself is subject to seasonal fluctuations, and the maximum value of such fluctuations should be added on the basis of 0.728 meters. Since the fluctuation itself is somewhat random, we replace it with the absolute value of the maximum residual value fitted by the data, so the most conservative estimate of sea level rise is:



Now we have a high prediction of future sea level rise, and what is the relationship between that height and the submerged area? We compared the elevation data of the global terrain with this height to determine which areas would be flooded. The accuracy of the SRTM 90m dataset from CIAT reached 90m, which can roughly estimate the global and subdivide the submerged area to each country or region. We are very fortunate that this work has been done. Dasgupta et al., back in 2007, gave us the area that would be submerged by a sea level rise of 1-5 meters19[6].

### People Affected by Sea Level Rise

This year, compared with 2007, the global mean sea level has risen by 4cm. We can correct for this error and fit their calculations to get the details. There are several reasons why it is difficult to give very precise estimates. The first is that future trends in climate and sea level rise are still highly uncertain; The second is that when we think about the risk of flooding we also have to think about astronomical tides and water levels in extreme weather conditions, which are very different on a global scale, and if we want to be precise we have to look at a lot of details, not averages; The third is that the global coastline topography varies greatly in slope, which makes it difficult to unify the change function of submerged area as sea level rises. Through observation, we find that with the rise of sea level, the change value of submerged area can be well fitted by a quadratic function. Combined with the global population density distribution, we can get the number of people affected by sea level rise.

Figure 5 Map of impacted area and sea level rise

Now we give the height of the sea level rise per decade, the area newly submerged and the population affected by the new increase, on a ten-year scale.

Table 2 several indicators

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 2030 | 2040 | 2050 | 2060 | 2070 | 2080 | 2090 | 2100 |
| Rising global sea level(mm) | 51.478 | 61.298 | 71.118 | 80.938 | 90.758 | 100.578 | 110.398 | 120.218 |
| Global new submerged area (sq.km.) | 5031 | 6047 | 7091 | 8169 | 9286 | 10446 | 11653 | 12912 |
| Increased global population affected (person) | 1063401 | 1300821 | 1556300 | 1832730 | 2133004 | 2460016 | 2816658 | 3205823 |

As can be seen from the table above, every ten years there are millions of people whose homes are flooded. But this does not mean that all of these people will have to move to other countries. They may be able to find new homes simply by moving within the country. It is only the populations of countries whose land area has been severely eroded that we should focus on, because they cannot resettle in their own countries. How much is the threshold for international migration when the land is submerged?

This is a problem affected by many factors. Some countries are large and sparsely populated, with high levels of economic development. Some countries have high population density and low economic level. In addition, different countries have different proportions of primary industry, secondary industry and tertiary industry. The more dependent the country is on the primary industry, the greater the dependence on land, so the greater the impact of sea level rise. For the above reasons, it is not convenient for us to directly give a uniform percentage of land inundation as the standard for the generation of displaced persons.

Only a small part of the land area of most coastal countries that are close to land is submerged, and the submerged area accounts for less than 20% of the land area when the sea level rises by one meter. We think that the population of these countries affected by sea water rise does not need to be relocated to other countries and is not included in EDPs. We list the countries most affected by sea level rise and the relevant data in the following table:

Table 3

|  |  |  |  |
| --- | --- | --- | --- |
| Country | Population (10 thousand) | Mean altitude(m) | Land area(sq.km.) |
| The Republic of Palau | 2.18 | 0.77 | 465.55 |
| The Republic of Nauru | Around 1.3 | Around 30 | 21.1 |
| The Kingdom of Tonga | 10.8 | Less than 30 | 747 |
| The Republic of Maldives | 44 | 1.2 | 90 thousand |
| The Kingdom of the Netherlands | 1726 | 321 | 41864 |

As we can see from the chart above, with so many people on the agenda for national relocation this century, which countries should host them?

### Optimization Model of EDPs’ Distribution

Because sea level rise is caused by the rise in temperature caused by greenhouse gas emissions, we believe that the responsibility should be apportioned according to historical carbon dioxide emissions. The following figure shows the combined greenhouse gas emissions of the world's major countries since 1990:

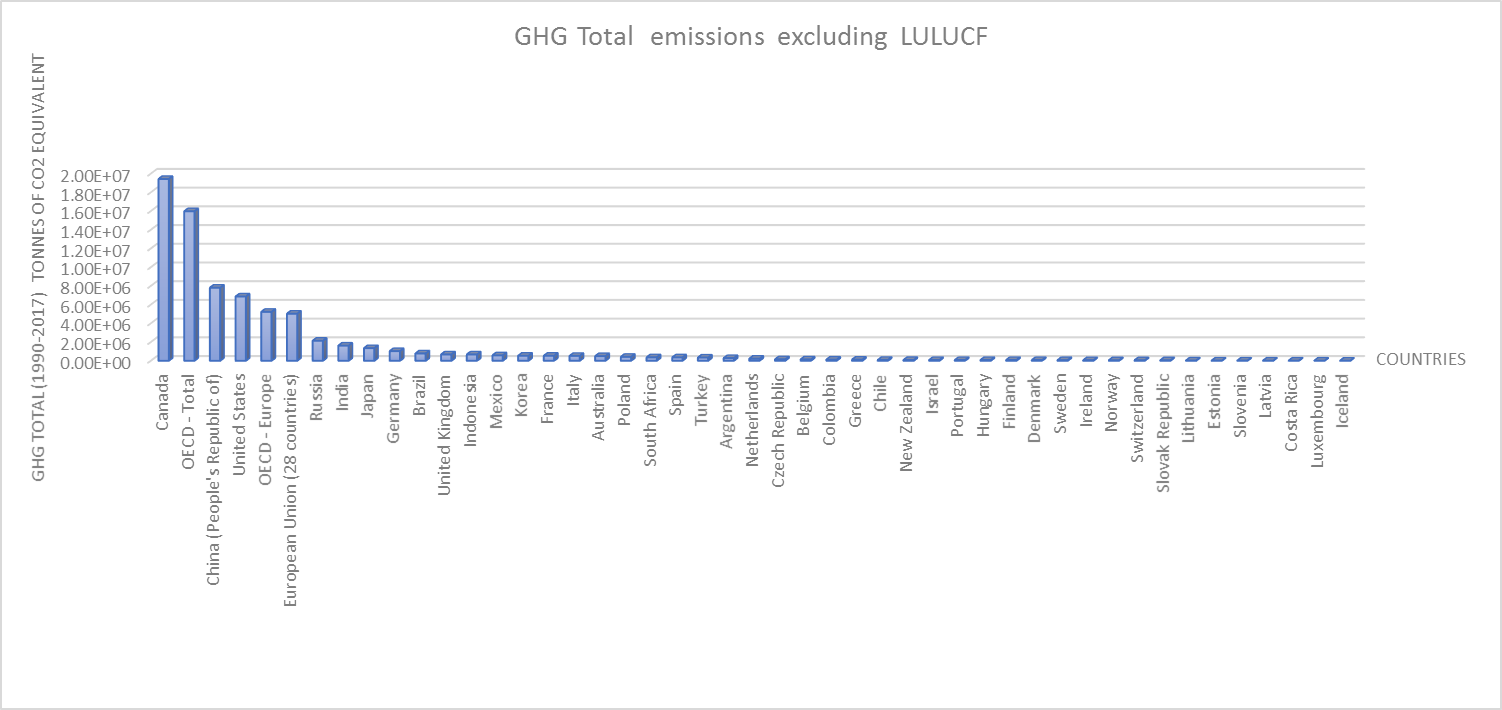


Figure 6 the combined greenhouse gas emissions of the world's major countries since 1990

We think that, on the basis of complying with the will of the EDP, countries have an obligation to provide accommodation in proportion to global greenhouse gas emissions. Countries are not allowed to reject EDPs’ entry applications until the number of asylum obligations has been reached. Although EDPs has lost their national territory and sovereignty, it has not lost its national independence and integrity. Therefore, we suggest bulk relocation. Citizens originally belonging to the same country go to the same country or several countries, instead of being scattered around the world. And countries with historically low emissions may not be able to take in enough of a country's inhabitants, even a small island state, in proportion to their obligations; These countries can then share their responsibilities in other ways, such as by providing aid funds.

**Steps:**

In order to allocate these EDPs reasonably, we establish the following optimization model.

Number each country and region as .

Their respective greenhouse gas emissions are .

The number of people in country *i* who need to migrate to another country due to sea level rise is . If there is no need to migrate to another country, it is set to 0.

The amount of EDPs that the country  is obliged to receive is 

The population density of country  is .

The country similarity between country  and country  is (as explained in detail below).

The average distance between country  and  is .

The willingness of people in  to go to  is .

We suppose there's a population in country  that wants to live in country  , which is, ie. .

Similarly, the acceptability of country  receiving country  can be defined as .

We set up a transfer matrix *T*,  is the number of people from country  to country .

Then the migration dispersion of the country  can be defined as 





We define the following optimization function.



s.t. 

The optimal migration matrix can be obtained by solving this equation.

## Model II: Model of Cultural Loss

### Cultural Classification and Loss of Culture

We have a simple culture classification for our purposes.

Firstly, culture can be divided into material culture and intangible culture. Material culture can be divided into portable and non-portable categories. The intangible cultural category can be divided into the behavioral category and the non-behavioral category.

Next, we define cultural damage. A material class is defined as damaged when it is damaged or lost. The destruction of intangible culture is defined as follows: for the culture of behavior, when all or most of the people in the nation lose the ability to perform the behavior or have the ability to perform the behavior but fail to happen after a certain year, the cultural behavior has been lost; A non-behavioral class is defined as a lost state when the culture is forgotten and unsearchable.

### Quantify culture

Because different countries have different populations, different areas and different cultural forms, their value cannot be compared with material richness and commercial value. In material terms, the total value of the culture of a large country is much greater than that of a small island country. In order to measure culture easily, we use the retention rate of national culture in this question to describe:



Where  represent the retention rate of culture, the retention rate of a certain item in culture, and the importance of this cultural category. The sum of  is equal to 1.  can be obtained by investigating a nation's evaluation of the importance of different cultural categories. We can consider different cultural categories equally important in the absence of a survey:



Refine  further, the formula is as follows:



In analogy,  is the cultural value weight of the behavior, and is the retention rate of the behavior. In a similar way, the sum of  is equal to 1.

We suppose  represents the retention rate of behavioral cultures. ( *j* = 1,2,3,…) represents the retention rate of various behaviors in , such as languages, festivals, life habits, etc. If the classification reaches a level, and the level cannot be subdivided, the retention rate of a factor *Q* in this level can be calculated by the following formula:



Where  refers to the number of people who retain a cultural behavior before migration, while  refers to the number of people who retain the behavior after migration.

Similar retention rates are calculated for other cultural categories. If *P* is non-behavioral and *Q* is assumed to be an identifier, then  is the total number of identifiers retained after migration, and  is the total number of identifiers existed before migration.

Due to the large number of cultural categories in this study, we do not discuss the two factors of language and behavior. We need to study the loss of culture in the process of national migration, which is to discuss what factors affect the behavior or language of these characteristics, what conditions will lead to the retention and acceptance of a behavior or a language, and what factors will limit it.

### Degree of Cultural Similarity & The Feasibility of Cultural Behavior

In our opinion, the more similar a behavior is to the cultural behavior of the local residents in the place of migration, the more likely it is to be retained. For example, when people from both countries choose to shake hands, the culture of shaking hands will be retained. A thumbs-up is a compliment in some countries, a derogatory gesture in others. Different but not conflicting depending on the enforceability of the act, for example people in one country like fishing, moving to a dry landlocked country is difficult to achieve and the cultural act of fishing cannot be preserved.

We set up the following set of comments to depict the degree of cultural similarity.

Table 4 degree of cultural similarity

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Similarity | Quite the same | Very similar | Different but not conflicting | generally conflicting | severely conflicting |
|  | 1.0 | 0.8 | 0.5 | 0.2 | 0 |

Similarly, we use a collection of comments to describe the feasibility of cultural behavior.

Table 5 the feasibility of cultural behavior

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Feasibility | Completely feasible | Very feasible | Generally feasible | Slightly limited | Severely limited |
|  | 1.0 | 0.8 | 0.5 | 0.2 | 0 |

The cultural retention rate is a function of *f* and *s*. The function is as follows:



Where *e* represents a random quantity. We take into account that culture itself can also decline or develop.

As the cultural retention rate is the weighted sum of each cultural subclass, the cultural retention rate is a function of the cultural similarity between the immigrating nation and the local residents of the place of migration. In other words, the higher the cultural similarity is, the higher the cultural retention rate is, with other factors unchanged.



In the formula above,  is the cultural retention rate of the part of culture that can be transferred with the national migration, *s* is the cultural similarity, and *E* is the part explained by other factors.

Immovable culture, such as buildings, will be submerged by the sea, but it does not mean total damage, and may be partially eroded by the sea. But the seabed remains its cultural value, so the retention rate of immovable culture is not equal to zero, so



Where 

 is the retention rate of the sunken part.  indicates the retention rate of the unsunk portion.  means no submerged area, and  is the area of the country before it was submerged.

How to depict cultural similarity? We divide culture into subclasses one by one, and the similarity of each subclass can be given by comparing and referring to the above comment set in a very specific way, and the analytic hierarchy process can be used to obtain the total cultural similarity.

Comment sets are used in the above modeling process. They contain many subjective factors, which can be dealt with by fuzzy algorithm.

**Method:**

When evaluating the cultural similarity of a certain cultural category at a certain level, it is assumed that there are *i* cultural subclasses that participate in the assessment of cultural similarity, and each subclass is rated with five levels. It is assumed that  is the percentage of the number of people who give grade *j* to the *i*th cultural category. Then we can get a rating matrix of *i* row *j* column, called fuzzy matrix *R*.

Suppose , , and the fuzzy matrix



is called the composition of *A* and *B*, where .

Suppose the weight vector of I subclasses is . Calculate  and get vector , and compare the element size of vector *C*. The subscript corresponding to the maximum value is the rating of the cultural category.

The above method can be used to measure the overall cultural similarity between two countries or nations, but sometimes we may prefer to retain some part of the culture when we choose the destination of migration, so it is necessary for us to come up with an algorithm to measure the relative importance of different cultural subclasses. As mentioned earlier, cultural subclasses have different value weights, and here we will give a systematic method for obtaining this weight.

We can use analytic hierarchy process to measure the relative importance of culture. We set three levels of norms to measure the relative importance of culture: cohesion, order, and value.

**Method:**

Suppose that there are several subclasses of a culture class, now we want to evaluate the weight of *i* subclasses. Then we can first compare these subclasses in pairs, and let  represent the importance of subclass *i* relative to subclass.

Table 6 The meaning of scale

|  |  |
| --- | --- |
| Scale | Meaning |
| 1 | Two factors are of equal importance |
| 3 | The former is slightly more important than the latter |
| 5 | The former is obviously more important than the latter |
| 7 | The former is more important than the latter |
| 9 | The former is more important than the latter |
| 2,4,6,8 | Represents the intermediate value of the above adjacent judgment |
| reciprocal | If the ratio of the importance of *i* to *j* is , then the ratio of the importance of *j* to *i* is |

Then you get the judgment matrix .

Find the maximum eigenvector  of A. At the same time, the eigenvector *t* is obtained, and the values of each element of the eigenvector represent the relative importance of each subclass.

**Step1: calculate the consistency index **



Step2: find the corresponding average random consistency index *RI*.

For *n* = 1, …, 9, Saaty gives the value of *RI*, as shown in Table 7.

Table 7 The Value of *RI*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|  | 0 | 0 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 |

**Step3: calculate consistency ratio** *CR*



When , the consistency of the judgment matrix is considered acceptable, otherwise the judgment matrix should be appropriately modified.

In the section of cultural classification, we divide the differentiation into multiple layers. We only need to assign weights to them layer by layer and multiply the weight layers to obtain the total ranking of all the lowest cultural categories.

### Discussions on Cultural Preservation

In light of the above analysis, it can be seen that the retention of culture is closely related to the degree of cultural similarity. When choosing a country for migration, we try our best to choose a country with a high degree of cultural similarity, but sometimes it is difficult for us to make the optimal arrangement due to international politics and other reasons. Because we recognize survival as our most important consideration, we sometimes accept less important choices. But this does not mean that culture will be lost. In the above functional relationship, the rate of cultural turnover is also related to the feasibility of cultural behaviors, which is largely influenced by artificial policies.

The rate of cultural loss is also related to the mutual tolerance between the two. If the two sides have more understanding and tolerance, the culture will have more space to retain. If the receiving country prohibits the settlers from carrying out the activities of the original cultural customs, in the long run, the culture of that behavior will be forgotten.

When we assess the risk of cultural loss, we need to consider the country to relocate residence and the policies of the government in that country. If the country of immigration carries out strict policies on the immigrants, or even persecutes and forcibly assimilates them, the national culture of the immigrants may be seriously lost.

Therefore, it is very important to do a good assessment of cultural loss when choosing the place of relocation, and it is also important to negotiate policies between the two sides.

## Model III: Model of Human Rights protection

### Human Rights Index (HDI)

Human rights involve many kinds of rights, just like when we study culture, we need to do some classification and simplification, and choose some parts of them as the main research object. First, we need to set a quantitative indicator to reflect the degree of human rights protection, and we choose the human rights index as this indicator. Human rights index can be further divided into freedom index, education index, human rights development index.

Human rights branch offices that assess the prospects of migrants entering a country need to consider the following factors. The first is the level of the country's own human rights index, the second is the level of the rule of law index, the third is the openness and inclusiveness of the country, and the fourth is the similarity between the countries of origin and the receiving countries of the immigrants.

We select several indicators as the factors to describe the similarity of countries, including population density, per capita GDP, dimension values, the annual average temperature, average elevation, cultural similarity, which are explained in detail in cultural risk analysis section), and other indicators of climate and economic factors, the value of the same country of different indexes into a line, write the same index value in different countries in a column structure matrix. The following formula is used to standardize the matrix:



Where 

If U is a real number domain, the integrand function is Riemann integrable and the generalized integral converges.





***U*** is a vector of different indicators for each country. A(u) and B(u) of u are the corresponding normalized values. N (A, B) is the Riemann closeness of country A and country B. Subscripts refer to different calculation methods. There are two methods. The greater the value, the greater the similarity between the two countries.

### Discussion

Imagine a farmer in agricultural country to a developed country but there was no land, the difficulty of solving the employment problem. It is easy to prove that EDPs in countries with high cultural similarity are easier to find work, to communicate with people, and more able to adapt to the local culture and law. Therefore, human rights are more likely to get the guarantee.

However, the protection of human rights comes at a price, which requires the receiving country to provide certain economic expenditure and management input, to provide job opportunities and educational resources. Driven by the pursuit of interests and selfish rationality, the receiving country may make irresponsible and even violation of human rights policy decisions. Prevention of terrorism also limits the freedom of the settlers. The expansion of nationalism will lead directly to the violation of EDP's human rights. Therefore, our human rights protection policies are designed to address these factors of violation and make requests to the governments of receiving countries.

## Model IV: Policy Assessment Model

This policy aims to solve the settlement of climate refugees, human rights protection of climate refugees and cultural protection of climate refugees. The stakeholders involved in this policy are climate refugees, governments of receiving countries and citizens of receiving countries.

The policy, which should be overseen by the United Nations, proposes that countries share responsibility for accepting refugees on the basis of their historical total greenhouse gas emissions, based on the causes of climate warming and sea-level rise. The policy proposes that receiving countries take measures to protect the human rights and culture of climate refugees. The goal of the policy is to enable climate refugees to settle and adapt to life in host countries, to have their human rights protected and their culture respected and protected.

### Policy Assessment Criteria and Methods

* Effectiveness assessment: The number of climate refugees accepted by each country is counted, compared with the number of those who share their obligations, and the acceptance rate is defined as the ratio of the number of people actually accepted and the number of people who should be accepted. To investigate the degree of completion of human rights indicators related to the number of climate refugees who have homes in the receiving country, the employment rate, the school attendance rate of children, etc.
* Cultural retention: The cultural retention rate is assessed by investigating the frequency of language use, the frequency of cultural behaviors such as festivals, and the completion rate of cultural items carried.
* Rate of return assessment: The per capita investment of the receiving country in climate refugees is calculated (the non-financial element is converted into the corresponding fund), the life satisfaction of climate refugees in the receiving country is investigated, and the ratio of the latter to the former is calculated after normalization to evaluate the policy yield rate.
* Equity assessment: to calculate whether the total expenditure of the receiving country, converted from financial and other related resource inputs, is balanced with the tax revenue and international aid and other compensation generated by climate refugees in the receiving country.
* Responsive assessment: to assess the impact and effectiveness of policies by gathering feedback from people around the world on policies, as well as from host governments and climate refugees.

The above method directly measures the results of various indicators after the implementation of the policy, but it cannot show how many of the values in the results are generated by the policy. We need a control group to compare in order to get the pure impact. So far, the case of which country has been flooded and fled to other countries is only in the forecast. If our policy is adopted by the United Nations, the relocation of refugees and the consequences of the relocation will occur together with the implementation of the policy. Therefore, we cannot directly obtain the effect of the policy, because there is no control group that relocates to other countries before the implementation of the policy. In fact, even if there is such a control group, it is difficult to serve as a control group because the countries of origin and the countries of reception are different, so we don't know how high the cultural retention rate and human rights index of climate refugees are when they migrate without our human rights protection policies and cultural protection policies.

We need to assess not only the impact of policies on the human rights and culture of climate refugees, but also the impact of policies on receiving countries. Besides the impact of increased financial expenditure, can a more friendly and liberal human rights protection policy increase the GDP and reduce the crime rate of the country in the short term? Will a strict lack of protection of human rights lead to a stable social order or more conflict between the two peoples? We cannot compare the impact of different policies on climate refugees in the same country in two batches, which is inhumane.

### The Game Score Table

In view of the above analysis, we cannot obtain the impact of the policy itself, but we can measure the direct results of human rights parameters such as the employment rate of refugees after the implementation of the policy, and cultural retention parameters such as the frequency of language use in the country of origin.

Now let's look at the impact of our policies on the behavior of countries towards refugees from the perspective of game theory. In the absence of a policy we assume that countries are unwilling to accept refugees out of self-interest. We assume that there is an island country C that is affected by sea level rise and needs to be relocated, and that there are two major countries A and B that are capable of hosting the residents of country C. We assume that if there is no country hosting C, then C will choose a random country to start a war, resulting in a large loss of power. We give the game score table.

Table 8

|  |  |  |
| --- | --- | --- |
| Score | Country A receiving | Country A refusing |
| Country B receiving | （-0.5, -0.5） | （0, -1） |
| Country B refusing | （-1, 0） | （-2, -2）\*0.5 |

It can be seen from the table that when country A does not know the decision of country B, his strategy of refusal is the best. When it comes to countries around the world, they are less likely to be the subject of a war by islanders, so most countries in the world choose not to accept islanders.

All countries are willing to accept refugees if our policy can provide a sufficient penalty for countries that do not accept climate refugees in accordance with their obligations, and we revise the score table as follows.

Table 9

|  |  |  |
| --- | --- | --- |
| Score | Country A receiving | Country A refusing |
| Country B receiving | （-0.5, -0.5） | （-3, -0.5） |
| Country B refusing | （-0.5, -3） | （-3, -3） |

Similarly, we can give the following score matrix for whether to choose to implement human rights protection policy and cultural protection policy:

Table 10

|  |  |  |
| --- | --- | --- |
| Score | The receiving country protect | The receiving country does not protect |
| Refugees obey | （-1, +1） | （0, -1） |
| Refugees against | （-1, +1） | （-2, -2） |

It can be seen from the above table that no matter whether the receiving country chooses to protect or not protect the human rights and culture of the refugees, the refugees will choose to comply, and the loss of non-protection is minimal for the receiving country, so the receiving country is unwilling to adopt the policy of protecting human rights and culture.

If our policy provides adequate incentives and compensations to countries implementing protection policies, the score table can be modified as follows:

Table 11

|  |  |  |
| --- | --- | --- |
| Score | The receiving country protect | The receiving country does not protect |
| Refugees obey | （+1, +1） | （0, -1） |
| Refugees against | （+1, +1） | （-2, -2） |

As you can see from the table, the receiving congress chooses to implement the protection policy. From the above analysis, it can be seen that in order to better protect the human rights and culture of climate refugees, the United Nations should implement corresponding incentives and punishments to ensure that other countries are willing to accept refugees and provide human rights and cultural protection in accordance with their obligations.

# Sensitivity Analysis

# Strengths and Weakness

## Strengths

* In order to simplify the calculation of Model I, we ignore the influence of complex factors in the process of modeling. We use sea level rise data from 1993 to 2019 over a 27-year period to simulate sea level rise over time and to predict future sea level rise.
* We quantify culture when we think about culture preservation. Similarly, we give the parameter of country similarity and give its calculation formula, which reduces the influence of human factors.
* We use the four dimensions of evaluation to analyze the effect and influence of policies, and use the game theory to analyze the impact of policies on the behavior of states.

## Weakness

* Because the algorithm we used in the modeling is simple, the self-cycling process of the sea level itself is ignored. The prediction of future sea level rise is inaccurate because we ignore many factors such as variation in the rate of glacier dissolution.
* The evaluation of cultural similarity and other indicators is greatly influenced by human factors. The human rights index still contains many dimensions and it is difficult to collect complete data. It is a challenge to analyze problems.
* We cannot set up a control group to compare the gains of proposed policies for climate refugees.

# References

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# Appendix

## Data

1. Global mean sea level data

Source:

NASA. https://podaac-tools.jpl.nasa.gov/drive/files/allData/merged\_alt/L2/TP\_J1\_OSTM/global\_mean\_sea\_level

1. World sea-level rise dataset

Source:

The WORLD BANK. https://datacatalog.worldbank.org/dataset/world-sea-level-rise-dataset

1. Population density

Source:

OECD. <https://stats.oecd.org/>

1. Greenhouse gas emissions data

Source:

OECD. <https://stats.oecd.org/>

## Program

% core code for calculation of estimation of culture similarity

% R Fuzzy matrix

% A The weight vector of subclasses of culture

[a,b]=size(R);

[c,d]=size(A);

for i=1:c

for j=1:b

x=R(:,j);

y=A(i,:)

C(i,j)=max(min([x';y]));

end

end

% A comparation matrix of evaluating the importance of subclasses of culture

E=eig(A);

[V,D]=eig(A);

[max\_lambda,I]=max(E);

t=V(:,I);

w=t./sum(t);

%w the weight of all the items in the same grade of subclasses of culture