A dynamic model of the refugee crisis

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Abstract. Markov Chain is used for creating a dynamic model of the refugee crisis. we assume that refugees move dynamically between destinations with the transition probabilities which rely on the environmental factors. The model is applied to the current EU refugee crisis, and we obtain the dynamic process of refugee number varying with time in different member states. Then it indicates that the number of refugees in the member states will become a stable value after a certain period of time.

Introduction

Recently, the European refugee crisis continues to simmer. A large number of refugees board Europe，causing serious impact on Europe's political, economic and security fields. [1] The influx of refugees with a large scale shows the characteristics of the geometric level of digital growth. [3]

The model is established to describe the dynamic process of refugee flow under the conditions of the total number of refugees and the number of refugees to be received by the receiving countries being known. And then we determine the appropriate entry speed of refugees.

First of all, we use the Markoff chain method, taking the current number of refugees in each country as a state. Then, the probability of the refugees from receiving country i transferring to receiving country j form the state transition matrix $\mathbf{P_{ij}}$, here $P_{ij} = k \cdot \left(\frac{x_{jm} - x_j}{x_1 + x_2 + x_3} \right)$.$\boldsymbol{p_{ij}}$ is proportional to the largest refugee reception of country j ,and inversely proportional to the total number of refugees to be allocated and the current number of refugees of country j. A group of the current number of refugees can determine a group of state transfer matrix, after several iterations, the final number of refugees will reach a stable state. And the process of the change of the number of refugees in the process is the dynamic process of refugee flows.

Then, we get the transfer matrix and the number of refugees under the final stable state.Conversely, as long as the refugees enter the country at the specific speed that should meet the number of refugees under the stable state, the country can avoid the refugee crisis. This entry rate is the optimal rate of entry for the refugees to move.

In the following introduction, we illustrate the feasibility of this model with a concrete example.

The Example

EU interior ministers have approved a controversial plan to relocate 120,000 migrants across the continent over the next two years. In these 12,0000 refugees，15,600 from Italy, 50,400 from Greece, and 54,000 from Hungary. The number of migrants EU countries being asked to take is shown by Fig. 1 [2]

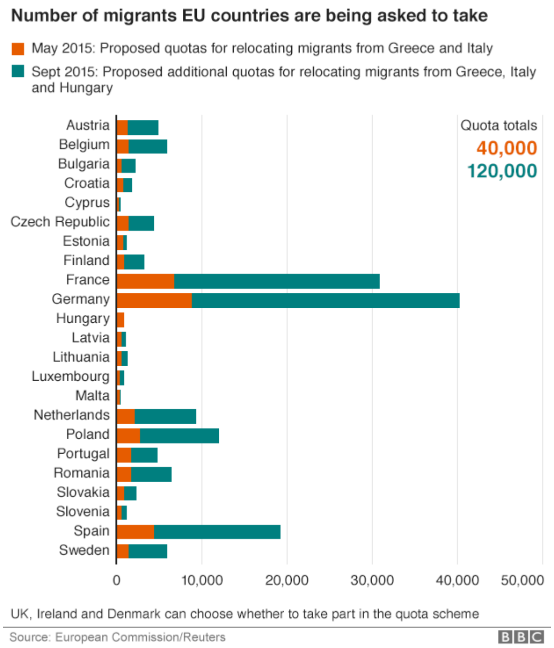

Fig. 1: Number of migrants EU countries being asked to take

Numerical Calculation

In order to simplify the model, we make some reasonable assumptions as follows:

- Due to the refugees of the initial state are concentrated in Italy, Greece, Hungary, therefore in the process of refugee transfer, there are no refugees transferred from other regions to the three regions
- Assuming that the refugee receiving countries only contain Germany, France, Spain, Poland, Others, and the initial number of refugees of these states are zero
- Assuming that 120,000 refugees have entered the area in full, no refugee will enter the area formed by these countries.

The Concrete Steps of Analytic Hierarchy Process

Step1 Divide the forecast object's state. Taking the number of refugees of each country as a state, we get 8 states that the number of refugees of eight areas including Greece, Italy, Hungary, Germany, France, Spain, Poland, and Others (x1~x8). And the initial state is (15,600 50,400 54,000 0 0 0 0 0)

Step2 Calculate the initial probability. According to the Equ(1.1), we calculate the initial state transition matrix.

$$P_{ij} = k \cdot \left(\frac{x_{jm} - x_j}{x_1 + x_2 + x_3} \right) \tag{1.1}$$

Step3 Calculate the probability under the steady state. We are trying to reach a steady state, in this state: X·P=X. We can determine the value of a group of probabilities according to a group of status by Equ(1.1), then we take several times of iterative calculation and finally obtained the transfer matrix under the steady state:

$$P = \begin{bmatrix} 0.9000 & 0 & 0 & 0.0337 & 0.0260 & 0.0159 & 0.0100 & 0.0144 \\ 0 & 0.9000 & 0 & 0.0337 & 0.0260 & 0.0159 & 0.0100 & 0.0144 \\ 0 & 0 & 0.9000 & 0.0337 & 0.0260 & 0.0159 & 0.0100 & 0.0144 \\ 0 & 0 & 0 & 0.3369 & 0.2597 & 0.1590 & 0.1001 & 0.1443 \\ 0 & 0 & 0 & 0.3369 & 0.2597 & 0.1590 & 0.1001 & 0.1443 \\ 0 & 0 & 0 & 0.3369 & 0.2597 & 0.1590 & 0.1001 & 0.1443 \\ 0 & 0 & 0 & 0.3369 & 0.2597 & 0.1590 & 0.1001 & 0.1443 \\ 0 & 0 & 0 & 0.3369 & 0.2597 & 0.1590 & 0.1001 & 0.1443 \end{bmatrix}$$

At the same time, in the process of iteration, the state is constantly changing. Here we make a state change chart of the number of refugees of eight countries, as the following Fig. 2 showing:

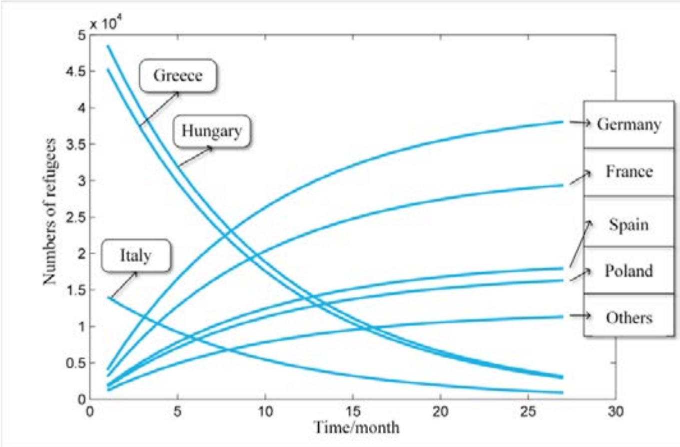

Fig. 2：Changes in the number of refugees of eight countries

Conclusion

In the model, the initial number of refugees in each state will directly influence the dynamic process of refugee number in different member states. With a 5% growth of the initial state respectively, the dynamic process of refugee number tends to change correspondingly. We change the initial state for three times, and the changes of the number of refugees are shown in the Tab. 1. Here we only show the changes of Greece, Italy and Hungary as other countries are similar to these states.

Tab. 1: The range of change in different situations

	The first time	The second time	The third time
Greece	0.3780~0.0244	0.3630~0.0235	0.3969~0.0256
Italy	0.1170~0.0076	0.1118~0.0072	0.1131~0.0073
Hungary	0.4050~0.0262	0.4252~0.0275	0.3900~0.0252

As can be seen from above, the result change slightly as the initial state changes, so we can come to the conclusion that the model is feasible and has great credibility.

References

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