Problem Chosen	2023HSB MCM/ICM Summary Sheet	Team Number
B		00638

Prediction of instability via Social Stability Early Warning Model

Colour revolutions, a political term referring to mass protest movements of people following national elections in the 1980s-2010s due to electoral opacity, electoral fraud or other political events, not all of which are revolutions in political science[1]. In recent decades, with the vagaries of economic, politics, and natural factors, various color revolutions have erupted. Social unrest has taken place and the stability of societies has been seriously challenged. Overcoming crises is not an easy task in the modern society where crises are getting increasingly frequent and intense. Therefore, we have developed a social stability early warning model with a view to using known social conditions to predict whether a society will experience greater unrest or even collapse in the coming period.

In this essay, we used subjective judgment combined with knowledge of related disciplines to determine the weight vector, and selected seven factors, including GDP（per capita）, GDP growth rate（per capita）, unemployment rate, college enrollment rate, CPI (Corruption Perceptions Index), inflation rate, and the number of integrated crisis from both qualitative and quantitative perspectives to establish a system of social stability indicators. After that, we used machine learning algorithm, TOPSIS method and GM (1,1) model to establish our social stability early warning model with high confidence. The model can distinguish the degree of social stability into three states: stable, medium, and unstable by calculating a society's composite score.

At first, we used the AHP method and the entropy weight method to determine the weight of each evaluation index, but the obtained model evaluation effect was unsatisfactory. Therefore, we used machine learning algorithms such as decision tree, random forest, and gradient boosting decision tree to learn and judge the training data, select the machine learning algorithm with best prediction effect, and obtain the weight of each index from it, so as to optimize our TOPSIS model. Finally, we chose a random forest model with recall and accuracy as the evaluation indicators, and used its weight vector as the weight vector of TOPSIS model. Meanwhile, the random forest model has 77.7% recall and 78.4% accuracy, which can also be a good early warning model for social stability.

For the available data, the countries and periods judged as "unstable" by the TOPSIS model covered 9 color revolutions and the rest two color revolutions were covered in the countries and periods judged as "medium". Combining our existing TOPSIS model and the GM (1, 1) model, we gave a forecast of social stability in Azerbaijan in 2023 and explained it with specific predicted values.

In addition to predicting the social unrest, we are also able to make contributions to the maintenance of social peace and stability by making more constructive recommendations on the current social development through the model. After adopting the suggestions given by the model, we made appropriate modifications to the existing data according to the results and found out that the social stability index is more inclined to the social stability result than the original one, which also reflects the feasibility and correctness of our suggestions.

Keywords: social stability, TOPSIS, random forest algorithm, GM(1, 1) model

[1] Polese, Abel; Beachain, Donnacha O. The Color Revolution Virus and Authoritarian Antidotes: Political Protest and Regime

CONTENTS

1. Introduction

1.1 Problem background

Since the end of the Cold War, some Western countries have used "color revolutions" as an important means to intervene in the internal affairs of other countries and subvert their destiny. Under the guise of "anti-corruption", "anti-dictatorship" and "improving people's livelihood", "color revolutions" are often used to fight for "democracy", "human rights" and "freedom". Participants engage in "street politics" and "democracy movement", seeking to achieve regime change. But actually the essence of a colour revolution is that some countries are trying to consolidate and maintain their global status by using low-cost and non-war means to foster regimes close to their own. Against the backdrop of the world's unprecedented changes, it is of great importance to track and judge the new trends of the "color revolution" in order to better understand the evolution of global strategies and safeguard national security interests.[2]

Figure 1：the Carnation Revolution [3]

1.2 Restatement

1. Establish a system of indicators to evaluate social stability from both qualitative and quantitative perspectives, and explore the correlations and causality relationships between these chosen indicators.
2. Build an early warning model of social stability based on the established indicator system through the synergy and balances between indicators.
3. Use the existing model to evaluate countries where color revolutions have failed to overthrow regimes and point out the reasons for the failed revolutions and make feasible suggestions based on the evaluation results.
4. Use the existing early warning model for social stability to assess countries and regions where color revolutions have led to regime changes and point out the causes of social instability to the point of regime changes.
5. Make recommendations for preventing color revolutions and maintaining social stability to the maximum extent possible.

[2] Zheng Dongchao. Alert to the new trend of "color revolution"[J]. Frontline, 2022, No.499(04):52-53.

1.3 Our Approach

According to the requirements of the topic, our main ideas and methods for solving the problem are as follows.

1. We selected appropriate social factors as evaluation indicators based on the background of this topic and sociological knowledge, establishing a system of indicators for social stability, and then we used Pearson's correlation coefficient and Spearman's correlation coefficient to explore the relationship between each indicator, thus providing a basis for building a model.

2. We used TOPSIS method to judge and predict the stability of the society through the already established indicator system.

3. We used the entropy weight method and machine learning tree methods to generate an objective weight vector of indicators and evaluated the effect of this weight vector in TOPSIS model to solve the problem that the AHP method might make prediction less effective.

4. We used the GM (1,1) model for short-term prediction, combining the prediction results with the TOPSIS social stability model. Then we use the model for prediction analysis to assess the social stability status of some countries and regions and made suggestions for maintaining social stability.

2. Model Overview and General Assumptions

2.1 Assumptions

The basic assumptions of this paper are as follows:

Assumption 1: The indicators we selected are representative and can reflect social stability comprehensively.

Assumption 2: In the social stability indicator system we establish, each indicator is not completely independent, and the indicators can check and balance each other and influence each other.

Assumption 3: The social stability indicator system we established can be applied to all countries.

Assumption 4: All data provided in the Annex are true and reliable from 1995 to 2021.

Assumption 5: It is reasonable to use average or adjacent values to fill the small amount of vacant data.

Assumption 6: It is reasonable to assume that a linear regression model is used to fill in a moderate amount of missing data for the same country.

Assumption 7: It is reasonable to use the average data of countries with similar national strength and situation as the target country to fill a large amount of missing data.

Assumption 8: For each specific country, the weight of positive and negative news stories for that country does not vary largely with the year.

Assumption 9: The "GDP growth rate （per capita）" indicator is considered an interval variable in this essay and that the resulting scoring mechanism for this indicator is reasonable.

2.2 Model Overview

The model contains seven indicators as the evaluation basis.

1. GDP per capita (in current dollars)

2. GDP per capita growth score (derived from a composite evaluation of annual GDP per capita growth rates)

3. Total unemployment (as a percentage of total labor force) (simulated ILO estimates)

4. Corruption Perception Index (CPI)

5. Tertiary enrolment (as a percentage of population)

6. Inflation as measured by the Consumer Price Index (annual inflation rate)

7. The overall social crisis (based on news coverage of the country)

The model is based on the TOPSIS method, combined with a vector of approximate optimal weights generated by the random forest algorithm, which constitutes an early warning model for evaluating the degree of social stability. A higher evaluation score obtained from the model represents a more stable society. If the evaluation score of a country in a certain year is lower than the instability threshold, the country is considered unstable and prone to different kinds of social movements in that year, which requires extra attention and precaution; if the evaluation score is higher than the stability threshold, the country is considered to have a stable social state in general and basically no serious social unrest will occur in that year; if the evaluation score is between the instability threshold and the stability threshold, the country is considered to have a moderate social stability, with a small possibility of social movements. The model makes three different judgments of "unstable", "medium" and "stable" in the test performance in the ratio of 1:2:1.

In summary, the entire modeling process can be shown as follows.

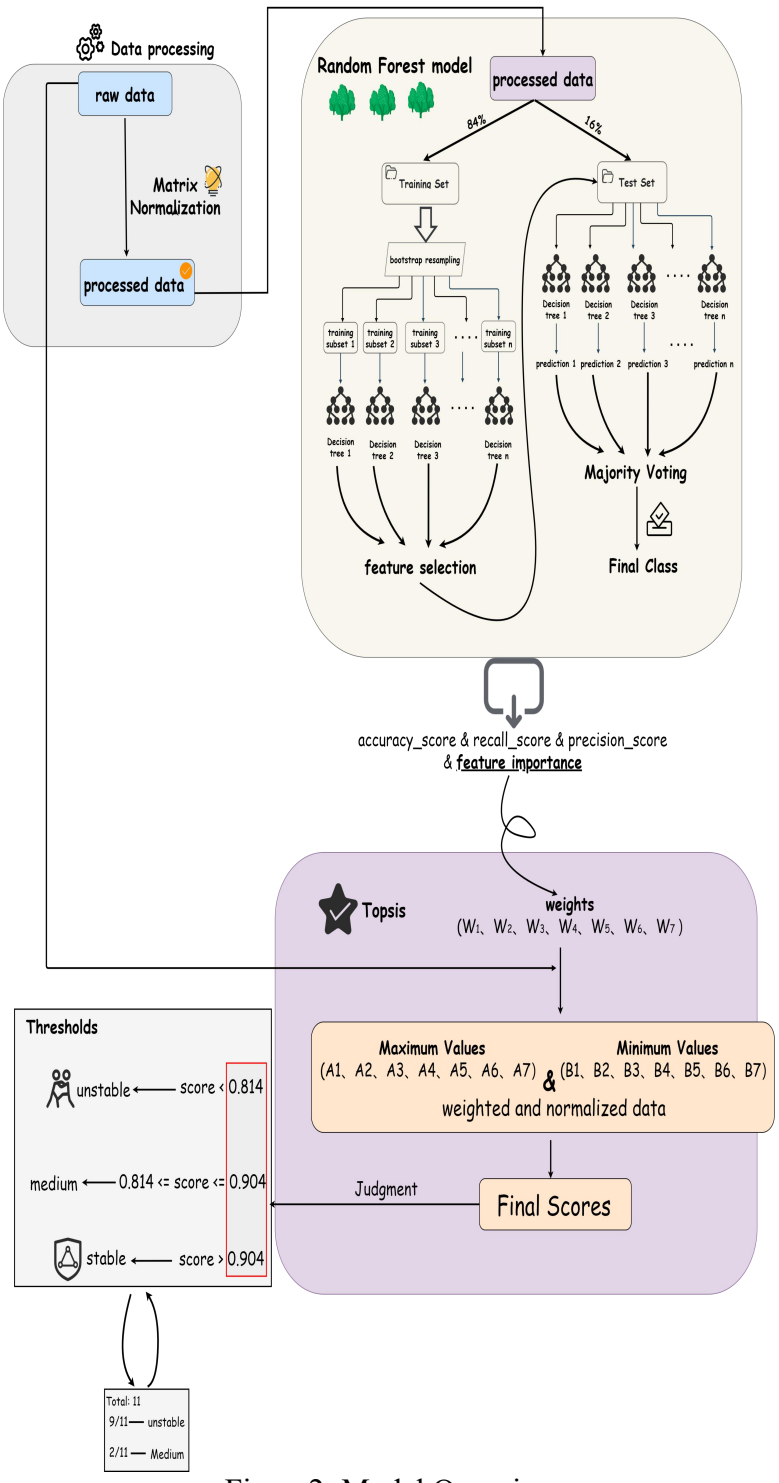

Figure2: Model Overview

3.Model Preparation

3.1 Notations

Symbols	Meaning
$X_i(i=1,2,3..7)$	Raw data for the seven indicators in order :per capita GDP,per capita GDP growth rate,unemployment rate,CPI,school enrollment,inflation,integrated crisis
$\sum_{1995-2021} X_i$	The summation of data item for the i^{th} country from 1995 to 2021
S_i^+	The distance between the i^{th} indicator and its maximum value in the topsis method
S_i^-	The distance between the i^{th} indicator and its minimum value in the topsis method
W_i	The weight of the i^{th} indicator
C_i	The normalized coefficient of the i^{th} indicator
MAX_i	The ideal optimal solution of the i^{th} indicator after processing
MIN_i	The ideal worst solution after the treatment of the i^{th} indicator

3.2 The Data

3.2.1 Data Collection

Name	Sources
GDP per capita growth (annual growth rate)	https://data.worldbank.org.cn
Inflation as measured by the consumer price index (annual inflation rate)	https://data.worldbank.org.cn
Unemployment rate	https://data.worldbank.org.cn
School Enrollment	https://data.worldbank.org.cn
GDP per capita (current prices in USD)	https://data.worldbank.org.cn
CPI	https://www.transparency.org
ICEWS Coded Event Data	https://dataverse.harvard.edu/

3.2.2 Data cleaning

We selected data from Armenia, Azerbaijan, Barbados, Belarus, Ecuador, Georgia, Germany, Guinea, Japan, Kazakhstan, Kuwait, Kyrgyzstan, Lithuania, Russia, Tajikistan, Tanzania, Tunisia, Turkey, Turkmenistan, Ukraine, and Uzbekistan. A small amount of vacant data obtained from the World Bank database was replaced by the average value. Based on completeness, all datasets were selected between 1995-2021. The data from ICEWS were processed due to the excessive amount of data and the dataset only counts the number of times of social conflicts that occurred in each country in each year in the above mentioned time period. Also, because of the inevitable differences in the data due to the different volume of countries, we adopted regularization and normalization means to unify to the same scale level.

4.Problem solving

4.1 Task 1

4.1.1 Selection of indicators

After an extensive reading of sociological, economic, and historical literature, we have selected seven indicators that may affect social stability in this question: GDP (per capita), GDP growth rate(per capita), college enrollment rate, unemployment rate, corruption perception index, inflation, and integrated crisis.

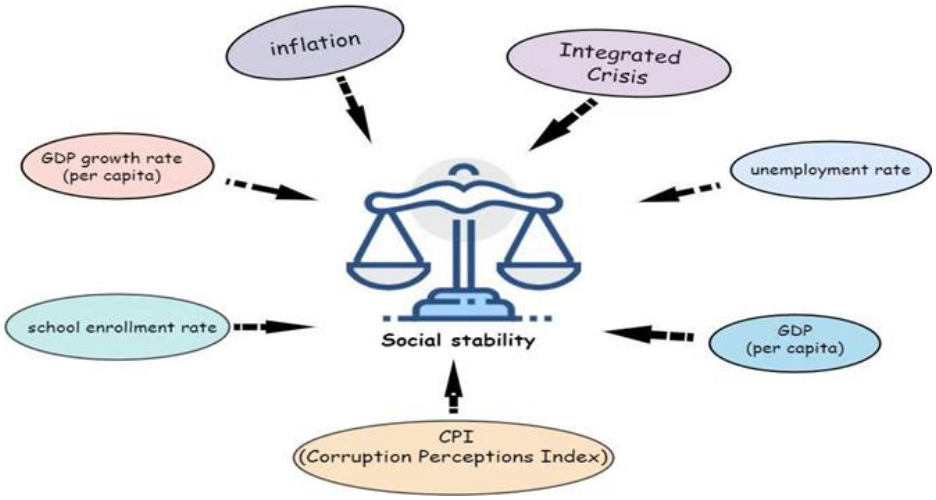

Figure 3:The indicator system of social stability

1. GDP (per capita)

GDP (per capita) is the quotient of the value of all final goods and labor produced in a country or region's economy divided by the total population of that country in a given period of time (usually one year).

2. GDP growth rate(per capita)

GDP growth rate(per capita) is the annual growth rate of GDP per capita, which is often used to measure how fast economic development changes from year to year.

3. School Enrollment Rate

School Enrollment Rate is an education indicator that refers to the ratio of actual annual college enrollment to the number of people who have the ability to enroll in college in a country, and is often used to measure a country's access to higher education and civic literacy.

4. Unemployment Rate

Unemployment rate is the ratio of the unemployed to the working population over a certain period of time, and is often used to measure the amount of idle labor capacity reflecting the unemployment situation in a country or region.

5. Corruption Perception Index

The Corruption Perception Index (CPI) is an assessment of the level of corruption of public officials and politicians in each country according to businessmen, academics and national analysts.

6. Inflation

Inflation, originally meaning an increase in the amount of money in circulation, but also meaning an increase in the price of related goods or services over a period of time (usually a year) and a decrease in people's purchasing power, is often used to measure such things as an overall increase in prices or an increase in the cost of living in a country.

7. Integrated crisis

An integrated social crisis, consisting of conflicts between socio-political actors (hostilities between individuals, groups, sectors, and nation-states), is often used as a measure of how well a country's social environment is doing.

4.1.2 Correlation and Causality

To explore the correlation between the variables, we calculated the Pearson correlation coefficient and the Spearman correlation coefficient between them. The formula for the Pearson correlation coefficient is:

$$\rho(x,y) = \frac{\operatorname{cov}(x,y)}{\sigma(x)\cdot\sigma(y)} = \frac{E[(x-\mu_x)(y-\mu_y)]}{\sigma(x)\cdot\sigma(y)}$$

The formula for the Spearman correlation coefficient is：

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

d^i denotes the difference of the place value of the i^{th} data pair and n denotes the total number of observed samples. [4]

We draw the correlation coefficient matrix heat map：

[4] Meidushaccc,"Mathematical Modeling: Correlation Analysis Learning - Pearson and Spearman Correlation Coefficients," https://blog.csdn.net/weixin_67565775/article/ details, Feb 5,2023

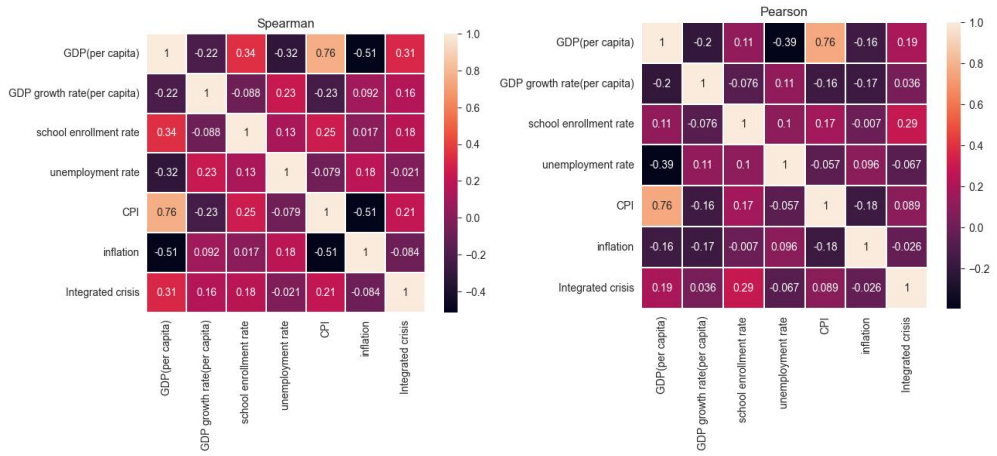

Figure 4: the correlation coefficient matrix heat map

From the figure, we can find that the correlation coefficient between CPI and GDP per capita is as high as 0.76 under both methods, which has a strong correlation. The rest of the correlation coefficients are lower, basically at the level of weak correlation or even almost no correlation.

Degree of relevance	**Very strong correlation**	**Strong correlation**	**Moderate correlation**	**Weak correlation**	**Very weak or no correlation**
Absolute value of correlation coefficient	0.8—1	0.6—0.8	0.4—0.6	0.2—0.4	0—0.2

Variable correlation intensity table

GDP per capita is positively correlated with the CPI, and a similar conclusion was reached in a theoretical economics snapshot published in February 2018: "Countries with higher CPI usually have higher GDP per capita. "Citizens of countries with higher CPIs have more freedom to do business, the country as a whole has a greater ability to attract foreign investment, and GDP per capita is more higher. At the same time, higher GDP per capita further increases the CPI, and sufficient national wealth can help to invest human and material resources to improve the national governance system and fight corruption. GDP per capita is negatively correlated with the unemployment rate, and the Austrian law [5] suggests that unemployment implies the non-utilization of factors of production, so that a rise in the unemployment rate is accompanied by a fall in real GDP, which is also consistent with the results of our qualitative study. Also low consumer demand in countries with low GDP per capita, which cannot provide enough jobs, will also backfire on the unemployment rate leading to its decrease.

The above causility is shown in the figure:

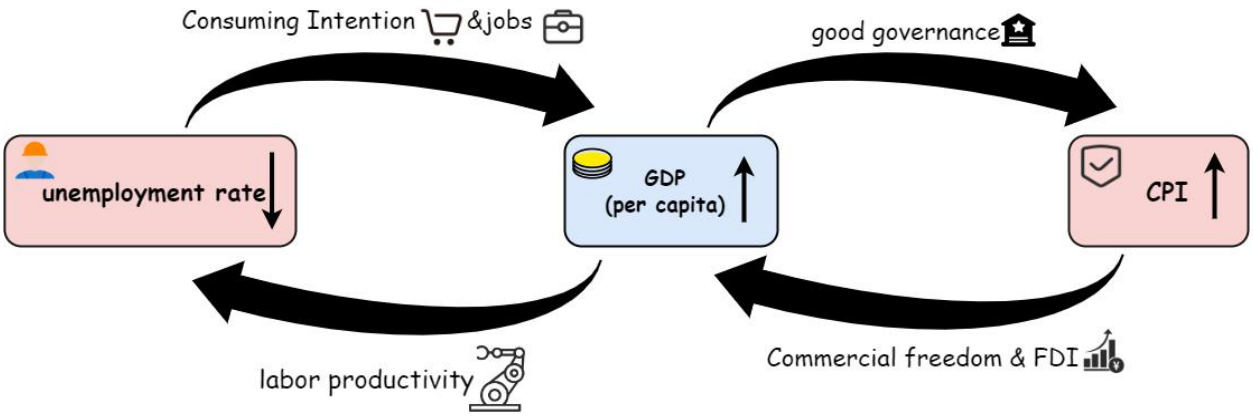

Figure 5: Diagram of causality

We distill the data for CPI and GDP (per capita) separately and plot the matrix scatter plot.

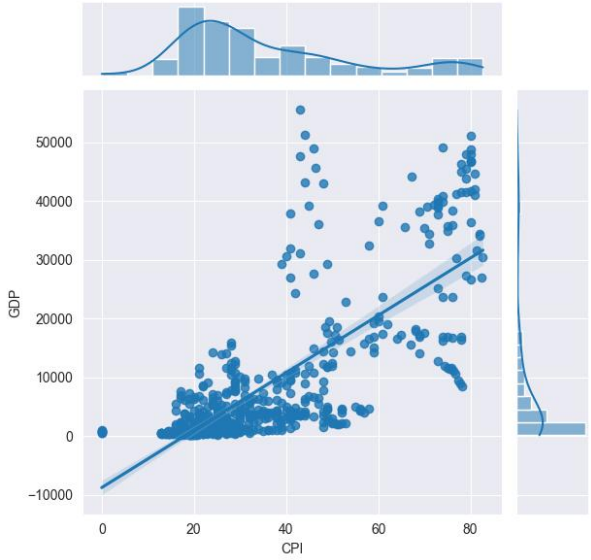

Figure 6 : the matrix scatter plot (CPI & per capita GDP)

It can be seen that the linear fit can not work very well. So, the least squares method was chosen to fit the curve to explore the functional relationship between the two. The results are shown in Figure 7:

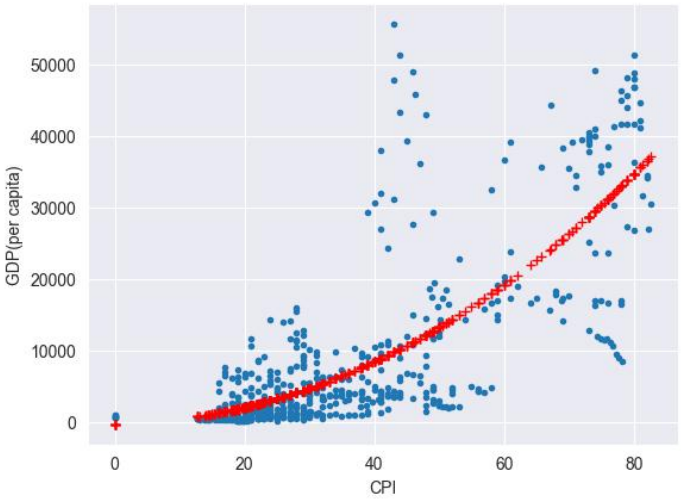

Figure 7: Function Fitting Plot

The fitted functional relationship is：

$$y = 0.007699x^3 + 4.545x^2 + 24.77x - 346.7$$

y is the GDP (per capita) and x is the CPI score.

4.2 Task 2

4.2.1 Data Processing

Our dataset contains changes in seven indicators for 21 countries over the period from 1995 to 2021 (27 years in total). To facilitate the modeling, we create a matrix (567*7) to store all the data. Where each row represents the data of seven different indicators for one country in one year, and each column represents the values taken for the same indicator in different countries and different years.

Considering the data collected, the values of the integrated social crisis are strongly correlated with the country size, and the indicators of integrated social crisis in some large countries can even exceed the values of small countries by two orders of magnitude. Therefore, in order to exclude the disturbances and errors caused by the size of the country, the indicator of the comprehensive social crisis is converted into the ratio of the comprehensive social crisis of the country in that year to the total social crisis of the country in those 27 years as follows:

$$integrated \quad crisis \quad score = \frac{x_7}{\sum_{1995-2021} x_7}$$

Before the experiment began, we envisioned that GDP (per capita) growth would be positively correlated with social stability. The faster the GDP per capita growth, the more stable the society will be. However, after the initial experiment, we found that in the 11 countries where color revolutions occurred, the GDP per capita growth rate of the country also tended to be faster

than the other year when the color revolutions occurred, which was not consistent with our initial assumption. After reviewing relevant information and literature, we found that in fact, in addition to economic regression and slow development, too fast economic development is also detrimental to social stability, and society is most stable when it develops at a moderate rate, which usually refers to an annual per capita GDP growth rate of about 3 percent. Therefore, we set this indicator as an interval type indicator and deal the indicator with the principle as follows.:

per capita GDP growth rate:

$$score = \begin{cases} 0 & x_2 \le -18 \\ 100 \times (1 - \frac{x_2 - 3}{30}) & -18 < x_2 < 3 \\ 100 \times (1 - \frac{3 - x_2}{21}) & 3 \le x_2 \le 33 \\ 0 & x_2 > 33 \end{cases}$$

Meanwhile, to avoid systematic errors caused by different magnitudes, we normalize all data by columns and reduce the magnitudes of each indicator to the same level.

4.2.2 Weight Determinations

4.2.2.1 The Entropy Weight Method

The AHP method, which subjectively assigns weights to each of the seven indicators, was very unsatisfactory for the experimental results we obtained after our attempts.It could not clearly distinguish the countries and years where color revolutions had occurred. Therefore, we tried the entropy weight method, a non-subjective method of assigning weights.

Each element in the probability matrix P is as follows:

$$p_{ij} = \frac{\tilde{z}_{ij}}{\sum_{i=1}^{n} \tilde{z}_{ij}}$$

Z is the matrix that has been normalized：

$$z_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{n} {x_{ij}}^2}$$

First calculate the entropy of each indicator：

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \ (j = 1, 2, ..., m)$$

The coefficient of variation is then calculated for each index：

$$\varepsilon = 1 - e$$

The obtained variance coefficient vector represents the amount of information contained in each indicator,which means the greater the amount of information contained in the indicator, the

larger the corresponding component in the variance coefficient vector, and it is a very objective choice to use the variance coefficient vector as the weight vector.

4.2.2.2 Random Forest Algorithm

After experiments, the weight vector obtained by the entropy weight method is still not effective enough to make the evaluation effect of the Topsis model satisfactory, so we use the random forest algorithm which is commonly used in early warning models.

Our team believes that the social stability early warning model needs to be more aggressive, which means we would rather hace the model give false warnings of instability when society is stable than have it fail to give any warning when the society is truly in turmoil. This is because the latter situation is significantly more dangerous in both cases. At the same time, we believe that the occurrence of a color revolution is only one of the many manifestations of social unrest, not a decisive factor in social unrest (other factors include demonstrations, terrorist attacks, general strikes, etc.), so after discussion, we simplify the effect the model needs to achieve as：

1. Distinguish between the degree of stability of societies and classify societies with color revolutions as "unstable" to the maximum extent possible.
2. The model should not over-predict, regarding too many societies' state as "unstable". The positive sample of data is "countries and years with color revolutions" and the negative sample is "countries and years without color revolutions". Therefore, we choose the accuracy and recall rate as the evaluation criterias of the random forest model, and hope that our model has as high a recall rate as possible, that is to say, to successfully classify the occurrence of color revolutions as "unstable" and to maintain the proportion of "unstable" judgments as much as possible. We want our model to get higher recall score, which means the model can successfully classify the occurrence of color revolutions as "unstable" and maintain the proportion of judgments of "unstable" societies as much as possible to avoid the model blindly identifying all societies as "unstable" in order to maximize the recall score.

Since what the random forest model predict is actually the probability that the sample is positive, we consider the society is unstable as long as the probability is not zero. According to this rule, after several experiments, the accuracy score and recall score of the random forest model we finally selected are as follows：

```
accuracy_score = 0.7840670859538784
recall_score = 0.7777777777777778
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The corresponding weight vector of the model is as follows：

w = [0.016133870975143155, 0.27124328336250164, 0.01683815759318027, 0.024425250495824176, 0.013710197760681922, 0.1388210119528406, 0.5188282278598283]

After discussion, our team decided to use the weight vector obtained from the random forest algorithm as the weight vector for the Topsis model instead of using the random forest model directly as the social stability early warning model. The main reasons were that the readability of the random forest model was unsatisfactory while the internal structure of the model was complex. It also had low interpretability, making it difficult to be interpreted precisely. At the same time, this random forest model cannot effectively triangulate the social stability situation

4.2.3 Threshold Determination (Topsis)

The weight vector obtained from the above random forest algorithm was used in the Topsis model to calculate the score of each country in each year. A higher score symbolizes a more stable society.

$$score = \frac{s_i^-}{s_i^- + s_i^+}$$

$$s_i^+ = \sqrt{\sum_{i=1}^{7} \left(\frac{x_i w_i}{c_i} - MAX_i \right)^2}$$

$$s_i^- = \sqrt{\sum_{i=1}^{7} \left(\frac{x_i w_i}{c_i} - MIN_i \right)^2}$$

After a trade-off between recall score and accuracy score, our team chose an instability threshold of 0.814 and a stability threshold of 0.904. If the composite evaluation score is lower than 0.814 , society is considered less stable and prone to social movements such as color revolutions(about 25 percent of the data belongs to this class); if the composite evaluation score is higher than 0.904, society is considered relatively stable and the country is not likely to experience large unrest(about 25 percent of the data belongs to this class); and if the composite evaluation score is between the two thresholds, society is considered moderately stable, which still have a small possibility to experience unrest.

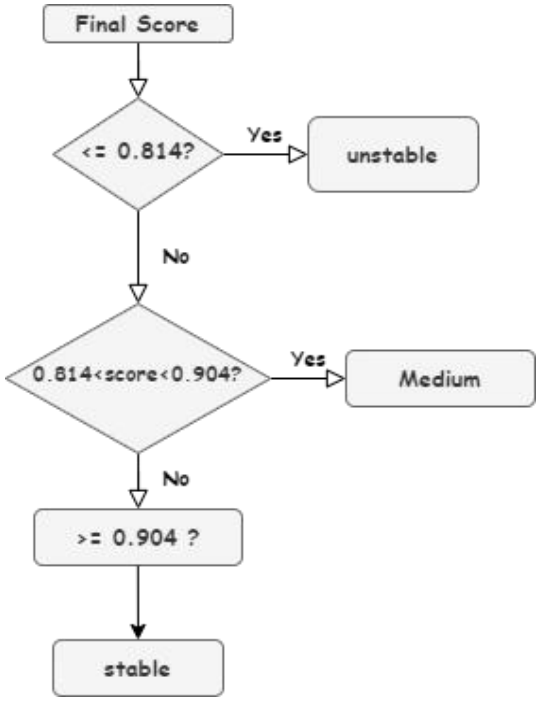

Figure 8 : Scoring Flowchart

For the 11 countries where color revolutions occurred, 9 of them were considered socially unstable in the year when the color revolution occurred, while the other two countries were considered to have middle social stability at the time of their color revolutions. On balance, we believe that 0.904 and 0.814 are the most appropriate thresholds to successfully predict the majority of color revolutions as "unstable" without overly judging the society as unstable. The results of this model are highly informative and practical. If a country is deemed "unstable" in a given year, the government of that country will need to take steps to stabilize society and prevent social movements from occurring.

At the same time, the model integrates seven evaluation indicators together and different indicators complement each other and check each other, and participate together to form the final prediction score, which makes the evaluation results more scientific.

4.2.4 Sensitivity analysis

Finally, we analyzed each indicator of the model separately from a sensitivity perspective, with the horizontal axis representing each indicator and the vertical axis representing the scores. The results of the analysis are as follows：

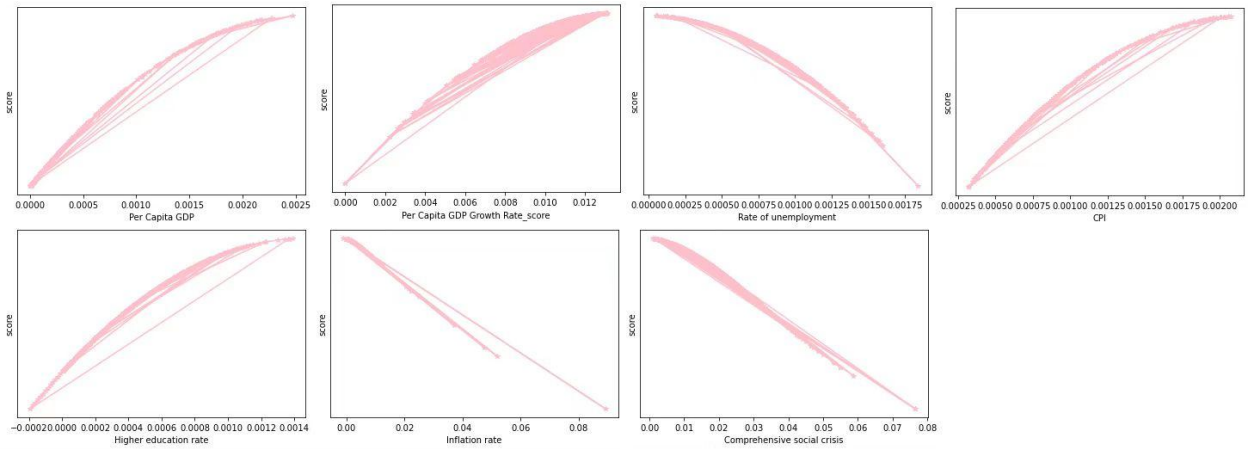

Figure 9 : Sensitivity Analysis Chart

4.3 Task 3

4.3.1 Social stability assessment

Out of the 21 countries selected, a total of 18 countries had color revolutions that attempted to overthrow the regime but ended in failure. For this question, let's take Azerbaijan as an example.

Azerbaijan had a violet revolution in 2005. The seven factors of Azerbaijan in 2005 are substituted into our model and the score is 0.776, which is within the warning range. Then we extracted the line graph of the seven factors of Azerbaijan over time, and it is obvious that the four factors of inflation rate, GDP per capita, GDP per capita growth rate, and integrated crisis have obvious abnormalities in their values after observation

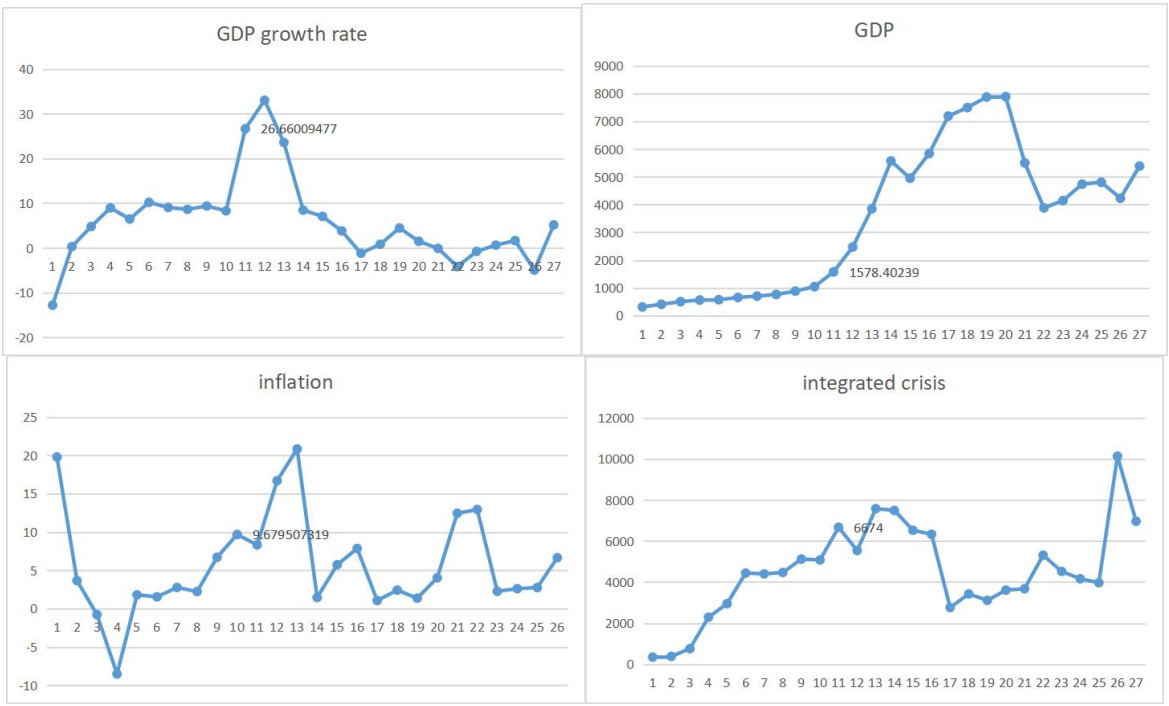

Figure 10：Line graph of the change in the values of the four factors

The graph shows that the four factors have seen a relatively large change in 2005, the year in which the color revolution occurred. The GDP per capita growth rate suddenly soared to 26.66% in 2005, and the GDP per capita also saw a significant increase, the inflation rate also became the highest existence around 2005, and the integrated crisis was surprisingly high, increasing by almost 20% compared to the previous year. The abnormalities of these four factors gradually unsettled the Azerbaijani society, intensified internal conflicts and tensed the external situation. This led to the occurrence of the Violet Revolution.

4.3.2 Prediction of future social stability (based on GM(1,1) model)

Our evaluation indicators as well as TOPSIS model explain the social situation in Azerbaijan at the time of color revolutions nicely and analyze the reasons for their occurrence. From this, we hope to forecast the social stability in Azerbaijan in the short term future, which can provide some reference information for the development and operation of the country.

The objective is to forecast the social stability of Azerbaijan in 2023, and since it is a short-term future forecast, we have chosen the GM(1,1) method. In order to make the most of available data and minimize the impact of the old data on the forecast results, we chose to use the last ten years of data for Azerbaijan to forecast the values of each indicator for 2023.

In order to determine whether the GM(1,1) model is applicable to our data, before conducting the forecasting analysis process, we perform a cascade test on the data items for Azerbaijan for the last ten years：

$$\sigma^{(0)}(k) = \frac{x^0(k-1)}{x^0(k)} \qquad \sigma^{(0)}(k) \in (e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}})$$

If the results of the cascade test for each indicator are within the interval, the gray prediction model can be considered applicable to the data; otherwise, the model needs to be given up or the data needs to be transformed.

Based on the results of the cascade test, we gave each indicator diffrent amount of transformation to ensure that each data item passed the cascade test. After that, the forecasting model can be constructed.

Firstly, each item of data for Azerbaijan over the past ten years was summed up item by item to eliminate the randomness of the data and to strengthen the regularity of each indicator.

$$Y[k] = \sum_{i=1}^{k} X[i]$$

Take GDP per capita as an example：

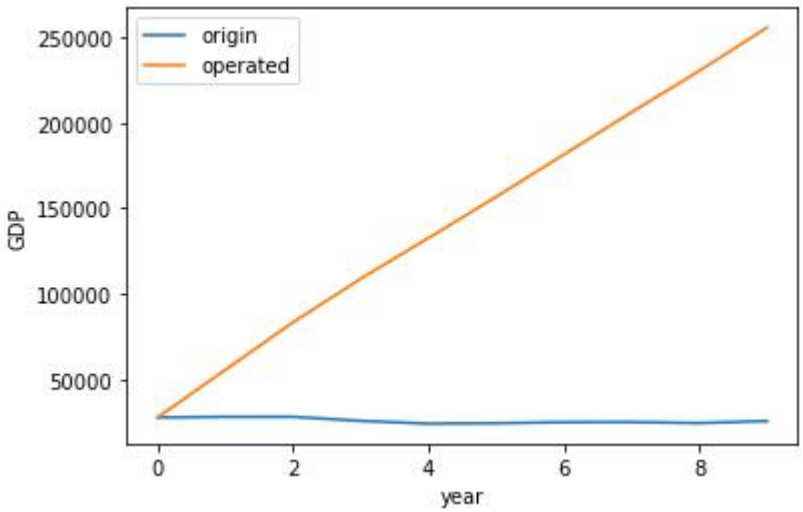

Figure 11: GDP per capita before and after accumulation

Then, based on the characteristics of the cumulative data, a linear model is constructed by using the least squares method. The slope and intercept of the fitted model for each indicator can be found. Based on the obtained linear expressions, we can calculate the predicted values of the cumulative data of seven indicators for Azerbaijan in 2023. Based on the cumulative values, we can calculate the predicted approximation of the indicator data for each year under our linear expression：

$$X[k] = Y[k] - Y[k-1]$$

Residual test (relative error test) for prediction results combined with real data.

$$\varepsilon(k) = |\frac{X[k] - \widehat{X}[k]}{X[k]}|$$

The model is considered correct if the results of the tests are all less than 0.2.

All data passed the residual test, so the GM(1,1) model is correct and valid. The obtained forecast data of seven indicators for Azerbaijan in 2023 are as follows:

1.GDP per capita (in current dollars): 5092.8

2.GDP per capita growth score (obtained from the combined annual growth rate of GDP per capita): -0.254

3.Total unemployment (as a percentage of total labor force): 5.179

4.Corruption Perception Index (CPI): 29.10

5.Higher education enrollment (% of population): 28.08

6.Inflation as measured by the Consumer Price Index (annual inflation rate): 5.84

7.Aggregate social crisis (based on news coverage of the country): 4919

Based on our TOPSIS Social Stability Early Warning Model, we calculated Azerbaijan's social stability score in 2023 using the seven projections, and the final score is about 0.841, which is between the stability and instability thresholds and is classified as "medium", indicating that Azerbaijan's social stability will be medium in 2023 .The likelihood of social unrest is low.

4.3.3 Recommendations for national development

The recommendations for the development of Azerbaijan are as follows.

1. Do not allow other countries to interfere excessively in the internal affairs of the country, because the intrusion of foreign powers can cut the society internally. The ruling class can take measures of political control to consolidate the regime, such as implementing religious policies, banning opposition activities, imposing political censorship, prohibiting the opposition from expressing its views, implementing political education, defending the purpose of propaganda regime, enforcing political institutions, etc.

2. The abnormally high GDP growth should be taken seriously. The abnormal growth of economy is often at the expense of other interests and can lead to inadequate and uneven social development and even unpopularity. So economic development should be done in a stable manner rather than leapfrogging.

3. Improve the socio-economic situation, raise the material living standard of the people, improve the efficiency of government services, improve the social security system and other measures to consolidate the regime.

4.4 Task 4

Data from Kyrgyzstan were selected for this question. The tulip revolution broke out in Kyrgyzstan in 2005 and was successful. Firstly, according to the model, the index for Kyrgyzstan in 2005 is 0.6297263, which is at the lower level of the index among all predicted data. It also confirms the established early warning model of social stability that the society is extremely volatile and prone to revolution in that year. Since the highest weight in the model is integrated crisis, which accounts for 51%, we can reasonably guess that the value of integrated crisis has fluctuated considerably when the obtained value appears more extreme. Secondly, the growth rate of GDP per capita, which has a weight of 27.2% in the model, is also taken into account. Since the weight of the first two has reached almost 80% and the forecast of Kyrgyzstan in 2005 shows extreme instability, the impact of other factors on this revolution is considered negligible here. The validation data are then shown in the figure:

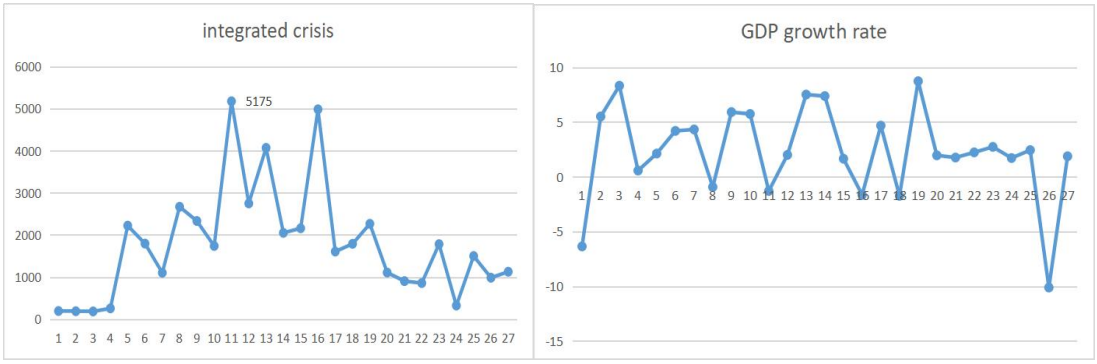

Figure 12 : Validation Data

It can be seen that the number of integrated crises increased dramatically in 2005, almost tripling compared to previous years, which was largely in line with our suspicions. The high number of social conflicts was a sign of serious internal conflicts in the society. Also, the graph below shows that the GDP growth rate in 2005 was negative, which indicates that Kyrgyzstan was in funding shortage that time. At that time, Kyrgyzstan was one of the poorest countries in Central Asia and the world. After independence, Kyrgyzstan's economy developed slowly and it didnot return to 80% of its pre-independence 1990 level until 2004, of which the shadow economy accounted for about 40% with foreign debt reaching $1.92 billion, which is equivalent to one year's GDP. Almost 60% of the population of Kyrgyzstan lives below the poverty line and unemployment rate was very high, especially in the south where almost three quarters of the population were unemployed. About 700,000 people worked in Russia, Kazakhstan and other countries. The social division was serious, the gap between rich and poor, north and south, and ethnic groups was prominent, especially the situation of rich north and poor south was becoming more and more obvious. The plan of social contradiction led to the increasing dissatisfaction of allergic people, especially poor people, with the government. At the same time, the serious corruption in Kyrgyzstan has eroded the foundation of the regime and the prestige of the rulers has been lost. In this situation, the opposition took advantage of the unfair parliamentary elections and incited the masses to take to the streets. Absolutely there were people who responded, so the Tulip Revolution broke out.[6][7][8]

4.5 Task 5

In order to prevent the outbreak of color revolutions and maintain social stability, we make the following recommendations based on the established social early warning model and social stability indicator system.

1. Strengthen political education and guide people to understand politics correctly. Strengthen education on socialist political civilization, guide citizens' political thoughts correctly,

[6] Wu Hongwei. The deep-seated reasons for the regime change in Kyrgyzstan and the future political direction[J]. Contemporary World, 2010(5):4.
[7] Yu Qianjing. A Study of Three Unusual Regime Changes in Kyrgyzstan since Independence from the Perspective of Power Elite Theory[D]. Shanghai International Studies University, 2022. DOI:10.27316/d.cnki.gswyu.2022.000040.
[8] Zhao Longgeng." Regime Change in Kyrgyzstan and the Challenges Facing the New Regime." Peace and Development .04(2005).

enhance their political consciousness, promote the understanding of social justice and fairness, and improve the political order.

2、Strengthen the protection of citizens' rights by the government and its departments. Establish a sound and effective system of laws and regulations, update and improve laws and regulations, ensure citizens' rights to litigation and administrative reconsideration, and ensure that their basic rights are effectively protected.

3. Strengthen social management. Establish a sound system of social security prevention, increase social management, resolutely combat illegal activities, timely detection and investigation of illegal acts, and maintain social order and security.

4、Strictly control religious activities and resolutely prevent religious activities from being used to influence political activities.

5、Establish a sound democratic mechanism, improve people's livelihood, strengthen social justice, enhance the economic income of the people, improve the living standard of the people, and ensure social stability.

6、Strengthen the power of the press and media, increase reporting efforts, address some social hotspots and issues of concern to the public, make timely reports, and send positive energy to society in a timely manner.

7、Not to overemphasize economic growth and reject GDPism. Maintain the balanced development of related aspects (such as ecology, employment, and residents' income)[9].

5. Summary

Through a series of studies and the results of the model, we can find out that social instability and the frequency of integrated crisis are highly related. This factor occupies more than 50% of the weight in the model. The discrepancy with the team's initial guess is that economic factors are actually not very much associated with the outbreak of revolutions. In addition, according to the data, when the economic development is extraordinarily rapid, the society will tend to be unstable. Excessive economic development brings many problems, mainly in the form of imbalance, uneven development of industries, lagging social security system, accelerating economic cycles, increased difficulty in adjusting and adapting to the legal system, increased difficulty in governance, confusion in thinking, and excessive gap between rich and poor, which affects social stability. From the economic point of view, a government can maintain social stability by ensuring healthy economic development and increasing total social wealth while making the distribution of social wealth as reasonable as possible. When a country can solve the problems of people's livelihood in the process of maintaining stable development, punishing corruption strictly, and making government work open and transparent, the society will develop steadily and get better. [10]

[9] Du X.Y.. The Double Impact of Economic Growth on Social Stability [J]. Journal of Armed Police Academy,2008,No.149(11):35-38.

[10] Wang Lei,Hu Angang. An empirical study on the relationship between economic development and socio-political instability - a comparative analysis based on cross-country data[J]. Comparative economic and social systems,2010,(01):83-89.9.

6.Appendix

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	Country Na	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2	Armenia	8.12	9.53	9.61	9.38	8.41	8.69	7.82	8.01	8.15	8.3	8.13	8.22	7.77	7.05	8.28	9.07	9.24	9.1	8.84	9.22	8.56	8.26	8.54	8.06	9	8.19	7.01
3	Azerbaijan	6.09	9.57	9.65	9.22	9.04	8.55	8.57	8.54	8.34	8.35	7.76	7.99	7.53	7.62	7.94	8	9.06	8.89	8.99	8.83	8.8	8.25	8.51	8.65	8.72	6.96	7.81
4	Barbados	9.73	9.74	7.85	7.49	9.06	8.73	8.61	7.21	7.4	7.67	6.89	7.61	7.97	8.24	8.73	8.87	9.25	9.15	8.81	9.36	8.66	9.67	8.55	9.61	8.67	8.77	8.57
5	Belarus	4.51	9.16	9.01	8.92	6.47	6.87	7.78	8.46	8.83	8.65	8.63	7.63	8.61	8.36	8.68	8.72	8.67	8.82	9.25	8.58	7.09	8.96	8.55	9.39	9.07	6.7	6.61
6	Ecuador	9.21	9.25	8.87	9.12	8.99	8.56	8.77	8.93	8.73	7.87	6.99	7.15	6.83	6.92	8.08	7.94	9.2	8.63	9.03	9.19	8.81	8.84	8.55	8.83	8.78	9.22	8.47
7	Georgia	8.24	9.28	9.46	9.36	8.75	8.49	8.31	7.98	7.77	7.32	8.05	7.99	7.51	5.41	7.61	8.74	9.11	8.92	8.81	8.92	9.09	9.33	8.54	9.19	9.25	9.28	8.67
8	Germany	9.62	9.39	9.26	9.12	8.6	8.47	8.1	8.37	8.16	8.14	8.09	8.17	7.66	8.32	8.6	8.98	9.09	9	8.95	8.66	7.73	7.83	8.55	8.14	8.73	8.82	8.77
9	Guinea	9.44	9.3	9.46	9.41	9.02	8.62	8.2	9.16	8.86	9.26	9.17	9.1	7.13	8.32	6.93	6.6	8.31	8.45	7.61	7.97	7.46	9.27	8.54	8.74	8.66	8.41	7.94
10	Japan	9.71	9.54	9.52	9.12	9.13	8.32	8.21	8	7.82	8.05	7.58	7.65	7.67	7.79	8.23	8.27	8.65	8.83	8.88	8.74	8.7	8.6	8.56	8.96	8.66	9.22	9.07
11	Kazakhstar	8.07	9.4	9.55	9.28	8.83	8.08	8.46	7.45	8.27	8.01	7.66	7.46	7.89	7.95	8.2	8.01	8.49	8.71	8.64	8.64	8.59	8.73	8.54	8.81	9.15	9.34	8.22
12	Kuwait	9.5	9.37	9.28	9.05	8.58	8.44	7.94	8.19	7.1	7.04	7.83	7.84	8.03	8.27	8.49	9.1	8.64	8.58	8.77	8.22	7.35	9.36	8.49	9.18	9.36	9.29	9.3
13	Kyrgyzstan	9.38	9.48	9.52	9.62	8.11	8.5	9.07	7.87	8.12	8.57	6.3	7.81	6.91	8.27	8.24	6.39	8.65	8.52	8.16	9.07	9.23	9.29	8.55	9.66	8.77	8.96	9.04
14	Lithuania	9.43	9.5	9.43	9.45	8.74	8.68	8.15	7.77	8.37	8.53	8.79	8.87	8.79	8.96	8.84	9.32	9.22	9.24	8.13	8.27	7.82	7.82	8.55	7.32	7.51	7.79	7.02
15	Russia	7.84	9.03	9.42	8.98	7.8	7.74	7.91	7.86	8.01	8.01	7.96	8.22	8.4	8.1	8.39	8.89	9.12	8.94	8.84	8.6	8.25	8.44	8.55	8.56	8.61	9.11	8.29
16	Tajikistan	9.04	8.65	9.15	9	8.48	7.75	7.23	7.85	8.24	8.17	8.31	8.09	8.28	7.68	8.31	8.16	8.15	8.41	8.78	8.37	8.37	9.48	8.54	9.37	9.48	9.69	8.05
17	Tanzania	9.41	9.37	9.46	9.14	8.52	8.14	7.41	8.53	8.49	8.42	8.14	8.68	8.94	8.46	8.77	8.84	8.55	8.14	7.63	8.18	7.39	7.84	8.54	9.08	8.98	8.85	8.55
18	Tunisia	9.54	9.56	9.65	9.51	9.43	9.39	9.02	9.32	9.14	8.78	9.24	9.42	9.34	9.04	9.22	9.27	6.38	6.94	6.55	6.74	6.12	8.38	8.54	8.68	8.65	8.88	7.48
19	Turkey	8.92	8.9	8.88	8.44	8.07	8.23	8.08	8.19	7.97	7.78	7.87	7.82	8.05	8.31	8.44	8.49	8.97	8.72	8.68	8.72	8.05	7.72	8.53	8.61	8.74	9.22	9.05
20	Turkmenist	9.24	9.45	9.12	9.35	8.54	8.16	8.53	7.69	8.7	9.17	8.68	8.82	6.73	7.37	7.77	8.22	8.24	7.82	8.3	8.46	8.21	9.02	8.55	9.09	8.85	9.49	8.56
21	Ukraine	6.33	8.84	9.45	9.46	8.88	8.7	8.27	8.64	8.77	7.94	8.15	8.24	8.36	8.39	8.74	9.05	9.4	9.26	8.73	5.38	7.13	8.42	8.52	8.76	8.47	9.03	7.26
22	Uzbekistan	9.55	9.56	9.62	9.27	8.45	8.08	8.2	7.72	7.58	7.2	6.28	7.5	8.01	8.7	8.54	8.43	9.17	9.14	8.92	8.98	8.91	8.49	8.52	8.95	9.17	9.28	8.28

Figure 13: Model scores of all current data

Tips:

1. For the ease of observation, all fractions are multiplied by ten.
2. Red font means unstable, black font means medium, blue font means stable.
3. The yellow background indicates that a revolution has indeed occurred.

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