| Team Number : | apmcm2213610 |
|---|---|
| Problem Chosen : | E |

2022 APMCM summary sheet

Nuclear weapons are weapons of mass destruction, and their existence has a significant impact on the world landscape. In this paper, we analyse the current development of nuclear weapons and predict the future trend by building a mathematical model, which is important for a deep understanding of nuclear weapons.

For question one, this paper uses Excel, Python and other software to perform basic data analysis on the attached data, and finally answers the question in the question：The countries that have had nuclear weapons are: China, USA, UK, France, India, Pakistan, Iran, South Africa, North Korea, and Russia. The largest decrease was in the United States and the largest increase was in Pakistan, which had the largest number of nuclear tests from 1962-1966. North Korea has been the most active in nuclear research in the last decade and the United States has the fastest rate of transformation.

For question two, an ARIMA model is developed using the time series data in the Appendix. First, we build and test the ARIMA model for each country separately, and then use the model to make predictions for 100 years after the test is passed. We assume that there will be no new nuclear states in the next 100 years. Based on the prediction results, we find that in 100 years, the countries with nuclear weapons are: China, North Korea, India, Pakistan, Russia, the UK, and the US. Their nuclear stockpiles are also calculated. In 100 years, the number of nuclear weapons in the world will be 12,726.

In response to question 3, we calculated the number of "Big Evans" needed to destroy the Earth's surface based on the equation of yield and radius, and the minimum yield needed to destroy the Earth. Finally, it was found that 248,775 "Big Evans" are needed to destroy the Earth; the most powerful nuclear bombs today cannot destroy the Earth; we should limit the total number of nuclear bombs in the world to never exceed the minimum number of bombs sufficient to destroy the Earth, i.e., about 248,775 bombs; in addition, for countries that already have nuclear weapons, we need to ensure that the total nuclear yield of all these countries does not exceed at least 345464769.374 million tons.

Finally, we reported our results and gave some suggestions for all countries to the UN.

Keywords: Nuclear Weapons, ARIMA model, Time Series

Contents

# 1. Introduction

## 1.1. Background

Since the advent of nuclear weapons, human warfare has entered a new, nuclear weapons-based era. Nuclear weapons are the most powerful weapons ever invented by man, using the enormous energy released by nuclear reactions as a destructive force. In 1945, the United States dropped two atomic bombs on Hiroshima and Nagasaki in Japan, which opened the eyes of the world to the horrific power of nuclear weapons. In this paper, we analyse the current development of nuclear weapons and predict the future trend by building a mathematical model, which is important for a deep understanding of nuclear weapons.

## 1.2. Problem requirements

- Basic data analysis

a. Which countries have ever had nuclear weapons?

b. Which country has reduced and increased its stockpile of nuclear weapons the most over the past two decades?

c. Which five years had the most nuclear weapons tests?

d. During the past decade, which country has been most active in nuclear weapons research?

e. The fastest transition from "not considering nuclear weapons" to "possessing nuclear weapons" is made by which country?

- Predict the number of nuclear weapons

a. Based on the attached data or the data you have collected, establish a mathematical model to predict the number of nuclear weapons and the states that possess them in the next 100 years;

b. Forecast the number of nuclear weapons in the next 100 years, the total number of nuclear weapons in 2123, and the changing trend of the number of nuclear weapons in various countries.

- Protect our planet

a. To establish a mathematical model of the detonation position of nuclear weapons and calculate at least how many nuclear bombs are needed to destroy the earth?

b. By mathematical model, what is the maximum destructive power of the nuclear bomb currently possessed? Will it be enough to destroy the earth?

c. How much should the total number of nuclear bombs in the world be limited in order to protect the earth and the environment on which we live, and how much should countries that already possess nuclear weapons be limited in theory?

- Prepare a non-technical article (up to 1 page). You should write a non-technical article (max. 1 page) to the United Nations (U.N.) to explain your team's findings and make some suggestions for all countries.

## 2. Problem analysis

### 2. 1. Analysis of Problem One

Question 1 requires us to do a preliminary analysis of the data given in the question. For sub-question a, we can get the answer in 3 ways: 1. search for the factual situation; 2. observe the countries appearing in sheet2, and having stockpiles can indicate that nuclear weapons were once possessed; 3. filter the countries in sheet4, with status=3. For sub-question b, we find the countries with the largest increase and decrease, respectively. The data can first be displayed visually, and the magnitude can then be calculated for those that are difficult to determine. For sub-question c, we counted the total number of nuclear tests for each five-year period from 1945 to 2022, and identified the five consecutive years with the largest number of nuclear tests. For sub-question d, we count the number of nuclear weapon tests by different countries in the last decade and identify the country with the highest number. For sub-question e, we define the "transition rate" as the number of years from the first 1 state to the last 2 state. We use python to count the sheet "position".

### 2. 2. Analysis of Problem Two

Question 2 is a prediction type problem. For time series data, ARIMA is often used to forecast them. In this paper, the modeling idea is to make a prediction for each country, and if the prediction is negative, then the country will no longer have nuclear weapons in 100 years. By looking at the results for each country after 100 years, the countries that still have nuclear weapons after 100 years are derived. Finally, the results for each country are summed to predict the change in nuclear weapons worldwide in 100 years.

### 2. 3. Analysis of Problem Three

This question a, b, c three sub-questions layer by layer, the first requires the establishment of nuclear weapons detonation location of mathematical models, to determine the location of nuclear weapons and its impact range, and the use of the established model, according to the relevant data collected when the total energy released by the relevant nuclear bomb explosion, calculate the minimum number of nuclear bombs sufficient to destroy the Earth; then requires the use of the model has been built to calculate the most powerful nuclear bomb --Finally, based on the results of the first two questions, we need to consider the actual situation and set limits on the extent of the development of nuclear weapons.

According to the question, the destruction of the Earth by nuclear weapons does not mean that the Earth is blown to pieces, but only that the living environment of human beings and creatures on the Earth has been destroyed, in other words, the model only needs to consider the impact of nuclear bombs on the living environment of the Earth's surface. In addition, nuclear bombs have a wide range of effects, and the extent of their effects on the living environment varies in different regions. The difficulty of the ontology lies in how to determine the range of effects that have a destructive nature after the explosion of a nuclear bomb.

The first question requires the minimum number of nuclear bombs to destroy the Earth, so we use the most powerful nuclear bombs (design TNT equivalent of 50 megatons) to maximize the effective impact of each bomb, at the same time, we assume that the effective impact of each nuclear bomb does not overlap each other, in short, the detonation location of nuclear weapons should be on the surface of the Earth based on the range of effects of nuclear bombs have a destructive nature after the explosion The number of nuclear bombs can be minimized by a uniform distribution.

The destruction range of nuclear bombs, the impact of many factors, including nuclear bomb yield, explosion location, terrain, weather, etc., and nuclear weapons kill and destroy factors also include light radiation, shock waves, early nuclear radiation and radioactive contamination four, and in different locations on the Earth's surface for the explosion of variable circumstances, the effect is not the same, so according to these impact factors difficult to determine the destruction range of nuclear bombs, here using international standards.

Ultimately, using the above model we can calculate the destruction area of the "Big Ivan", and at the same time also calculated the "Big Ivan" destructive power, based on the total area of the Earth, using the mathematical model of the coverage problem, you can get the minimum number of nuclear bombs to destroy the Earth. Theoretically, the total number of nuclear bombs in the world should never exceed the minimum number of bombs sufficient to destroy the Earth, and since not every nuclear bomb has the same yield as "Big Ivan", the actual destruction power should not be sufficient to destroy the Earth in its entirety, but conservatively, we should limit the total number of nuclear bombs in the world to never exceed the minimum number of bombs sufficient to destroy the Earth. minimum number of nuclear bombs.

## 3. Model assumptions

- In 2017, the UN General Assembly adopted the Treaty on the Prohibition of Nuclear Weapons, so we assume that no new nuclear-armed states will be created in the next 100 years.
- For the question 3, we assume that the Earth is flat and that the topography does not affect the detonation range of nuclear weapons.
- Assume that no new policies regarding nuclear weapons or potentially affecting nuclear weapons stockpiles will emerge in the future.

## 4. Symbol description

| Significance | Symbol | Significance | Symbol |
|---|---|---|---|
| Period | $t$ | Error for period t | $\varepsilon(t)$ |
| Data for period t | $y(t)$ | Proportionality constant | $C$ |
| Error | $\varepsilon$ | Destruction radius | $R$ |

# 5. Solution of question 1

## 5. 1. Question a

This question requires the data from the table to obtain the countries that have possessed nuclear weapons. According to the actual situation, the countries that have had nuclear weapons are: China, USA, UK, France, India, Pakistan, Iran, South Africa, North Korea, and Russia. For the data in the table, we can use the sheet "Inventory" to find the countries that have had a stockpile of nuclear weapons: China, United States, United Kingdom, France, India, Pakistan, Iran, South Africa, North Korea, and Russia. Similarly, we can use sheet "position" to filter out the countries with a status of 3: China, USA, UK, France, India, Pakistan, Iran, South Africa, North Korea, and Russia. The results are consistent, so the countries that have had nuclear weapons are: China, USA, UK, France, India, Pakistan, Iran, South Africa, North Korea, and Russia.

## 5. 2. Question b

For this question, we have displayed a line graph of all countries in the sheet "Inventories" for the period 2002-2022, with the US and Russia in one graph and the other countries in another for ease of presentation. The results are shown below.

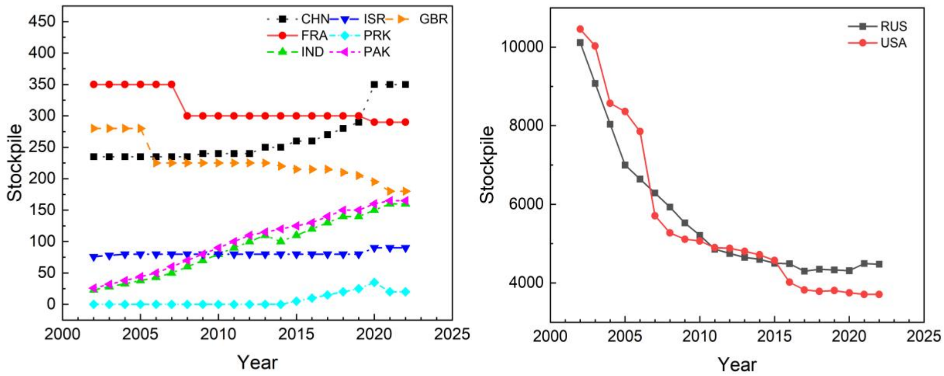



**Figure 5.1: Stockpile folding chart by per country, 2002-2022**

It is clear from the images that the United States has seen the largest reduction in its nuclear weapons stockpile over the 20-year period. For the magnitude of the increase, the magnitude of the increase needs to be calculated for all countries that increased their stockpiles. The formula for the magnitude of the increase is After growth minus before growth. The results of the calculation are shown in the graph below.


**Figure 5.2: Increase in inventory**

As a result, the country with the largest increase was Pakistan.

## 5. 3. Question c

We counted the total number of nuclear tests for each five-year period from 1945-2022, and the results are shown below

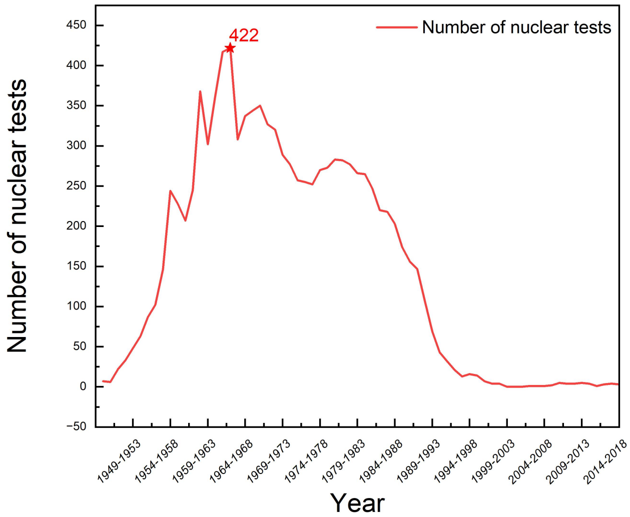



**Figure 5.3: Number of nuclear tests**

We can clearly see that in the five years 1962-1966, there were 422 nuclear tests.

## 5. 4. Question d

Firstly, our team believes that the measure of active nuclear weapons research is the number of nuclear tests, so only North Korea has conducted a total of seven nuclear tests in the period 2010-2019, making it the most active in the last decade of nuclear weapons research.

## 5. 5. Question e

For this problem, we define the 'speed of transition' as the number of years elapsed between the first 1 state and the last 2 state. Using python, the statistics for sheet "position" were calculated as follows.

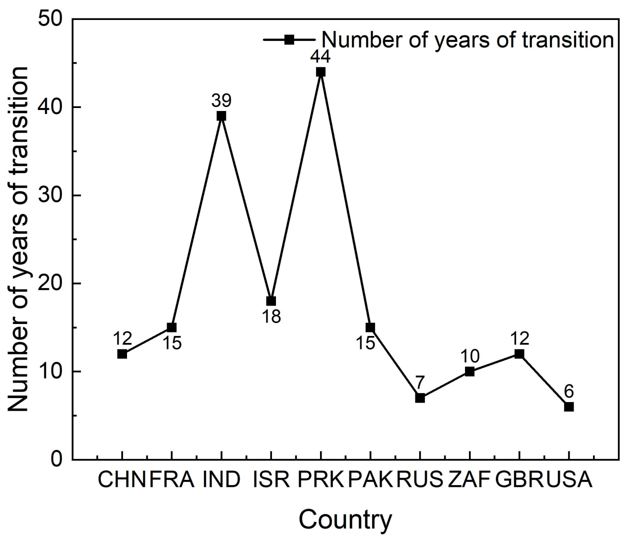



**Figure 5.4: Number of years of transition**

The US has the fastest rate of transition at 6 years.

# 6. Model building and solution of question 2

## 6. 1. Model Establishment

For forecasting time series data, the ARIMA (Auto-regressive Integrated Moving Average Model) model, also known as ARIMA(p,d,q), is a commonly used forecasting statistic. Where p represents the lags of the time series data itself used in the forecasting model, also known as the AR/Auto-Regressive term; d represents the number of orders of differencing required for the time series data to be stable, also known as the Integrated term; and q represents the lags of the forecast errors used in the forecasting model, also known as the MA/Moving Average term[1].

The diagram below clearly illustrates the workflow of ARIMA

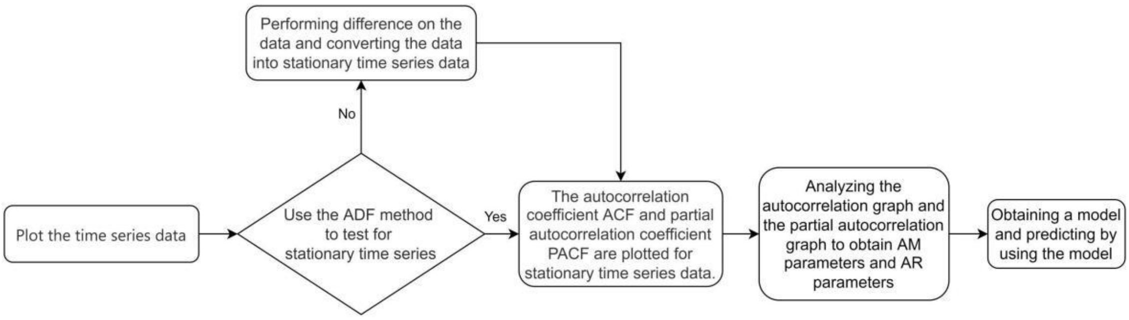



**Figure 5.4: Algorithm flow chart of ARIMA**

The following is a projection of the nuclear weapons stockpiles of each of the present-day nuclear-armed states.

(1) China

In order to avoid affecting the accuracy of the model, the data with zero inventory were first removed, and a total of 59 valid data were obtained.

The data was modelled using SPSSPRO software and the modelling process was as follows.

- ADF Inspection Form

**Table 6.1: ADF Inspection Form**

| Variables | Differential orders | t | P |
|---|---|---|---|
| Stockpile | 0 | 1.837 | 0.998 |
| | 1 | -5.023 | 0.000*** |
| | 2 | -6.727 | 0.000*** |

The ADF test shows that the significance p-value is 0.000*** at the difference of order 1, which presents significance at the level and rejects the original hypothesis that the series is a smooth time series.

- ACF

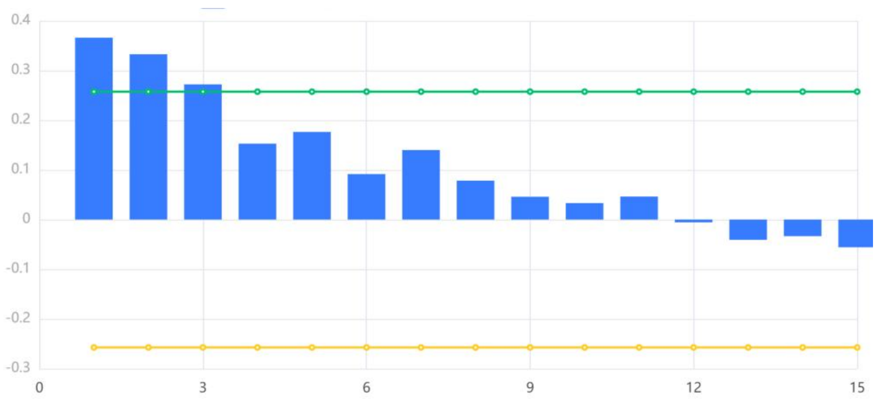



**Figure 6.1: ACF Figure of China**

It can be noticed that the ACF plot shows a trailing phenomenon with an order of 3

- PACF

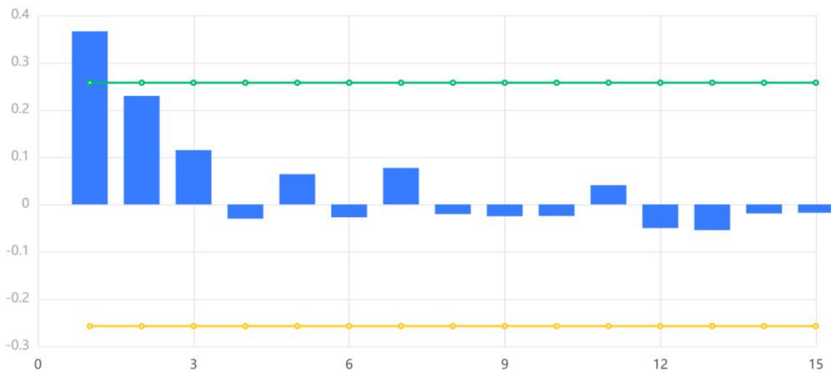



**Figure 6.2: PACF Figure of China**

The PACF diagram also shows a trailing phenomenon, of order 1, so that p,q = min(1,3) = 1

- Defining the model

Based on the above analysis, the model was confirmed as ARIMA(1,1,1) and the model was next tested and the results were tabulated as follows.

**Table 6.2: Model parameters table of China**

| Item | Symbols | Value |
|---|---|---|
| | Df Residuals | 55 |
| Sample size | N | 59 |
| Q-statistic | Q6 (P-value) | 0.01 (0.919) |
| | Q12 (P-value) | 0.82 (0.992) |
| | Q18 (P-value) | 1.277 (1.000) |
| | Q24 (P-value) | 1.583 (1.000) |
| | Q30(P-value) | 2.376 (1.000) |
| Information guidelines | AIC | 429.876 |
| | BIC | 438.118 |
| Goodness of fit | $R^2$ | 0.982 |

From the analysis of the Q-statistic results it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the goodness of fit of the model, $R^2$, is

0.982, which is a good fit.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) = 6.381 + 0.825 * y(t - 1) - 0.564 * \varepsilon(t - 1)$$

Calculated data for the next 100 years and presented in images.

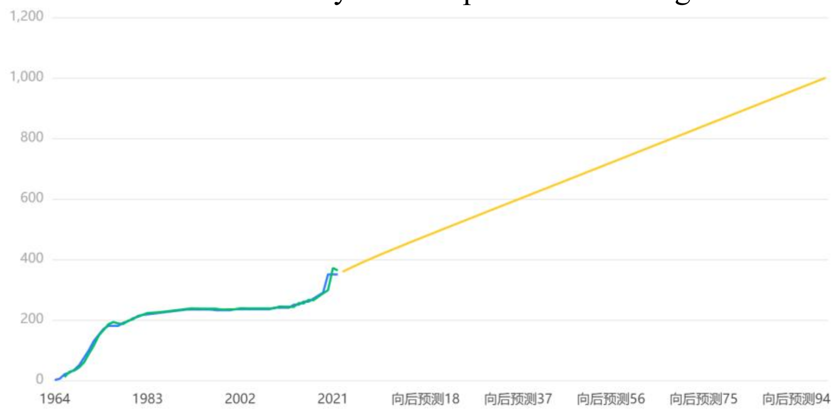



**Figure 6.3: Prediction results graph of China**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graphs, the fitted series trends fit the true series trends very closely, indicating a good fit.

The model predicts that in 100 years, China will have 1,000 nuclear bombs.

The following countries follow the same approach, using the AIC method guidelines for optimal parameters.

(2) France

In order to avoid affecting the accuracy of the model, the data with zero inventory were first removed, and a total of 59 valid data were obtained.

- Defining the model

Model: ARIMA(0,2,1)

**Table 6.3: Model parameters table of France**

| Item | Symbols | Value |
|---|---|---|
| | Df Residuals | 55 |
| Sample size | N | 59 |
| Q-statistic | Q6 (P-value) | 0.053 (0.818) |
| | Q12 (P-value) | 3.853 (0.697) |
| | Q18 (P-value) | 14.773 (0.254) |
| | Q24 (P-value) | 20.91 (0.284) |
| | Q30(P-value) | 29.9 (0.188) |
| Information guidelines | AIC | 550.113 |
| | BIC | 556.242 |
| Goodness of fit | $R^2$ | 0.95 |

From the analysis of the Q-statistic results it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the goodness of fit of the model, $R^2$, is 0.95, which is a good fit.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) = -0.531 - 1.0 * \varepsilon(t-1)$$

Calculated data for the next 100 years and presented in images.


**Figure 6.4: Prediction results graph of France**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graphs, the fitted series trends fit the true series trends very closely, indicating a good fit.

According to the model's predictions, in 2041 the number of French nuclear warheads will be reduced to zero. There will be no nuclear weapons in 100 years' time.

(3) India

In order to avoid affecting the accuracy of the model, the data with a stock of 0 was first removed and a total of 26 valid data were obtained.

- Defining the model

Model: ARIMA(0,1,0)

**Table 6.4: Model parameters table of India**

| Item | Symbols | Value |
| --- | --- | --- |
| | Df Residuals | 24 |
| Sample size | N | 26 |
| Q-statistic | Q6 (P-value) | 0.254 (0.614) |
| | Q12 (P-value) | 4.356 (0.629) |
| | Q18 (P-value) | 8.604 (0.736) |
| | Q24 (P-value) | 9.613 (0.944) |
| Information guidelines | AIC | 151.485 |
| | BIC | 153.923 |
| Goodness of fit | $R^2$ | 0.991 |

From the analysis of the Q statistic results, it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the goodness of fit of the model, $R^2$, is 0.991, which is a good fit.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) = 6.4 + y(t-1)$$

Calculated data for the next 100 years and presented in images.

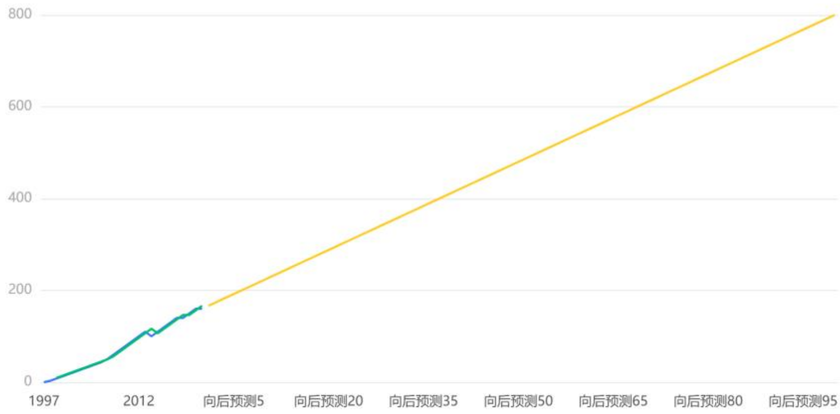



**Figure 6.5: Prediction results graph of India**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graphs, the fitted series trends fit the true series trends very closely, indicating a good fit.

The model predicts that in 100 years, India will have 800 nuclear bombs.

(4) Israel

In order to avoid affecting the accuracy of the model, the data with a stock of 0 was first removed and a total of 26 valid data were obtained.

- Defining the model

Model: ARIMA(0,2,1)

**Table 6.4: Model parameters table of Israel**

| Item | Symbols | Value |
|---|---|---|
| | Df Residuals | 52 |
| Sample size | N | 56 |
| Q-statistic | Q6 (P-value) | 0.064 (0.801) |
| | Q12 (P-value) | 0.463 (0.998) |
| | Q18 (P-value) | 1.185 (1.000) |
| | Q24 (P-value) | 4.206 (1.000) |
| | Q30(P-value) | 5.136 (1.000) |
| Information guidelines | AIC | 203.17 |
| | BIC | 209.137 |
| Goodness of fit | $R^2$ | 0.996 |

From the analysis of the Q statistic results, it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the goodness of fit of the model, $R^2$, is 0.996, which is a good fit.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) = -0.036 - 1.0 * \varepsilon(t-1)$$

Calculated data for the next 100 years and presented in images.

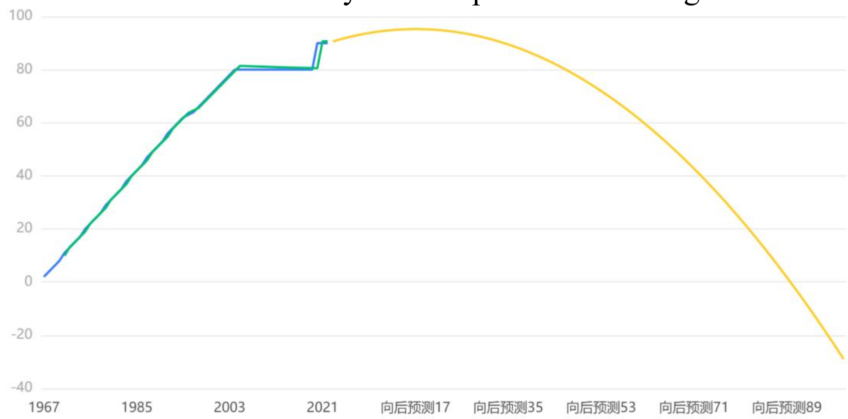



**Figure 6.6: Prediction results graph of Israel**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graphs, the fitted series trends fit the true series trends very closely, indicating a good fit.

According to model projections, the number of nuclear bombs in lsrael will be reduced to zero in 2112.

(5) North Korea

In order to avoid affecting the accuracy of the model, the data with a stock of 0 was first removed, and a total of 9 valid data were obtained.

- Defining the model

Model: ARIMA(1,0,0)

**Table 6.5: Model parameters table of North Korea**

| Item | Symbols | Value |
|---|---|---|
| | Df Residuals | 7 |
| Sample size | N | 9 |
| Q-statistic | Q6 (P-value) | 0.042 (0.837) |
| Information guidelines | AIC | 67.397 |
| | BIC | 67.989 |
| Goodness of fit | $R^2$ | 0.387 |

From the analysis of the Q statistic results it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the model has a goodness of fit $R^2$ of

0.387, which is a poor fit, due to the small amount of data.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) = 14.083 + 0.74 * y(t - 1)$$

Calculated data for the next 100 years and presented in images.


**Figure 6.7: Prediction results graph of North Korea**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graph, the fitted series trends fit the true series trends relatively well and the fit is average.

The model predicts that in 100 years' time, North Korea will have 14 nuclear bombs.

(6) Pakistan

In order to avoid affecting the accuracy of the model, the data with zero inventory were first removed and a total of 25 valid data were obtained.

- Defining the model

Model: ARIMA(0,1,0)

**Table 6.6: Model parameters table of Pakistan**

| Item | Symbols | Value |
|---|---|---|
| | Df Residuals | 23 |
| Sample size | N | 25 |
| Q-statistic | Q6 (P-value) | 0.386 (0.534) |
| | Q12 (P-value) | 5.346 (0.500) |
| | Q18 (P-value) | 9.891 (0.626) |
| | Q24 (P-value) | 11.778 (0.858) |
| Information guidelines | AIC | 123.7 |
| | BIC | 126.056 |
| Goodness of fit | $R^2$ | 0.996 |

From the analysis of the Q statistic results, it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the goodness of fit of the model, $R^2$, is 0.996, which is a good fit.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) = 6.792 + y(t - 1)$$

Calculated data for the next 100 years and presented in images.


**Figure 6.8: Prediction results graph of Pakistan**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graphs, the fitted series trends fit the true series trends very closely, indicating a good fit.

The model predicts that in 100 years' time, Pakistan will have 844 nuclear bombs.

(7) Russia

In order to avoid affecting the accuracy of the model, the data with zero inventory were first removed, and a total of 77 valid data were obtained.

- Defining the model

Model: ARIMA(0,2,0)

**Table 6.7: Model parameters table of Russia**

| Item | Symbols | Value |
|---|---|---|
| | Df Residuals | 74 |
| Sample size | N | 77 |
| Q-statistic | Q6 (P-value) | 0.495 (0.482) |
| | Q12 (P-value) | 17.307 (0.008***) |
| | Q18 (P-value) | 21.12 (0.049**) |
| | Q24 (P-value) | 26.001 (0.100*) |
| | Q30(P-value) | 30.108 (0.181) |
| Information guidelines | AIC | 1179.694 |
| | BIC | 1184.329 |
| Goodness of fit | $R^2$ | 0.982 |

From the analysis of the Q-statistic results it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the goodness of fit of the model, $R^2$, is 0.982, which is a good fit.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) =- 0.503 - 0.999 * \varepsilon (t - 1) + 0.25 * y(t-1)$$

Calculated data for the next 100 years and presented in images.

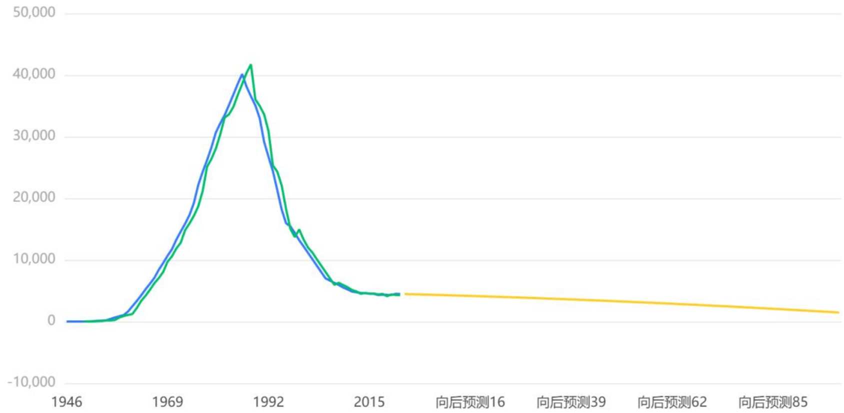



**Figure 6.9: Prediction results graph of Russia**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graphs, the fitted series trends fit the true series trends very closely, indicating a good fit.

The model predicts that in 100 years, Russia will have 1,465 nuclear bombs.

(8) United Kingdom

In order to avoid affecting the accuracy of the model, the data with zero inventory were first removed and a total of 71 valid data were obtained.

- Defining the model

Model: ARIMA(2,0,1)

**Table 6.8: Model parameters table of United Kingdom**

| Item | Symbols | Value |
|---|---|---|
| | Df Residuals | 67 |
| Sample size | N | 71 |
| Q-statistic | Q6 (P-value) | 0.004 (0.948) |
| | Q12 (P-value) | 0.597 (0.996) |
| | Q18 (P-value) | 2.323 (0.999) |
| | Q24 (P-value) | 10.858 (0.900) |
| | Q30(P-value) | 17.576 (0.823) |
| Information guidelines | AIC | 682.297 |
| | BIC | 693.611 |
| Goodness of fit | $R^2$ | 0.896 |

From the analysis of the Q statistic results it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the goodness of fit of the model, $R^2$, is 0.896, which is a good fit.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) = 275.813 + 1.971 * y(t-1) - 0.982 * y(t-2) - 1.0 * \varepsilon(t-1)$$

Calculated data for the next 100 years and presented in images.

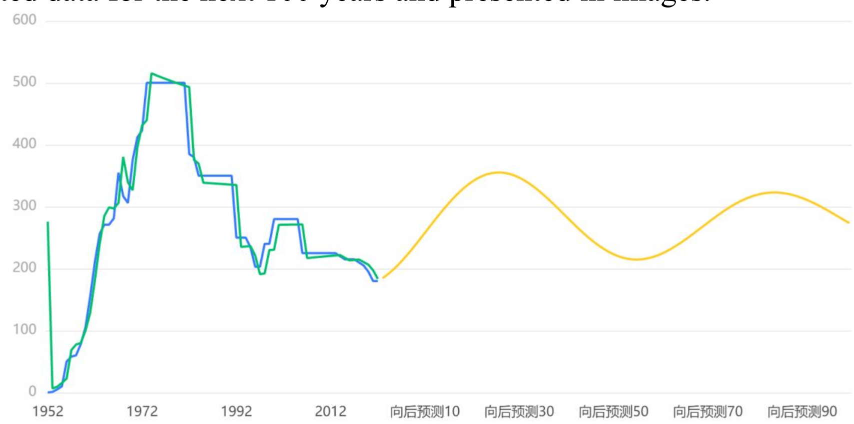



**Figure 6.10: Prediction results graph of United Kingdom**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graphs, the fitted series trends fit the true series trends very closely, indicating a good fit.

The model predicts that in 100 years' time, the UK will have 274 nuclear bombs.

(9) United States

- Defining the model

Model: ARIMA(2,1,2)

**Table 6.9: Model parameters table of United States**

| Item | Symbols | Value |
|---|---|---|
| | Df Residuals | 72 |
| Sample size | N | 78 |
| Q-statistic | Q6 (P-value) | 0.007 (0.933) |
| | Q12 (P-value) | 1.295 (0.972) |
| | Q18 (P-value) | 6.037 (0.914) |
| | Q24 (P-value) | 7.963 (0.979) |
| | Q30(P-value) | 14.125 (0.944) |
| Information guidelines | AIC | 1278.752 |
| | BIC | 1292.815 |
| Goodness of fit | $R^2$ | 0.992 |

From the analysis of the Q-statistic results it can be obtained that Q6 does not present significance at the level and the hypothesis that the residuals of the model are white noise series cannot be rejected, while the goodness of fit of the model, $R^2$, is 0.992, which is a good fit.

- Forecasting with models

The search for optimal parameters based on the AIC method leads to the recursive formula.

$$y(t) = 48.13 + 0.358 * y(t-1) + 0.299 * y(t-2) + 0.587 * \varepsilon(t-1) - 0.066 * \varepsilon(t-2)$$

Calculated data for the next 100 years and presented in images.


**Figure 6.11: Prediction results graph of United States**

The graph above represents the raw data (blue), the model fitted values (green), and the model predicted values (yellow) for this time series model. As can be seen from the graphs, the fitted series trends fit the true series trends very closely, indicating a good fit.

The model predicts that in 100 years, the US will have 8330 nuclear bombs

## 6. 2. Solution and Analysis

### 6. 2. 1. Question a and b

According to the previous model, we add up the results of each country's prediction to get the final prediction of the total number of nuclear weapons. The final results are shown in the following figure. Summarizing the model results above, the final results are as follows.

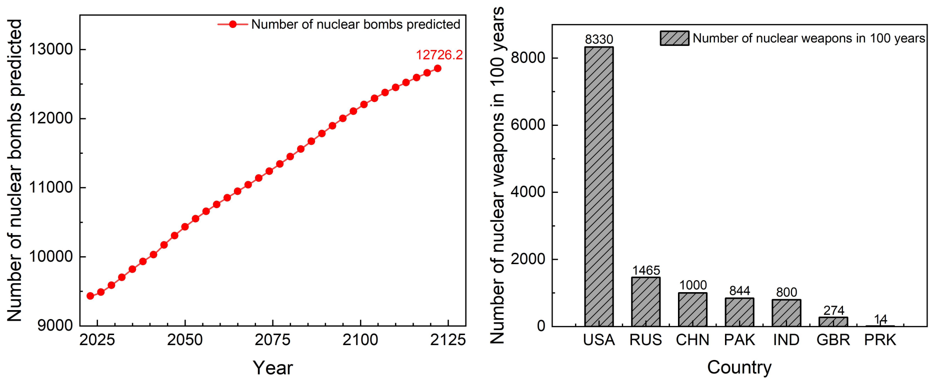



**Figure 6.12: Prediction results graph of World and each country**

From the graph, the total number of nuclear weapons will reach 12,726 in 100 years.

# 7. Model building and solution of question 3

## 7. 1. Model Establishment

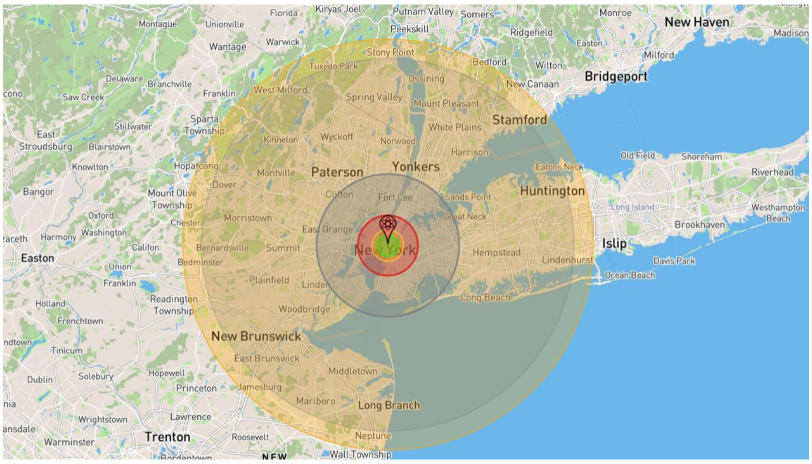



**Figure 7.1: Nuclear bomb explosion range demonstration map**

According to international standards, the formula for the effective kill radius of nuclear weapons is

$$R = C * T^{\frac{1}{3}}$$

In the formula, R is the effective killing radius of nuclear weapons, the unit is front, C is the proportionality constant, generally taken as: 1.493885, T represents the equivalent equivalent of the nuclear weapon, the unit is tons.

The design TNT equivalent of "Big Ivan" is 50 megatons, i.e. 50 million tons, as given in the question. Therefore, the effective kill radius of a single "Big Ivan" is

$$1.493885 * 5000^{\frac{1}{3}} \approx 25.545074(\mathrm{km})$$

Assuming that the detonation power of the nuclear bomb is spread out in a circle centered on the location of the explosion, the effective killing area of "Big Ivan" is

$$3.1415926 * 25.545074^{\frac{1}{2}} \approx 2050.048782(\mathrm{km}^2)$$

According to available data, the Earth is an irregular sphere with slightly flattened poles and a slightly bulging equator, with an equatorial radius of 6378.137 km and a polar radius of 6356.752 km, and a surface area of about 510 million square kilometers.

In the mathematical model of the coverage problem.

$$n * s = S$$

In the formula, n represents the number of units, s represents the area covered by a single unit, and S represents the total area to be covered.

Therefore, the minimum number of nuclear bombs to destroy the Earth is approximately

$$n = \frac{S}{s} = \frac{5.1 * 10^8}{2050.048782} \approx 248775$$

In addition to this, by applying the reverse thinking to the above process, we can calculate the minimum equivalent to destroy the Earth:

$$S = \pi R^2 = \pi\left(C * T^{\frac{1}{3}}\right)^2$$

In the formula, S represents the surface area of the Earth and C is the proportionality constant for the effective kill radius of a nuclear weapon, so the minimum equivalent is

$$\left(\frac{\sqrt{5.1 * 10^8}}{1.493885}\right)^3 = 345464769374004447.51\ \text{（ton）}$$

## 7. 2. Solution and Analysis

### 7. 2. 1. Question a , b and c

Theoretical calculations and nuclear bomb simulator simulations show that:

a. According to the international standard model of the effective kill radius of nuclear weapons, it would take at least about 248,775 nuclear bombs to destroy the Earth

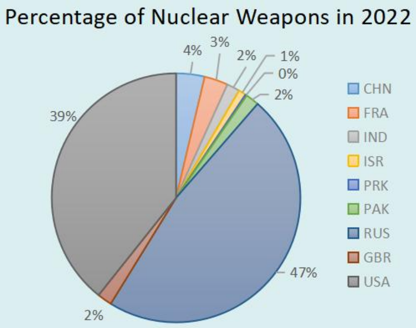
b. According to the above model, the maximum destructive power of the current nuclear bombs comes from the "Big Ivan", with a total destruction area of about 2050 square kilometers, which is obviously not enough to destroy the Earth, but the impact on human beings and our living environment is still tragic.

c. Theoretically, the total number of nuclear bombs in the world should never exceed the minimum number of bombs sufficient to destroy the Earth, and since not every nuclear bomb has the yield of "Big Ivan", the actual destruction power should not be sufficient to destroy the Earth in its entirety, but conservatively, we should limit the total number of nuclear bombs in the world to never exceed the minimum number of bombs sufficient to destroy the Earth. In addition, for countries that already have nuclear weapons, we should make sure that the total nuclear yield of all these countries does not exceed at least 345,464,769,374 million tons, and conservatively, we should multiply a certain proportional constant on top of that.

## 8. **Solution of question 4**

# In nuclear war, there are NO WINNERS

Dear UN Secretary-General, Hello. We are a team from China studying nuclear weapons related issues. Next, our team will report our findings to you and give our opinion on the control of the number of nuclear weapons in the world.




Currently, the distribution of nuclear weapons around the world is shown in the figure to the right. By collecting data and analyzing it, the world's nuclear weapons stockpile today is around 9,000, with the specific country percentages shown on the left. We built a predictive model of the data and found that the number of nuclear weapons will continue to rise over the next 100 years, but the percentage of nuclear weapons owned by each country will continue to equalize.

Nuclear weapons, as a weapon of mass destruction effect, also have an important impact on the world strategic landscape. If nuclear weapons were possessed by only one country, it would have a very significant impact on world peace and even the survival of civilization. Fortunately, after the United States possessed nuclear weapons, more and more countries acquired nuclear weapons technology one after another, preventing the then two camps of the Cold War from deteriorating into a hot war. But how long could this state of peace be maintained by nuclear weapons? The number of nuclear weapons is increasing, and the risks involved will also increase. Several conferences and agreements in recent years, such as the Nuclear Security Summit [2]; the new Nuclear Posture Review issued by the United States [3]; and including Secretary-General Ban Ki-moon's call for all states to work toward the entry into force of the CTBT as soon as possible [4], are all working toward a nuclear-free world.

While our research concludes that the nuclear weapons currently in existence are nowhere near enough to wipe out the planet, they are enough to wipe out a country, and thousands of innocent people would die as a result. This is not what we would like to see, so despite predictive models that suggest the number of nuclear weapons will rise in the future, countries should be conscious and stop producing them.

We recommend that countries with nuclear weapons make a clear commitment that their nuclear weapons will be used only to deter nuclear attack and that they will not be the first to use them under any circumstances. Russia and the United States, as the countries with the most nuclear weapons, need to take the lead. If all nuclear-armed states were to commit, this would pose no threat to non-nuclear states and the proliferation problem would be mitigated. Likewise, the non-nuclear states need to consciously adhere to the CTBT. Let's work together toward a nuclear-free world.

# 9. Strengths and Weaknesses of the Model

## 9. 1. Strengths

- The ARIMA model is very simple and requires only endogenous variables without resorting to other exogenous variables.

## 9. 2. Weaknesses

- ARIMA requires the time series to be stable, or stable after differencing, and the more the number of differences, the more information is lost.
- ARIMA models by nature can only capture linear relationships and cannot expose non-linear relationships.

# 10. References

[1] Jian Yining,Zhu Di,Zhou Dongnan,Li Nana,Du Han,Dong Xue,Fu Xuemeng,Tao Dong,Han Bing. ARIMA model for predicting chronic kidney disease and estimating its economic burden in China[J]. BMC Public Health,2022,22(1).

[2] Loukianova Anya Improving Nuclear Security—One Summit at a Time [J] Global Summitry,2015

[3] 张金荣,詹家峰.奥巴马政府《核态势评估》报告评析[J].国际论坛,2010,12(04):7-14+79.DOI:10.13549/j.cnki.cn11-3959/d.2010.04.002.

[4] https://www.un.org/zh/86111

# Appendix

```
# %%
# Basic Analytical Package
import numpy as np
import pandas as pd
# %%
# Read original data
position=pd.read_excel('2022_APMCM_E_Data.xlsx',sheet_name='positio
n')

# %%
# Variable initialization
Countrytemp=''
Besttimelong=1e3
BestCountry=''
starttime=0
endtime=0
Valid_Dict={}
flag=False

# %%
# Statistical ergodic
for index,row in position.iterrows():

Country,Abbreviation,Year,Status=row['Country'],row['Abbreviation'],row['
Year'],row['Status']
    if Status == 0:
        starttime=Year
        flag=True
    elif Status == 3:
        endtime = Year
        if flag == True:
            Valid_Dict[Country]=endtime - starttime-1
            flag=False
        if Besttimelong > endtime - starttime-1:
            Besttimelong = endtime - starttime-1
            BestCountry = Country
    Countrytemp = Country
print('The country has made the fastest transition from "not considering
nuclear weapons" to "possessing nuclear weapons" is',BestCountry,'only
using',Besttimelong,'year.\n')

print('the time used of other succeed countries:\n',Valid_Dict)
```

```
import numpy
import pandas
from spsspro.algorithm import statistical_model_analysis
#
data = pandas.DataFrame({
    "A": numpy.random.random(size=20)
})
result = statistical_model_analysis.arima_analysis(data=data, p=0, d=0,
q=0, forecast_num=10)
print(result)
```