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Research on Wildlife Trade Based on SARIMA and Multiple Regression

Zhihong Liao [a], Jinyuan Song [b] and Jingyu Yang [c]

Sichuan University, Chengdu 610207, China.
[a]1732407275@qq.com, [b]1097537934@qq.com, [c]1733942830@qq.com

Abstract: At the start, this paper firstly converges the data set given in the topic to count out the data from 1990-2021. After that, uses the count function of MATLAB on the pd library to statistically analyze the family data, so as to get the greatest number of wild animal groups and species transactions, and concludes that: among the species varieties, the category of Cercopithecidae has the most number, followed by Felidae, Cebidae. among the specific genera of animals, Macaca had the highest number, followed by Papio and Potos. Next, this paper analyzes the statistical options so as to obtain the most important trade purposes, and concludes that: the analysis of the global wildlife trade records from 2003 to 2021 shows that the purposes of wildlife trade are the most used for wildlife trade, zoo use, and circus performances. After that, this paper uses the number of trade imports and exports over the years as the basic data to measure the state of the trade market, and later analyzes it by constructing the growth rate of trade transactions as an indicator to assess the state of the wildlife trade market. The concludes that: with the change of time, the economy was relatively stable in the pre-wild trade market, and there was a market turmoil in 2012, and then it stabilized. Market turbulence was observed in both 2018-2022, with a depressed status quo in the wild trade market. Then, this paper will use multiple regression analysis to analyze the number of import and export transactions of wildlife trade each year and the degree of epidemic, so that the correlation between the two can be judged by the regression coefficient, and the conclusion is: the severity of the epidemic will indeed have a certain impact on the wild trade market, and this relationship shows a typical negative correlation, that is, the higher the severity of the epidemic, the lower the import and export The lower the severity of the epidemic, the higher the import and export trade in the wild trade market. Last, the annual wildlife trade import and export quantities are used as the basic data, and the total global GDP is collected as an indicator of the global economy, so that a multiple regression model is constructed to analyze the relationship between the global wildlife trade import and export quantities and the total global GDP, and concludes that: based on this analysis, this paper concludes that the global wildlife trade ban needs to be adhered to at least for a long period of time, and that the wildlife trade does affect the global economic situation.

Keywords: S-ARIMA; Multiple regression; Wildlife Trade; MATLAB.

1. Background

In the long history of human development, there are traces of wild animals, which are closely related to the survival of human beings. In primitive society, wild animals were important sources of food and materials for human beings. This stage was called dependent utilization [1].

Gradually, humans learned to domesticate wild animals into poultry and domestic animals. This stage is called transformational utilization. In the modern society, people can hunt wild animals on a large scale and the demand for wild animals is very strong, so there has been a large-scale commercial trade in wild animals. In this stage, many species, such as the dodo and the North American traveling pigeon, were hunted to extinction due to large-scale commercial trade demand. People gradually realize that the uncontrolled and predatory use of wild animals is unsustainable, and relevant laws and regulations are needed to regulate the trade of wild animals. So we began to make a transition to the stage of coordinated utilization of wild animals.

However, at this stage, a new study found that illegal wildlife trade is having a far-reaching negative impact on biodiversity. Researchers report that many species, including those living in the Reserve, are threatened by hunting and trapping to meet trade needs [2].

"This study adds to the evidence that wildlife trade is a major threat." Said Scott Robertson, an environmentalist with the Wildlife Conservation Society. Analysts estimate that the annual income of illegal wildlife trade is between US $5 billion and US $20 billion, involving tens of millions of individuals who capture or kill thousands of species of animals, while about 150 million families rely on eating or selling wild animals for a living.

David Edwards, a conservation biologist at the University of Sheffield in the United Kingdom, said that for decades, many environmentalists believed that wildlife trafficking was making certain species extinct, but some believed that "trade is usually sustainable".

In order to achieve coordinated utilization, we have introduced some laws and regulations. First, the international wildlife trade management method – the Convention on International Trade in Endangered Wildlife, also known as the Washington Convention, CITES Convention. The core spirit of the Convention is to manage the international trade of wild animal and plant species by means of species classification and licensing, so as to achieve the purpose of protecting wild animals.

2. Assumptions

2.1. Assumptions

1. It is assumed that in this paper, after data pre-processing, there is no anomalous data to interfere with the problem.

2. Assume that in this paper, all the data are smooth, so the global wildlife trade import and export quantities at any moment can be obtained.

3. Assume that in this paper, the influence of other factors on the global wildlife trade is not considered.

4. Assume that in this paper, the impact size of the epidemic level can be expressed by the basic regeneration number R0.

5. It is assumed that in this paper, the time of onset of the epidemic is calculated from the very beginning of the onset.

2.2. Notations

Table 1. Symbol definition table

Symbol	Meaning
σ	which is the standard deviation.
X	the standard data
μ	the mean of the dataset
y_t	Observations at period t
δ	Constant term for time series forecasting
μ_t	Random error
$y_{t-1} \cdots y_{t-p}$	lagged time series
$\theta_1 \cdots \theta_p$	Coefficients of the regression model

3. Question Analysis

3.1. Model establishment and solution of problem 1

For question one, the question asks for an analysis of the data set provided to find the most traded species and groups of wild animals. For this problem, this paper firstly combines the data set given in the title and calculates the data from 1990 to 2021. After that, this paper screens the data set, selects the living wild animals at the present stage as the sample data, and uses MATLAB to carry out statistical analysis on the count function in pd library to obtain the maximum number of wild animal groups and species traded. Finally, this paper makes a theoretical analysis and verification of the trading animal groups and the maximum number of species trading, so as to prove that the conclusions obtained in this paper are consistent with the reality.

Based on this, the flow chart of the first question is drawn in this paper as follows:

Fig.1 The flow chart for solving Problem 1

3.1.1. Statistical model of vulnerable animal population and species

Based on the above analysis, this paper firstly pre-processes the data set provided by the sponsor. Then, the data set from 1990 to 2021 was used to count the total number of entries in each year, as shown in the figure below.

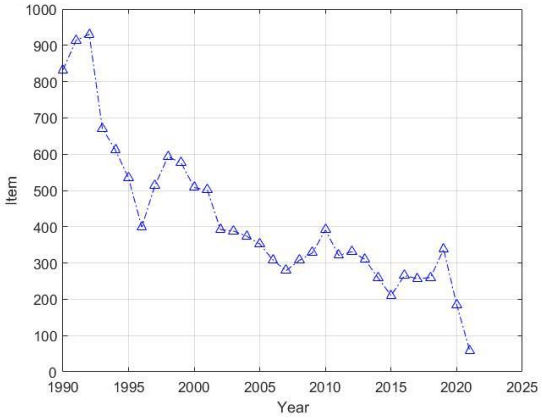

Fig.2 Project maps for each year

According to the above figure, the trend of the project chart in each year shows that the number of wild trade transactions decreases sharply with the increase of years. Further, the family data in the data are collected for statistical analysis, and the results are as follows:

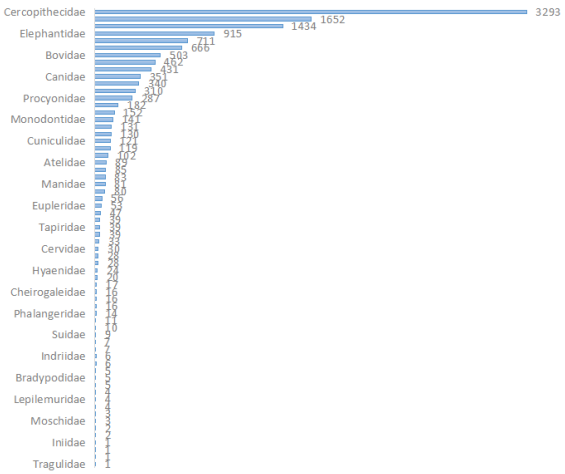

Fig.3 Ranking of species number transactions in wild trade markets from 1990 to 2021

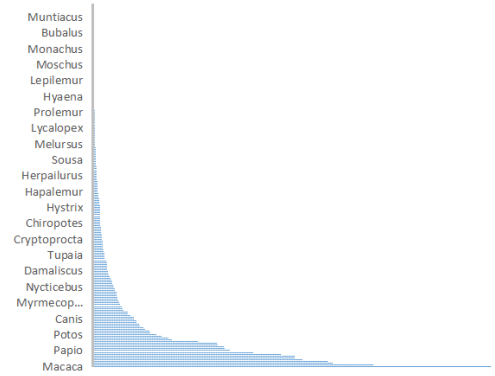

Fig.4 Ranking of animal group transactions in the wild trade market from 1990 to 2021

According to the analysis in Figure 4.1 and 4.2, Cercopithecoidea has the largest number of species, followed by Felidae and Cebidae. In the specific genus of animals, Macaca is the most abundant, followed by Papio and Potos.

3.2. Model establishment and solution of problem 2

In the second question, the purpose of trade of these animals is analyzed. For this problem, this paper considers that the Purpose option of the attached data is calculated on the basis of the screening of the first question, so as to draw the statistical distribution map. Further, this paper analyzes the statistical options, so as to get the main purpose of the transaction, and explore its reasons, so as to analyze the direct direction of the purpose.

Based on this, the flow chart of the second question is drawn in this paper as follows:

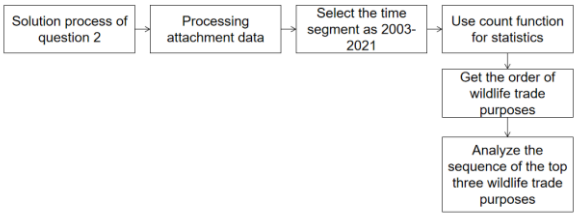

Fig.5 The flow chart for Question 2

3.2.1. Analysis on the purpose of wild trade

To solve this problem, on the basis of the first question, this paper makes statistics on the choice Purpose stated in the data, and the results are shown as follows:

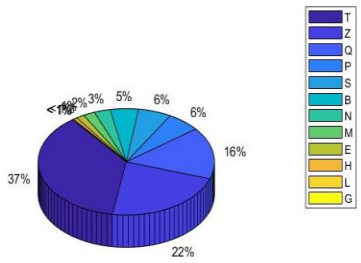

Fig.6 Statistical chart of wild trade market transactions from 1990 to 2021

Table .2 Wild trade market Transaction purpose explanation table

Code	Explanation
B	Breeding in captivity or artificial
E	Propagation Educational
G	Botanical garden
H	Hunting trophy
L	Law enforcement / judicial / forensic
M	Medical (including biomedical research)
N	Reintroduction or introduction into the wild
P	Personal
Q	Circus or travelling exhibition
S	Scientific
T	Commercial
Z	Zoo

Based on this, this paper analyzes the 3D pie chart above, and it can be seen that the darker the color, the more quantity, and the brighter the color, the less quantity. Through the above analysis, it can be seen that T, Z, Q and choice have the most purposes. In order to understand the specific meaning of each indicator, this paper explains the transaction purpose in the above figure through the search options in the attached table, and the results are shown in the table 2.

Through analysis of the above table, it can be seen that T stands for wildlife trade, Z for zoo use, and Q for circus performance.

Therefore, among the purposes of wildlife trade in this question, those used for wildlife trade, zoo use and circus performance are the most.

3.3. Model establishment and solution of problem 3

To answer question three, the author asks for an analysis of the trade situation in the past 20 years. First of all, by determining the data set, this paper learns that the time node of the past 20 years is 2003-2022. After that, this paper integrated the data set from 2003 to 2022, took the number of trade imports and exports over the years as the basic data to measure the state of the trade market, and then constructed the growth rate of trade transactions as the state index to evaluate the wildlife trade market, so as to analyze it. MATLAB software is used to draw a line chart of the trade growth rate, so as to observe the changes of the global trade market in the past 20 years.

Based on this, the flowchart of the solution of the third question is drawn in this paper as follows:

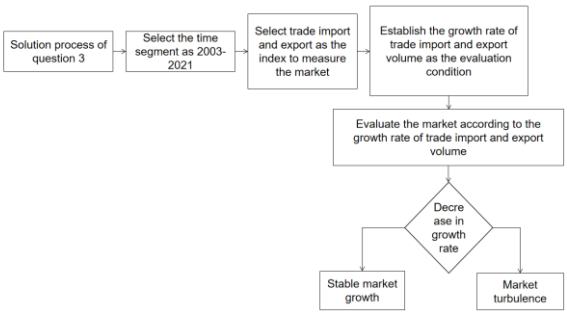

Fig.7 The flow chart for question three

3.3.1. Trade status assessment model

To solve this problem, this paper firstly collates the attached data and selects the data from 2003-2022 as the data set.

After that, this paper integrated the data from 2003 to 2022, and took the import and export in the attached data as the representation of the market state of wildlife trade. As we can see from the observation that there are multiple lines of data in each year's data, this paper uses the sum function for summation, so as to obtain the annual trade import and export quantity, as shown in the following table.

Based on this, this paper draws the import and export quantity trend chart of wild trade market from 2003 to 2021, and the results are shown as follows:

Based on this, this paper defines the growth rate of import and export volume, as shown below.

Volume growth rate of import trade：

$$V\_I_{in}(i+1) = \frac{V\_I_{in}(i) - V\_I_{in}(i-1)}{V\_I_{in}(i-1)}$$

Volume growth rate of export trade：

$$V\_I_{out}(i+1) = \frac{V\_I_{out}(i) - V\_I_{out}(i-1)}{V\_I_{out}(i-1)}$$

Based on this, this paper uses MATLAB software to calculate the growth rate of import and export volume, and the results are shown as follows:

Table .3 Quantity of import and export of wild trade market from 2003 to 2021

Year	Importer reported quantity	Exporter reported quantity
2003	8537	11885
2004	11519	6987
2005	8819	9600
2006	5919	5849
2007	3221	3216
2008	3113	4088
2009	3671	3507
2010	5002	5233
2011	2196	4200
2012	2791	3665
2013	2600	3575
2014	3488	4054
2015	2804	2483
2016	2723	2916
2017	4277	3793
2018	6408	4174
2019	1434	8018
2020	598	6802
2021	428	1333

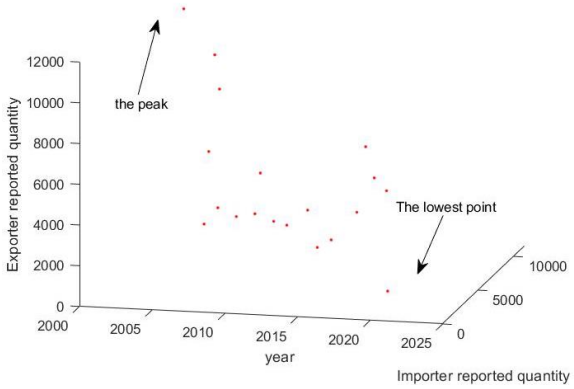

Fig.8 3D map of import and export quantity of wild trade market from 2003 to 2021

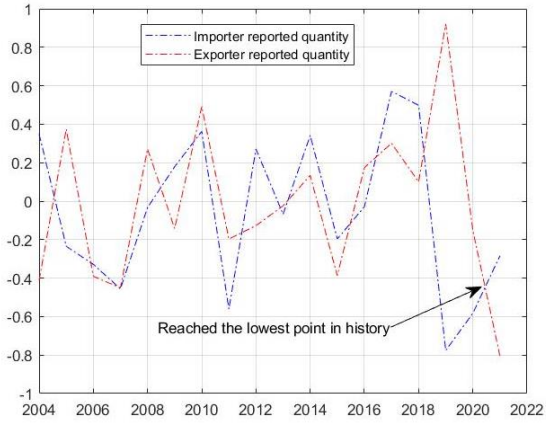

Fig.9 Image of growth rate of import and export of wild trade market from 2003 to 2021

According to the analysis in the figure above, with the change of time, the economy was relatively stable in the early stage of the wild trade market, and there was a market turbulence in 2012, and then it stabilized. In 2018-2022, there was market turmoil and a downturn in the wild trade market.

3.4. Model establishment and solution of problem 4

In response to question 4, we need to explore whether wildlife trade is related to the epidemic situation of major infectious diseases. For this problem, this paper first analyzes the annual import and export volume of wildlife trade. Then, the transmission time and epidemic degree of major infectious diseases are obtained by consulting relevant literature. Then this paper will use multiple regression analysis to conduct regression analysis on the annual import and export volume of wildlife trade and the epidemic degree, so as to determine the correlation between the two through regression coefficient

Based on this, the flow chart for solving the fourth question in this paper:

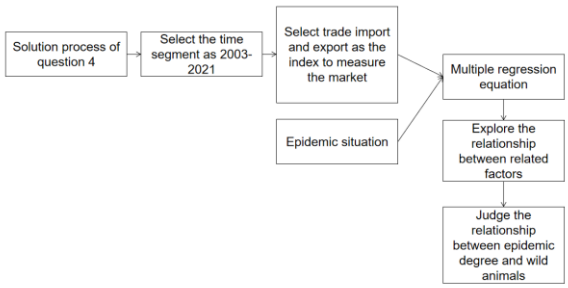

Fig.10 The flow chart problem 4 solution

3.4.1. Analysis of Wildlife Market Trade Market and Epidemic Degree

Based on this, this paper makes statistics on infectious disease events that have occurred in the historical process, and conducts multiple regression analysis on the import and export quantity of wild animal trade market.

First of all, this paper analyzes the infectious disease events in history and the corresponding time, as shown in the following table.

Table .4 Sequence of influenza virus events in 2003-2021

Year	Event
2003	SARS
2009	SWINE FLU
2014	Ebola Virus
2019	COVID-19

Based on this, this paper analyzes the events of influenza virus and the corresponding import and export quota of wild market trade, and draws the image using matlab as follow.

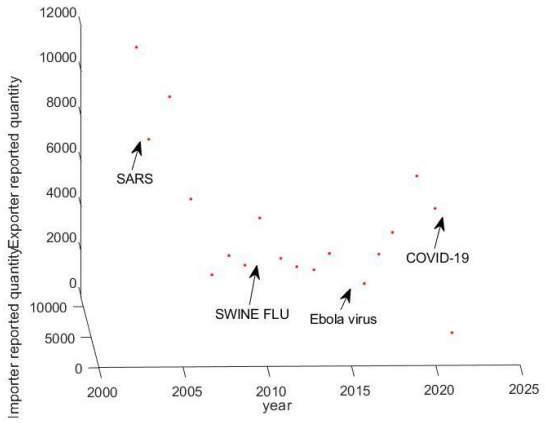

Fig.11 Influenza related to wild trade market from 2003 to 2021

According to the analysis of the above figure, when an influenza event occurs, the value of the global wild trade market will decline significantly, which will lead to a depression in the wild market trade.

Based on this, this paper further introduces the basic regeneration number R0 to evaluate the extent of infectious diseases. R0 is an estimate of the transmission speed of a specific infectious disease in a specific population. It is usually calculated based on three parameters: 1) the duration of contact infection after infection, 2) the possibility of infection between infected individuals and susceptible individuals, and 3) the contact rate.

Specifically, R0 refers to the average number of people that can be infected by one person. If R0＜1, it means that the disease is under control or not spreading fast; If R0 is 1, one person can spread to another on average; If R0>1, the disease can spread from one person (index) to a wider population.

Therefore, this paper queries R0 of infectious diseases, as shown in the following table.

Table .5 Sequence of influenza virus events in 2003-2021

Year	Event	Basic regeneration number
2003	SARS	1.08
2009	SWINE FLU	1.6
2014	Ebola Virus	1.9
2019	COVID-19	5.7

Based on this, the basic regeneration number in the remaining years without influenza is set as 0, so as to conduct regression analysis. Therefore, this paper introduces multiple regression analysis as follows.

The multiple linear regression model predicts the linear relationship between the independent variable y and multiple dependent variables x and errors ε. Let y be the dependent variable and the independent variable be $x_1, x_2, \ldots, x_n$, then the multiple linear regression model is expressed as follows [8]:

$$y = \beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n + \varepsilon$$

Among them, $\beta_0, \beta_1 \ldots, \beta_n$ are unknown parameters, assuming random error ε:

$$E(\varepsilon) = 0, Var(\varepsilon) = \sigma^2$$

The theoretical regression equation is

$$E(y) = \beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n$$

For practical problems, assuming that n sets of sample data are obtained, the multiple regression equation can be expressed as:

$$\begin{cases} Y = X\beta + \varepsilon \\ E(\varepsilon) = 0_n, Var(\varepsilon) = \sigma^2 I_n \end{cases}$$

while

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ \ldots \\ y_n \end{bmatrix}, X = \begin{bmatrix} 1, x_{11}, x_{12}, \ldots, x_{1n} \\ 1, x_{21}, x_{22}, \ldots, x_{2n} \\ \ldots \\ 1, x_{m1}, x_{m2}, \ldots, x_{mn} \end{bmatrix}, \beta = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \ldots \\ \beta_n \end{bmatrix}, \varepsilon = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \ldots \\ \varepsilon_n \end{bmatrix}$$

Get an estimate of the vector β by least squares:

$$\hat{\beta} = (X'X)^{-1}X'y$$

The estimated model is:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \ldots + \hat{\beta}_n x_n$$

The regression line fitting effect is determined by the proportion of the regression square sum SSR to the total square sum SST, that is, the coefficient of determination $R^2 = \frac{SSR}{SST}$. The closer it is to 1, the better the regression line fits the original data distribution.

The estimated standard deviation represents the size of the error between the actual and predicted values. The formula is:

$$s_e = \sqrt{\frac{\sum(y_i - \hat{y_i})^2}{n-p-1}} = \sqrt{\frac{SSE}{n-p-1}} = \sqrt{MSE}$$

The smaller the value s_e , the smaller the difference between the actual value and the predicted value, and the closer the forecast is to the actual value. If s_e=0, it means that the actual value is equal to the predicted value.

The significance test includes linear relationship test and regression coefficient test.

The linearity test is as follows:

If the null hypothesis ($H_0: \beta_I = 0$) is established, the distribution of MSR/MSE obeys the F(p,n-p-1) distribution, is [9]:

$$F = \frac{SSR/p}{SSE(n-p-1)} = \frac{MSR}{MSE} \sim F(p, n-p-1)$$

If the null hypothesis is rejected, it is determined that there is a significant linear correlation between the independent variable and the dependent variable.

The regression coefficient test is as follows:

$$H_0: \beta_I = 0$$

Tests statistic:

$$t = \frac{\hat{\beta}_i}{s_{\hat{\beta}_i}} = \frac{\hat{\beta}_i}{\frac{s_e}{\sqrt{\sum x_i^2 - \frac{1}{n}(\sum x_i)^2}}} \sim t(n-p-1)$$

If the null hypothesis is rejected, it means that there is a significant linear correlation between the independent variable and the dependent variable.

Thus, the model is constructed by using multiple regression, and the basic regeneration number R0 is taken as the dependent variable, and the time, import and export trade volume of wild market are taken as the dependent variables. The results are as follows.

$$R0 = -144.3764 + 0.0566 * \text{year} - 1.92 * 10^{-4} * \text{In} - 3.74 * 10^{-4} * \text{Out}$$

Therefore, according to the analysis of the above relationship, if the coefficient in front of the relationship is larger, it means that the relationship between them is closer, otherwise, it means that the relationship between them is less obvious. For the coefficient of each index, if the coefficient of this index is positive, it means that there is a positive correlation between the independent variable and the basic regeneration number R0, and vice versa.

Based on the above analysis, we can see that the severity of the epidemic does have some impact on the wild trade market, and this relationship shows a typical negative correlation, that is, the higher the severity of the epidemic, the lower the import and export trade volume of the wild trade market, and the lower the severity of the epidemic, the higher the import and export trade volume of the wild trade market.

3.5. Model establishment and solution of problem 5

As for problem 5, we need to judge whether wildlife trade is prohibited for a long time, and whether wildlife trade will have a huge impact on the economy and society, and explain the reasons. To solve this problem, this paper first uses the

annual import and export volume of wildlife trade as the basic data, and collects the total global GDP as the indicator to measure the global economy, so as to build a multiple regression model to analyze the data relationship between the import and export volume of global wildlife trade and the total global GDP, and according to the relationship between the three, Answer whether wildlife trade should be banned for a long time and its impact on the global economy.

Based on this, the flow chart for solving Problem 5 in this paper:

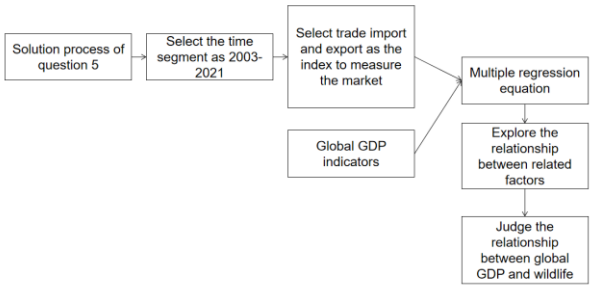

Fig.12 The flow chart of problem 5 solution

3.5.1. Regression analysis of the global economy and wildlife trade

Based on this, the relevant website (https://www.shujujidi.com/caijing/97.html)is inquired to obtain the data of global GDP over the years (in trillion dollars), and plotted the trend chart, as shown in the figure below.

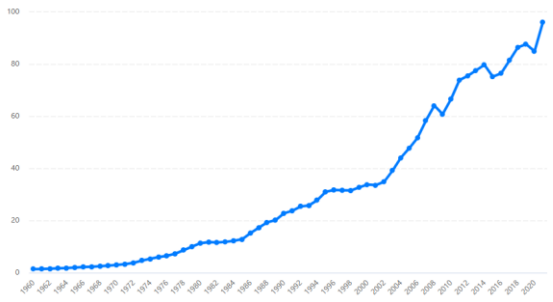

Fig.13 Global GDP trend from 1960 to 2021

Based on the above figure, this paper uses the S-ARIMA time series prediction model to forecast the future trend of global GDP and the import and export volume of wild trade. Therefore, this paper first introduces the S-ARIMA time series prediction model, as shown below.

With the widespread application of linear time series models, the models have been continuously improved. The SARIMA model is gradually developed on the basis of the autoregressive model (AR) and the moving average model (MA) [10]. In this problem, the concentration of CO2 can be regarded as a data series that changes over time, referred to as a time series. Therefore, the above model can be used to predict the future concentration trend of the time series, and the specific steps are as follows

(1) Autoregressive model AR

According to the relationship between current data and historical data, the autoregressive model can use historical data to predict future development trends. The autoregressive model has the following formula

$$y_t = \delta + \theta_1 y_{t-1} + \theta_2 y_{t-2} + \cdots + \theta_p y_{t-p} + \mu_t$$

In the formula, y_t is the observed value of period t, δ is the constant item, μ_t is the random error, $y_{t-1} \cdots y_{t-p}$ is the lagged time series, $\theta_1 \cdots \theta_p$ is the regression model coefficient.

(2) Moving Average Model MA

If it is found that there is no correlation between the historical time series and the current time series, it is considered that the change is caused by external factors. At this time, the MA moving average model is used for prediction. The specific formula is as follows

$$y_t = \mu_t + \mu_1 + \theta_1 \mu_{t-1} + \theta_2 \mu_{t-2} + \cdots + \theta_p \mu_{t-p}$$

(3) Autoregressive Moving Average Model ARMA

If it is found that the current time series is affected by historical time series and external factors at the same time, the autoregressive moving average ARMA model is used for prediction. The specific formula is as follows

$$y_t = \theta_1 y_{t-1} + \theta_2 y_{t-2} + \cdots + \theta_p y_{t-p} + \mu_t + \theta_1 \mu_{t-1} + \theta_2 \mu_{t-2} + \cdots + \theta_p \mu_{t-p}$$

(4) Autoregressive Difference Moving Average Model ARIMA

Depending on how stationary the data is, predictive models can be constructed in different ways. Among them, the ARMA model is modeled for the stationary data, and the ARIMA model is calculated after the difference of the non-stationary data. The mathematical expression of the difference is as follows, where $\Delta^d y_t = (1-L)^d y_t$ is the introduced d-order difference operator.

$$w_t = \Delta^d y_t = (1-L)^d y_t$$

ARMA modeling is carried out after difference, and the formula is as follows, where w_t is the time series in a stationary state obtained after difference processing.

$$y_t = \theta_1 y_{t-1} + \theta_2 y_{t-2} + \cdots + \theta_p y_{t-p} + \mu_t + \theta_1 \mu_{t-1} + \theta_2 \mu_{t-2} + \cdots + \theta_p \mu_{t-p}$$

(5) Autoregressive Moving Average Model SARMA

If there is a seasonal change trend in the time series, the SARIMA model can be used for prediction. The model is simplified to SARIMA (p,d,q)(P,D,Q), and the specific formula of the model is as follows

$$\theta_p(L)\Phi(L^s)(1-L)^d(1-L^s)^D X_t = \theta_q \Theta(L^s)\mu_t$$

(6) Testing of Time Series Forecasting Models

Based on this, the timing test and stability test are carried out on the above-mentioned model, so that the accuracy of the model can be judged.

Therefore, this paper forecasts the global GDP and the import and export volume of wild trade, as shown below:

Table .6 2023-2025 S-ARIMA Time Series Forecasting Results

Year	Global GDP	Import volume of wild trade	Export volume of wild trade
2023	96.7	334	1043
2024	97.5	223	869
2025	98.3	132	634

Then, take the global GDP as the dependent variable Y, and take the import and export value and time of wild trade as the independent variable X to conduct multiple regression analysis. The results are as follows:

$$\text{Gobal GDP} = -4620 + 2.3344 * \text{time} - 6.31 * 10^{-4} * \text{In} - 7.96 * 10^{-4} * \text{Out}$$

According to the analysis of the above formula, the global GDP shows a typical proportional promotion relationship with time, while there is a typical negative correlation with global wildlife trade, that is, wildlife trade has an inhibitory effect on the growth of global GDP.

Therefore, through the analysis of the above equation, we can see that wildlife trade will have a negative impact on the world economy. However, through reading the relevant literature, we can see that a large part of the population in the global economy still depends on wildlife trade for survival. If we directly ban wildlife trade across the board, it may lead to economic bankruptcy and homelessness for many people. However, a lot of research and analysis show that under the current conditions, the emerging zoonosis may continue to grow at a constant rate, saying that wildlife trade is the main cause of the disease, and that those who rely on wildlife trade to survive have always suffered from infectious diseases, and the medical expenses have exceeded their own profit costs.

Based on the above analysis, this paper believes that it is necessary to adhere to the global wildlife trade ban at least for a long time, and wildlife trade will indeed affect the global economic situation.

4. Summary

This article examines the relevance of wildlife trade, infectious diseases, and the global economy now that global epidemics are rampant. At the start, this paper firstly converges the data set to count out the data from 1990-2021. After that, uses the count function of matlab on the pd library to statistically analyze the family data, so as to get the greatest number of wild animal groups and species transactions. Next, this paper analyzes the statistical options, and concludes that the purposes of wildlife trade are the most used for wildlife trade, zoo use, and circus performances. After that, this paper uses the number of trade imports and exports over the years as the basic data to measure the state of the trade market, and later analyzes it by constructing the growth rate of trade transactions as an indicator to assess the state of the wildlife trade market. Then, this paper will use multiple regression analysis to analyze the number of import and export transactions of wildlife trade each year and the degree of epidemic, so that the correlation between the two can be judged by the regression coefficient. Last, the annual wildlife trade import and export quantities are used as the basic data, and the total global GDP is collected as an indicator of the global economy, so that a multiple regression model is constructed to analyze the relationship between the global wildlife trade import and export quantities and the total global GDP.

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