Team Control Number

201927558

Problem Chosen

C

Summary

As for question one, we preprocess and filter the collected data. Then we build a multiple regression model.Setting Hog stock, Soybean meal feed price, Pork consumption, Average price of chicken in China to x_1, x_2, x_3, x_4 as independent variables. According to the discrete coefficient formula, we use SPSS to discrete values corresponding to the independent variables and the index with the smallest discrete value is determined. Then construct a multiple linear regression model for Average price of pork in China. Then, still using pork price as the dependent variable, it is fitted to obtain the judgment coefficient β_1, β_2, β_3, β_4. The factor corresponding to the larger is the main factor affecting pork price.

As for question two, first, we should explore the period of time when the price of pork is the highest. We establish an observation sequence. Fitting the data using a time series model and Self-covariance based on sample to analysis of the highest price of pork during that period. Then according to the cost optimization model, set the transportation distance x the function $Q(x)$ about the cost of pork, and calculate the transportation distance when the minimum cost of pork is calculated by minimizing the most restrictive conditions; According to the forecast model, the demand for domestic pork is calculated according to the forecast model, and a reasonable plan for purchasing from other countries is proposed.

As for question three, selecting the three most representative provinces in China, namely Henan Province, Jilin Province, and Gansu Province, and integrating a pig supply chain to conduct a one-time inspection of the factors affecting pork prices in each province, and analyzing the impact on the provinces. The main factors, then the farmers and enterprises to pursue the overall profit of the pig supply chain as the objective function, to maximize it, and propose the optimal breeding program.

***Key* word:** **Multiple regression analysis** **Difference equation** **Time series model** **Polynomial fitting** **Cost optimization model**

Content

I. Introduction

1.1 Background

The rapid growth of pork prices in China in the past six months has attracted the attention of the government and that of a large number of residents. China is the largest pork producing and consuming country in the world,which pork production accounts for about half of the world's total output, its prices level is affecting physical and mental health of domestic consumers and restricting the pork industry to enhance international competitiveness. In general, the situation of pork price is that summer is the off season of pork sales and winter is the peak of pork sales. The price of pork will generally decrease in summer.But it is different in 2019, since the beginning of this year, pork prices have been in a rising channel. In less than 160 days, pork prices increased from 14.68 yuan/kg on May 28, 2019 to 40.11 yuan/kg on November 1, 2019.Such a price has greatlyexceeded the budget of ordinary people's living expense s, whilch leads the increase of people's living costs. The impact of this phenomenon maybe consequences of the economic downturn.Therefore, the problem of pork prices needs to be solved urgently. The stability of pork prices is related to the coordinated development of food safety, national economy and social livelihood.In view of the problem of the sharp rise of pork price, it is also really important to establish a proper mechanism through the analysis of the price fluctuation law.

1.2 Work

For question one: Analyzing the factors that affect the fluctuation of pork price by using the data over the years. Thses factors may influence the National Pork constant, soybean meal feed price, the national average price of chicken, pork consumption, etc. Then making regression analysis on the pork price this year and comparing it with the normal price to determine whether the price is reasonable. Matching the influencing factors with the normal price of pork to judge whether the fluctuation of pork price is highly related to the general fluctuation of pork price.

For question two: On the basis of question one, when the price of pork is rising, we should not only take into account the region where pig farming is impossible and the reasonable use of remote area for pig farming so as to put forward a reasonable breeding plan and ensure that the price of pork will fall steadily in a short period of time. If the pork breeding can not be completed normally in a short period of time, it is necessary for us to put forward a reasonable procurement program from other countries on the premise of taking into account the relative stability of domestic pork price.

For question three:When the demand for pork in different regions is relatively stable and long-distance transportation of pigs and pork can not be adopt, we propose an optimal farming plan taking into account different time zones in different regions by choose from different angles. In order to ensure the stability of pork price and

solve the problem of the peak demand of pork in a certain area, we can put forward an effective pork storage strategy, baseing on different influencing factors in question one.

II. Problem analysis

2.1 Data analysis

First of all, preprocess the data: we should judge whether the data is reasonable by importing the data into SPSS software. Then calculate the discrete value, eliminate the data with large deviation, and keep the fluctuation of other values within the normal range.

Secondly, fit analysis and comparison between the inserted data and the original data. Explore the change of coefficient of goodness of fit R^2. Study the change of independent variable to dependent variable. Explore whether the main influencing factors are related to the fluctuations in previous years.

2.2 Analysis of question one

A: The problem needs to analyze the factors that affect the fluctuation of pork price based on the historical data of previous years. We assume that the data collected are authentic and can objectively reflect the change of pork price without considering the intervention of national policies. First of all, analyzing the indicators that affect the rise of pork price, such as the National Pork constant, soybean meal feed price, the national average price of chicken, pork consumption and so on. Establishing multiple regression model. The pork price is set as the dependent variable, each index is set as the independent variable. Set up regression coefficient independent of indepe ndent variable so that we can get the multiple regression model. Then the regression coefficients in the model are estimated by the least square method, so that the sum of squares of the errors is minimized. When the regression model and coefficient pass the test, using **SPSS** to draw multiple regression results. Finally, the size of each regression coefficient represents the influence of each factor on pork price.

B: We need explore whether the recent fluctuation of pork price is highly related to the general fluctuation of pork price. We assume that the data collected in recent months are true and effective and are not interfered by national policies. That is to explore whether the recent fluctuation of pork price is the same as the previous factors that affect pork price. Take pork price as the dependent variable, carry on the regression analysis with the previous data, and obtain the regression coefficient. According to the size of the regression coefficient, we can obtain the approximate pork price. Then compares with the actual value of pork price to determine whether it is reasonable. If not, then the pork price and each variable value are regressed again to obtain the regression coefficient and the determination coefficient R^2. The larger corresponding R2 is, the main factor affecting the pork price is.

2.3 Analysis of question two

A: Pig breeding has certain periodicity. When the price of pork is high, a reasonable breeding plan should be put forward because of the situation that it is impossible to raise pigs in areas and remote areas. The fluctuation of pork price caused by some non seasonal factors has a similar waveform, i.e. cyclical fluctuation. First of all, we establish a time series model. Based on the past change law of a set of time series, the possibility, trend and law of pork price change in the future are inferred. According to the historical data collected in question one, establish an observation sequence $y_1, \cdots, y_T$. Calculate the primary moving average and the secondary moving average to find the standard error of prediction. Using MATLAB program to find out the period of the highest pork price. According to the factors influencing the fluctuation of pork price analyzed in question one, establish optimization model, constrain its cost, study on reasonable pig raising area and measures, make the cost is minimized and greater than zero.

B: If pork breeding cannot be completed in a short period of time, according to the prediction model of the possibility, trend and law of change of pork price in the future, we can judge the demand of pork in the future. At the same time, considering the freight and tax of pork, and on the premise of ensuring the relative stability of domestic pork price, we propose a reasonable purchaser from other countries case.

2.4 Analysis of question three

A: Due to the relatively stable demand of pork in different regions. The optimal b reeding scheme should not only greatly satisfy the demand of consumers, but also ma ximize the individual profit of farmers. First, the objective function is to maximize individual profit, using mathematical expressions.Because the problem is a typical un constrained optimization so we can derive x_1,x_2. Find out the corresponding input of t he farmers in the process of pork breeding. Then we can get the optimal income of the farmers. Optimal income according to individual profit, in the process of pork breedi ng, the corresponding amount of input is used to make an optimal breeding plan.

B: according to the factors that affect the fluctuation of pork price analyzed in question 1, we can make relevant predetermined plans to effectively store pork reason ably; or we can integrate a pig supply chain according to the prediction of pork demand in question 2 to effectively meet the peak demand of pork in a certain region.

III. Symbol and Assumptions

3.1 Symbol Description

Symbols	Noun interpretation
Y	Average price of pork
X_1	Hog stock
X_2	Soybean meal feed price
X_3	Average price of pork in China
X_4	Pork consumption
T	Date
χ	Expectation of average price of pork in China
σ	Standard deviation of average price of pork in China
$f_1(x_1)$	Farmer cost function
$f_2(x_2)$	Enterprise cost function
$\vec{a}$	The best investment of farmers
$\vec{\tau}$	The best investment of the company
π	Representing the overall profit of the supply chain
$\hat{\gamma}_k$	Self covariance
Q(x)	Pork cost
C	Minimum cost
$y_t^{(1)}$	Pork demand

3.2 Fundamental assumptions

Hypothesis 1: assuming the data collected are true and credible, it can objectively reflect the change of pork price.

Hypothesis 2: assuming the state's policy intervention in pork prices is small, it can be ignored.

Hypothesis 3: assuming the effect of natural factors on pork quality is not considered.

Hypothesis 4: assuming it is legal and reasonable to assume that the pork purchased from other countries meets the national meat quality standards.

IV. Model

4. 1 Question one

4.1.1 Problem analysis

According to the relevant data, we have determined that x_1, x_2, x_3, x_4 are the influencing factors of Y for analysis and discussion.

First of all, let's analyze whether the data of pork price in the past decade is reasonable.

Table 1

Descriptive statistics	Number of cases	Minimum value	Maximum value	Mean value	Standard deviation
Average price of pork in China (yuan / kg)	9	11.17	19.03	15.0867	2.26542

It can be seen from table 1 Average price of pork in China (yuan / kg) is 15.0867 yuan/kg. The standard deviation is 2.26542.According to the formula:

$$V\sigma = \frac{\sigma}{\chi} \qquad (1)$$

The discrete value of Y is 0.15016007477, which is relatively weak. We will imp ort the data into SPSS software.

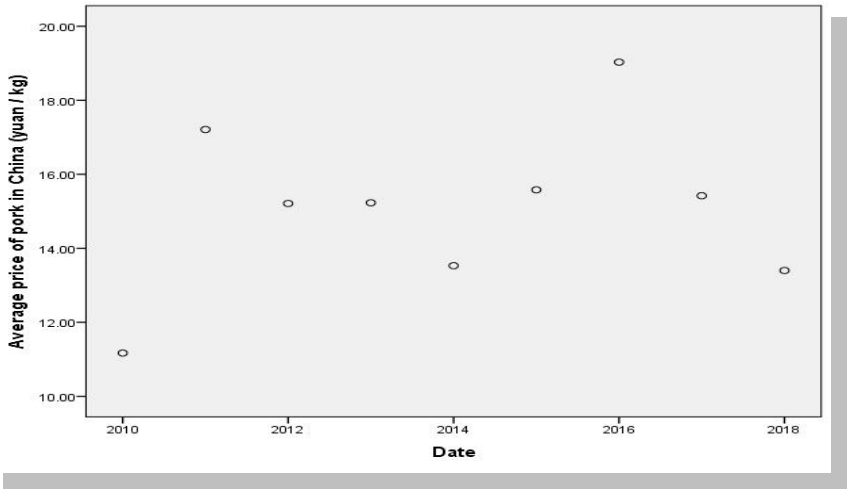

Figure 1

According to Figure 1, it can be seen that the price of pork has been kept in a normalrange according to the fluctuation range in recent ten years, and its value conforms to the reality of life. We have not found outliers.

In order to ensure the rationality of multiple linear regression model, we verify hypothesis 1, that is, there is no multiple collinearity between independent variables.

Correlation		Average price of pork in China	National Pork Standard (.MILLION TONS)	Soybean meal feed price (yuan / ton)
Pirsson correlation	Average price of pork in China	1.000	.031	-.129
	Hog stock	.031	1.000	-.657
	Soybean meal feed price (yuan / ton)	-.129	-.657	1.000
	Average price of chicken in China	.164	.462	.091
	Pork consumption (million tons)	.245	.849	-.321
Significance (single tail)	Average price of pork in China	0.00	0.00	0.00
	Hog stock	000.	0.00	0.02
	Soybean meal feed price (yuan / ton)	0.00	0.02	0.01
	Average price of chicken in China	0.03	0.00	0.00
	Pork consumption (million tons)	0.02	0.02	0.04
Number of cases	Average price of pork in China	9	9	9
	Hog stock	9	9	9

	Soybean meal feed price (yuan / ton)	9	9	9
	Average price of chicken in China	9	9	9
	Pork consumption (million tons)	9	9	9

Table 2

Table 3

Correlation		Average price of chicken	Pork consumption
Pirsson correlation	Average price of pork in China	.164	.245
	Hog stock	.462	.849
	Soybean meal feed price (yuan / ton)	.091	-.321
	Average price of chicken in China (yuan / kg)	1.000	.831
	Pork consumption (million tons)	.831	1.000
Significance (single tail)	Average price of pork in China	.00	.00
	Hog stock	.01	.02
	Soybean meal feed price (yuan / ton)	.02	.00
	Average price of chicken in China (yuan / kg)	.00	.03
	Pork consumption (million tons)	.03	.00
Number of cases	Average price of pork in China	9	9
	Hog stock	9	9
	Soybean meal feed price (yuan / ton)	9	9
	Average price of chicken in China (yuan / kg)	9	9
	Pork consumption (million tons)	9	9

The above figure is the correlation coefficient matrix. According to the correlatio n coefficient matrix, we can preliminarily determine whether there is a collinearity pr oblem between explanatory variables. As can be seen from the above table, **p** value w as less than 0.05, within 95% confidence interval.Two of the four variables are significant, but Hog stock, Pork consumption, Soybean meal feed price, Hog stock. Those standard correlation coefficients are all over 0.07. It indicates that there may be common problems among these variables.

Since it is shown that there may be common problems among these variables, wil l the following study on the common problems of these independent variables affect t he accuracy of the model?

Table 4

Collinearity diagnosis	Eigenvalue	Condition index	Hog stock	Soybean meal feed price	Average price of chicken in China
4.992	1.000	.00	.00	.00	.00
.006	29.732	.00	.00	.02	.00
.002	54.469	.00	.03	.01	.09
.000	167.004	.06	.02	.55	.52
.000	367.509	.94	.95	.41	.38

It can be seen from table 4 that the Eigenvalue of these four indicators is greater t han 0.01, and the condition index is less than 30. Therefore, we believe that the multicollinearity among explanatory variables is not serious, and does not affect the

accuracy of the average price of pork in China multiple linear regression.

4.1.2 Structue Average price of pork in China

We start to construct about Average price of pork in China, that is, the multiple li near regression model of Y value.

$$\boldsymbol{Y}=\boldsymbol{\beta}_0+\boldsymbol{\beta}_1\boldsymbol{x}_1+\cdots+\boldsymbol{\beta}_m\boldsymbol{x}_m+\boldsymbol{\varepsilon} \qquad (1)$$

$$\boldsymbol{\varepsilon}\sim\boldsymbol{N}(0,\boldsymbol{\sigma}^2) \qquad (2)$$

Formula: $\beta_0, \beta_1, \cdots \beta_m$,and X_1， $X_2, \cdots, X_m$, are unrelated unknown parameters.

Now 5 independent observation data can be obtained $[\boldsymbol{b}_i,\boldsymbol{a}_{i1},\boldsymbol{a}_{i2},\boldsymbol{a}_{i3},\boldsymbol{a}_{i4}]$ bi is the o bserved value of **Y**. [a_{i1},a_{i2},a_{i3},a_{i4}],x_1,x_2,x_3,x_4 are observation value. We chose the data of 18 years of unknown parameters unrelated to 2011-20. Immediate i=1

Book: $\boldsymbol{X}=\begin{bmatrix}\boldsymbol{1}\ \boldsymbol{a_{11}} & \boldsymbol{a_{12}}\cdots & \boldsymbol{a_{14}}\\ \boldsymbol{1}\ \boldsymbol{a_{21}} & \boldsymbol{a_{22}}\cdots & \boldsymbol{a_{24}}\\ \vdots & \vdots & \ddots & \vdots\\ \boldsymbol{1}\ \boldsymbol{a_{81}} & \boldsymbol{a_{82}} & \cdots & \boldsymbol{a_{84}}\end{bmatrix}(\boldsymbol{a})$， $\boldsymbol{Y}=\begin{bmatrix}\boldsymbol{b}_1\\ \vdots\\ \boldsymbol{b}_8\end{bmatrix}(\boldsymbol{b})$ ， $\boldsymbol{\varepsilon}=\begin{bmatrix}\boldsymbol{\varepsilon_1}\\ \vdots\\ \boldsymbol{\varepsilon_8}\end{bmatrix}(\boldsymbol{c})$， $\boldsymbol{\beta}=\begin{bmatrix}\boldsymbol{\beta}_0\\ \vdots\\ \boldsymbol{\beta}_4\end{bmatrix}(\boldsymbol{d})$

By substituting (a) (b) (c) (d) into formula (1), we can get

$$\boldsymbol{Y}=\boldsymbol{X\beta}+\boldsymbol{\varepsilon} \qquad (4)$$

$$\boldsymbol{\varepsilon}\sim\boldsymbol{N}(0,\boldsymbol{\sigma}^2\boldsymbol{E}_8) \qquad (5)$$

And our main analysis variables X_1,X_2,X_3,X_4 corresponding parameter coefficients

Table 5

	B	Std.Error	Beta	t	Sig.
(constant)	274.212	.162		3.148	.005
Hog stock	-.032	.010	-3.245	-3.283	.000
Soybean meal feed price	-.017	.010	-.699	-1.671	.000
Average price of chicken in China	-3.731	.319	-1.879	-2.304	.012
Pork consumption	6.639	.274	4.339	3.148	.005

As can be seen from table 5: The chi square of hog stock, Soybean meal feed price, Pork consumptio are less than or equal to 0.05, The correlation coefficient of these three indexes to **Y** is significant. But The chi square of sverage price of chicken in China is 0.12. Because of the small deviation of its value, we can approximately think that it is linear significant to **Y** within 90% confidence interval.

That is, we can get the formula:

$$\boldsymbol{Y}=274.212-0.032\boldsymbol{x}_1-0.017\boldsymbol{x}_2-3.731\boldsymbol{x}_3+0.639\boldsymbol{x}_4 \qquad (6)$$

After consulting the data, we can see that in 2019 X_1=5330milliontons, X_2=3280y uan/ton, X_3=19.85yuan/ton, X_4=4.95 millionton. Substitute Y=13.80 yuan/kg in 2019. In order to ensure the robustness of the predicted y value in 2019, we use the interpolation method to predict the results, the code is as follows:

```
pork=[11.17,17.21,15.21,15.23,13.53,15.58,19.03,15.42, 13.40];
year = 2010:2018;
p1 = pchip(year, pork, 2019)  %Hermite interpolation
p2 = spline(year, pork, 2019) %Prediction by cubic spline interpolation
figure(4);
plot(year, pork,'o',2019:2020,p1,'r*-',2019:2020,p2,'b*-')
legend('Sample point','Hermite interpolation','Prediction by cubic spline interpolation','Location','NorthEast')
```

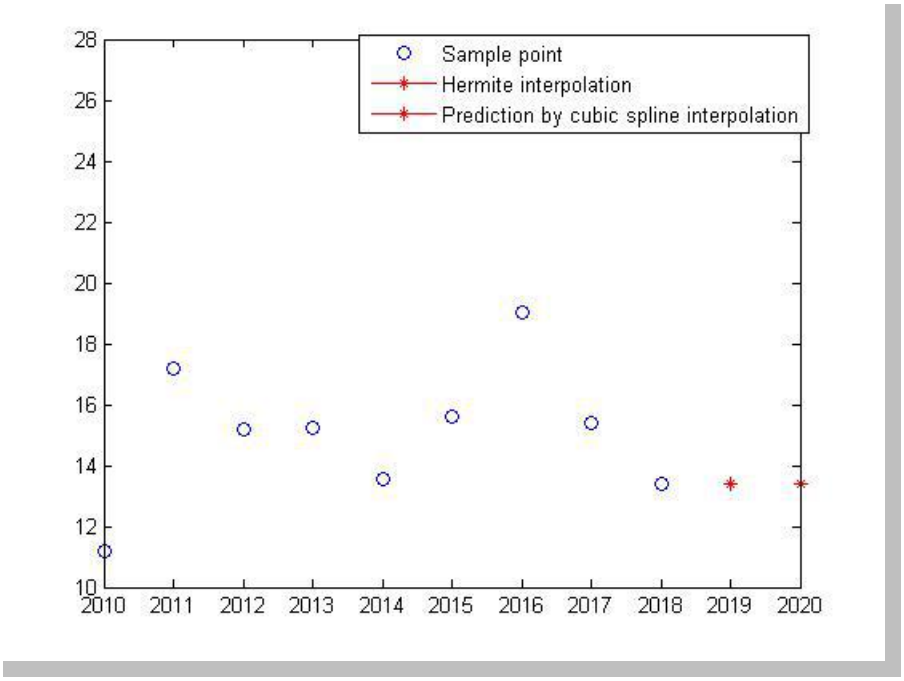

Figure 2

We can see from the predicted image that the prediction range is between 13-14. The y value of 2019 predicted by our multiple regression model conforms to this rang e, that is, the prediction result is reasonable.

We have roughly determined the average pork price of each province on Novemb er 3, 2019 by consulting the websites such as China Statistical Yearbook and today's p ig price from 2010 to 2019. See Appendix 1 for the data.

In order to better reflect the average price of pork between provinces, we visualiz ed the increase of pork price in each province on the map of China.

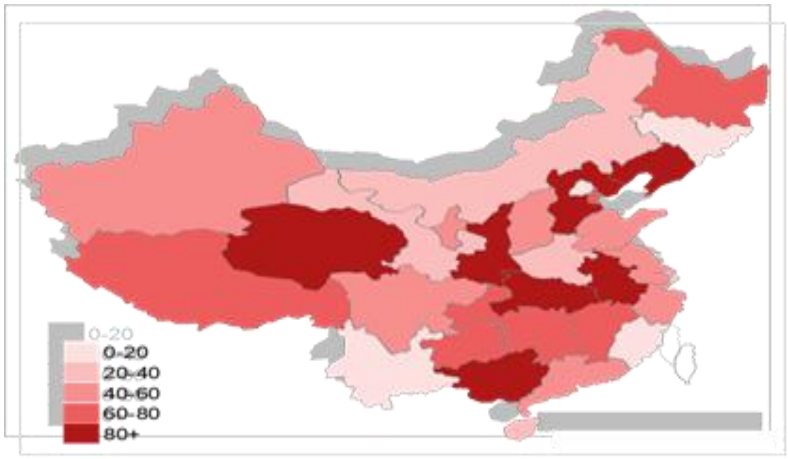

Figure 3

It can be seen from Table 5 and Figure 3 that the average pork price in China is g enerally too high. The average pork price in each province is mainly 40-50 yuan / kg, and the average pork price in Central China is higher. However, we predict that the pr ice of normal pork in 2019 is 13.80 yuan/kg, which means that the price of pork is seri ously unreasonable.

4.1.3 Result prediction

In order to find out whether the fluctuation price of pork is highly related to the g eneral fluctuation of pork, we need to put the average price of Chinese pork predicted in 2019 into table 6 below, and then carry out regression analysis.

Table 6

Date	Average price of pork in China (yuan / kg)	Hog stock	Soybean meal feed pr	Average price of chick	Pork consumption
2011	17.21	5100	3058.00	16.00	4.64
2012	15.21	5400	2984.30	16.80	5.01
2013	15.23	5600	2860.00	17.20	5.32
2014	13.53	5800	2913.40	17.70	5.78
2015	15.58	5600	3092.50	18.00	5.61
2016	19.03	5400	3048.20	18.20	5.54
2017	15.42	5400	3061.90	18.80	5.49
2018	13.40	5350	3114.50	19.10	5.45
2019	13.80	5330	3280.00	19.85	4.95

Next, we will compare the fitting degree of data without 2019 with the goodness of fit of data put into 2019. If the coefficient of goodness of fit $\mathbf{R^2}$ changes significantl y, it means that the influence of independent variables on dependent variables changes. Then we can get the main influencing factors and whether they are related to the fluct uations of previous years.

Two sets of data are substituted into MATLAB respectively, and the code is as follows:

```
y_hat =274.212-0.032*X1-0.017*X2-3.731*X3+0.639*X4  %FIT VALUE OF Y
SSR = sum((y_hat-mean(y)).^2)  %SSR
SSE = sum((y_hat-y).^2) %SSE
SST = sum((y-mean(y)).^2) %SST
SST-SSE-SSR
R_2 = SSR / SST
```

The results are summarized in Table 7 below.

Table 7

DATE	R	R Square	Adjust the R-SQUARE	Standard estimate error	R-SQUARE variation	F variation	Degree of freedom
2010-2018	.864[a]	.747	.694	1.01135	.747	2.953	4
2018-2019	.558	.311	.239	1.22603	.311	.565	5

It can be seen from Table 7 that the Adjust the R Square is reduced from 0.694 to 0.239, and the original goodness of fit is also reduced from 0.747 to 0.311. Therefore, we can see that the goodness of the two groups of data fits significantly, that is, the recent fluctuation of pork prices. It is not highly correlated with the general price of pork. The result of this reason may be that we default to Average price of chicken in China and Average price of pork in China, and we can also know other meats based on common sense. The price volatility is not the main factor affecting the rise of pork, so we eliminated the Average price of chicken in China and analyzed it in the same way. And the results are summarized in the following table 8.

Table 8

DATE	R	R Square	Adjust the R-SQUARE	Standard estimate error	R-SQUARE variation	F variation	Degree of freedom
2011-2018	.872	.760	.674	.61135	.747	2.953	4
2011-2019	.818	.669	.589	1.42603	.311	.565	5

At this time, the two sets of data, Adjust the R-SQUARE, still fluctuate, but the fluctuation degree is significantly lower than that of Table 7, so we can roughly think that the recent fluctuations in pork prices are highly correlated with the general price of pork, namely Hog stock, Soybean meal. Feed price, Pork consumption is the main influencing factor of Average price of pork in China.

4.2 Question two

4.2.1 Problem analysis

Table 9

Line1	Line2	Line3	Line4	Line5	Line6	Line7	Line8	Line9	Line10	Line11
Date (month)	1	2	3	4	5	6	7	8	9	10
Average national pork price	15.1	17.4	19.8	25.3	36.2	33.2	33.1	40.2	41.6	42.5

We need to study the highest peak of pork prices. We have established a time series model. In the first question, we have analyzed the main factors affecting pork price fluctuations. First, we need to use the historical data of the previous months and use the time series model to analyze the data. Fitting to explore the period of high prices.

4.2.2 Time series model

For stationary sequence the simple of $Xt,X_1,X_2,\cdots,X_{10}$,The mean of the average pork price can be used to estimate the mean of the entire sequence, namely:

$$\hat{\mu}=\frac{1}{n}\sum_{i=1}^{n}x_i=\bar{X} \qquad (7)$$

Bringing the price of each pork into the formula, that is:

$$\hat{\mu}=24.13\text{yuan/kg}$$

There are also sample self-covariances:

$$\hat{\gamma}_k=\frac{1}{n}\sum_{i=1}^{n-k}\left(X_{i+k}-\bar{X}\right)\left(X_t-\bar{X}\right),0\leqslant k\leqslant n-1 \qquad (8)$$

The self-covariance of the pork price is:

$$\hat{\gamma}_k=4.2$$

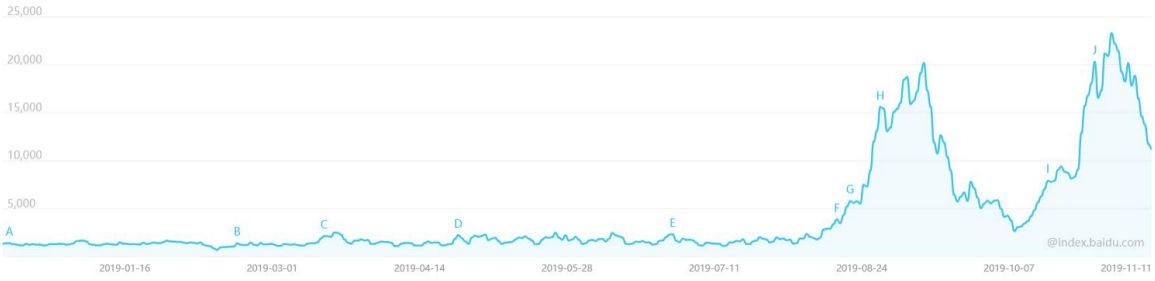

Figure 4

It can be seen from the pork price trend in Figure 4 that the pork price was relatively stable before August 24, 2019, and there was no significant increase or decrease. However, after that, the price of pork suddenly increased sharply, especially in During the month of November, it was in the period of higher pork prices.However, because the time series model is mainly based on the periodic characteristics of pork price, it does not consider other uncertain factors and has limitations.[1]
Then, using SPSS to fit all the data, you get:

Table 10

Dependent variable: National pork average price of kilograms						
Source		Type III square sum	df	Mean square	F	Sig.
intercept	Hypothesis	2048.468	1	2048.468	399.146	.000
	error	41.057	8	5.132[a]		
	Hypothesis	41.057	8	5.132	.	.
	error	.000	0	.[b]		

For each source, the expected square mean is equal to the sum of the coefficients in the cell multiplied by the variance component, plus a quadratic term containing the effect in the quadratic term. It can be seen from the test results that there is no significant difference in the data, and all of them satisfy the assumption of normality. The square mean of the data does not change much, and the data fits well.

4.2.3 Cost optimization model

According to the influencing factors in the analysis of problem 1, the cost of pork farming is taken as the objective function, and the optimization model is established with the cost minimization and greater than zero as the constraint. The distance of transporting pork is used as a limiting condition, so that its cost tends to be minimized.

The pork cost is expressed as a function of transport distance Q（x）,when x=0, the pork cost is Q（0）=0，As the transportation distance increases, Q(x) decreases at the demand rate r, and the cost also increases. However, when the distance reaches a certain position, the price of pork increases, so that the cost is reduced to the minimum value. Obviously there is:

$$Q=rX \qquad (9)$$

The cost in one cycle is

$$C(X)=\overline{C}=c_1+c_2 r\frac{X^2}{2} \qquad (10)$$

Finding X is the minimum of C in (9), easily to get

$$X=\sqrt{\frac{2c_1}{c_2 r}}$$

Substituting (9):

$$Q=\sqrt{\frac{2c_1 r}{c_2}}$$

Calculating the minimum cost from (10)

$$C=\sqrt{2c_1 c_2 r}$$

It can be seen that when c1 increases, the transportation distance and cost

increase; when c2 increases, the transportation distance and cost decrease; when r increases, the transportation distance decreases and the cost increases.

Therefore, in the case of considering areas where pigs are not possible and in the case of raising pigs in remote areas, the best breeding areas are located $\sqrt{\frac{2c_1}{c_2 r}}$,which can minimize the cost of raising pigs, that is $\sqrt{2c_1c_2r}$,which the price of pork can be reduced in a short period of time.

4.2.4 Price forecasting model

The pork prices for the first ten months are shown in the table below (source Baidu). The least squares method is used to fit the coefficients of the difference equation.

Table 11

Date (month)	1	2	3	4	5	6	7	8	9	10
Pork demand	361	777	1193	1609	2025	2441	2857	3273	3689	4105

We believe that the demand for pork in the first ten months will increase linearly, and the demand can be set as:

$$By\ \ \mathbf{x} = [[\mathbf{1:10}]', \mathbf{ones(10,1)}];$$
$$\mathbf{y} = [\mathbf{361\ 777\ 1193\ 1609\ 2025\ 2441\ 2857\ 3273\ 3689\ 4105}];$$
$$\mathbf{z} = \mathbf{xy};$$
$$Answer\ is\ \ \mathbf{a} = \mathbf{z(1)} = \mathbf{416}, \mathbf{b} = \mathbf{z(2)} = -\mathbf{55}$$

The forecast for November is $y_{11}^{(1)} = 4521$, $y_{12}^{(1)} = 4937$ ……

It can be seen that the demand for pork after October may continue to increase upwards. From the above analysis of the change in pork prices, it is known that when purchasing from other countries, the domestic demand for pork is increasing. Trends, as well as the normal fluctuations in pork prices in China, select pork in countries where the cost of pork is not higher than the price of pork in China, and the tax and shipping costs are relatively small to ensure the stability of domestic pork prices.

4.3 Question three

4.3.1 Problem analysis

We know that we have obtained the data of the average pork price in each province on November 3 (see Appendix I). Below, we return to the problem of the increase in pork prices in each province in 2019.

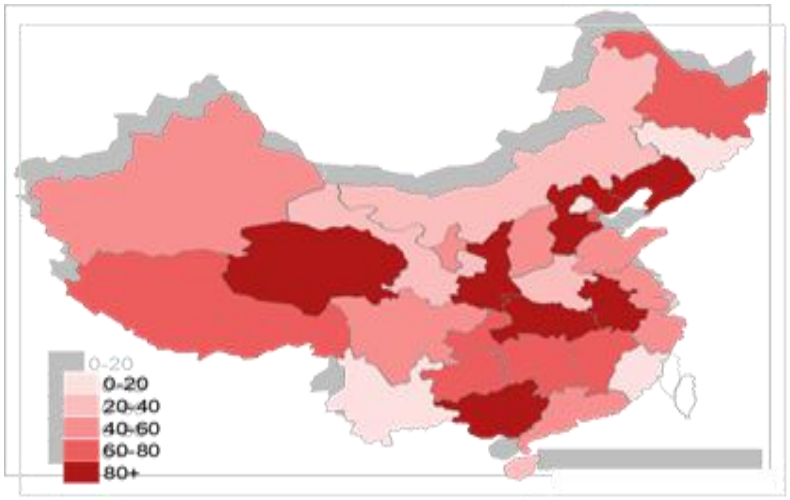

Figure 5

It can be seen that the recent increase in pork prices in Henan Province, Jilin Province, Gansu Province and other provinces is significantly lower than other regions, that is,pork prices are relatively stable. China's pig production has obvious regional characteristics, and the price of pork also has significant regional differences.[2]

Figure 6 shows the General pork supply chain network structure, which reflects the network structure of pork purchase, terminal sales, fixed-point slaughter, pork distribution and terminal sales. This is a schematic diagram of the process of producing the price of pork to the terminal. It can be seen from the figure that these four market segments affect the final pork price, that is, whether the farmer wants to invest in a good income or the country wants to stabilize the pork price. We must consider these four factors.

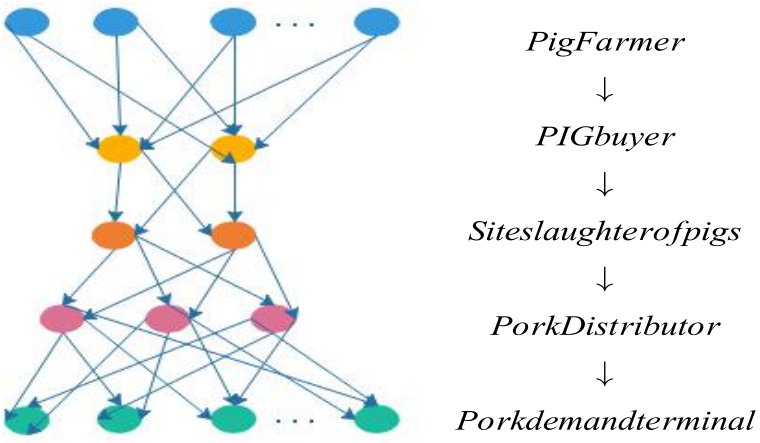

Figure 6

Since we can't find the specific values of these four factors and analyze them, we consulted the relevant data and information experts to get some logical data and formulate the indicator importance level, which reflects the price of pork in the three

provinces. The degree of influence is displayed in the form of a scoring matrix. If a certain province has the highest score, then this link is the most important factor affecting the price of pork in the province.

Based on the analysis of the selection and coupling mechanism of the key chain nodes in the pork quality chain under the supply chain environment, guided by the theories of supply chain management, quality chain management and system control, and with the methods of system analysis, comparative analysis, model analysis and causal analysis, this paper focuses on the Research of pork quality chain management.[3]

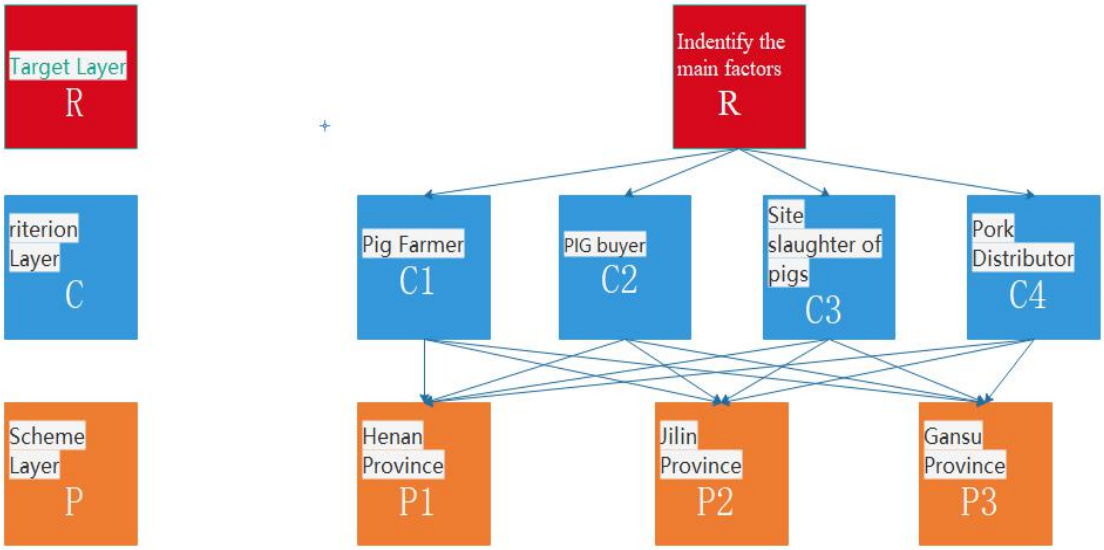

Figure 7

Figure 7 is a hierarchical structure diagram that identifies the main market segments of pork prices in each province. The uppermost layer is the target layer R, which is the main factor (R), and the lowest layer is the plan layer, namely the three provinces studied in Henan Province (P1), Jilin Province (P2), Gansu Province (P3), and the middle layer is the criterion layer. They are the four major market factors affecting pork prices, namely C1, C2, C3, and C4.

By consulting the data, we have determined the comparison criteria between the two indicators of the indicators, as shown in Table 12.

Table 12

Scale	Implications
1	It means that the two factors are equally important
3	One factor is slightly more important than the other*
5	One factor is obviously more important than the other**
7	One factor is more important than the other***
9	One factor is more important than the other****

Note: The number of "*" reflects the importance of one indicator to another.

4.3.2 Construction judgment matrix N-C and C-P

The four factors of the reference layer, C_1, C_2, C_3, *and* C_4, are compared in pairs to obtain the judgment matrix N-C.

Table 13

Judgment matrix M-C

N	C1	C2	C3	C4
C1	1	1/3	5	4
C2	3	1	8	6
C3	1/5	1/8	1	1/3
C4	1/4	1/6	3	1

Judgment matrix C-P

C1	P1	P2	P3	C2	P1	P2	P3	C3	P1	P2	P3	C4	P1	P2	P3
P1	1	3	4	P1	1	1/3	1/4	P1	1	1/2	3	P1	1	3	4
P2	1/3	1	3	P2	3	1	1/4	P2	2	1	3	P2	1/3	1	1/2
P3	1/4	1/3	1	P3	4	4	1	P3	1/3	1/3	1	P3	1/4	2	1

Similarly, we can construct the judgment matrix C—P as shown in the following table.

The judgment matrix of the appeal cannot be used directly, and a consistency test is needed. The calculation formula is as follows:

$$CR = \frac{CI}{RI} \qquad (11)$$

Where CI is the consistency indicator, the calculation formula is as follows

$$CI = \frac{\lambda_{\max} - n}{n - 1} \qquad (12)$$

RI is the average random consistency indicator need to refer to the following table

Table 14 Average random one-time index（RI）

n	2	3	4	5	6	7	8	9	10
RI	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.52

If CR < 0.1, the consistency of the judgment matrix can be considered acceptable. We substituted the five judgment matrices into the Matlab code we wrote (see the appendix for the code), and first tested it for consistency, and obtained the consistency ratio CR.

4.3.3 Regional analysis and solution

Table 15

Judgment matrix	N—C	C1—P	C2—P	C3—P	C4—P
λ_{max}	4.1546	3.0735	3.0656	3.0536	3.0839
CR	0.0485	0.0707	0.0678	0.0516	0.0842

Since all the judgment matrices have a consistency ratio of less than 0.1, all passed the consistency test.

We then use the eigenvalue method to find the weight of each judgment matrix.

Table 16

	Index Weight	Henan Province	Jilin Province	Gansu province
Pig farmers	0.2700	0.6144	0.2684	0.1172
Pig purchaser	0.5786	0.1130	0.2351	0.6519
Pig slaughter	0.0508	0.3325	0.5278	0.1396
Pig distributor	0.1006	0.6301	0.1515	0.2184

From the weight table in Table 16, we can get the specific scores of the three provinces between the four market influencing factors, and put the values into the following table:

Table 17

	Henan Province	Jilin Province	Gansu province
Pig farmers	0.1659	0.0724	0.0316
Pig purchaser	0.0654	0.1360	0.3771
Pig slaughter	0.0169	0.0268	0.0071
Pig distributor	0.0634	0.0152	0.0220

From Table 17, it can be concluded that for the Henan Province, in order to have the best breeding program, we need to focus on the pig farmers in the market environment, because this is the most important reason for the fluctuation of pork prices in the region. For Jilin Province and Gansu Province, we need to strictly control the pig purchaser to achieve the optimal breeding program. Therefore, the country can control the price of pork stably, and the general farmers and enterprises can maximize their own interests.

We need to construct a reasonable model from the perspective of the farmers and the core enterprise to achieve the best breeding plan, thus controlling the normal price of pork and obtaining the optimal breeding program.

Farmers and enterprises pursue the maximization of the overall profit of the pig supply chain，so the corresponding objective function, the overall profit maximization mathematical formula is:

$$\boldsymbol{Max} = \{\boldsymbol{\pi} = (\boldsymbol{p} - \boldsymbol{c})\boldsymbol{D}(\boldsymbol{p}, \boldsymbol{f}_1(\boldsymbol{x}_1), \boldsymbol{f}_2(\boldsymbol{x}_2)) - \boldsymbol{f}_1(\boldsymbol{x}_1) - \boldsymbol{f}_2(\boldsymbol{x}_2)\} \qquad (13)$$

$\boldsymbol{f}_1(\boldsymbol{x}_1)$ is farmer cost function, $\boldsymbol{f}_2(\boldsymbol{x}_2)$ is enterprise cost function,among them $\boldsymbol{x}_1 > 0$ is the corresponding investment of farmers, $\boldsymbol{x}_2 > 0$ represents business input. $\boldsymbol{\pi}$ represents the overall profit of the supply chain. The problem is typical unconstrained, so the x1, x2 can be derived to find the optimal input of the farmers and core enterprises:

$$\frac{\partial \boldsymbol{\pi}}{\partial \boldsymbol{x}_1} = (\boldsymbol{p} - \boldsymbol{c})\frac{\partial \boldsymbol{D}}{\partial \boldsymbol{x}_1} - \frac{\partial \boldsymbol{f}_1(\boldsymbol{x}_1)}{\partial \boldsymbol{x}_1} = \boldsymbol{0} \qquad (14)$$

$$\frac{\partial \boldsymbol{\pi}}{\partial \boldsymbol{x}_2} = (\boldsymbol{p} - \boldsymbol{c})\frac{\partial \boldsymbol{D}}{\partial \boldsymbol{x}_2} - \frac{\partial \boldsymbol{f}_2(\boldsymbol{x}_2)}{\partial \boldsymbol{x}_2} = \boldsymbol{0} \qquad (15)$$

Through the above equations, solve the corresponding investment $\vec{a}$ and $\vec{\tau}$ of farmers and enterprises in the pig supply chain integration model based on contract governance and relationship governance.,$\vec{a}$ represents the best investment of farmers in the pig supply chain integration model based on contract governance and relationship governance，$\vec{\tau}$ represents the best investment of the enterprise in the hog supply chain integration model based on contract governance and relationship governance.

V.Test the Models

In question one, we have modeled the multiple regression analysis equations and eliminated outliers.

Model optimization for problem three-level analysis:

Because the method of weighting is not one, in addition to the eigenvalue method, there are geometric averaging method and arithmetic averaging method. In order to ensure the robustness of the result, we write the code (see Appendix IV) to solve the problem by arithmetic average method and geometric mean method. The weights of the three data are scored, and the average is obtained to obtain more robust results.

Table 18

The weighted list of the optimized matrix N-C

Arithmetic average method	Geometric mean method	Eigenvalue method	Average of the three
0.2692	0.2693	0.2700	0.2695
0.5724	0.5805	0.5786	0.5772
0.0525	0.0506	0.0508	0.1539
0.1059	0.0996	0.1006	0.1020

In the same way, we can also get the value of the judgment matrix C-P optimization, and import all the new values into the following table 19.

Table 19

	Index Weight	Henan Province	Jilin Province	Gansu province
Pig farmers	0.26595	0.6124	0.2641	0.1154
Pig purchaser	0.5772	0.1169	0.2356	0.6489
Pig slaughter	0.1539	0.3314	0.5223	0.1378
Pig distributor	0.1020	0.6328	0.1498	0.2160

VI. Strengths and Weakness

The mathematical model uses MATLAB, SPSS and other mathematical software to integrate and analyze the data, so the results obtained are small in error and high in

accuracy. And using the least squares method, the modeling process is vivid and easy to understand.

6.1 Strengths of the model

1. Modeling uses standard deviation, and continuously regressing the data to fit, greatly reducing the error in the modeling process, making the final result more accurate;

2. Compare and analyze candidate mathematical models from multiple aspects, and selecting the mathematical model with the least impact on the results, which enhances the reliability and credibility of the mathematical model;

3. The selected data is more realistic, and the combination of detailed analysis and chart makes the conveyed results more vivid and closely related to reality.

6.2 Weakness of the model

1. The data collected is limited and the impact of contingency on the results cannot be ruled out;

2. The rigor of the algorithm needs to be improved.

VII. Conclusion

7.1 Summary of the problem

For the first question, since no additional data is provided in the title, and the title requires the use the historical data, so we need to collect historical data from some related materials or some websites of the country and summarize them. Secondly, for these data, different mathematical models and algorithms are selected to analyze the data, and the mathematical models and related algorithms with the smallest error are selected to ensure the reliability of the final result.

For the second question, first of all, collect the price and sales of pork in the past few months from the Internet, and sort out the data. Secondly, the data is fitted, the values with large deviations are eliminated, and the new data is reorganized and summarized. Then established the time series model and optimization model, determining the objective function, and the minimum cost is taken as the constraint condition. The position where the minimum value is located is the best breeding area. At the same time, the demand for pork is predicted, taking into account the domestic pork price. In the case, developing a reasonable procurement plan from other countries.

For the third question, we selected the three most representative provinces in all provinces of the country to analyze the factors that had the greatest impact on pork demand. At the same time, considering that the supply quantity is greater than the demand quantity and maximizing the interests of the farmers, the individual profit is taken as the objective function. Under the condition of no constraint, we found the

input and maximum income of farming, so as to propose the most Excellent breeding program. According to the factors affecting the fluctuation of pork prices in question 1, an effective pork storage strategy is proposed for each factor to effectively cope with the peak demand of pork.

7.2 Summary of the model

In the process of establishing a mathematical model, it is necessary to consider the influence of error on the result, often the error has the least impact on the result, and the result is more reliable and more reliable. In processing data, it is first necessary to pre-process the data, and to eliminate the data with large deviations and reorganize the data. When appling to the algorithm, the improved algorithm has higher rigor and higher accuracy, and the results reflect higher credibility. Therefore, when we use mathematical models and algorithms, we should optimize the model to enhance the accuracy and credibility of the results.

References

[1] Wu Pei, Li Zhemin. Research on pork price prediction in China -- Analysis Based on arima-gm-rbf combined model [J]. Price theory and practice, 2019 (01): 75-78

[2] Gu Jingqiu, Peng Cheng, Wu Huarui, Wu jianzhai. Spatial and temporal distribution pattern and influencing factors of pork price [J]. Journal of Zhejiang agriculture, 2018,30 (05): 872-879

[3] Sha Ming. Research on pork quality chain management under supply chain environment [D]. Shandong Agricultural University, 2012

Appendix

Appendix 1：

November 3 average pork prices in China's provinces

Province	Price of pork (yuan / kg)
anhui	48
beijing	52.77
chongqing	51.83
fujian	50.33
gansu	50.09
guangdong	53.25
guangxi	45.60
guizhou	47.15
hainan	32.11
hebei	46.78

heilongjiang	50.12
h nan	42.98
hubei	48.42
hunan	48.36
jiangsu	47.82
jiangxi	56.80
jilin	45.31
liaoning	52.37
neimenggu	47.65
ninxia	38.12
qinghai	50.39
shandong	50.86
shanghai	52.36
shanxi3	51.01
shanxi1	52.96
sichuan	54.07
tianjin	49.60
xinjiang	16.7
xizang	14.3
yunnan	38.56
zhejiang	46.64

Appendix 2：

Interpolation＆Fitting optimization code

```
pork=[11.17,17.21,15.21,15.23,13.53,15.58,19.03,15.42, 13.40];
year = 2010:2018;
p1 = pchip(year, pork, 2019)  %Hermite interpolation
p2 = spline(year, pork, 2019) %Prediction by cubic spline interpolation
figure(4);
plot(year, pork,'o',2019:2020,p1,'r*-',2019:2020,p2,'b*-')
legend('Sample point','Hermite interpolation','Prediction by cubic spline interpolation','Location','NorthEast')
y_hat =274.212-0.032*X1-0.017*X2-3.731*X3+0.639*X4  %FIT VALUE OF Y
SSR = sum((y_hat-mean(y)).^2)  %SSR
SSE = sum((y_hat-y).^2) %SSE
SST = sum((y-mean(y)).^2) %SST
SST-SSE-SSR
```

Appendix 3：

2019 and recent data on pork prices and related factors

Date	Average price of pork in China (yuan / kg)	National Pork Stand	Soybean meal feed pri	Average price of chicke	Pork consumption
2011	17.21	5100	3058.00	16.00	4.64
2012	15.21	5400	2984.30	16.80	5.01
2013	15.23	5600	2860.00	17.20	5.32
2014	13.53	5800	2913.40	17.70	5.78
2015	15.58	5600	3092.50	18.00	5.61
2016	19.03	5400	3048.20	18.20	5.54
2017	15.42	5400	3061.90	18.80	5.49
2018	13.40	5350	3114.50	19.10	5.45
2019	13.80	5330	3280.00	19.85	4.95

Appendix 4:

Analytic hierarchy process code

```
disp('Please enter Judgment Matrix A')
A=input('A=');
[n,n] = size(A);
Sum_A = sum(A);
SUM_A = repmat(Sum_A,n,1);
Stand_A = A ./ SUM_A
disp('The arithmetic average method yields the following results:');
disp(sum(Stand_A,2)./n)
Prduct_A = prod(A,2);
Prduct_n_A = Prduct_A .^ (1/n);
disp('The geometric mean method yields the following weights:');
disp(Prduct_n_A ./ sum(Prduct_n_A))
[V,D] = eig(A);
TZZmax = max(max(D));
[r,c]=find(D == TZZmax , 1);
disp('The weight obtained by the eigenvalue method is：');
disp( V(:,c) ./ sum(V(:,c)) )
CI = (TZZmax - n) / (n-1);
RI=[0 0.0001 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 1.54 1.56 1.58 1.59];

CR=CI/RI(n);
disp('Consistency index CI');disp(CI);
disp('Consistency ratio CR');disp(CR);
if CR<0.10
    disp('Because CR & Lt; 0.10, the consistency of the judgement matrix a is acceptable!');
else
    disp('Note: CR & GT; 0.10, so this judgment Matrix a needs to be modified!');
end
```