Influence Factors of Grain Yield Fluctuation Based on Multiple Linear Regression Analysis

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Abstract

Grain security is important for national stability and economic social development. Based on modern business cycle theory, this paper divides grain yield into 8 cycles between 1987 and 2013 in Heilongjiang province. We analyze the structure of grain yield fluctuation in Heilongjiang province through variance, covariance and sensitivity coefficient. We analyze the influence factors with multiple linear regression analysis. The results show that grain yield fluctuation has short significant features cycle. Maize yield is accounting for the dominant position. The factors such as grain planting area, effective irrigation area, the per unit area yield of grain, agricultural fertilizer amount and total power of agricultural machinery have positive impact. Natural disasters have the negative impact on grain yield.

Key words: GRAIN SECURITY, GRAIN YIELD, CEREALS FLUCTUATION, INFLUENCE FACTORS

1. Introduction

Food is essential to the survival of humans life, which is the important strategically commodity. It is an important part of national security strategy. At present, the world's population has reached 7 billion, the demand for food is progressively increasing. How to ensure steady supply of food is great importance for meeting the needs of society and the state security [1].Change of grain yield shows characteristics such as nonlinearity, randomness, dynamic and multiple time scale change because of the social and economic conditions, natural disasters and production technology.

Many scholars have made many researches in the aspect of grain yield fluctuation, according to their researches content which can be summarized as three kinds: fluctuation characteristics research, natural factors influence and social economic factors influence analysis [2]. Most of the research only focus on analysis of fluctuation characteristics for grain yield

which confined to short-wave research of three or four years. There are very little research on grain yield of the long wave. Attention paid to grain yield fluctuation complexity is not enough. Influence factor study only focus on certain aspects of the climate, natural disasters or fertilization. Grain yield fluctuation is the result of multiple comprehensive factors, so single factor analysis is very difficult to grasp the main cause. Multiple linear regression analysis is better to understand the reasons to explore grain yield fluctuation.

Heilongjiang province is the major base of commodity grain production in China. The yield and price of grain has not been very stable in Heilongjiang province, which presents the characteristics of periodic fluctuation. Grain yield fluctuation between the years is bigger. The methods such as researching grain yield fluctuation rule, studying the four major food crops yield of output fluctuation law and analyzing the influence factors of yield fluctuation which

are helpful to find contribution to total grain yield fluctuation. They are beneficial to stabilize grain production and safeguard national food security [3]. On the basis of modem theories of economic cycle this article analyzes grain of Heilongjiang province with the data such as total grain output data, four crops yield data, the factors affecting food production related data [4]. We study the structure of grain production fluctuation through the fluctuation index, fluctuation cycle, variance, covariance, and sensitivity index. We analyze the influence factors of grain production fluctuation with multiple linear regression analysis. It summarizes the fluctuation rules of grain yield. We explore the fluctuating cause of grain yield.

2. Analysis of grain yield fluctuation cycle

According to the time sequence for the unit with the year, the duration of the peaks and troughs should be for at least two years. The range needs more than 5%. We form a complete cycle fluctuations of the morphological characteristics in terms of "valley, peak, valley" .We choose grain yield in Heilongjiang province from 1987 to 2013 that is sort by grain yield chain relative ratio. At last we divide the grain yield fluctuation into 8 cycles. (Table 1)

Table 1. The cycles of grain yield in Heilongjiang province between 1988 and 2013

Number	From the year	Year rang	Crest (%)	Trough (%)	Amplitude (%)
1	1988-1991	3	38.56	-5.61	44.17
2	1991-1993	2	9.33	-6.41	15.74
3	1993-1995	2	7.86	-1.03	8.89
4	1995-1998	3	19.38	-3.09	22.47
5	1998-2000	2	2.2	-17.21	19.41
6	2000-2003	3	10.92	-17.21	28.13
7	2003-2009	6	24.79	3.03	21.76
8	2009-2013	4	15.16	3.03	12.13
	Average	3	16.025	-5.56	21.587

From table 1 that include grain yield chain relative ratio in Heilongjiang province, we can find that it has obvious fluctuation characteristics. The eight fluctuation cycle that divided by this paper is given priority to with medium-term fluctuations. The longest cycle is for 6 years. The others are that 2 years cycle account to three, 3 years account to three, 4 years account to 1.The average period of cycle is 3 years. According to the analysis of wave height, the average peak wave of grain yield growth rate reaches 16.025%, which reflects the high-speed growth. There are three high-sized peak wave cycle such as 1,4,7, the peak positions of which are as high as 38.56%, 19.38%, 24.79%. There are two middle-sized peak wave cycle. There are three low-sized peak wave cycle ,the peak positions of which are as high as 9.33%, 7.86%, 2.2%.There are six cycles belong to ancient typical fluctuation cycle from the depth of the fluctuations. The rest are growth fluctuation cycle. In terms of volatility, the grain yield of Heilongjiang province is larger. The average amplitude is 16.025%.The larger one is 1988-1991 that the amplitude is 44.17%. The second one is 2000-2003 that the amplitude is 28.13%.

There are seven cycles that amplitude is more than 10%, which accounts for about 87.5% of the total number of cycles. It illustrates that the grain production prone to volatility in Heilongjiang province.

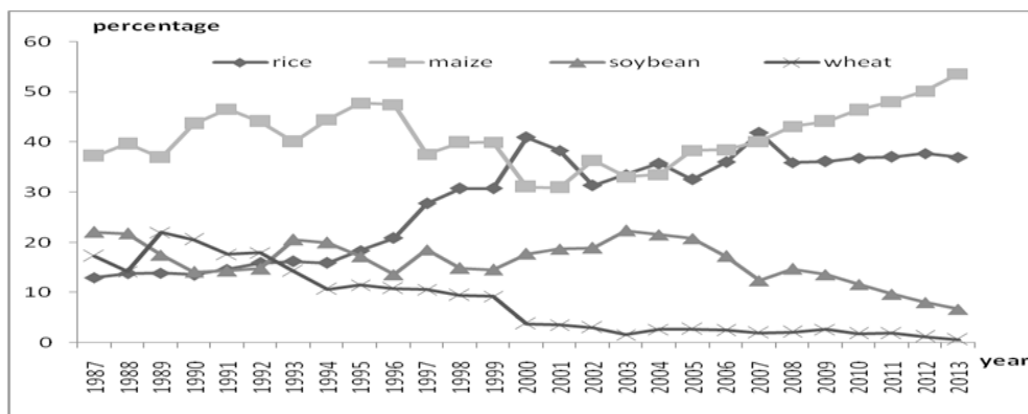**3. Analysis of structure grain production yield fluctuation**

3.1. The source and instructions of data

This article selects the four types of rice, maize, soybean and wheat grain crops as the research object. We do not analyze potato and other cereal because of their very small proportion of the total grain output. Based on the above, this article selects 27 groups of sample data which include the total grain yield and four major ones.

3.2. The analysis of proportion between four major grain crops and total grain output

The proportion of corn account for total grain output is overall stability, which is still in the main position in Heilongjiang province. The highest proportion is 53.12% in 2013.The lowest proportion is 30.09% in 2001. The average proportion is 41.19%.The proportion of rice account for total grain output is steady rise. The highest proportion is 41.83% in 2007.The lowest proportion is 12.99% in 1987. The average proportion is 28.01%.The proportion of soybean account for total grain output is slightly fell. The highest proportion is 22.32% in 2003.The lowest proportion is 6.66% in 2013. The average proportion is 16.21%.

The proportion of wheat account for total grain output is gradually decline. The highest proportion is 22.01% in 1989.The lowest proportion is 0.65% in 2013. The average proportion is 8.08%.

Figure 1. Four crops accounting for proportion of total output of grain in Heilongjiang Province between 1987 and 2013

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3.3. The analysis of fluctuation between four major grain crops and total grain output

Variance decomposition is a kind of earliest and most common use method that sees as stochastic descriptive tool .It shows that the total grain output variance is all the kinds and regional production variance from the view of mathematics. We can get the contribution of each area to the total variance from the decomposition of total yield.

Total variance can be expressed as: $V(Q) = \sum_h \sum_k \sum_i \sum_j Cov(Q_{hj}, Q_{kj})$,Q represents the total output, i and j represents the grain crops, h and k represent different regions. This paper only study the effect of fluctuations between four major grain crops and total grain output in Heilongjiang province, so this becomes the above formula: $V(Q) = \sum_I \sum_J Cov(Q_i, Q_j)$ .This article conducts the sum of covariance for some crops and other plants as covariance item of the crop. This article conducts the ratio of the total variance and some crops as the contribution. The variance contribution of crop indicates the effect that the crop yield fluctuation on the total grain output fluctuation. The covariance contribution indicates the effect that crops and others output act on the total grain output fluctuation. (Table 2)

Table2. Variance of four crops in Heilongjiang Province between 1987 and 2013

	Total grain output	Rice	Maize	Soybean	Wheat
Variance	1485560	392042.4	471626.9	13359.6	18241.63
Contribution ratio		26.39%	31.74%	0.90%	1.22%
Covariance	2430539	705976.5	782197.4	54232.57	-100770
Contribution ratio		29.05%	32.18%	2.23%	-4.15%

From the results of variance decomposition the biggest contribution to the total variance is maize 31.74%,the second one is rice 26.39%, the third one is wheat 1.22%.From the result the covariance bet-

ween wheat and rice is negative. The covariance between wheat and maize is negative. It shows that they have tendency to complement each other. The direction of a wave is often offset another direction. From the results of covariance decomposition the biggest contribution to the total covariance is maize 32.18%, second one is rice 29.05%, the third one is soybean 2.23%. The covariance of wheat is negative. The maize is the main source of output fluctuations.

3.4. The analysis of sensitivity between four major grain crops and total grain output

The principle of Sensitivity analysis is elasticity coefficient. The sensitive coefficient is larger, which suggests that the greater influence of target parameter. If the sensitive coefficient is positive, indicate the target and the parameter values in the same direction. If the sensitive coefficient is negative, indicating the target and the parameter values in the opposite direction.

Sensitive coefficient = target change percentage / parameter change percentage =total yield change percentage / crop yield change percentage

Based on the related data of statistical yearbook, we calculate the sensitive coefficient between total grain output and rice, wheat, maize, soybean production. (Table 3)

Table3. Sensitive coefficient between total grain output and four crops production

Rice	Maize	Soybean	Wheat
1.18	3.74	3.15	1.03

Through calculation results, sensitive coefficient between total grain output and rice, wheat, are positive. The sensitive coefficient between total grain and maize is one of the biggest. The impact on total grain

output and maize is one of the biggest.

4. Analysis of empirical influence factors for grain yield fluctuation

4.1. Model specification

This article analyzes the selection of data with the multiple linear regression analysis. We study the influence factors of grain yield fluctuation through the model as follows:

$$Y = C + \sum_{i=1}^{n} \beta_i X_i + \varepsilon \tag{1}$$

Y represents the total output, C represents constant term, β_i represents regression coefficient for corresponding variable, X_i represents corresponding variable, ε represents random perturbation terms, values of n range is from 1 to 7.

4.2. Setting of variable

According to the formula (1) and considering the data availability, we take the independent variables with the method of substitution variables. Variables include grain sown area (X_1),effective irrigation area (X_2),per unit area yield of grain(X_3),agricultural fertilizer quantity (X_4),inundated area (X_5),agricultural machinery total power (X_6)and agriculture workers (X_7).We substitute food crops planting area and the effective irrigation area with and investment. We substitute labor input with the first industry workforce. We substitute capital investment with agricultural fertilizer quantity and agricultural machinery total power. We substitute natural disasters with inundated area

4.3. Results analysis

Based on the index of influence factors, we select the data from 1987 to 2013 in Heilongjiang province, which has carried on the multiple linear regression analysis through SPSS19.0.The analysis results are as follows:

$$Y = -1300.956 + 0.271X_1 + 0.256X_2 + 0.307X_3 + 0.188X_4 - 0.061X_5 + 0.278X_6 - 0.144X_7$$

$$（0.009）\quad（0.004）\quad（0.020）\quad（0.000）\quad（0.047）\quad（0.038）\quad（0.004）\quad（0.396） \tag{2}$$

$$R^2 = 0.993 \quad F = 553.939 \quad P = 0.000$$

The brackets values are the probability. F is joint inspection parameters. P is corresponding P values. From the regression result shows that the value of R^2 is 0.993, which shows that model the overall goodness is very good. F is 553.939 and P is 0.000 which shows that model is further analysis on the parameters of the whole regression results.

Firstly, the variables such as X_1, X_2, X_3, X_4 and X_6 are significantly positive under the 1% significant level. It shows that the variables such as grain sown area, effective irrigation area, per unit area yield of grain, agricultural fertilizer quantity and agricultural machinery total power are positive for grain yield. The per unit area yield of grain is primary factor of stability and improving for grain yield. The output

elasticity is 0.278, which is agricultural machinery total power of grain yield. It shows that agricultural mechanization has very important influence on grain production. The output elasticity is 0.271, which is grain sown area of grain yield. It means the area sown increase 1% which can lead to 0.271% growth of the total grain output. Grain production depends on the cultivated land resources. To guarantee grain security in our country we must ensure the stability of cultivated land area. The output elasticity is 0.256, which is construction of water conservancy facilities of grain yield. It indicates that water conservancy facilities construction has a very important role on grain yield increase. The supply of water has very great significance to stabilize grain production. The constant

improvement of water conservancy infrastructure that can stable the grain output volatility. The output elasticity is 0.188, which is agricultural fertilizer quantity of grain yield. It means the fertilizer inputs increase 1% which can lead to 0.188% growth of the total grain output. It shows that grain production increase depends on the chemical fertilizer inputs in Heilongjiang province.

Secondly, the X_5 is -0.0601 under the 1% significant level. It shows that inundated area has a reverse effect on total grain yield. It means the inundated area increase 1% which can lead to 0.188% decrease of the total grain output. Natural disasters are primary factor of the grain yield fluctuation especially the extreme natural disasters that has a huge impact on food production. The annual precipitation is concentrated in 6 ~ 9 month of Heilongjiang province, which is dramatic and uneven. To stable grain production, we must increase the ability of defense the natural risk.

Thirdly, the variables X_7 failed to pass the test of significance explanation, which shows that labor input do not increase grain production. In terms of labor input is not significance, Cheng Mingwang thinks the current agricultural production has involution in China [5]. Employment proportion of agriculture is still on the high side in our country. Agriculture employment proportion curve is still in a state of decline. It is still not reached the value of "rural surplus labor transfer trap". In addition, the factors of "labor on" should not be ignored. Hiring other rural labor force is also very common, which increases the average workload of individual labor.

5. Conclusions

The grain yield fluctuation can be divided into 8 cycles in Heilongjiang province that is medium-term fluctuations. The average cycle length is 3 years. It is the ancient typical that has characteristics such as high growth, strong shock and continuous cycle. The grain yield is like to fluctuate. From 1988 to 2013, the average growth rate of the crest, trough and amplitude for total grain output are 16.025%, 5.56%, 21.59%.

The proportion of corn account for total grain output is overall stability. The proportion of rice account for total grain output is steady rise. The proportion of soybean account for total grain output is slightly fell. The proportion of wheat account for total grain output is gradually decline. The maize is the biggest contribution to the total covariance. The sensitive coefficient between total grain and maize is one of the biggest. The impact on total grain output and maize is one of the biggest.

The variables such as grain sown area, effective irrigation area, per unit area yield of grain, agricultural fertilizer quantity and agricultural machinery total power are significantly positive. Inundated area has a reverse effect on total grain yield. Labor input does not increase grain production. Natural disasters have the negative impact on grain yield.

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