

PAPER • OPEN ACCESS

Agricultural Sustainable Development and Economic Stability in Northeast China under Climate Change

To cite this article: Yilin Chen and Nan Wu 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **562** 012113

View the [article online](#) for updates and enhancements.

Agricultural Sustainable Development and Economic Stability in Northeast China under Climate Change

Yilin Chen¹ and Nan Wu²

¹School of Humanities and Social Science, Beijing Institute of Technology, 5 South Zhong Guan Cun Street, Haidian District, Beijing, China, 100081.

²School of Humanities and Social Science, Beijing Institute of Technology, 5 South Zhong Guan Cun Street, Haidian District, Beijing, China, 100081.

Email: cyl98n@163.com

Abstract. At present, a sustainable agricultural development is extremely important for economic backwardness in the northeast of China to stabilize local economy and prevent economic disaster. The paper is constructing an economic climate model of northeast region, the inspection result of this model represents: climate warming, drought, and extreme climate bring significant negative effect towards cereal output in northeast region; and this paper also represents the analysis results that the price, labor force, capital and technology inputs have a positive effect on cereal output. Recognizing these impacts correctly and taking active measures will be favorable to ensure a sustainable development and regional economic stability of the northeast region.

1. Introduction

In recent years, the economic development of northeast China has encountered sever problems. According to the data of the National Bureau of Statistics, in the first half of 2016, the GDP growth rates of Heilongjiang, Jilin and Liaoning provinces were 5.7%, 6.7% and -1%, ranking at the bottom of the country; at the same time, (National Population and Family Planning Commission) the survey data of the National Family Planning Commission shows that the fertility rate in northeast China is far lower than the national level, and the net migration of the population has been going on for more than 20 years. It is not difficult to find that the economic structure of northeast China is undergoing some drastic changes. As an important industrial and agricultural production base in China, the difficult industrial transition has caused a degree of decline in the economy of northeast China. According to statistics, the added value of the secondary industry in northeast China (Heilongjiang, Jilin and Liaoning provinces) decreased by 8.7% in 2015. Although the added value of the primary industry and the tertiary industry reached 3% and 10.5%, they were still dragged down by the industrial sector's shrinkage, the Northeast's economic growth level has always been at the bottom of the country.

In the face of the dilemma of economic development in northeast China, it is particularly important to maintain the stability and development of regional economy and society to maintain the sustainable and stable development of agriculture while accelerating the industrial transformation and upgrading. As an important commodity grain base in China, the northeast region produces nearly one-fifth of the grain in China. Of its 22.19 million hectares (2015) of crop acreage, 91% of the land is used for food cultivation. However, agricultural production has been affected by climatic factors from ancient times. In recent years, due to the aggravation of climate change, agricultural production around the world is facing unknown dangers. According to the IPCC's fifth climate assessment released in November 2014, the global average temperature has increased by 0.85°C over the past 100 years resulting from



greenhouse gas emissions associated with human industrial activities [1]. In addition, the uneven spatial and temporal distribution of precipitation and extreme weather phenomena has intensified globally. Thus, climate change is having a lasting and far-reaching impact on human production and life, and agricultural production is bearing the brunt of the impact. In order to realize the healthy development of agriculture in northeast and to support the transformation of economic development mode, it is necessary to cope with the potential impact of climate change on agricultural production actively. Therefore, this paper chooses the empirical research method of multiple linear regressions to analyze the influencing factors of food production in Northeast China, in order to give suggestions to agricultural sustainable development policies to deal with climate change.

2. The Current Situation of Agricultural Production in Northeast China and the Hidden Problems

2.1 There is a Significant Decline in the Growth rate of Food Output and Total Agricultural Output

Since the founding, northeast China has become an important heavy industrial base of China, but also because of the fertile soil and suitable climate, the Northeast has become a veritable granary in China. Since the beginning of the new century, the proportion of food production in the Northeast has increased from 12% in 2000 to around 19% in 2011-2015.

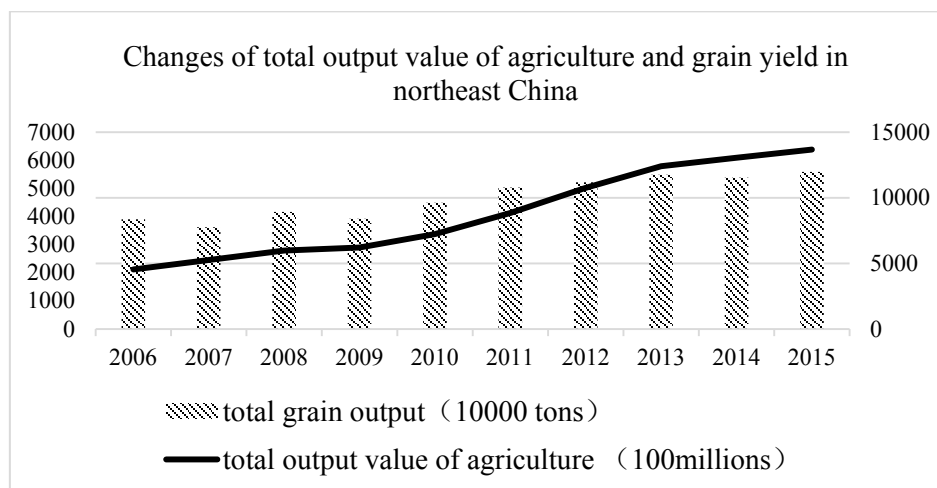


Figure 1. Changes of total output value of agriculture and grain yield in northeast China

From Figure 1, we can see that the total food output and total agricultural output in northeast China have achieved good results in rapid growth in the past decade. Along with the increase in output, the quality of food in Northeast region has been improved under the influence of a large amount of capital and technology. However, there are hidden problems behind such developing achievements. As the economic development rate in the northeast region slows down, the growth rate of agricultural production investment may also decline. It can be clearly seen from Figure 1 that after 2013, the growth rate of food output and total agricultural output in northeast China showed a dramatic decline. In addition, while northeast China has encountered economic difficulties in recent years, migration in northeast China, especially rural migration, is also very significant.

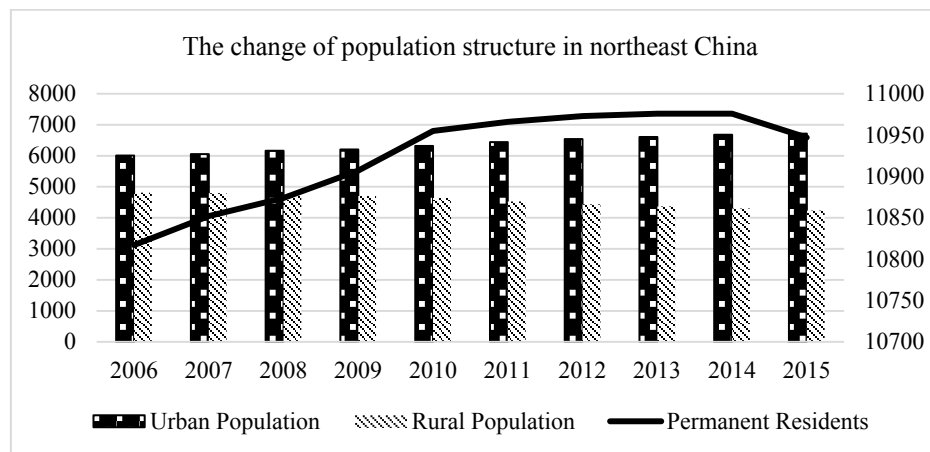


Figure 2. The change of population structure in northeast China

Figure 2 shows the changes in urban and rural population structure of in northeast China over the past decade. The broken line represents the change of permanent population in northeast China in recent ten years, corresponding to the axis on the right. The histogram shows the changes of urban population and rural population in northeast China in recent ten years, corresponding to the left axis. It can be seen that although the urban population in northeast China did not increase on a large scale, it continued to increase for ten years. However, the rural population has been declining year by year. Due to the negative impact brought by the decrease of rural population, the permanent population in northeast China even showed a slight decline in 2015. The reason for the population flow is that the Beijing-Tianjin-Hebei, Yangtze river delta metropolitan circle jobs than the northeast China has a big advantage, and a large number of the northeast rural labor choose to leave home, seeking higher income and a decent life, while the agricultural business is left for the aged, children and women, in the long run, the change trend of the negative impact of agricultural production may be irreversible and profound.

2.2 Climate Change Aggravates the Instability of Agricultural Production.

Agricultural production is different from the production of industrial products, and only considering labor, capital and other factors cannot build a comprehensive and effective production function. Agricultural production has been a process of "depending on the weather" since ancient times. Although agricultural production technology has made great progress in thousands of years, climate still has a significant impact on agricultural production. In recent years, global climate change has intensified, adding more uncertainty to agricultural production in northeast China. Now for this problem, academia has a different voice: Zhao Zongci and Luo Yong (2007) using multiple models found that the temperature in northeast China will be from current warming 3.0 °C or above, precipitation may increase. Wu Haiyan etc. (2014) found that the impact of climate change on agricultural production in northeast China was very complex, and it could not be distinguished by simple advantages and disadvantages. It is mainly manifested as the increase of temperature, increase of heat resources, extension of suitable period for crop growth and expansion of suitable planting area in the growing season of main crops in northeast China, which provides potential possibility for the improvement of light and temperature production capacity and yield of crops. However, the yield and quality of crops will also be negatively affected due to factors such as light and water resources, as well as the limitation of increasing carbon dioxide concentration. Zhao Jin etc. (2014) used crop model APSIM to study the impact of climate change on spring maize in the three northeastern provinces. Through the study, it is found that the north boundary of spring maize planting in the three provinces in northeast China has obvious north-to-west movement, and the planting area of spring maize may increase. In the possible planting area of spring maize, if the adaptation of variety and cultivation management measures is not taken into account, the proportion of the area with the highest irrigated yield would shrink, and the yield per unit area of irrigated yield of spring maize would decrease.

However, due to the increase of possible planting area, the total irrigated yield of spring maize in the three northeastern provinces will still increase.

To sum up, climate change adds much uncertainty to agricultural production, especially grain production in northeast China. Considering the economic difficulties in northeast China, agricultural economy plays an important role in the stable and healthy development of regional economy. Therefore, this study has significant practical significance for the research on the sustainable development of agriculture in northeast China under the climate change.

3. Analysis of Main Factors Affecting Agricultural Production in Northeast China

Northeast China has very favorable natural and socioeconomic conditions for the development of agriculture. Northeast China is located in temperate humid and semi humid climate zone, rain and heat at the same time; Terrain is mainly plain, supplemented by plateau and mountain terrain, conducive to agricultural diversification; The soil condition is the best in the world, the black soil and chernozem are widely distributed, the soil layer is deep and the organic matter content is high. In addition, the social and economic conditions in northeast China are conducive to large-scale mechanized farming with large areas and few people and developed industries, which can support the large supply of machinery, equipment, fertilizer and other means of production. This paper will analyze the influence of human, capital, land and climate on agricultural production in northeast China.

3.1 Human Resources.

Northeast China is a vast region, but its population density is relatively low compared with the rest of the country due to its cold winter climate. In recent years, the "population crisis" in northeast China has gradually attracted the attention of the whole society. Along with the decline of the economy in northeast China, the population in northeast China has flowed out in large numbers, and even the negative growth of the permanent population has appeared. According to the national bureau of statistics, the permanent population of northeast China (Heilongjiang, Jilin and Liaoning provinces) was 109 million in 2015, about 190,000 fewer than the previous year. The proportion of northeast China's population in the total population decreased year by year, from 16.8% in 1982, 11.79% in 1990, 8.22% in 2010 and 7.93% in 2015. As mentioned above, the main outflow of population in northeast China is rural population, and most of them are young and middle-aged labor force. As most of the pillar industries in northeast China are heavy industries, they can no longer provide sufficient and high-quality employment opportunities to meet the needs of rural migrant workers in cities. Therefore, for the farmers in northeast China who expect to go to urban development, going south seems to be the only possibility, and a large outflow of population is inevitable. Although the mechanization level of agricultural production in northeast China is higher than the national average level, the agricultural production in northeast China is facing great hidden problems due to the large loss of young and middle-aged labor force and the increasingly fierce situation. Li Min et al. (2010) analyzed the aging problem of agricultural labor force in Liaoning province by means of empirical analysis through the follow-up survey of going to the countryside for five consecutive years. The results show that the aging phenomenon of agricultural labor force has appeared in Liaoning province, and this year the aging phenomenon is further intensified; It believes that the outflow of labor force is an important reason for the aging of the agricultural labor force. Peng Daiyan et al. (2015) pointed out through theoretical analysis that under the combined action of internal forces such as the market system, household registration system, land system and external forces such as the widening urban-rural income gap, the rural young and middle-aged labor force in China continues to shift outward, which may lead to the imbalance of the labor force structure and may threaten China's food security. It can be seen that at present, human resources are still a necessary condition for agricultural production, and a large number of young and middle-aged people moving out may have a negative impact on agricultural production in northeast China.

3.2 Capital.

As with other productive activities, capital is important for agricultural production. In agricultural production activities, capital is often reflected by fertilizer, agricultural machinery, irrigation water and

equal means of production. As for the role of means of production in production activities, scholars often measure it in the form of production function. Ji Xiaoyan et al. (2016), based on the data of Jiangsu province from 2000 to 2014, used the production function model to calculate the impact of technological progress, efficiency change, labor input and other factor inputs on agricultural production in north, south and central Jiangsu. The results show that the input of agricultural machinery power is beneficial to the growth of agricultural output value in all the regions of Jiangsu province. Fertilizer input is negatively correlated with the total agricultural output of southern Jiangsu, but not significantly with the agricultural output of the other two regions. Liu Fengqin (2006) studied the conditions of large-scale agricultural land management in northeast China. The research results show that agricultural mechanization is the substitution of labor force, but the boundary of substitution only depends on the relative price change of agricultural machinery and rural labor force, and the degree of substitution has nothing to do with the scale of land. It can be seen that increasing the input of means of production (capital) within a reasonable range is conducive to agricultural production. However, the impact of inputs such as fertilizers and pesticides on agricultural output does not necessarily increase monotonously, and the input of capital also needs to consider the situation of costs and benefits. According to the actual situation in different regions, there may be situations in which excessive input may lead to negative impact on agricultural production.

3.3 Land Resources.

Land is an essential factor in agricultural production. For northeast China, vast and fertile black soil is its rare wealth. According to the second national land survey conducted from 2007 to 2009, China's national cultivated land area is 135,385 million hectares, of which the cultivated land area of northeast China is 27.938 million hectares, accounting for 20.6% of the country, per capita cultivated land area is more than twice the national average level, land resources can't be considered as infertile. In addition to the cultivated land that has been developed, there are a large number of undeveloped land resources suitable for cultivation in northeast China, for instance, Heilongjiang province alone has more than 50 million acres of wasteland resources available for reclamation. Although land resource of northeast area is rich, but still exist hidden problems. However, it is particularly alarming that serious soil and water loss has occurred in the black soil belt of northeast China in recent years, and the land ecological environment has been damaged. Due to the destruction caused by human activities, the black soil layer in northeast China decreased from 60-70cm thick at the initial stage of reclamation to 20-30cm today, and the organic matter content also decreased from 6-15% at the initial stage to 1.98% [2]. It can be seen that the current land resource problem in northeast China is not alarmist, and the protection of cultivated land area and quality should arouse the attention of the whole society.

3.4 Climate.

In recent years, climate disasters have occurred frequently, and the global climate change caused by human activities has attracted extensive attention from all walks of life. According to the fifth climate assessment report of IPCC, climate change in China has been obvious in the past 50 years, which is mainly characterized by rising temperature, unstable precipitation and frequent extreme climate phenomena. Specific to the northeast region, according to the survey, the average temperature in northeast China from 1991 to 2000 to $0.55^{\circ}\text{C} \cdot 10\text{ a}^{-1}$ the tendency of rate rises, significantly higher than the $0.23^{\circ}\text{C} \cdot 10\text{ a}^{-1}$ the average [3]. As the temperature rises, the frost-free period in northeast China will be prolonged, the accumulated temperate zone will move north and east, and the suitable planting area of main crops will be expanded, which is beneficial to the agricultural production in northeast China. However, due to the impact of global climate change, the water shortage in northeast China is becoming increasingly serious. In the 1990s, there were 3-4 severe droughts in northeast China, and since the beginning of the new century, there have been eight droughts in northeast China in a decade, which have brought great negative effects on regional agricultural production. In addition, extreme weather phenomena such as hail and frost are bound to increase gradually under the background of global climate change, which also threatens the sound and stable development of agricultural production in northeast China.

4. Food Production Function Simulation in Northeast China Based on C-D-C Model

As mentioned above, human, land, capital and climate have different degrees of influence on agricultural production in northeast China. However, previous studies focused on agricultural models and agricultural countermeasures, but few on the production function of economic tools. Quantifying this effect in the form of the production function in this paper is undoubtedly helpful for the country to evaluate the direction of investment in agricultural production. Therefore, in this paper, the author selected the grain production in northeast China as a case to study the impact of different factors on the grain production in northeast China through empirical analysis. As grain is the main output of agricultural production in northeast China, the results of this study can also provide suggestions and references for guiding agricultural production in northeast China.

4.1 Proposal of Hypothesis.

Based on the existing research results, this paper can propose the following two hypotheses:

(1) according to the IPCC report and the research results of domestic scholars, the future climate change in northeast China is mainly manifested as climate warming, precipitation reduction or uneven distribution, and frequent disasters caused by extreme weather. This paper assumes that the above climate change has a negative impact on grain production in northeast China.

(2) it can be found from the literature summary that increasing the input of economic factors can have a significant positive impact on food production. This paper assumes that the input of economic factors and climate factors can replace each other and under the framework of reproduction function, the government can make up for the adverse impact of climate change on crops by increasing the input of economic factors.

Therefore, this paper will try to verify the correctness of the above two assumptions through empirical research, so as to further put forward policy suggestions based on the research results.

4.2 Model Construction.

Production behavior in modern society is a process in which social organizations transform input factors into output factors and the input of various production factors directly affects the output of final products. Although food production is the most basic mode of production in social production, it still basically follows this logic. In the contemporary western economic system, scholars introduce the production function to analyze the relationship between the input amount of various factors of production and the maximum output of production. The production function in mathematical form is generally expressed as $Q = f(X_1, X_2, X_3, X_4 \dots X_n)$, $X_1, X_2, X_3, X_4 \dots X_n$ represents the input amount of n production factors needed in the production process, and Q represents the output. Generally speaking, variables such as labor, capital, land and entrepreneurial ability often appear as input factors of production function.

Among the production functions, Cobb-Douglas Production Function (C-D production function for short) is a relatively mature model, which has been recognized by the mainstream academia. According to the above summary, the input factors of food production are mainly divided into two categories: climatic factors and non-climatic factors. Climatic factors mainly include temperature, rainfall, disasters and other factors. Non-climate factors include factors of production such as arable land, fertilizer use, food prices and irrigation. Referring to the C-D production function and the C-D-C model of Chou Jieming (2006), the author introduced the climate factor into the production function to construct the economy-climate model of northeast China. In this paper, three climatic factors, namely average temperature, precipitation and disaster area, as well as seven non-climatic factors, including the lagging item of the retail price index of food commodities, the area under cultivation of food crops, the fold quantity of agricultural fertilizer application, the total power of agricultural machinery, agricultural practitioners, effective irrigation area and technical variables, were selected. According to the form of production function, the following model can be established after logarithmic treatment of both sides of the equation:

$$\ln(\text{out}_t) = \alpha_0 + \alpha_1 \ln(\text{temp}_t) + \alpha_2 \ln(\text{prec}_t) + \alpha_3 \ln(\text{dis}_t) + \alpha_4 \ln(\text{area}_t) + \alpha_5 \ln(\text{prc}_{t-1}) \\ + \alpha_6 \ln(\text{mach}_t) + \alpha_7 \ln(\text{labor}_t) + \alpha_8 \ln(\text{ft}_t) + \alpha_9 \ln(\text{irri}_t) + \alpha_{10} \text{tech}_t + v_t \quad (1)$$

α_0 represents the constant term, $\alpha_1, \dots, \alpha_9$ represents the coefficients, and v represents the error term; t represents time, out represents food production, $temp$ represents the average temperature, $prec$ represents precipitation, dis represents inundated area, $area$ represents food crop farming area, prc represents food commodities retail price index, $mach$ represents total power of agricultural machinery, $labor$ represents agricultural labor, ft represents agricultural fertilizer Purity, $irri$ represents the effective irrigation area, $tech$ represents technological progress variables.

4.3 Selection and Processing of Variables.

In this paper, data from three provinces in northeast China were collected for research, and the time span was from 1987 to 2013. The specific data selection and processing process of each variable is as follows:

(1) Average temperature (°C) and rainfall (mm)

Temperature data is from globalweather.tamu.edu, the Meteorological Data website provided by Texas A&M university. The process of the research will cover nine cities in Heilongjiang province including Harbin, Daqing, and Qiqihar; nine cities in Jilin province including Changchun, Jilin, and Yanji; and 12 cities in Liaoning province including Shenyang, Dalian, and Tieling, averaging their daily meteorology data to calculate yearly average temperature of each province. The data of rainfall and temperature came from the same source. In terms of data processing, this paper adds the daily rainfall of each city in a single province to obtain the data year by year, then takes the average value, and finally obtains the average annual total precipitation of each province.

(2) Grain output (ten thousand tons), disaster area (one thousand hectares), grain crop cultivation area (one thousand hectares)

The data of grain yield, disaster area, grain crop cultivation area, total power of agricultural machinery, agricultural fertilizer purity and effective irrigation area were collected from the provincial annual data collected by the national bureau of statistics. The data of Heilongjiang, Jilin and Liaoning provinces from 1987 to 2013 were selected in this paper.

(3) Retail price index of food commodities

Taking into account of the inflation factor, this paper calculate inflator by comparing each year and each province food commodities retail price index from the national bureau of statistics with the year consumer price index. Finally, the annual retail price index of grain commodities in each province was obtained based on the 1986 data (1986 price index = 100). Considering that the period of grain production is relatively long and the impact of grain price on grain output has hysteresis, the price index introduced in this model is a phase lag term.

(4) Agricultural employees (10,000 people)

The data of agricultural practitioners are difficult to obtain. This paper, by referring to the methods of Zhu Honggen (2010), Zhou Wenkui (2012) and others, selects the data of agricultural, forestry, animal husbandry and fishery practitioners in different provinces published by the national bureau of statistics for calculation. Assuming that the per capita productivity level of agriculture, forestry, animal husbandry and fishery is equal, the percentage of the total output value of agriculture in the total output value of agriculture, forestry, animal husbandry and fishery is multiplied by the practitioners of agriculture, forestry, animal husbandry and fishery to estimate the number of labor force engaged in agricultural production.

(5) Technological progress variables

In this paper, the yield per unit area of grain is used to reflect technological progress and replace technological variables. The data were obtained from the website of the national bureau of statistics, and with the yield per unit area of grain in 1987 as the base period 1, the technological progress variables of each year were obtained successively.

(6) Regional dummy variables

In order to make the model fitting result better, this paper introduces two dummy variables to distinguish the three provinces. $F1=1$ represents Heilongjiang province; $F2=1$ represents Jilin province; $F1=F2=0$ represents Liaoning province.

4.4 Modeling Process and Results.

After data selection and processing, the least square regression analysis of each variable should be carried out according to the form of C-D formula. After using SPSS stepwise regression, it was found that although the independent variables retained by stepwise regression all passed the significance test at 1% level, the R square after model adjustment was as high as 0.992, which may be due to excessive independent variables and over-fitting. In order to reduce the influence of overfitting, Principal Component Analysis was used to reduce the dimensionality of the independent variables.

According to the division method above, independent variables are classified into climatic variables and non-climatic variables. Principal component analysis was performed.

As shown in the following table, in the climate variable group, the cumulative contribution rate of the first two principal components reached 81.875%, so these two principal components were selected. Coefficients and principal component expressions are obtained according to the component matrix and characteristic values.

Table 1. Total variance of interpretation

Component	Initial Eigenvalues			Extraction Sums of Squared Loading		
	Total	SD (%)	Cumulative Percentage	Total	SD (%)	Cumulative Percentage
1	1.459	48.630	48.630	1.459	48.630	48.630
2	.997	33.245	81.875	.997	33.245	81.875
3	.544	18.125	100.000			

Table 2. Component Matrix

	Component	
	1	2
templn	.592	.720
precln	.617	-.692
disln	-.853	.000

$$W1_t = 0.491 \ln(\text{temp}_t) + 0.511 \ln(\text{prec}_t) - 0.706 \ln(\text{dis}_t) \quad (2)$$

$$W2_t = 0.721 \ln(\text{temp}_t) - 0.693 \ln(\text{prec}_t) + 0.0002 \ln(\text{dis}_t) \quad (3)$$

Similarly, for the non-climatic variable group, the cumulative contribution rate of the first two principal components reached 86.588%, so the seven independent variables could be reduced to two principal components. Coefficients and principal component expressions are obtained according to the component matrix and characteristic values.

Table 3. Total variance of interpretation

Component	Initial Eigenvalues			Extraction Sums of Squared Loading		
	Total	SD (%)	Cumulative Percentage	Total	SD (%)	Cumulative Percentage
1	4.500	64.280	64.280	4.500	64.280	64.280
2	1.562	22.307	86.588	1.562	22.307	86.588
3	.366	5.229	91.817			
4	.231	3.305	95.122			
5	.196	2.794	97.916			
6	.115	1.649	99.565			
7	.030	.435	100.000			

Table 4. Component matrix

	Component	
	1	2
prc+1ln	.872	-.297
arealn	.630	.650
ftln	.916	-.287
machln	.908	-.196
laborln	.099	.948
irriln	.953	.049
tech	.873	.171

$$P1_t = 0.411 \ln(\text{prc}_{t-1}) + 0.297 \ln(\text{area}_t) + 0.432 \ln(\text{ft}_t) + 0.428 \ln(\text{mach}_t) + 0.047 \ln(\text{labor}_t) + 0.449 \ln(\text{irri}_t) + 0.412 \text{tech}_t \quad (4)$$

$$P2_t = -0.238 \ln(\text{prc}_{t-1}) + 0.520 \ln(\text{area}_t) - 0.230 \ln(\text{ft}_t) - 0.157 \ln(\text{mach}_t) + 0.758 \ln(\text{labor}_t) + 0.039 \ln(\text{irri}_t) + 0.127 \text{tech}_t \quad (5)$$

Hence, will get $W1_t, W2_t, P1_t, P2_t, F1, F2$, six groups of variables and dependent variables $\ln(\text{out}_t)$, stepwise regression analysis, the final six independent variables were knocked out, regression results are seen in the following table.

Table 5. Model Summary

Model	R	R-Squared	Adjustment of R-Squared	The error of the standard estimate	Durbin-Watson
1	.987 ^a	.974	.972	.0628393	1.499

Table 6. Anova table

	Model	Quadratic sum	df	Mean square	F	Sig.
1	Regression	10.951	6	1.825	462.195	.000 ^b
	Residual	.292	74	.004		
	Total count	11.243	80			

Table 7. Coefficient

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Standard error	Trial version.		
1 (Constants)	.232	.462		.502	.617
F1	-.124	.042	-.156	-2.909	.005
F2	-.290	.027	-.367	-10.800	.000
P1	.405	.015	.861	27.196	.000
P2	.294	.046	.300	6.441	.000
W1	.116	.016	.206	7.468	.000
W2	-.115	.032	-.105	-3.576	.001

Table 8. Residual statistics

	Minimum value	Maximum value	Mean value	Standard deviation	N
Predicted value	6.917611	8.691740	7.691635	.3699768	81
Residual	-.1621267	.1185378	.0000000	.0604369	81
Normal expected value	-2.092	2.703	.000	1.000	81
Standard residual error	-2.580	1.886	.000	.962	81

The regression results showed that the adjusted R square of the model was 0.974, and the fitting results were relatively ideal. The F test of the model and the t test of each coefficient all pass the significance test at the level of 1%. The standardized residual of the model obeys the approximate normal distribution, and the D-W test value is 1.499, indicating that there is no obvious correlation in the residual of the model. In conclusion, the model fitting effect is much ideal.

Based on the coefficients obtained from the regression model, the principal component expression is substituted to obtain the final production function, as shown below.

$$\begin{aligned} \ln(\text{out}_t) = & 0.232 - 0.026 \ln(\text{temp}_t) + 0.139 \ln(\text{prec}_t) - 0.082 \ln(\text{dis}_t) + 0.097 \ln(\text{prc}_{t-1}) \\ & + 0.273 \ln(\text{area}_t) + 0.107 \ln(\text{ft}_t) + 0.128 \ln(\text{mach}_t) + 0.242 \ln(\text{labor}_t) + 0.194 \ln(\text{irri}_t) \\ & + 0.207 \text{tech}_t - 0.124 F1 - 0.290 F2 \end{aligned} \quad (6)$$

It can be seen from the model that climate warming, drought and extreme weather have obvious negative effects on grain output in northeast China. According to the model gotten by this paper, when the average temperature in northeast China rises to 1°C, the grain output will decline by 0.5%; When precipitation in northeast China decreases by 10%, grain yield will decrease by 1.5%. When the disaster area in northeast China increases by 10%, the grain output will decrease by 0.8%. Prices, Labour, capital and technology inputs all have a positive impact on food production, not meteorological factors. Among them, the cultivated area of grain crops, agricultural labor, effective irrigation area and technical variables have a significant positive impact on grain yield, with the coefficients reaching 0.273, 0.242, 0.194 and 0.207 respectively.

Thus, the two hypotheses proposed in this paper have been empirically proved.

5. Analysis of Climate Change Trend and Impact Estimation in Northeast China

The United Nations intergovernmental panel on climate change (IPCC) was established in 1988. Its main task is to evaluate and study the current situation of climate change, the potential impact of climate change on society and economy, and how to deal with such problems. So far, the IPCC has

issued five reports in 1990, 1995, 2001, 2007 and 2014, which continuously pay attention to global climate change.

Based on the fourth scientific assessment report published by IPCC in 2007, Zhao Zongci and Luo Yong (2007) estimated the 21st century climate change trend in northeast China. By studying the 23 global climate system models and emission scenarios in the IPCC report, Zhao Zongzi et al. estimated the changes of temperature and other climate elements in northeast China under the three emission scenarios of high emission of human activities (A2), medium emission (A1B) and low emission (B1). The following conclusions are obtained:

Table 9. Estimation of annual mean temperature change in northeast China (relative to 1980-1999)

Year	2011-2030	2046-2065	2080-2099
B1	0.5-1.5	1.5-2.0	3.0-3.5
A1B	0.5-1.5	2.5-3.0	3.5-4.0
A2	1.0-1.5	2.0-3.0	>4.0

Table 10. Under the medium emission scenario (A1B), the changes of average temperature and precipitation in winter (December to February) and summer (June to August) in northeast China in the late 21st century (2080-2099)

Items	Summer	Winter
Temperature change	0.5-1.5	1.5-2.0
Precipitation change	0.5-1.5	2.5-3.0

It can be seen from the research results that in the late 21st century (2080-2099), the average annual temperature in northeast China will rise by 3.5-4 degrees (A1B) under the moderate emission scenario, while the precipitation will show an uneven spatial and temporal distribution, but the overall trend is upward. Combining with climate data of this paper, the annual average temperature will be 5.68°C in northeast China at the end of the 20th century (1987-1999). Referring to Zongci Zhao and others' studies on climate change estimates, the average temperature in northeast China will reach 9.18 °C to 9.68 °C and the annual rainfall will rise to 790.2 mm to 890.2 mm about a century later. By introducing the above climate change data into the regression model obtained in this paper, it can be seen that under the premise that the remaining production factors do not change, the grain yield in northeast China affected by climate factors may decline by as much as 1.4% in the late 21st century (2080-2099), and may also increase by 2.6%.

But at the same time, according to the second hypothesis of this research model, the input of economic factors and climate factors in the production function can be replaced with each other and by appropriately increasing the input of economic factors, the possible adverse impact of climate change on food production can be made up. In order to avoid the late 21st century climate's influence of the possibility of 1.4% decline in grain production in northeast China, in the process of food production we need to increase at least 5.2% of the arable land, appropriate amount of fertilizer or 13.8% or 11.4% of the agricultural machinery power, or 5.9% of the workforce, to offset the negative impact of climate change and ensure the steady growth of grain production in northeast China.

6. Conclusions and Policy Suggestions

The stagnation of economic development in northeast China is testing the wisdom of the government. Under the "new normal" state when the development of heavy industry is hindered, it is of great significance to explore and grasp new economic growth points. With climate change becoming increasingly severe, it is a new idea to realize sustainable agricultural development on the basis of maintaining the position of commodity grain base in northeast China and provide support for the economic recovery in northeast China. According to the empirical research in this paper, it can be found that:

(1) The trend of climate change is threatening agricultural production in northeast China. The

increase of temperature, the decrease of precipitation and the increase of natural disasters are obviously disadvantageous to the grain production in northeast China. By analyzing and evaluating the future climate change trend in northeast China, it can be found that in the 21st century, climate change may have negative effects on agricultural production in northeast China.

(2) Input of economic factors such as price, labor, capital and technology have a positive impact on grain production in northeast China. Among them, increasing the area of grain cultivation, putting in more labor force, expanding irrigation area and improving the level of farming technology have a significant positive impact on grain production. By increasing input of economic factors, the impact of climate change on food production can be effectively compensated.

According to the above conclusions, on one hand, in order to cope with the adverse impact of climate change on agriculture in northeast China, the state should provide policy support for agricultural development in northeast China from the aspects of capital, labor and technology. On the other hand, the northeast region is facing unprecedented economic challenges. Coping with the adverse effects of climate change on agricultural production is compatible with revitalizing regional economy, thus, the government should allocate and guide resources with "visible hands", implementing the supply-side structural reform of agriculture, developing modern agriculture to provide jobs and driving the economic growth point of regional economic development. Therefore, this paper puts forward the following policy Suggestions:

(1) The government should strengthen the impact assessment of climate change, minimize the impact of climate change on agricultural production, and ensure national food security. Specifically, in northeast China, the reduction of precipitation poses a great threat to grain production in northeast China, and the construction of water conservancy facilities and improvement of irrigation level can make up for the negative effect brought by climate change. The government will increase investment in infrastructure construction to boost domestic demand, create more jobs and stimulate the economic difficulties in northeast China.

(2) Both the cultivated land area and labor input have relatively positive effects on grain production. To avoid excessive urbanization which easily causes occupation of good land, it can be seen that the government should protect the rural arable land area and maintain national food security. At the same time, the government should also implement policies to effectively increase farmers' income from agricultural operations, to attract farmers back to the countryside and to avoid further outflow of rural agricultural labor force in northeast China.

(3) Improve the level of agricultural science and technology constantly.

Although the development cycle of agricultural science and technology is relatively long, its significance to agricultural production cannot be underestimated. The government shall increase input in agricultural scientific research and strengthen financial support for relevant universities and research institutions. We should give full play to the role of government and market in allocating resources, and guide more private enterprises to participate in the research and development of agricultural science and technology through industrial policy support. Only through the continuous innovation of agricultural science and technology, can we fully resolve the impact of climate change on agricultural production, improve the efficiency of agricultural production, and make it truly become the innovation growth point of economy in northeast China.

The report of the 19th National Congress of the CPC points out: "The agriculture and rural farmers issue is a fundamental one concerning the national economy and people's livelihood." Therefore, maintaining the stable development of agriculture in northeast China and comprehensively implementing the rural revitalization strategy are conducive to ensuring the economic stability of northeast China and providing a strong foundation for the industrial revitalization and transformation.

7. References

- [1] Cobb C W, Douglas P H. A Theory of Production [J]. *American Economic Review*, 1928, **18**(1).
- [2] Riahi K. *Fifth Assessment Report*, IPCC [J]. 2014.
- [3] Geng X, Weiss J. Development in North East People's Republic of China: An analysis of enterprise performance 1995–2002 [J]. *China Economic Review*, 2007, **18** (2).

- [4] Schreurs M A. Multi-level Governance and Global Climate Change in East Asia [J]. *Asian Economic Policy Review*, 2010, **5** (1).
- [5] Sui Y, Lang X, Jiang D. Temperature and precipitation signals over China with a 2°C global warming [J]. *Climate Research*, 2015, **64** (3).
- [6] Wang J X, Mendelsohn R, Dinar A, et al. The impact of climate change on China's agriculture. [J]. *Agricultural Economics*, 2009, **40** (3).
- [7] Xia Q, Simmons C. Diversify and prosper: Peasant households participating in emerging markets in northeast rural China [J]. *China Economic Review*, 2004, **15** (4).
- [8] YANG Wei, JIN Feng-Jun, WANG Cheng-Jin, DING Jin-Xue, Efficiency of Economic Growth and Its Spatial and Temporal Pattern in Northeast China [J]. *Scientia Geographica Sinica*, **2011**(5).
- [9] ZHAO Zongci, LUO Yong. Projections of climate change over northeastern China for the 21st century [J]. *Journal of Meteorology and Environment*, 2007, 03.
- [10] WU Hai-yan, SUN Tian-tian, FAN Zuo-wei, ZHAO Lan-po. The Major Food Crops in Response to Climate Change and Its Yield Effect in Northeast of China [J]. *Journal of Agricultural Resources and Environment*, 2014, 04.
- [11] ZHAO Jin, YANG Xiao-guang, LIU Zhi-juan, et al. The Possible Effects of Global Warming on Cropping Systems in China. The Possible Impacts of Climate Change on Climatic Suitability of Spring Maize in the Three Provinces of Northeast China [J]. *Scientia Agricultura Sinica*, 2014, 16.
- [12] Wang Xiaofeng, Zhang Zhengyun, Wen Xin. Demographic factor's effect on the economic growth in northeast China [J]. *Contemporary Economic Research*, 2016 (5).
- [13] Li Min, Zhao Liange. The influence of rural labor mobility on the aging of agricultural labor force based on the empirical analysis of Liaoning province [J]. *Chinese Rural Economy*, 2010(9).
- [14] Peng Daiyan, Luo Lili. Transfer of young and middle-aged rural labor force and China's food security [J]. *Academic Journal of Zhongzhou*, 2015(9).
- [15] Ji Xiaoyan, Zhou Shudong. Total factor productivity and its impact on agricultural economic growth based on an empirical study in Jiangsu province [J]. *Science and Technology Management Research*, 2016(21).
- [16] Liu Fengqin. A Study of the Conditions of the Scale Operation of Farmland, and of the Effect thereof: Taking the Northeastern Countryside as a Case [J]. *Management World*, 2006(9).
- [17] LIHui, LIU Chun-yan. Bearing Capacity of Land Resources and Farmers' Urbanization in Northeast China [J]. *Jilin University Journal Social Sciences Edition*, 2007(2).
- [18] GAO Feng, WANG Bao-Shu. A study on global warming and the temperature changes in the northeast region [J]. *Marine Forecasts Casts*, 2008, **25**(1).
- [19] Xie Jie. Research on influence factors of grain production in China [J]. *Inquiry Into Economic Issues*, 2007(9).
- [20] Wei Hong, Wang Lei. Analysis of the impact of grain price and farmers' income on grain yield based on the VEC model [J]. *Journal of Agrotechnical*, 2011(6).
- [21] Hei Puming, Li Dongsheng. Empirical study on grain yield and price fluctuation based on food security [J]. *Journal of Agrotechnical*, 2009(2).
- [22] WU Hai-yan, SUN Tian-tian, FAN Zuo-wei, ZHAO Lan-po. The Major Food Crops in Response to Climate Change and Its Yield Effect in Northeast of China [J]. *Journal of Agricultural Resources and Environment*, 2014(4).
- [23] CHOU Jie-Ming, and YE Du-Zheng. Assessing the Effect of Climate Changes on Grains yields with a New Economy-Climate model [J]. *Climatic and Environmental Research*, 2006, 11(3).
- [24] ZHOU Shudong, ZHOU Wenkui, LIN Guanghua, QIAO Hui. The Impact of Future Climate Change on China's Food Security [J]. *Journal of Nanjing Agricultural University (Social Sciences Edition)*, 2013(1).