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Article

An Empirical Analysis of Factors Affecting China's Comprehensive Grain Production Capacity

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Abstract: China, with the largest population in the world, is also the largest grain consumer. Grain security is fundamental to national welfare and the economy, playing a crucial role in socioeconomic development. Since the reform and opening-up, China's grain output has doubled, successfully overcoming the global grain crisis in 2006 and the global food crisis caused by the COVID-19 pandemic in 2020. However, we cannot be overly optimistic; we must realize that China's grain output growth has relied on soil fertility depletion and excessive pesticide and fertilizer usage, putting significant pressure on the environment. This paper analyzes the factors influencing China's grain output based on data from 1980 to 2020. Through this, it reflects the comprehensive grain production capacity and offers feasible suggestions based on the findings. The analysis is carried out from both theoretical and empirical perspectives. On the theoretical side, the paper considers the impact of variables such as the area of irrigated arable land (X1, in thousand hectares), total agricultural machinery power (X2, in ten thousand kilowatts), grain crop sowing area (X3, in thousand hectares), fertilizer use (X4, in ten thousand tons), and natural population growth rate (X5, in percentage) on grain output. On the empirical side, five grain-related indicators are selected for principal component analysis, and the model is tested using Eviews. The relative importance of factors affecting comprehensive grain production capacity varies with different stages of grain production and development. Finally, the paper offers recommendations for improving China's comprehensive grain production capacity based on the research findings.

Keywords: grain security; comprehensive grain production capacity; significance test

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1. Introduction

1.1. Research Background

There is a well-known saying in China: "Food is the first necessity of the people." This proverb applies not only to China but to any country worldwide. Food security is one of the three major security issues in global economic development. Since 1997, China's grain trade has expanded continuously. As a traditional agricultural giant and a developing country, China's requirements for grain output and demand are very high. However, due to outdated agricultural technology and limited arable land, China remains an agricultural giant but not a strong agricultural power. The COVID-19 pandemic has triggered a series of new food crises. Internationally, grain supply has been hit by natural disasters such as desert locust plagues in Africa and wildfires in Australia. The Russia-Ukraine conflict has added to these challenges, posing a catastrophic risk to global food security. Grain issues are directly linked to national welfare. In the short term, grain output is the most direct reflection of national food security, while in the long term, improving comprehensive grain production capacity is the key to solving food problems[1]. In the past, China's grain output growth relied on the depletion of soil fertility and the use of pesticides and fertilizers. This extensive production method has placed a heavy burden on the environment. Therefore, China must consider the following questions to improve its comprehensive grain production capacity in the future:

1. What is the current level of China's comprehensive grain production capacity?

2. What are the factors affecting China's comprehensive grain production capacity, and what are the key factors?

3. How can China improve its comprehensive grain production capacity under new conditions?

1.2. Research Significance

1). Theoretical Value: By analyzing the factors affecting China's comprehensive grain production capacity from both current and potential levels, this research provides deeper insights into its current state. This project breaks away from previous limitations on technological factors by combining scientific advancements with the grain industry. It connects the grain industry with large-scale agriculture, enhancing attention to certain indicators through weighted analysis and further improving existing evaluation theories on comprehensive grain production capacity[2].

2) Practical Value: Following a logical flow of identifying, analyzing, and solving problems, this study employs econometric methods such as multiple linear regression to assess the factors influencing China's comprehensive grain production capacity. The results provide decision-making references for ensuring stable grain supply and prices and for adjusting the agricultural supply-side structure in the post-pandemic period. Enhancing grain production capacity not only meets the demands of consumption upgrading but also addresses resource constraints, which is of great practical significance in ensuring national food security.

2. Literature Review

2.1. Research on Grain Security

Food security, which is closely related to national welfare, has long been a focus of academic attention. International research on food security mainly focuses on two factors: welfare effects of national policies and natural resource constraints. In terms of policy welfare, Jayatilleke (2017) used a general equilibrium model to study the dual subsidies to food producers and consumers in India during the 2007-2008 global food crisis, along with restrictions on food exports, stabilizing India's food prices[3]. He emphasized the importance of a "middle-ground" policy in ensuring India's food security. Hanjra (2010) analyzed the impact of factors such as climate change, energy crises, and population growth on food security, concluding that ensuring food security requires tackling climate change, conserving land and water, reducing energy use in the food system, and supporting domestic food supply and international trade reforms. Although China has sustained a large population with limited arable land, the increasing demand for high-quality food and water scarcity pose significant challenges for agricultural production.

2.2. Research on Comprehensive Grain Production Capacity

Improving China's comprehensive grain production capacity is critical for ensuring national food security and enhancing the country's agricultural production. Internationally, research on factors affecting grain output mainly focuses on crop variety structures, natural resource endowments, and technological inputs. Cordell (2008) predicted that China's grain output would gradually decline in the next 50-100 years and highlighted the need to secure China's phosphorus supply[4].

Domestically, the definition of comprehensive grain production capacity has evolved over time. In 2002, China's 16th National Congress first defined it as "the capacity to stably produce a certain grain output through the joint input of various production factors under specific economic and technical conditions." This definition has been continuously enriched. Most scholars agree that comprehensive grain production capacity includes land protection, production technology, and policy support, with emphasis on stability and sustainability. Researchers have analyzed factors such as fertilizers, pesticides, and mechanization, finding these to be major contributors to grain output in different periods. Recent studies have used factor analysis to quantitatively evaluate provincial grain production capacities, such as in Hubei, where despite improvements since 1994, issues such as reduced farmer motivation and weak disaster resilience persist. Modern production factors contribute significantly to grain output, indicating that agricultural modernization plays a crucial role in enhancing production capacity[5].

2.3. Literature Review Summary

The review provides valuable insights into improving China's comprehensive grain production capacity. While international research lacks a clear concept of comprehensive grain production capacity, focusing solely on grain output, Chinese scholars have offered a consistent understanding of the term. However, there is a need for deeper exploration of its potential production levels. Additionally, while macro-level analyses dominate the current research, practical measures to improve grain production capacity have yet to be thoroughly studied[6].

3. Variable Selection and Theoretical Assumptions

3.1. Variable Selection

In China, grain output is influenced by various factors. Therefore, conducting an empirical analysis of the factors affecting grain output and identifying the dominant factors is a meaningful task for assessing the country's comprehensive production capacity. From a macro perspective, natural resources, human and material inputs, technological investments, policy environment, and infrastructure all have an impact on China's grain output. Through literature review, we found that these factors significantly affect grain production in China[7].

This paper employs regression analysis. Regression analysis is a method or theory for studying the correlation between one variable and another. It begins by analyzing sample data to determine the relationship between variables, then tests the reliability of that relationship. Afterward, it identifies significant or non-significant variables and uses the resulting equation to predict or control the value of a specific variable based on known values of other variables, offering an accuracy measure. From various aspects of comprehensive grain production capacity, this paper selects several representative and quantifiable indicators, as presented in Table 1.

It is assumed that comprehensive grain production capacity is reflected by grain output. Grain output Y (in ten thousand tons) is linearly related to the area of irrigated arable land X1 (in thousand hectares), total agricultural machinery power X2 (in ten thousand kilowatts), grain crop sowing area X3 (in thousand hectares), fertilizer use X4 (in ten thousand tons), and the natural population growth rate X5 (in percentage). A preliminary model is established as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \qquad (1)$$

Table 1. Variable Names and Meanings.

Variable Name		Variable Meaning
Independent Variables	Comprehensive grain production capacity (with grain output as index) (10,000 tons)	On the whole, "the comprehensive grain production capacity refers to the output capacity of a certain period of time in a certain area, depending on certain social, economic and technical conditions, formed by the comprehensive input of various grain production factors, which can make the grain output achieve relatively stable". Not just current food production, but also a measure of future food production capacity.

Dependent Variable	Irrigated Arable Land Area X_1 (thousand hectares)	Cultivated land irrigation area determines the situation of grain growth and is positively correlated with grain yield. Considering the extensive use of cultivated land, it is summarized as cultivated land irrigation area here.
	Total Agricultural Machinery Power X_2(ten thousand kilowatts)	The total power of agricultural machinery refers to the total power of all kinds of power machinery used in agriculture, forestry, animal husbandry and fishery. Therefore, studying the influence of the total power of agricultural machinery on the total agricultural output value can effectively reflect the changes in the scale of the total agricultural output value, and play an important role in solving the shortcomings of agriculture in the future.
	Grain Crop Sowing Area X_3 (thousand hectares)	Grain sown area is the primary factor affecting grain output, which is positively correlated with grain output. Considering that cultivated land is not only used for grain production, but also has multiple cropping and rotation, compared with cultivated land area, grain sown area is more representative in measuring the impact of land on grain output.
	Fertilizer Use X_4 (ten thousand tons)	Fertilizer use reflects the success of agricultural water conservancy construction and can effectively indicate grain quality, contributing to research on comprehensive grain production capacity.
	Natural Population Growth Rate X_5 (%)	Introducing population as a variable helps analyze whether grain demand affects comprehensive grain production capacity.

3.2. Theoretical Assumptions

- Hypothesis 1: Ceteris paribus, China's grain output is positively correlated with irrigated arable land area.
- Hypothesis 2: Ceteris paribus, China's grain output is positively correlated with total agricultural machinery power.
- Hypothesis 3: Ceteris paribus, China's grain output is positively correlated with grain crop sowing area.
- Hypothesis 4: Ceteris paribus, China's grain output is positively correlated with fertilizer use.
- Hypothesis 5: Ceteris paribus, China's grain output is positively correlated with the natural population growth rate.

3.3. Descriptive Statistics

The descriptive statistics are shown in Table 2:

Table 2. Descriptive statistics.

	Y	**X1**	**X2**	**X3**	**X4**	**X5**
Mean	55421.37	59234.85	79133.35	112836.2	4857.490	6.737619
Median	55911.30	60347.70	92780.50	113466.0	5403.600	5.890000
Maximum	66949.20	69160.50	111728.1	119230.0	6022.600	14.39000
Minimum	32055.50	44035.90	14745.70	104278.0	1269.400	1.450000
Std. Dev.	10298.93	7926.203	30738.72	4807.057	1404.205	3.366363
Skewness	-0.590402	-0.529889	-0.954377	-0.349482	-1.479659	1.097773
Kurtosis	2.404656	2.173187	2.529160	1.797226	3.981581	3.511595

4. Model Construction and Parameter Estimation

The model is set as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon \quad (2)$$

Table 3. Variable Explanations.

Symbol	Meaning
Y	China's grain output (ten thousand tons)
X1	Irrigated arable land area (thousand hectares)
X2	Total agricultural machinery power (ten thousand kilowatts)
X3	Grain crop sowing area (thousand hectares)
X4	Fertilizer use (ten thousand tons)

Parameter Estimation.

Table 4. OLS estimation results are presented.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	1.475672	0.250644	5.887526	0.0000
X2	0.036683	0.069862	0.525071	0.6072
X3	-0.155860	0.180354	-0.864185	0.4011
X4	0.738736	1.236470	0.597455	0.5591
X5	1148.204	317.1390	3.620506	0.0025
C	-28630.59	12755.89	-2.244500	0.0403
R-squared	0.981478	Mean dependent var	55421.37	
Adjusted R-squared	0.975303	S.D. dependent var	10298.93	
S.E. of regression	1618.494	Akaike info criterion	17.85134	
Sum squared resid	39292820	Schwarz criterion		18.14977
Log likelihood	-181.4390	Hannan-Quinn criter.		17.91610
F-statistic	158.9655	Durbin-Watson stat		1.728615
Prob(F-statistic)	0.000000			
Variable	Coefficient	Std. Error		t-Statistic
X1	1.475672	0.250644		5.887526
X2	0.036683	0.069862	0.525071	0.6072
X3	-0.155860	0.180354	-0.864185	0.4011

The form of the model after regression from the analysis results is:

$$Y = -28630.59 + 1.4757X_1 + 0.0367X_2 - 0.1559X_3 + 0.7387X_4 + 1148.204X_5$$

t = （-2.24） （5.89） （0.53） （-0.86） （0.60） （3.62）

R^2=0.9815

From the regression results, the model has an R-squared value of 0.9815, indicating strong explanatory power. The F-statistic is 158.9655, and $p < 0.05$, making the F-test highly significant. However, the t-tests for variables X_2、X_3、and X_4 are not significant, and the sign of X_3 does not align with economic intuition, suggesting potential multicollinearity. Therefore, the model needs to be revised.

5. Model Testing and Revisions:

5.1. Economic Significance Test

Based on the regression results, holding other factors constant:

- For each unit increase in irrigated arable land area, China's grain output increases by 1.4757 units.
- For each unit increase in total agricultural machinery power, China's grain output increases by 0.0367 units.
- For each unit increase in grain crop sowing area, China's grain output decreases by 0.7387 units.
- For each unit increase in fertilizer use, China's grain output increases by 0.3764 units.

- For each unit increase in natural population growth rate, China's grain output increases by 1148.204 units.

It can be observed that the correlation between the explanatory variable X3 and the dependent variable does not match practical meaning, while the other explanatory variables pass the economic significance test.

5.2. Goodness-of-Fit and Statistical Inference Test

(1) Goodness-of-Fit Test: With $R^2 = 0.9815$, the model shows a high degree of fit.

(2) F-test: At a significance level of 0.05, $F = 158.9655$ is clearly greater than the critical value, indicating that all variables combined have a significant impact on the model.

(3) T-test: The results of the parameter estimation show that the t-tests for the parameters have not passed.

5.3. Multicollinearity Test and Revisions

Using EVIEWS software to generate the correlation coefficient matrix, as shown in Table 5:

Table 5. Correlation Coefficient Matrix.

1.000000	0.976441	0.943464	0.567807	0.891746	-0.744115
0.976441	1.000000	0.954627	0.540544	0.893096	-0.837726
0.943464	0.954627	1.000000	0.404598	0.960687	-0.846018
0.567807	0.540544	0.404598	1.000000	0.239066	-0.111153
0.891746	0.893096	0.960687	0.239066	1.000000	-0.828795
-0.744115	-0.837726	-0.846018	-0.111153	-0.828795	1.000000

The correlation coefficient matrix shows a strong correlation between the explanatory variables, indicating the presence of multicollinearity in the model. Hence, revisions are required.

First, stepwise regression was applied to each explanatory variable using EVIEWS software. The regression results after revision are shown in Table 7:

Table 6. Revised OLS Regression.

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
C	-32922.25	9568.971	-3.440522	0.0034
X1	1.509184	0.236831	6.372397	0.0000
X5	1108.830	301.0909	3.682710	0.0020
X4	1.240982	0.765583	1.620963	0.1246
X3	-0.128962	0.168967	-0.763238	0.4564
R-squared	0.981137	Mean dependent var	55421.37	
Adjusted R-squared	0.976421	S.D. dependent var	10298.93	
S.E. of regression	1581.436	Akaike info criterion	17.77431	
Sum squared resid	40015021	Schwarz criterion	18.02301	
Log likelihood	-181.6303	Hannan-Quinn criter.	17.82828	
F-statistic	208.0564	Durbin-Watson stat		1.746934
Prob(F-statistic)	0.000000			
Variable	Coefficient	Std. Error		t-Statistic
C	-32922.25	9568.971		-3.440522
X1	1.509184	0.236831		6.372397
X5	1108.830	301.0909		3.682710
X4	1.240982	0.765583	1.620963	0.1246
X3	-0.128962	0.168967	-0.763238	0.4564

The revised model is as follows:

$$Y = -32922.25 + 1.5092X_1 - 0.1289X_3 + 1.2410X_4 + 1108.830X_5$$

5.4. Heteroscedasticity Test and Correction

White Test:

The revised equation was tested using the White test in EVIEWS, and the results are shown below:

Heteroskedasticity Test: White

F-statistic	7.574365	Prob. F(14,6)	0.0101
Obs*R-squared	19.87541	Prob. Chi-Square(14)	0.1341
Scaled explained SS	10.98915	Prob. Chi-Square(14)	0.6869

Figure 1. White Test Results .

At a significance level of $\alpha=0.05$, since $p=0.1341>0.05$, the model does not exhibit heteroscedasticity.

5.5. Autocorrelation Test and Correction

To assess autocorrelation in the model, we employed the LM test, with the results shown below:

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.364892	Prob. F(2,14)	0.7007
Obs*R-squared	1.040441	Prob. Chi-Square(2)	0.5944

Figure 2. Autocorrelation Test Results.

At a significance level of 0.05, $p > 0.05$, indicating no autocorrelation in the model.

Based on the above tests and corrections, the final model is established as (3):

$$Y = -32922.25 + 1.5092X_1 - 0.1289X_3 + 1.2410X_4 + 1108.830X_5 \quad (3)$$

The model's predictions are illustrated in Figure 4:

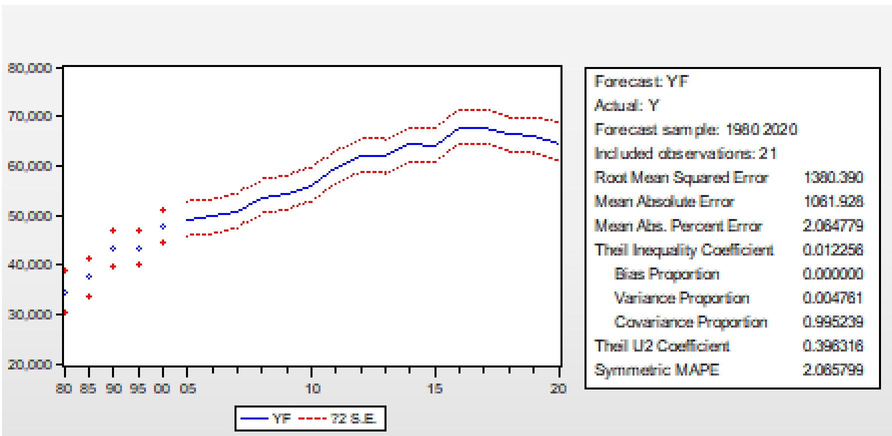

Figure 3. Model Predictions.

6. Conclusion and Recommendations

The key factors influencing China's comprehensive grain production capacity include irrigated arable land area X1 (thousand hectares), grain crop sowing area X3 (thousand hectares), fertilizer use X4 (ten thousand tons), and natural population growth rate X5 (%), all positively correlated. Through econometric analysis, this paper provides a more accurate assessment of the influence of these factors. However, due to data collection challenges, additional variables could not be included in the model. In reality, the factors affecting grain production are numerous and complex, making it impossible to incorporate every factor into the model. Therefore, some error may exist due to necessary compromises made based on the importance of factors, data availability, and mathematical conditions of the model[8].

To improve China's comprehensive grain production capacity, attention should be given to factors negatively impacting production. Efforts should be made to enhance disaster resilience in grain production and minimize the effect of natural disasters on grain output. For instance, the larger the disaster-affected area, the lower the grain output. Natural disasters have significantly impacted China's agricultural production compared to the previous year, leading to reduced grain production. Therefore, efforts should focus on minimizing the effects of natural disasters. Enhancing meteorological forecasting and agricultural water conservancy infrastructure, promoting disaster mitigation technologies in agriculture, and accelerating infrastructure development can help mitigate the impact of natural disasters.

The appropriate use of agricultural mechanization should be promoted in suitable regions. The widespread use of agricultural machinery has boosted grain production, and improvements in China's agricultural labor productivity largely depend on the increased use of agricultural machinery. Adjusting the agricultural industry structure and promoting mechanization in suitable areas can shift the growth model of agriculture and improve grain output.

Stabilizing arable land area is another important factor. Recently, efforts to return farmland to forests have greatly reduced the grain sowing area, and there have been serious violations of land use regulations, both of which negatively affect grain output. Thus, it is essential to implement land protection policies, stabilize grain sowing areas, enforce basic farmland protection regulations, and continually improve grain production capacity.Since 1990, China has significantly increased its investment in agricultural infrastructure, which has greatly contributed to stabilizing agricultural production.

References

1. Cheng Guoqiang, Zhu Mande. Impact of the COVID-19 Pandemic on Food Security: Trends, Effects, and Responses [J]. China Rural Economy, 2020(05): 13-20.
2. Wang Xiaojun, He Yaping, Jiang Heping. Food Security in China During the 14th Five-Year Plan: Situation, Problems, and Countermeasures [J]. Reform, 2020(09): 27-39.
3. Guo Yanzhi, Guo Jingli, Wang Xiudong. Analysis of Factors Affecting China's Comprehensive Grain Production Capacity [J]. Issues in Agricultural Economy, 2007(S1): 22-25.
4. Fan Xiaodi, He Puming. Comprehensive Evaluation of Hubei Province's Grain Production Capacity Based on Factor Analysis [J]. Hubei Agricultural Sciences, 2015, 54(16): 4103-4106.
5. Wang Guomin, Zhou Qingyuan. An Empirical Analysis of Factors Affecting China's Comprehensive Grain Production Capacity [J]. Journal of Sichuan University (Philosophy and Social Sciences Edition), 2016(03): 82-88.
6. Jiang Songying, Liu Ying, Jin Ya. Analysis of Factors Affecting China's Comprehensive Grain Production Capacity and Its Changes [J]. Statistics and Decision, 2016(14): 118-121.
7. Yin Chengjie. Thoughts on Improving China's Comprehensive Grain Production Capacity [J]. Issues in Agricultural Economy, 2005(01): 5-10+79.
8. Zhang Xuelang, Li Junkui. Comprehensive Grain Production Capacity and National Food Security [J]. Journal of Hunan Normal University (Social Science Edition), 2011, 40(06): 107-110.
9. Xin Xiangfei, Wang Jimin. Stabilizing and Improving China's Comprehensive Grain Production Capacity [J]. Macroeconomic Management, 2015(12): 56-58+65.

10. Zhao Yuxin, Li Wenqi. Analysis of the Mechanism of the "Four Modernizations" in the Construction of China's Comprehensive Grain Production Capacity [J]. Agricultural Economy, 2016(06): 3-5.