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Empirical Analysis of Key Factors Influencing China's Grain Production Capacity

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Abstract: China, as the world's most populous country, is also its largest consumer of grain. Ensuring grain security is vital for national stability and economic development, underpinning socioeconomic progress. Since the reform and opening-up period, China's grain production has doubled, successfully mitigating challenges such as the global grain crisis in 2006 and the food crisis triggered by COVID-19 in 2020. However, this achievement has come at a cost, with grain output heavily reliant on practices that deplete soil fertility and involve excessive use of pesticides and fertilizers, causing significant environmental strain. This study investigates the factors influencing China's grain production from 1980 to 2020, aiming to evaluate its comprehensive production capacity and provide practical recommendations. The analysis integrates theoretical and empirical approaches. Theoretically, the study examines the effects of variables such as irrigated arable land area (X1, thousand hectares), agricultural machinery power (X2, ten thousand kilowatts), grain sowing area (X3, thousand hectares), fertilizer consumption (X4, ten thousand tons), and natural population growth rate (X5, percentage) on grain output. Empirically, it utilizes principal component analysis and model testing through Eviews, incorporating five grain-related indicators. The findings reveal that the influence of these factors shifts across different stages of grain production and development. Based on the results, the paper offers targeted strategies to enhance China's grain production capacity sustainably.

Keywords: comprehensive grain production capacity; grain security; empirical study; principal component analysis; sustainability

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1. Introduction

1.1. Background

In China, there is an age-old adage: "Food is the foundation of life." This principle resonates not only within China but across the globe. Food security remains a cornerstone of global economic stability and is regarded as one of the three pivotal security challenges worldwide. Since 1997, China's grain trade has experienced steady expansion. As a nation with a long-standing agricultural heritage, China's demand for grain is immense. However, outdated farming practices and the scarcity of arable land hinder its transition from being an agricultural heavyweight to a modern agricultural power [1].

Recent global crises, such as the COVID-19 pandemic, have brought new food security challenges to the forefront. On the international stage, grain supplies have suffered severe disruptions due to natural disasters like locust infestations in Africa and devastating wildfires in Australia. The ongoing conflict between Russia and Ukraine has further exacerbated the strain on global food systems, creating unprecedented risks to international food security.

For China, the grain issue is closely tied to national stability and prosperity. In the short term, grain output is a direct indicator of food security. In the long term, however, the solution lies in bolstering the country's overall grain production capacity. Historically, China has relied on intensive agricultural methods, depleting soil nutrients and overusing chemical inputs such as fertilizers and pesticides. This unsustainable approach has placed a significant strain on the environment.

Moving forward, it is imperative for China to address several critical questions to enhance its grain production capacity:

How developed is China's current grain production capacity?

What are the driving forces behind grain production, and which factors play the most decisive role?

Under the evolving domestic and global circumstances, what strategies can China adopt to sustainably enhance its grain production capacity?

1.2. Significance of the Study

1) Theoretical Contribution:

This study delves into the factors influencing China's grain production capacity, offering a deeper understanding of its current status and future potential. Moving beyond the traditional focus on technological elements, the research integrates scientific advancements with the grain industry. By linking the grain sector with large-scale agricultural practices and applying weighted analysis to highlight key indicators, it enriches existing evaluation frameworks for comprehensive grain production capacity, advancing the theoretical discourse in this area [2].

2) Practical Contribution:

With a systematic approach to problem identification, analysis, and solution development, this study employs econometric techniques such as multiple linear regression to evaluate the factors shaping China's grain production capacity. The outcomes of this research offer crucial insights for policymakers, aiding in decisions aimed at stabilizing grain supply and prices, as well as optimizing the agricultural supply structure in the post-pandemic period. Strengthening the country's grain production capacity is not only essential for addressing evolving consumption patterns but also for overcoming resource limitations, making it a key element in ensuring food security at the national level.

2. Theoretical Foundations and Previous Research

2.1. Studies on Grain Security

Food security, a critical determinant of national prosperity, has long been a central focus in global research. Scholars typically approach the topic by examining two key dimensions: the role of national policies in shaping food security outcomes and the constraints imposed by natural resources. For example, Jayatilleke (2017) used a general equilibrium model to evaluate India's dual subsidies to food producers and consumers during the 2007-2008 global food crisis, alongside export restrictions intended to stabilize local food prices [3]. His findings underscored the importance of policy measures that strike a balance to protect national food security. In a broader context, Hanjra (2010) explored the intersection of climate change, population growth, and energy crises, identifying these as pivotal drivers of food insecurity. His work argued that sustainable food security solutions must address environmental challenges such as climate change, promote efficient land and water management, reduce energy consumption in food production, and advocate for both domestic reforms and international trade adjustments.

When it comes to China, while the country has successfully fed a massive population despite limited arable land, it faces new, escalating challenges. The growing demand for higher-quality food and the increasing scarcity of water resources are two significant obstacles threatening long-term agricultural sustainability.

2.2. Studies on Comprehensive Grain Production Capacity

Enhancing China's comprehensive grain production capacity is essential for safeguarding national food security and boosting agricultural output. Globally, research on the factors influencing grain yield often centers around crop variety selection, the availability of natural resources, and technological advancements. For instance, Cordell (2008) forecasted a long-term decline in China's grain production over the next 50-100 years, emphasizing the critical importance of securing China's phosphorus supply [4].

Within China, the concept of comprehensive grain production capacity has evolved over time. In 2002, during the 16th National Congress, it was first defined as the "ability to consistently produce a certain volume of grain through the coordinated input of various production factors under specific economic and technological conditions." This definition has since been expanded and refined. Scholars generally agree that comprehensive grain production capacity involves land preservation, production technologies, and supportive policies, with a focus on both stability and sustainability. Research has also examined the roles of fertilizers, pesticides, and mechanization, identifying them as key drivers of grain production at different stages. Recent studies utilizing factor analysis have quantitatively assessed provincial grain production capacities. In Hubei, for example, although progress has been made since 1994, challenges such as diminished farmer motivation and insufficient disaster resilience remain. These studies suggest that modern agricultural inputs significantly impact grain production, underlining the crucial role of agricultural modernization in enhancing production capacity [5].

2.3. Summary of Literature

This literature review provides important insights into ways to improve China's comprehensive grain production capacity. While international research lacks a unified definition of this concept, typically focusing only on grain output, Chinese scholars have consistently framed it in terms of broader production factors. However, further research is needed to explore its potential to reach higher production levels. While much of the existing literature takes a macro-level approach, there is a noticeable gap in research focused on practical strategies for boosting grain production capacity [6].

3. Selection of Variables and Theoretical Assumptions

3.1. Selection of Variables

In China, multiple factors influence grain production. Therefore, conducting an empirical analysis to examine these factors and identify the key drivers of grain output is essential for evaluating the nation's overall production capacity. From a macroeconomic standpoint, factors such as natural resources, human and material inputs, technological advancements, policy framework, and infrastructure all play significant roles in shaping China's grain output. A review of existing literature reveals that these variables have a marked impact on grain production in the country [7].

For the purpose of this study, regression analysis is employed as the primary analytical method. Regression analysis helps to explore the relationship between a dependent variable and one or more independent variables. By analyzing sample data, it identifies and quantifies the correlations between variables, tests the strength of these relationships, and distinguishes significant from insignificant variables. The established equation can then be used to predict or control the value of a specific variable based on known values of other influencing factors, with an associated measure of accuracy. In this study, we select a set of key, measurable indicators that reflect different aspects of comprehensive grain production capacity. These indicators are summarized in Table 1.

It is hypothesized that the comprehensive grain production capacity is represented by the grain output. The grain output, denoted as Y (in ten thousand tons), is assumed to have a linear relationship with several factors: the area of irrigated arable land (X1, in thousand hectares), total agricultural machinery power (X2, in ten thousand kilowatts), the sowing area of grain crops (X3, in thousand hectares), fertilizer usage (X4, in ten thousand tons), and the natural population growth rate (X5, as a percentage). Based on these assumptions, a preliminary model can be established as follows:

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

Table 1. Definition and Explanation of Variables.

Variable Name		Variable Meaning
Independent Variables	Comprehensive Grain Production Capacity (measured by Grain Output Index) (in 10,000 tons)	In general, comprehensive grain production capacity refers to the output potential of grain in a specific region over a given period, influenced by a combination of social, economic, and technological factors. It is the result of the integrated input of various production elements, allowing for a relatively stable level of grain output. This concept not only reflects current food production capabilities but also serves as an indicator of future production capacity.
Dependent Variable	Irrigated Arable Land Area X_1 (thousand hectares)	The area of irrigated cultivated land plays a crucial role in determining grain growth conditions and is positively correlated with grain yield. Given the widespread use of cultivated land, this factor is collectively referred to as the irrigated cultivated land area.
	Total Agricultural Machinery Power X_2 (ten thousand kilowatts)	The total agricultural machinery power refers to the combined power of all types of machinery used in agriculture, forestry, animal husbandry, and fisheries. Examining how the total power of agricultural machinery impacts overall agricultural output value provides valuable insights into the changes in agricultural scale. This analysis plays a vital role in addressing the future challenges faced by the agricultural sector.
	Grain Crop Sowing Area X_3 (thousand hectares)	The area sown with grain is a key factor influencing grain output and is positively correlated with it. Since cultivated land serves multiple purposes beyond grain production, including crop rotation and intercropping, the grain sown area provides a more accurate measure of land's impact on grain output than the total cultivated land area.
	Fertilizer Use X_4 (ten thousand tons)	Fertilizer usage reflects the effectiveness of agricultural water conservancy efforts and serves as a key indicator of grain quality, playing an important role in studies related to comprehensive grain production capacity.
	Natural Population Growth Rate X_5 (%)	By incorporating population as a variable, we can analyze the extent to which grain demand influences the overall capacity for grain production.

3.2. Theoretical Assumptions

Assumption 1: Holding other factors constant, there is a positive relationship between China's grain output and the area of irrigated arable land.

Assumption 2: All else being equal, China's grain output is positively influenced by the total power of agricultural machinery.

Assumption 3: With all other variables held constant, the grain sown area has a positive correlation with China's grain output.

Assumption 4: Assuming other factors remain unchanged, an increase in fertilizer use positively impacts China's grain output.

Assumption 5: Under the assumption of constant conditions, China's grain output is positively correlated with the natural growth rate of the population.

3.3. Descriptive Statistics

The descriptive statistics are shown in Table 2:

	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 4. 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:

OLS estimation results are presented in Table 5:

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			

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

$$Y = -28630.59 + 1.4757\mathrm{X}_1 + 0.0367\mathrm{X}_2 - 0.1559\mathrm{X}_3 + 0.7387\mathrm{X}_4 + 1148.204\mathrm{X}_5$$

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 Evaluation

Based on the regression analysis, assuming all other factors remain constant:

A one-unit increase in irrigated arable land area leads to an increase of 1.4757 units in China's grain output.

A one-unit rise in total agricultural machinery power results in an increase of 0.0367 units in grain output.

A one-unit growth in grain crop sowing area corresponds to a decrease of 0.7387 units in grain output.

A one-unit increase in fertilizer application is associated with a rise of 0.3764 units in grain output.

A one-unit increase in the natural population growth rate results in an increase of 1148.204 units in grain output.

It is evident that the relationship between the grain crop sowing area (X3) and grain output contradicts practical expectations. In contrast, the other independent variables pass the economic significance test.

5.2. Goodness-of-Fit and Statistical Significance Evaluation

Goodness-of-Fit Test: With an R2R^2R2 value of 0.9815, the model demonstrates a high level of explanatory power and a strong fit to the data.

F-test: At a significance level of 0.05, the computed F-value of 158.9655 exceeds the critical value, confirming that the collective influence of all variables is statistically significant.

T-test: The t-test results for the individual parameters indicate that the parameter estimations have not met the necessary criteria for statistical significance.

5.3. Multicollinearity Test and Revisions

Using EVIEWS software to generate the correlation coefficient matrix, as shown in Table 6:

Table 6. 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 reveals a significant relationship between the explanatory variables, suggesting the existence of multicollinearity within the model. As a result, adjustments are necessary.

To address this issue, stepwise regression was conducted on each explanatory variable using EVIEWS software. The revised regression outcomes are presented in Table 7:

Table 7. 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			

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 2. 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 3. 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:

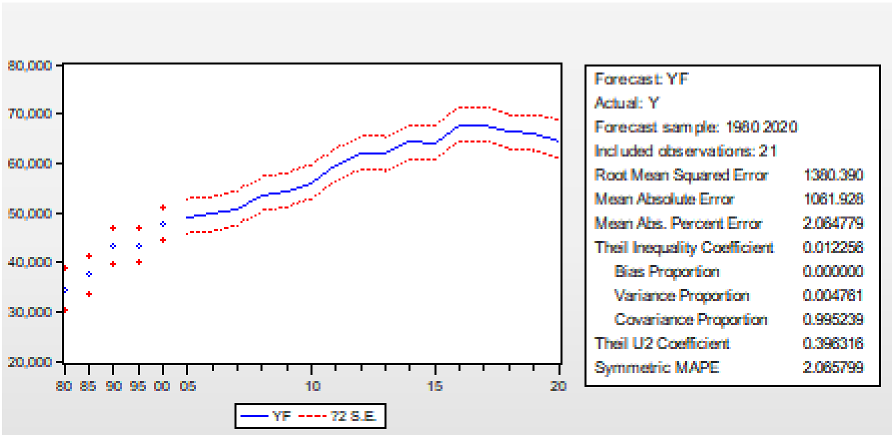

Figure 4. Model Predictions.

6. Conclusion and Recommendations

In evaluating the key factors impacting China's comprehensive grain production capacity, it is evident that irrigated arable land area (X1, in thousand hectares), grain crop sowing area (X3, in thousand hectares), fertilizer usage (X4, in ten thousand tons), and the natural population growth rate (X5, in percentage) all play a crucial role, each showing a positive correlation with grain output. This analysis, conducted through econometric methods, provides a more refined understanding of how these factors influence production capacity. However, due to limitations in data acquisition, it was not possible to include all potentially relevant variables. Given the complexity of factors affecting grain production, it is impractical to incorporate every possible influence into the model. As such, certain compromises had to be made, resulting in potential errors arising from limited data, factor prioritization, and model constraints [8].

To effectively enhance China's overall grain production capacity, attention must be given to addressing the negative factors that hinder growth. A major concern is improving the resilience of grain production systems to natural disasters. For example, the larger the area affected by disasters, the greater the reduction in grain output. The adverse impacts of natural calamities on China's agricultural production have become more pronounced in recent years, leading to declines in yield. To mitigate this, investments should focus on disaster risk reduction strategies, including enhancing meteorological forecasting capabilities, strengthening agricultural water infrastructure, and promoting advanced disaster mitigation technologies. Furthermore, accelerating infrastructure development is crucial to reducing the long-term effects of such catastrophes on grain production.

Another area requiring attention is the promotion of agricultural mechanization, particularly in regions where its application is most effective. The widespread adoption of agricultural machinery has significantly improved grain production efficiency, with labor productivity in the agricultural sector rising largely due to mechanization. By adjusting the agricultural structure and expanding mechanization where feasible, it is possible to shift from traditional to more productive agricultural practices, thereby enhancing grain output.

Equally important is stabilizing the total area of arable land. Recent policies aimed at returning farmland to forests have reduced the available land for grain production, while violations of land use regulations have further exacerbated the situation. These challenges highlight the necessity for stronger land protection measures to secure the stability of grain sowing areas. Enforcing stricter regulations on basic farmland protection, along with continuous efforts to safeguard land for cultivation, will be essential to ensuring sustained grain production growth. Since 1990, China's increased investments in agricultural infrastructure have made significant strides in stabilizing production levels, contributing to the long-term resilience of the agricultural sector.

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