Exploring the Correlation and Interplay between the Chinese Agricultural Industry and Economic Influencing Factors: A Study Utilizing Backpropagation (BP) Neural Network and Time Series Analysis

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Abstract. Agriculture's vital role in the economy impacts food supply and consumption. This study uses the Multiple Linear Regression Model (MLR) and the Backpropagation Neural Network (MLP). MLR emphasizes fertilizer, arable land, and precipitation's roles in grain production and consumption, highlighting the need for sustainable practices. MLP reveals complex relationships between economic variables and wheat futures prices. China's Food Consumer Price Index negatively correlates with wheat futures, while the USD to CNY exchange rate shows a positive correlation, emphasizing global trade dynamics. Shanghai Security and Equity of Agricultural Theme Index (SSEAT) robustly correlates with wheat futures, highlighting the impact of agricultural business on prices. Integrated strategies harmonizing agricultural, monetary, and trade policies are crucial for stability.

Keywords: Agriculture, Time Series Analysis, Multiple Linear Regression Model, China's Food Consumer Price Index, Backpropagation Neural Network, Chinese wheat future prices.

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1 Introduction

On March 31, 2023, FAO broadened its actions, seeking global aid for Turkey and Syria post-quake with 20% agricultural loss hindering reconstruction. Food supply shocks, whether natural or human-induced, stress a nation's macroeconomy, impacting consumption, trade, employment, and more. The 2010 Russian wheat export ban due to drought caused a global supply drop, emphasizing the significance of food inflation as a crucial indicator for formulating monetary policies. In addition, high food prices may impede the consumption of real estate, security, and luxury goods. During the 2007-2008 crisis, households grappling with higher food expenses might have curtailed their savings or delayed major purchases, which affected the real estate and automotive industries. Furthermore, when a country grapples with food shortages, whether due to natural or human causes, grain prices will surge. China, facing grain shortages, once tapped into reserves. Thus it continually released these reserves to meet the inflated demand to stabilize prices, and ensure food security. This measure requires a strong economic foundation. Conversely, emerging countries typically rely on international aid or lease farmland to mitigate food crises' macroeconomic impact [1]. Therefore, it is vital to figure out how agriculture and the economy interact.

2 Literature Review

2.1 Status of Agricultural Development

The preceding text has emphasized the indispensable role of agriculture in any economic entity. Therefore, a preliminary understanding of agricultural development across various countries is crucial before delving into the specific impacts of agriculture. Extensive statistics and research by international organizations and scholars worldwide have contributed to our knowledge of agricultural development. This chapter will provide insights into the agricultural development of major global producers, with a particular focus on research related to China.

The United States boasts a highly advanced and produces a wide array of foods through advanced technology and well-developed capitalization. Khan et al. (2021) highlighted agricultural technological advancements like the Internet of Things (IoT), sensory equipment, and unmanned monitors have significantly optimized crop yields

in the U.S. [2]. Concerning capitalization in U.S. agriculture, Lyson and Guptill (2009) pointed out that commodity agriculture and civic agriculture are closely intertwined with the U.S. economy [3].

Agriculture stands as a cornerstone of the Indian economy, with nearly half of its population dependent on agriculture and allied industries [4]. Padmaja et al. (2022) observed that smallholder farmers have historically played a pivotal role in Indian agriculture [5]. However, it is currently undergoing a critical transformation due to worsening environmental and resource conditions. Indian agriculture highlights the significance of its populous agrarian population and the urgent need for reform. China, renowned for its immense scale, agricultural diversity, and strong nationalization, has undergone a profound shift from traditional farming practices to modern techniques, primarily due to government investments [6]. China's agricultural development has been greatly influenced by government guidance, including land reforms, rural-urban migration, and market liberalization [7]. The implementation of innovative policies and technological advancements has also contributed to high-quality growth [8].

2.2 Overview of Agricultural Policy

Current farming policies in the United States encompass a comprehensive range of measures aimed at supporting farmers, ensuring food security, and promoting sustainable practices. The Agricultural Act of 2018 serves as the primary legislative framework governing these policies. Additionally, conservation initiatives play a vital role in greening and advancing sustainability within agriculture [9]. U.S. farming policies are instrumental in addressing the evolving challenges and opportunities within the agricultural sector.

In the case of India, the Green Revolution once had a positive impact on food production, rural livelihoods, and poverty alleviation. However, it also resulted in imbalanced agricultural development, including resource depletion, environmental degradation, reduced crop diversity, and water scarcity [10][11]. Consequently, the Indian government has been implementing sustainable farming practices, government support systems, market-oriented policies, and rural-urban migration to address these issues.

China's agricultural policies are continually adjusted to align with supply-side strategies and market demands in response to developmental needs. Presently, China's

agricultural policies focus on two key aspects: "Agricultural Modernization" and "Rural Revitalization" [12]. These two strategies worked together to further boost agricultural productivity and ensure food security. To attain rural revitalization, a series of measurements, such as improving both arable land area, development of agricultural mechanization, and agricultural technology, geared toward enhancing comprehensive production and capacity of agriculture. In terms of deepening agricultural structural adjustments, there is a need to optimize the layout of agricultural production, promote high-quality grain projects, advance agricultural greening, and reduce the use of pesticides and fertilizers [13]. These agricultural policies are designed to enhance agricultural productivity, secure farmers' income, and national food security, and ultimately facilitate a transition in agricultural production toward high-quality efficiency and green development [14][15].

2.3 Relationship between Agriculture and Finance

Academia vigorously discusses and confirms the positive role of the application of finance in agriculture in ensuring food security, reducing poverty and promoting sustainable development. Financial instruments are gradually emerging as effective policy tools for advancing agricultural development.

Sharma and Kaur (2016) highlight that a growing number of individuals, including farmers, are utilizing M-services to access convenient banking services, saving time and costs [16]. This trend brings consumers closer to the financial services provided by banks. Furthermore, Aflaki and Cuellar Benavides (2018) suggest that Blockchain Technology (BT) accelerates the financial inclusion movement by supporting near real-time payment and reducing transactional, operational, and administrative costs [17]. In addition, innovation in financial instruments has enabled agriculture to progress towards a more stable, sustainable, and prosperous future. Agricultural insurance has become a vital mechanism for mitigating the financial risks faced by farmers. As illustrated by Hansen et al. (2018), index-based insurance plays a crucial role in helping farmers manage risks associated with abnormal weather variations, adopt better risk-mitigation methods, and safeguard their assets [18]. Likewise, Manogna and Mishra (2020) assert that an efficient price-discovery derivatives market benefits almost every sector of the economy, facilitating market planning and mitigating price risk [19].

Moreover, Green Bonds and ESG (Environmental, Social, and Governance) principles have emerged to support green projects such as clean energy, electric vehicles, and agriculture through collaborative efforts [20][21]. Consequently, companies and agricultural industries can enhance their performance in sustainable development and long-term productivity.

3 Method

3.1 Multiple Linear Regression Model

Time Series Analysis's application, Multiple Linear Regression Model (MLR), models the relationship between a dependent variable and multiple independent variables. MLR, a widely used statistical approach, creates a fitting linear equation, quantifying each variable's influence. Applied in medicine, biology, finance, and more, MLR guides decision-making using historical data.

$$y = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \beta \quad (1)$$

y refers to grain consumer price index, x_1 refers to fertilizer application amount, x_2 refers to arable land area, and x_3 refers to precipitation.

This essay uses multiple linear regression to analyze factors influencing agricultural production, with China's grain consumer price index as the dependent variable representing grain prices. Independent variables include fertilizer application, average precipitation, and cultivated land area. Regression analysis yields β values, indicating correlation coefficients. The focus is on examining correlations without calculating the random error term size.

3.2 Backpropagation Neural Network

Backpropagation (BP) Neural Network (MLP) is a self-updating artificial neural network model using data and a supervised algorithm. It processes examples through input, hidden, and output layers, adjusting weights and biases for accurate predictions. Valuable in quantitative finance, it excels with nonlinear data. Unlike the linear regression model focusing on agriculture, the BP neural network considers agriculture and economic indicators. It gauges the correlation strength when the error is <5, achieving a high fitting degree in training and test sets.

For agricultural indicators, China's wheat futures price is chosen due to wheat's crucial role in China. Economic indicators include China's food Consumer Price Index (CPI) and USD to CNY exchange rate, reflecting economic insights. The Shanghai Security and Equity of Agricultural Theme Index (SSEATI) gauges the investment market. Using the BP neural network model, the wheat futures price is the independent variable, and the other three indicators are dependent variables in multiple linear regression. This assesses the correlation strength, forming the basis for recommendations.

4 Analysis of Current Agriculture

China's shift from traditional to modern agriculture relies on historical knowledge, advanced breeding, and governmental policies. Despite global leadership in agricultural output, challenges arise from population pressures and resource scarcity. Scarce arable land and challenging topography hinder crop cultivation and complicate mechanized agriculture. The correlation between agricultural production and fertilizer use in China and other nations emphasizes the need for balanced fertilizer practices.

4.1 Arable Land Area and Agriculture

Cultivated land area and agricultural production exhibit a positive correlation, with more land leading to increased production. China's per capita arable land closely relates to agricultural output. FAO data indicates a global decrease in per capita arable land, with China's significantly lower at 0.09 hectares compared to the world's 0.2 hectares. Over 57 years (1961-2018), China's per capita arable land and food self-sufficiency rate consistently decreased due to urbanization. China's "guarding 18 mu of arable land" policy aligns with the positive correlation between land area and grain production.

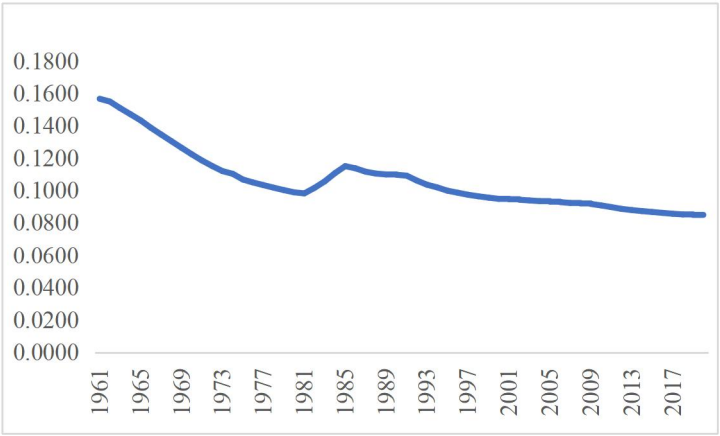

Fig. 1. Arable land variations in per capita of China, 1961-2018

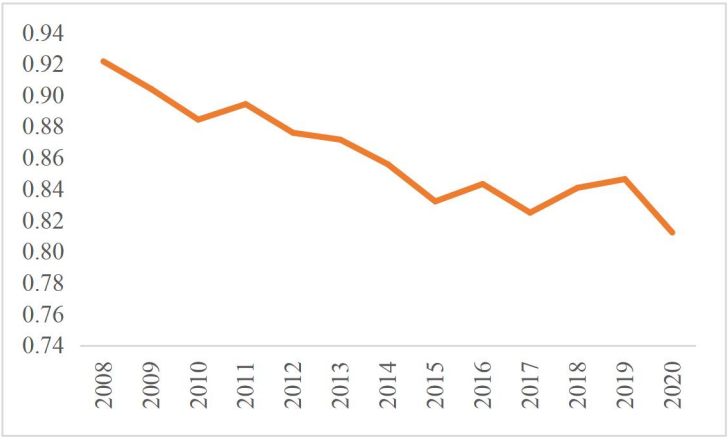

Fig. 2. China's food self-sufficiency rate, 2008-2020

Increasing cultivated land doesn't guarantee continuous yield growth; excessive per capita land can reduce productivity due to challenges in efficient management. China's aging population and negative growth in 2022 put pressure on per capita arable land. Modernized agriculture is crucial, with China aiming for over 75% mechanization by 2025. Compared to developed countries with 90% or higher mechanization rates, there's growth potential in China's sector. Arable land positively correlates with production, and mechanization is a key strategy to sustain productivity amid demographic challenges.

4.2 Fertilizer Application and Agriculture

Fertilizers are crucial for boosting agricultural yields by providing essential nutrients like nitrogen, phosphorus, potassium, and micronutrients. They overcome soil fertility limitations, ensuring a regular crop growth cycle and increasing yields per acre. In China, fertilizer application is a key strategy for securing agricultural output, with FAO statistics from 2002 to 2021 showing consistent global leadership in the use of nitrogen, phosphorus, and potassium fertilizers. This highlights the pivotal role of fertilizers in supporting agricultural productivity in the country.

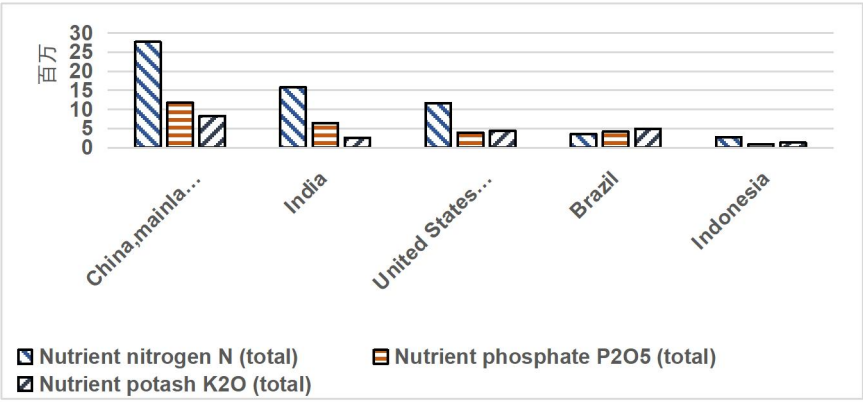

Fig. 3. Top five countries in the world in terms of total NPK fertilizer application

Excessive and improper fertilizer use can lead to adverse consequences like land salinization and groundwater pollution, depleting valuable resources and disrupting agricultural production. Such practices hinder sustainable agriculture and pose risks to individuals near cultivated areas. To address this, China's "No. 1 Document" emphasizes reducing and optimizing chemical fertilizer use, promoting organic alternatives, and guiding agriculture toward a green, ecological, and sustainable path. Stanley Agriculture Group, a leading fertilizer company, actively engages in soil testing and application optimization, promoting efficient and sustainable chemical fertilizer use. While chemical fertilizers enhance production, avoiding excessive application is crucial for maintaining output value and ensuring long-term environmental sustainability.

4.3 Precipitation and Agriculture

Precipitation holds great importance in agricultural production, with historical farming practices tailored to accommodate variations in rainfall throughout the year. This adaptability arises from the distinct water requirements of crops at different growth stages. Too little or too much rainfall can have detrimental effects, potentially leading to crop failure. For instance, heavy rainfall in eastern Inner Mongolia and Heilongjiang, attributed to Typhoon Dusu Rui, resulted in a reduction in rice and wheat yields. Moreover, two consecutive years of drought in Hunan and Jiangxi also caused a decline in grain production, as indicated by Rent Wanderlust data. In response to the negative impacts of Typhoon Dusu Rui on agriculture in North, Northeast, and Southeast China, the financial sector allocated a total of 2.687 billion yuan in three installments to support various recovery efforts. The significance and criticality of precipitation in agricultural production are evident from the diverse climatic impacts experienced by China's grain-producing regions in recent years.

In general, a moderate increase in precipitation can indeed boost agricultural production. However, excessive precipitation can have the opposite effect, leading to reduced production. Balancing and managing precipitation levels are essential to ensure optimal crop yields.

5 Data Collection And Analysis

5.1 Multiple Linear Regression Model

Table 1. Results of multiple linear regression of agricultural indicators

Variable	Beta	Standard Error
Fertilizer Application Amount	.481	.002
Arable Land Area	.426	0
Precipitation	-.219	0

Enhancing soil fertility through the application of fertilizers has been a significant driving force behind the increased production and higher yields of grain crops. Advances in synthetic fertilizer technology have further improved their effectiveness, establishing them as an indispensable element in modern agricultural

production. The data presented reveal a positive impact of fertilizer application on China's grain Consumer Price Index (CPI), scoring 0.481. This underscores the pivotal role that fertilizers play in promoting both grain production and consumption in China.

The extent of arable land serves as a critical indicator of a nation's agricultural production capacity and has an indelible influence on grain production. Throughout history, expanding the arable land area has been a primary method for increasing grain production. Data reflects the impact of arable land area on China's grain CPI, with a score of 0.426, indicating a positive role in enhancing grain production and consumption. Thus, safeguarding arable land is essential to ensure fundamental grain production and consumption.

Precipitation exerts a nuanced influence on grain production. Moderate precipitation generally benefits grain production, while excessive precipitation can lead to crop damage, resulting in reduced grain production. Different crops have distinct requirements for precipitation. As per the data, an increase in precipitation demonstrates a negative impact of -0.219 on China's grain CPI, signifying a negative correlation between heightened precipitation and grain production and consumption. Balancing precipitation levels is crucial for maintaining optimal grain yields.

5.2 Backpropagation Neural Network

This paper selects data on Chinese wheat futures prices, Chinese food cpi, USD/CNY exchange rate, and Shanghai Agricultural Theme Index from July 1, 2017, to July 31, 2023. MATLAB 2023a software is used to train and analyze the BP neural network model. Assuming the error is less than 5, the iteration and fitting of the training set and test set are shown in the following table.

According to the fitting results of the third training set and test set, it can be found that there is a close relationship between economic indicators and agricultural indicators. After training, the BP neural network model can also predict the wheat futures price through the data of China's food CPI, SD/CNY exchange rate, and SSEATI. With the wheat futures price as the dependent variable and the other three indicators as the independent variables, the significance and coefficients of multiple linear regression are as follows.

Table 2. Results of multiple linear regression of agricultural financial indicators

Variable	Beta	Standard Error
CPI of Chinese Foods	-.294	<.001
Exchange Rate of USD against CNY	.276	<.001
SSEATI	.617	<.001

China's Food Consumer Price Index (CPI) serves as an indicator of fluctuations in food prices over time and the variations in food inflation during specific periods. Data analysis reveals a negative correlation between China's food CPI and wheat futures prices. This trend may be attributed to substitution effects and import-export policies. First, when overall prices rise due to supply and demand dynamics or inflation, consumers tend to opt for more affordable alternatives, such as rice and corn products. This shift in demand causes the price of China's wheat to decrease due to the altered supply-demand relationship. Additionally, to alleviate the pressure of rising food prices, the government may increase wheat imports and release wheat reserves, thereby augmenting the wheat supply and leading to lower wheat prices.

The exchange rate between the USD and CNY mirrors the supply and demand for CNY in international trade and financial markets, significantly impacting China's macro and micro economy about foreign trade and investment. Data suggests a positive correlation between the USD/RMB exchange rate and Chinese wheat futures prices. In the international trade arena, when the CNY depreciates, China's export commodities become more competitively priced. Consequently, the demand for China's wheat in the international market rises, leading to an increase in its futures prices. In international financial markets, investors may shift their CNY foreign exchange assets to wheat futures assets as a hedge against anticipated CNY depreciation, contributing to a short-term rise in Chinese wheat futures prices.

The Shanghai Security and Equity of Agricultural Theme Index (SSEATI) reflects the conditions of Chinese agricultural companies and enterprises that engage in various aspects of the wheat business, including acquisition, processing, and sales. As a result, it is closely intertwined with Chinese wheat futures prices. The tabulated data also reinforces this relationship, with the beta coefficient of SSEATI after multiple linear regression analysis being 0.617, demonstrating a robust positive

correlation. Wheat, a fundamental raw material and commodity for agricultural firms and enterprises, not only affects their revenues but is also impacted by their operations. In the short term, when companies and businesses perform well, expand their wheat and by-product production, and increase the market demand for wheat, wheat prices, and its futures rise accordingly. This price increase boosts the revenue of agricultural companies and enterprises, thus driving growth in the Shanghai Agricultural Theme Index.

6 Conclusion

The impact of fertilizer use and arable land management on China's agriculture and Grain Consumer Price Index (CPI) is substantial, contributing to increased yields. However, excessive application may lead to adverse consequences, weakening food supply and causing elevated prices. Higher food costs affect living expenses, reducing consumption in sectors like services, entertainment, and real estate. Sustainable and efficient food provision is crucial for stable food prices and, given China's large population, balanced policy intervention is imperative for long-term agricultural sustainability. Examining financial indicators reveals the intricate relationship between economic and agricultural dynamics. China's Food CPI correlates negatively with wheat futures prices, showing how food price variations influence the wheat market. The USD to CNY exchange rate correlates positively, indicating international trade dynamics' influence on wheat prices. The Shanghai Security and Equity of Agricultural Theme Index (SSEATI) robustly correlates with wheat futures, emphasizing the significance of agricultural business performance. Policymakers must recognize the interconnectedness between financial and agricultural markets, harmonizing policies for stability. Adaptable responses to changes in agricultural dynamics and adjusting monetary policies can mitigate risks. Encouraging research and innovation in agricultural technology and financial instruments is vital for growth in both sectors.

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