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Research on the Impact and Spillover Effects of Urbanization Process on Grain Production

-- Empirical Study based on Spatial Durbin Model

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Abstract

Food security is an important strategic issue for the country. With the advancement of urbanization, food security needs to be re examined. Based on panel data from 31 provinces (regions, cities) in China from 2011 to 2022, this study analyzed the cluster effect of grain production using Moran index, and explored the impact of urbanization process on grain production and its spatial spillover effects through spatial Durbin model. Finally, the convergence of grain production was studied based on alpha and beta convergence models. The research results show that: (1) there is a significant cluster effect in grain production in various provinces, manifested as high-value clustering and low value clustering; (2) The urbanization rate promotes grain production in the province while suppressing grain production in neighboring provinces, while economic activity suppresses grain production in the province but promotes grain production in neighboring provinces. Overall, the urbanization rate significantly promotes grain production, while economic activities have a significant inhibitory effect on grain production; (3) There is no "catch-up effect" in grain production among provinces and grain functional zones, and the gap is showing a widening trend. This study aims to provide a reference basis for formulating food security policies.

Keywords

Gain Production; Urbanization Process; Moran Index; Spatial Durbin Model; Convergence Model.

1. Introduction

Food security is an important cornerstone of national economic security and social stability. For China, which has a population of 1.4 billion, ensuring food security is not only an economic issue, but also a core issue of national security and political stability. Since the 18th National Congress of the Communist Party of China, under the guidance of the Chairman's important discourse on national food security, China has undergone historic changes in the field of food security [1], proposing a new food security concept of "ensuring basic self-sufficiency in grains and absolute security of food rations", which provides important guidance for food production and policies. With the continuous development of the social economy and the acceleration of urbanization, China's agricultural production is facing new opportunities and challenges.

Urbanization is an important component of the modernization process and a vital driving force for economic growth and social development. However, the process of urbanization has also had adverse effects on food production. For example, the new urbanization has had a certain impact on agricultural non-point source pollution in the process of promoting urban-rural integration and modernization of agriculture and rural areas [2]. In addition, the reduction of rural labor force and the reduction of agricultural land will also decrease food production [3]. Meanwhile, urbanization may also improve agricultural production efficiency by improving infrastructure, promoting technological progress, and expanding markets [4]. Therefore, exploring the impact of urbanization on grain production, especially its spatial effects, has important theoretical and practical significance.

The impact of urbanization on national food security is multidimensional, and many scholars in China have conducted in-depth research and discussions on it [5]. The academic community mainly focuses on the impact of urbanization on arable land and its direct relationship with food security. As early as the beginning of the 21st century, due to the reliance on farmland conversion for urban development, research mainly focused on the impact of urbanization on farmland reflecting food security [6], leading to heated discussions. Some scholars believed that urbanization had no significant impact on food security [7], while others believed that urbanization had a serious impact on food security and needed to re-examine land policies [6,8]. In recent years, research on urbanization and food security has mainly focused on the impact direction. Scholars such as Gao Yanlei (2019) used a mediation effect model to explore the mechanism by which urbanization affects food security, and the results showed that urbanization has a significant positive impact on food security [9]. However, scholars such as Hou Mengyang (2022) used a moderated mediation effect model to analyze a sample of 330 prefecture level cities, and the results showed that urbanization had a significant negative impact on grain production [10]. With the proposal of Green Total Factor Productivity (GTFP), scholars have constructed efficiency indicators through methods such as Data Envelopment Analysis to evaluate agricultural green total factor productivity, reflecting agricultural production efficiency under the premise of resource conservation and environmental protection [11-13]. This type of research focuses more on achieving sustainable development and improving production efficiency. In terms of the impact of urbanization process, some scholars have found a single threshold effect between new urbanization and agricultural green total factor productivity [14-15].

Existing research has mostly focused on the single impact of urbanization on food security or agricultural green total factor productivity, with little systematic exploration of the spatial impact and complex interactive mechanisms of urbanization on food production. Most scholars use the ratio of urban population to total population within a province as an urbanization indicator in indicator selection, but this indicator only reflects population urbanization and fails to consider the interaction mechanism. Due to the fact that urban areas account for approximately 85% of the total retail sales of consumer goods, this study uses the total retail sales of consumer goods as an indicator of economic activity. This study is based on existing literature and uses spatial Moran's I test to investigate the spatial autocorrelation of grain production, economic activity, and urbanization rate in various provinces, revealing their spatial clustering characteristics. Furthermore, the Spatial Durbin Model (SDM) is employed to analyze the direct impact and spatial spillover effects of urbanization on grain production. Finally, based on the convergence of α and β, the catch-up effect of per capita grain yield is detected. The main contribution of this study lies in: (1) using spatial economics methods to reveal the spatial distribution cluster effects of grain production, economic activities, and urbanization rates at the provincial level in China; (2) By analyzing the spatial Durbin model, this study delves into the direct and indirect spatial effects of urbanization on grain production, providing a new perspective for understanding the dynamic relationship between urbanization and agricultural production; (3) Detecting the convergence of grain yield based on alpha and beta convergence, revealing the differences in grain yield in different regions; (4) Providing reference for the formulation of regional agricultural policies and optimization of resource allocation can help ensure national food security in the process of promoting urbanization.

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2. Mechanism Analysis and Data Sources

2.1. Mechanism Analysis

At present, many scholars can draw different conclusions about the impact mechanism of urbanization process on grain production based on their research focus, because urbanization process has the possibility of promoting and inhibiting both population migration and economic activities. This study is based on literature for partial summary.

(1) In the process of urbanization, the promotion of agricultural technology and improvement of infrastructure have enhanced agricultural production efficiency, resulting in an increase in output per unit of land. The increase in urban population and market demand brought about by economic activities have stimulated the expansion of grain production scale, and farmers have increased their production efforts to meet market demand. However, the loss of agricultural labor and the reduction of arable land have weakened agricultural production capacity, and increased resource competition and ecological pressure have had a negative impact on the agricultural ecosystem, further constraining the sustainability of food production.

(2) In addition to the direct influencing factors mentioned above, technology diffusion and resource optimization allocation are key factors. The improvement of agricultural technology and infrastructure not only directly promotes local food production, but also enhances agricultural production efficiency in neighboring areas through inter regional technology diffusion and resource optimization. The increase in market demand brought about by urbanization indirectly incentivizes farmers to expand production scale and increase production inputs by supporting agricultural market prices. Urbanization has promoted agricultural industrialization and product processing, increased agricultural added value, and indirectly promoted grain production. However, the negative effects brought about by the reduction of agricultural labor force and arable land area will also indirectly affect the agricultural production capacity of a wider region through changes in the labor market and land use, weakening its sustainability.

2.2. Data Sources

This study is based on panel data from 31 provinces (regions, cities) in China from 2011 to 2022. Due to missing data in some regions, the sample does not include Hong Kong, Macao, and Taiwan. The main data selected are the total grain production, urbanization rate, and total retail sales of consumer goods in each province, sourced from the China Statistical Yearbook, National Bureau of Statistics, and provincial statistical yearbooks.

Table 1. Variable Description and Statistical Description

Category	Variable Name	Variable Handling and Unit	Mean	SD	Max	Min
Dependent Variable	Cereal Production	Total cereal production within provinces/ten thousand tons, log transformed	7.039	1.342	8.971	3.359
Independent Variables	Urbanization Rate	Ratio of permanent urban population to total population within provinces, log transformed	4.055	0.229	4.495	3.127
	Economic Activity	Total retail sales of social consumer goods/billion RMB,log transformed	8.825	1.064	10.712	5.470

Note: Due to the use of logarithmic transformations for all indicators, let lnY represent cereal production, lnU represent the urbanization rate, and lnT represent economic activity.

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3. Research Design

3.1. Construction of Spatial Weight Matrix

This study constructed the adjacency space weight matrix W1 and the economic geographic distance weight matrix W2. The geographic weight matrix W1 depends on whether the geographic locations of two provinces are adjacent. This article uses queen adjacency (with common boundaries or points), and the calculation process of W1 is as follows:

$$W_{1,ij} = \begin{cases} 1, & \text{Province i and Province j are adjacent} \\ 0, & \text{Province i and Province j are not adjacent} \end{cases} \tag{1}$$

The economic geographic distance weight matrix W2 uses the per capita gross domestic product (GDP) of two economic units and geographic distance to determine their spatial correlation. The calculation process of W2 is as follows:

$$W_{2,ij} = \begin{cases} gdp_i \times gdp_j / d_{ij}, & i = j \\ 0, & i = j \end{cases} \tag{2}$$

In the formula, GDP represents per capita regional GDP, d represents the distance between provincial capitals (latitude and longitude), and i and j represent provinces.

3.2. Spatial Econometric Model

(1) Spatial autocorrelation is divided into global spatial autocorrelation and local spatial autocorrelation. Global spatial autocorrelation determines the degree of aggregation of indicator lnY from a macro perspective, while local spatial autocorrelation analyzes the spatial correlation between adjacent units. The formulas for global Moran index IG and local Moran index IL are as follows:

$$I_G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(\ln Y_i - \overline{\ln Y}\right)\left(\ln Y_j - \overline{\ln Y}\right)}{VAR\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \tag{3}$$

$$I_L = \frac{\left(\ln Y_i - \overline{\ln Y}\right)}{VAR} \times \sum_{j=1}^{n} W_{ij}\left(\ln Y_i - \overline{\ln Y}\right) \tag{4}$$

In the formula, lnY_i and lnY_j represent the grain production of different provinces, $\overline{lnY}$represents the mean of lnY, n is the number of provinces, VAR is the variance value, W_{ij} represents the spatial weight matrix, and here are W_1 and W_2 constructed by (1) and (2).

(2) The spatial Durbin model is commonly used to examine spatial dependency relationships and the spatial spillover effects of explanatory variables. In model selection, the study selected spatial lag model (SAR), spatial error model (SEM), and spatial Durbin model (SDM) [16], with the following specific expressions:

$$\ln Y_{it} = C + \rho W \ln Y_{it} + \beta_1 \ln U_{it} + \beta_2 \ln T_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{5}$$

$$\ln Y_{it} = C + \beta_1 \ln U_{it} + \beta_2 \ln T_{it} + \mu_i + \gamma_t + \varepsilon_{it}, \varepsilon_{it} = \lambda w \varepsilon_t + \mu_{it} \tag{6}$$

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$$\ln Y_{it} = C + \rho W \ln Y_{it} + \beta_1 \ln U_{it} + \beta_2 \ln T_{it} + \theta_1 W \ln U_{it} + \theta_2 W \ln T_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (7)$$

In the formula, U_{it} and U_{it} respectively represent the urbanization rate and economic activity of region i in the t-th year, C is a constant term, ε is a random disturbance term, u_i is the individual fixed effect of region i, γ_t is the time fixed effect of year t, and ρ, β, and θ are the parameters to be estimated.

3.3. Convergence Model

Convergence models are commonly used to study whether regions have the same development trend under different levels of development. For the issue of convergence, this study uses the commonly used alpha and beta convergence in academia [17]. Alpha convergence refers to the process in which the deviation of a certain indicator between different regions tends to decrease over time. β convergence refers to whether regions with lower initial economic levels have a higher growth rate than regions with higher economic levels. This study selected absolute β convergence to detect whether there is a "catch-up effect" in grain production in different regions based on research needs. β convergence follows the definition of Yang Chen (2020) as follows:

$$\frac{1}{T}\ln\left(\frac{\ln Y_{i,t}}{\ln Y_{i,0}}\right) = b_0 + b\ln\left(\ln Y_{i,0}\right) + \sigma \quad (8)$$

In the formula, $Y_{i,0}$ represents the grain production in the base period of region i, $Y_{i,t}$ represents the grain production in the end period of region i, T represents the time span, $b_0$is a constant term, b is the convergence coefficient, and σ is the random error.

4. Empirical Results

4.1. Analysis of Spatial Cluster Effects

(1) Global spatial autocorrelation analysis

This study calculated the global Moran index I_G for grain production, urbanization rate, and economic activity from 2011 to 2022, as shown in Table 2.

Table 2. Global Moran Index of Research Indicators

Year	Model1: W_1			Model2: W_2		
	Cereal Production	Urbanization Rate	Economic Activity	Cereal Production	Urbanization Rate	Economic Activity
2011	0.202**(1.968)	0.391***(3.673)	0.265***(2.554)	0.127**(1.896)	0.249***(3.463)	0.223***(3.120)
2012	0.209**(2.031)	0.379***(3.595)	0.264***(2.550)	0.127**(1.897)	0.249***(3.428)	0.223***(3.110)
2013	0.209**(2.023)	0.379***(3.611)	0.264***(2.545)	0.127**(1.897)	0.249***(3.437)	0.222***(3.101)
2014	0.207**(2.014)	0.381***(3.616)	0.261***(2.525)	0.121**(1.831)	0.249***(3.423)	0.220***(3.072)
2015	0.210**(2.037)	0.396***(3.726)	0.297***(2.810)	0.123**(1.862)	0.249***(3.461)	0.234***(3.220)
2016	0.219**(2.118)	0.404***(3.790)	0.301***(2.844)	0.131**(1.954)	0.249***(3.462)	0.237***(3.253)
2017	0.214**(2.077)	0.405***(3.804)	0.310***(2.909)	0.129**(1.931)	0.249***(3.432)	0.241***(3.304)
2018	0.210**(2.052)	0.394***(3.734)	0.316***(2.954)	0.119**(1.820)	0.249***(3.330)	0.246***(3.349)
2019	0.205**(2.016)	0.384***(3.662)	0.317***(2.958)	0.118**(1.816)	0.249***(3.272)	0.246***(3.349)
2020	0.200**(1.971)	0.378***(3.625)	0.345***(3.188)	0.113**(1.753)	0.249***(3.234)	0.258***(3.487)
2021	0.196**(1.937)	0.377***(3.619)	0.359***(3.315)	0.113**(1.751)	0.249***(3.223)	0.268***(3.605)
2022	0.196**(1.925)	0.380***(3.651)	0.364***(3.353)	0.111**(1.725)	0.249***(3.252)	0.269***(3.619)

Note: *** and ** indicate significance at the 1% and 5% levels, respectively. The values in parentheses are the z-values for the estimated coefficients of the corresponding explanatory variables, and this applies similarly throughout.

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The results in Table 2 show that under two spatial weight matrices, the global Moran index of grain production, urbanization rate, and economic activity are significantly positive, and all pass the 5% significance level test, rejecting the null hypothesis H0: there is no global spatial autocorrelation, indicating that grain production, urbanization rate, and economic activity in each province exhibit positive and stable spatial correlation characteristics.

(2) Local spatial autocorrelation

This study calculated the local Moran index (I-L) of grain production, urbanization rate, and economic activity from 2011 to 2022. Select the years with the highest and lowest spatial autocorrelation of grain yield, and draw a local Moran scatter plot of grain yield.

According to the local Moran scatter plot, each province is mainly located in the first and third quadrants, indicating that grain production is mainly characterized by high high clustering and low low clustering, and this trend has not changed significantly due to changes in years, indicating sustainability.

After conducting global and local Moran index tests, it was found that grain production, urbanization rate, and economic activity have significant spatial autocorrelation. Therefore, further research on spatial econometric models can be conducted.

4.2. Analysis of Spatial Durbin Model Results

(1) Verification of spatial econometric models

Before constructing the spatial Durbin model, this study conducted LM test, LR test, and Hausman test in sequence to ensure the rationality of the spatial Durbin model. According to Table 3, during the Hausman test, it was found that the chi square statistic was negative, resulting in the inability to determine whether a fixed effect or a random effect exists. According to the research of scholars such as Lian Yujun (2014) [19], based on Table 3, we have added a modification of the Hausman test. Currently, there are usually two methods in the academic community to correct negative Hausman test results, namely, assuming that the residual variance of the fixed effects model is greater than the residual variance of the random effects, and assuming that the residual variance of the fixed effects model is less than the residual variance of the random effects. In this study, we set the two hypotheses as Hausman_1 test and Hausman_2 test respectively, and conducted an over test to ensure the rationality of the modified Hausman test.

Table 3. Testing and estimation results of spatial econometric models

Test Method	Statistic	Model 1: W_1	Model 2: W_2	Conclusion
LM Test	LM_error	108.763***	81.240***	Spatial correlation exists at the 1% significance level
	RobustLM_error	108.703***	65.862***	
	LM_lag	33.540***	31.190***	
	RobustLM_lag	33.481***	15.813***	
LR Test	SDM vs. SAR	30.31(0.000)	36.04(0.000)	At the 1% significance level, SDM model is preferred over SAR and SEM
	SDM vs. SEM	46.68(0.000)	54.54(0.000)	
Hausman Test	χ^2Statistic	-3.07	-2.88	Test anomaly
Hausman_1 Test	χ^2Statistic	36.68***	36.68***	At the 1% significance level, fixed effects SDM model is preferred
Hausman_2 Test	χ^2Statistic	40.50***	40.50***	
Over-identification Test (Random Effects)	χ^2Statistic	40.502***	40.505***	At the 1% significance level, fixed effects model is reasonable
	χ^2 Statistic	77.852***	77.852***	

According to Table 3, a brief interpretation of the test results shows that the LM test, LR test, and modified Hausman test all reject the corresponding null hypothesis at the 1% significance

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level, indicating that the constructed spatial econometric model is spatially correlated and belongs to the fixed effects spatial Durbin model at the 1% significance level.

(2) Analysis of spatial Durbin model results

The results of individual fixation, time fixation, and double fixation are shown in Table 4. According to Table 4, the study found significant differences in the results of individual fixed effects and time fixed effects. Under individual fixed effects, urbanization rate has a significant positive effect on grain yield, but under spatial effects, the higher the surrounding urbanization rate, the lower the local grain yield. The impact of economic activities on grain production is opposite to the urbanization rate, and the spatial lag coefficient (ρ) of grain production is significantly negative, indicating that there is a reverse spatial spillover effect on grain production. Under the fixed time effect, the impact coefficients of urbanization rate and economic activity on grain yield are opposite to the results of individual fixed effects, and there is a positive spatial spillover effect on grain yield. The dual fixed effects result combines the characteristics of the first two, showing that the impact of urbanization rate and economic activity on grain yield is still significant, but the direction and individual fixed effects are consistent. Overall, changes in grain production are not only influenced by urbanization and economic activities in the region, but also significantly influenced by surrounding areas.

Table 4. Fixed effects SBM model estimation results

Variable	Model1:W_1			Model2：W_2		
	Individual Fixed	Time Fixed	Double Fixed	Individual Fixed	Time Fixed	Double Fixed
lnU	1.559*** (10.06)	-3.137*** (-11.02)	1.595*** (10.80)	1.672**** (11.08)	-3.003*** (-11.18)	1.611*** (11.17)
lnT	-0.493*** (-10.25)	1.025*** (19.90)	-0.479*** (-10.44)	-0.460*** (-9.57)	1.047*** (19.40)	-0.449*** (-9.66)
$WlnU$	-0.851*** (-4.38)	1.840*** (3.37)	-0.0913 (-0.37)	-1.331*** (-5.82)	1.120 (1.56)	-0.224 (-0.60)
$WlnT$	0.356*** (5.42)	-0.780*** (-8.37)	0.319*** (4.86)	0.426*** (5.46)	-0.916*** (-6.84)	0.343*** (4.08)
ρ	-0.184** (-2.53)	0.514*** (9.41)	-0.281*** (-3.82)	-0.246** (-2.52)	0.617*** (9.40)	-0.479*** (-4.56)
ε	0.008*** (13.60)	0.703*** (13.40)	0.007*** (13.48)	0.008*** (13.59)	0.766*** (13.27)	0.007*** (13.46)
N	372					
R^2	0.4628	0.480	0.430	0.425	0.386	0.410
$LogL$	373.426	-477.764	391.323	375.726	-490.696	391.801

(3) Effect decomposition

When $\rho \neq 0$ in the SDM model, the regression results of the spatial model cannot accurately explain the spatial spillover effects between variables. Therefore, the spatial spillover effects were analyzed using partial differential method [20], and the results are shown in Table 5. There are significant differences in the impact of individual fixed effects and time fixed effects on urbanization rate and economic activity between the two models. Under individual fixed effects, the direct effect of urbanization rate is significantly positive, while the indirect effect is significantly negative. The total effect is significantly positive, indicating that urbanization has a positive impact on grain production at the individual level, but urbanization in neighboring areas may bring competitive pressure, resulting in negative effects. Under the fixed time effect, the urbanization rate shows a significant negative direct effect, while the indirect effect is not significant. The overall effect is significantly negative, indicating that urbanization may lead to

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a reduction in agricultural land and labor transfer over time, thereby having adverse effects on grain production. The direct effect of economic activities under individual fixed effects is significantly negative, the indirect effect is significantly positive, and the total effect is significantly negative, indicating that the resource competition triggered by economic activities within individuals is more significant. Under the fixed time effect, the direct effect of economic activity is significantly positive, the indirect effect is significantly negative, and the total effect is significantly positive, indicating that over time, economic activity may enhance market linkage and technological exchange, which has a positive impact on grain production, but competition in peripheral areas also leads to certain negative effects. Under the dual fixed effects, the results exhibit both individual and temporal fixed effects. Therefore, overall, the total effect of urbanization rate is significantly positive, while the total effect of economic activity is significantly negative, that is, urbanization rate promotes grain production, while economic activity inhibits grain production.

Table 5. Results of Effect Decomposition Estimation of Spatial SDM Model

Fixed Effects Selection	Variable	Model 1: W_1			Model 2: W_2		
		Direct Effect	Indirect Effect	Total Effect	Direct Effect	Indirect Effect	Total Effect
Individual Fixed Effects	lnU	1.611*** (9.68)	-1.013*** (-5.62)	0.598*** (4.69)	1.737*** (10.65)	-1.462*** (-7.38)	0.275* (1.85)
	lnT	-0.517*** (-11.93)	0.402*** (7.14)	-0.115*** (-2.96)	-0.484*** (-11.29)	0.457*** (7.10)	-0.027 (-0.59)
Time Fixed Effects	lnU	-3.094*** (-10.94)	0.519 (0.54)	-2.575** (-2.49)	-3.091*** (-10.72)	-1.679 (-0.84)	-4.770** (-2.25)
	lnT	0.980*** (20.92)	-0.489*** (-2.74)	0.490** (2.49)	1.006*** (20.47)	-0.677** (-1.97)	0.329* (0.90)
Double Fixed Effects	lnU	1.631*** (10.24)	-0.456** (-2.09)	1.175*** (6.65)	1.678*** (10.34)	-0.736*** (-2.60)	0.942*** (4.24)
	lnT	-0.513*** (-12.07)	0.391*** (6.94)	-0.123*** (-3.26)	-0.491*** (-11.25)	0.423*** (6.46)	-0.069*** (-1.58)

4.3. Convergence Analysis of Grain Yield

(1) The alpha convergence of food security

(2)

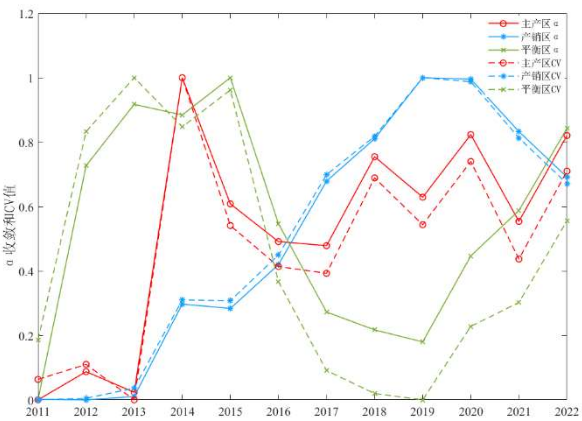

Figure 1. Convergence of Main Grain Producing Areas, Main Selling Areas, and Balanced Areas from 2011 to 2022

Scholars habitually divide provinces into grain functional zones (main grain producing areas, main grain selling areas, and balanced production and sales areas) according to the standards of the National Medium - and Long Term Plan for Food Security (2008-2020) when studying grain production. When studying alpha convergence, it is more reasonable to divide the functional zones in this study. When obtaining alpha convergence values and CV values, the study found that the trends were similar, but there were certain differences in the values. However, this study mainly studied the convergence between different regions, so the alpha convergence values and CV values were normalized to emphasize the trend changes, and the results were plotted in Figure 3. According to Figure 3, although there are still differences in values between alpha convergence and CV, the trends are the same. From a holistic perspective, there is no alpha convergence. It can be observed in different time periods that the main production areas have an alpha convergence trend from 2014 to 2017, the main sales areas have an alpha convergence trend from 2020 to 2022, and the equilibrium areas have an alpha convergence trend from 2015 to 2019. It is possible to achieve convergence under specific conditions.

(2) β convergence of food security

To verify whether there is a phenomenon of provinces with lower grain production catching up with provinces with higher grain production in the country, this study uses absolute β convergence. Based on methodological formulas, the convergence coefficient b is calculated to be 0.009, which is significant, indicating that there is no catch-up effect in grain production among provinces, and the differences show a significant increasing trend. At the same time, this study also calculated the main grain producing areas, main selling areas, and balanced areas, and obtained coefficients of 0.0022, 0.0204, and 0.0003, respectively. Therefore, there is no catch-up effect in each grain functional area.

4.4. Robustness Analysis

To verify the robustness of the model, the study adopted a spatial adjacency distance matrix and an economic geographic distance weight matrix. The results showed that there was no significant change in the impact on the results. And when studying the convergence of alpha, comparing the CV value with the convergence value of alpha, the results showed differences except for the coefficient, and the trend of change was the same. Therefore, the conclusion drawn from this study is robust.

5. Conclusion and Suggestions

5.1. Conclusion

The issue of food security plays an important role in national strategy. With the advancement of urbanization, its impact on food production and spatial spillover effects have become urgent research topics. Based on panel data from 31 provinces (regions, municipalities) in China from 2011 to 2022, this study analyzed the cluster effect of grain yield and explored the mechanism of urbanization on grain yield. The main conclusions are as follows:

(1) Across the country, there is a clear cluster effect in the grain production of various provinces, manifested as high-value and low value clustering of grain production, indicating that the spatial distribution of grain production is not balanced.

(2) The urbanization rate has a significant promoting effect on the grain production of the province, but at the same time, it has a restraining effect on the grain production of surrounding provinces. In addition, economic activities have a negative impact on the grain production in our province, but to some extent, they have promoted the grain production in neighboring provinces. This indicates that the impact mechanism of urbanization rate and economic activity on grain production is complex and needs to be carefully considered in policy formulation.

(3) Regional differences in grain production: The grain production of various provinces and grain functional zones did not reflect the "catch-up effect", that is, the gap in grain production

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between regions showed an expanding trend during the research period, indicating that the differences in grain production capacity between different regions are increasing.

5.2. Suggestions

Based on the above conclusions, this article proposes the following four policy recommendations to ensure effective food security in the process of urbanization: firstly, optimizing the layout of urbanization and land use. In the process of urbanization, it is necessary to plan urban expansion reasonably, strictly implement the policy of balancing land occupation and compensation, prevent problems such as "occupying advantages to compensate for disadvantages" and "occupying more to compensate for less", and ensure that food security is not affected by the urbanization process. The second is to promote the improvement of the quality of agricultural labor force. With the migration of rural population to urban areas, improving the quality of agricultural labor has become crucial. We should strengthen vocational education and training for rural labor force, promote the development of professional farmers, and improve agricultural production efficiency and grain output. The third is to promote agricultural technology innovation and promotion. In the situation where the factors of grain production are inevitably decreasing, it is necessary to increase investment in agricultural technology and promote the promotion and application of agricultural mechanization and informatization. Make up for the shortcomings of land and labor through technological progress, and ensure a steady increase in grain production. The fourth is to strengthen regional coordination and cooperation. To reduce the gap in grain production between regions, establish a cross regional cooperation mechanism for grain production, and promote resource sharing and coordinated development among provinces. Economically developed regions should increase technical and financial support for areas with weaker food production to achieve national food security goals.

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