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Spatial Spillover Effect and Nonlinear Relationship between Factor Misallocation and High-Quality Agricultural Economy: Evidence from 154 Cities in Major Grain-Producing Areas of China

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Abstract: Promoting the high-quality development of agriculture is an inevitable requirement toward realizing the transformation from a large agricultural country to a powerful one, and optimizing factor allocation is a prerequisite. In this paper, we use spatial econometric models to analyze the impact of factor misallocation on the high-quality development of the agricultural economy based on panel data from 154 prefecture-level cities in major grain-producing regions from 2004 to 2020. We found that factor misallocation was relatively low at the prefecture level, with an average annual decrease of 0.82 percent, compared to an average annual increase of 1.29 percent for the high-quality development of the agricultural economy. Factor misallocation inhibited improvements in high-quality agricultural economic development in adjacent cities. This conclusion remained stable after a series of tests, and the inhibitory effect exhibited significant spatiotemporal heterogeneity due to differences in geographical location, developmental level, and factor allocation methods. At the same time, a mechanism test demonstrated a continuous weakening of the inhibitory effect, accompanied by the optimization and upgrading of the agricultural industry, as well as an improvement in agricultural scientific and technological progress. In addition, nonlinear tests demonstrated that the impact of factor misallocation on the high-quality development of the agricultural economy exhibits significant nonlinear features as agricultural science and technology advances.

Keywords: factor misallocation; high-quality development of agricultural economy; spillover effect; nonlinear feature

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1. Introduction

The realization of a powerful agricultural country is inseparable from high-quality agricultural development [1]. At present, China's agricultural development is facing such problems as tighter resources and environmental constraints, weakening the competitiveness of agricultural products in the market and upgrading the food consumption structure for residents. Accelerating agricultural transformation and upgrading and promoting high-quality development are both imperative and necessary for agriculture development [2]. Optimizing the allocation of factors is considered a prerequisite for promoting high-quality agricultural development; however, there has been no substantial change in the extensive agricultural development model resulting from improving agricultural efficiency [3]. The input factors aimed at increasing and stabilizing production introduce problems such as repeated and inefficient input, resulting in the long-term problem of factor misallocation in China's agriculture. As a ballast stone for China's food security, major grain-producing regions accounted for 78.25 percent of the country's grain production in 2022, laying a solid material foundation for high-quality agricultural development. However, compared with the main grain sales areas, their factor misallocation is more severe, and the level of high-quality agricultural development needs to be improved [4,5]. Therefore, clarifying the impacts of factor misallocation in major grain-producing areas on high-quality agricultural development has become an effective way to formulate factor allocation policies and promote improvements in high-quality agricultural development.

Reasonable evaluation of high-quality agricultural development is the prerequisite for further analysis. Some scholars have argued that a comprehensive evaluation system is necessary to measure high-quality agricultural development, due to its multidimensional characteristics [6]; some scholars believe that, due to the subjectivity and randomness of index selection, the comprehensive evaluation method weakens the comparability of the evaluation results, and a single index should be used for measurement [7]. As high-quality agricultural development faces the imbalance of agricultural multi-functional coordinated development [8], expanding multi-functional agriculture to promote farmers' income is the essential connotation of high-quality agricultural development [9]. Therefore, in this paper, we break down agricultural development based on the agricultural multifunctional theory and only focus on its economic function. Although the proportion of agricultural economic output in the GDP has been declining in recent years, its status in national economic development has not declined [10], so it is necessary to analyze the high-quality development of the agricultural economy.

As for the impact of factor misallocation on agricultural development, scholars generally expand or optimize the research framework based on the studies of Hsieh and Klenow (2009) [11] or Aoki (2012) [12] and use mathematical models to deduce the impact of factor misallocation on agricultural development. The scope of the research is reflected at the provincial [13], regional [14], national [15], and global levels [16]. Focusing on the impact of the misallocation of three major production factors, namely capital [17], labor [18], and land [19], on agricultural development, some scholars also analyzed the misallocation of science and technology [20] and human capital [21] on agricultural development.

Our main aim in this paper is to reveal the spillover effects, mechanisms, and nonlinear features of factor misallocation among prefecture-level cities in major grain-producing regions on high-quality agricultural economic development. The main marginal contribution of this paper includes three aspects: The first is an exploration of the impacts of factor misallocation on high-quality agricultural economic development in prefecture-level cities in major grain-producing areas; the analysis of prefecture-level cities has a smaller space of policy guidance and can better improve the accuracy of estimation results and policy guidance. The second is the spatial mobility of factors, which is included in the econometric model to analyze the spillover effect of factor misallocation on the high-quality development of the agricultural economy. Existing studies have confirmed the impact of factor misallocation on local agricultural development; however, with the advancement of factor marketization reform and the continuous improvements in factor spatial mobility, it is still necessary to further prove whether local factor misallocation has an impact on agricultural development in adjacent cities. The third includes revealing the mechanism and nonlinear characteristics of factor misallocation affecting the high-quality development of the agricultural economy. There are relatively few studies on how factor misallocation affects the high-quality development of agriculture, and most of them analyze the previous two variables based on linear models, ignoring the possible nonlinear characteristics between them. With regard to this, we used the spatial econometric model to analyze the spillover effect and action mechanism of factor misallocation on high-quality agricultural economy in prefecture-level cities in major grain-producing areas and further studied the nonlinear relationship between them by using the threshold model.

The rest of this article is arranged as follows: Section 2 includes theoretical analysis and assumptions. Model construction, variable description, and data sources are placed in Section 3. The empirical chapter of Section 4 contains three aspects. Firstly, this section describes the current situation of factor misallocation and the quality of the agricultural economy. Secondly, we analyze the impact and action mechanism of factor misallocation on the quality of the agricultural economy. Finally, in this paper, we explore the nonlinear impacts of factor misallocation on the quality of the agricultural economy. Discussion and Conclusions are placed in Sections 5 and 6, respectively.

2. Theoretical Analysis

2.1. Factor Misallocation and High-Quality Development of the Agricultural Economy

The high-quality development of the economy cannot be achieved without the rational allocation of production factors [22], but due to the influences of institutional mechanisms, there has been a long-standing problem of factor misallocation in China's agricultural sector. Based on the provincial or national level, previous articles have shown that alleviating factor misallocation can not only promote improvement in agricultural total factor productivity [23] but can also improve the level of high-quality agricultural development [24]. In addition, mitigating factor misallocation will also help to eliminate the income gap within agriculture [25], thereby promoting improvement in the level of high-quality development of the agricultural economy. On the other hand, there is a certain spatial correlation between agricultural production and factor misallocation [26,27], and the spillover effect of factor misallocation will not only play a role in the initial spillover due to the existence of geographical or administrative boundaries [28], but the local factor misallocation may also affect the agricultural development of adjacent areas through the spatial spillover effect. With the promotion of China's factor marketization reform, the efficiency of factor allocation has been further improved, and the problem of factor misallocation has been alleviated. Existing studies have shown that moderate factor misallocation will not inhibit economic development, and only excessive factor misallocation will have a negative impact [29]. Therefore, the impact of factor misallocation on the high-quality development of the agricultural economy may not always follow linear characteristics, and it is likely to show significant nonlinear characteristics with a change in the degree of factor misallocation. Therefore, in this paper, we proposed the following:

Hypothesis 1. *Factor misallocation not only has spatiotemporal heterogeneity and spatial spillover effects on the high-quality development of the agricultural economy, but also has significant nonlinear characteristics.*

2.2. Factor Misallocation, Agricultural Industrial Upgrading, and High-Quality Development of the Agricultural Economy

Krugman used the theory of increasing returns to scale, and analytical tools to bring geographical factors into, the analysis of competitive equilibrium and economies of scale and conducted an in-depth analysis of the causes of industrial agglomeration from the perspective of economic geography. From the perspective of industry, the high-quality development of agriculture in the main grain-producing areas can effectively improve the developmental efficiency of its agricultural industry. Under the background of high-quality development, the agricultural industrial structure tends to be reasonable, the layout is constantly optimized, and the agricultural industry is gradually transformed and upgraded. Industrial upgrading is one of the themes of modern economic development. Speeding up industrial upgrading can not only improve the speed of economic development, but also help to obtain higher economic returns. The process of industrial upgrading is accompanied by the flow of production factors. With the flow of production factors, to a certain extent, the factor endowment structure of each region has changed. Each region can adjust its internal economic structure according to the principle of comparative advantage and optimize the factor allocation efficiency, in order to promote improvement in the level of economic development. Macro-research shows that industrial upgrading can effectively mitigate the negative impact of factor misallocation on high-quality economic development [30]. However, the existing literature has not fully emphasized the application of this influence channel in the agricultural field [31]. As economic development moves toward a high-quality stage, industrial systems and structures must also be aligned with the stage of economic development. Therefore, in this paper, we proposed the following:

Hypothesis 2. *Agricultural industrial upgrading plays a regulatory role in the process of factor misallocation, affecting the high-quality development of the agricultural economy.*

2.3. Factor Misallocation, Agricultural Scientific and Technological Progress, and High-Quality Development of the Agricultural Economy

According to Barro and Romer's "endogenous growth" theory, the progression of agricultural science and technology is the endogenous driving forces for the high-quality development of the agricultural economy in major grain-producing areas. Technological progress can not only promote long-term economic growth but also effectively drive economic structural transformation and help to achieve high-quality economic development [32]. Scientific and technological innovation are the first steps toward driving high-quality development of the agricultural economy. The progress of agricultural science and technology improves the use and output efficiency of production factors and increases the added value of agricultural products, while reducing the consumption of resources, to achieve the same input of factors through which to create more wealth value and eventually lead to the labor productivity and economic efficiency of steady improvement, thus promoting the high-quality development of the agricultural economy. With the advancement of agricultural science and technology, especially the popularization and application of labor-saving technology, the allocation of both agricultural capital and labor can be effectively adjusted, and the allocation efficiency of factors can be improved, thereby promoting the high-quality development of the agricultural economy. Therefore, in this paper, we proposed the following:

Hypothesis 3. *Agricultural scientific and technological progress plays a regulatory role in the process of factor misallocation, affecting the high-quality development of the agricultural economy.*

3. Materials and Methods

3.1. Research Methods

To examine the impact of factor misallocation on the high-quality development of the agricultural economy, a general spatial econometric model was constructed [33]:

$$y_{it} = \rho\sum_{j=1}^{n} W_{ij}y_{jt} + \beta X_{it} + \varphi\sum_{j=1}^{n} W_{ij}x_{it} + \mu_i + v_t + \varepsilon_{it} \quad \varepsilon_{it} = \lambda \sum_{j=1, j\neq i}^{n} W_{ij}\varepsilon_{jt} + \mu_{it} \tag{1}$$

where subscripts i and t represent regions and years, y_{it} indicates the high-quality developmental level of the agricultural economy in prefecture-level city i in year t. X_{it} is the explanatory variable for this article. P represents the spatial lag coefficient of the quality of the agricultural economy. M_i, v_t, $\varepsilon_{it,}$ and λ represent the space effect, time effect, random error term, and spatial autocorrelation coefficient, respectively. The spatial weight W_{ij} is expressed as the reciprocal of the shortest distance between cities.

3.2. Data Sources

The data in the article mainly come from the EPS database, and a small number of missing values were supplemented by searching for statistical yearbooks of prefecture-level cities, national economic and social development statistical bulletins, or by using the mean method.

3.3. Variable Selection

(1) Dependent variable: High-quality development of the agricultural economy ($HQ_{economic}$): the high-quality development of the agricultural economy is defined as the coordinated development of the agricultural economy with high efficiency and equity. Following the principles of scientificity, comprehensiveness, representativeness, and comparability in indicator selection, and fully considering the availability and continuity of the data, this article evaluates the quality of the agricultural economy by selecting indicators

from two aspects: efficiency and fairness. The selection of specific indicators is shown in Table 1.

Table 1. Indicators of a high-quality agricultural economy.

Target Layer	Subsystem	Criterion Layer	Index Layer
Efficient and fair coupling coordination system	Efficient	Land productivity	Gross output value of agriculture, forestry, animal husbandry, and fisheries/area sown by crops
		Labor productivity	Gross output value of agriculture, forestry, animal husbandry, and fishery industry/employees engaged in primary production capacity
		Capital productivity	Gross output value of agriculture, forestry, animal husbandry, and fishery/stock of agricultural capital
		Energy consumption rate	Total output value of agriculture, forestry, animal husbandry, and fishery/rural electricity consumption
		Contribution of output to the family	Per capita gross output of agriculture, forestry, animal husbandry, and fishery/rural household disposable income per capita
		Contribution of output to the region	Gross output value of agriculture, forestry, animal husbandry, and fishery/regional GDP
	Fair	Urban–rural income ratio	Per capita disposable income of urban residents/per capita net income of rural residents
		Urban–rural consumption ratio	Per capita consumption expenditure of urban residents/per capita consumption expenditure of rural residents
		Per capita share of grain	Grain output/(rural population × 400 kg)

Firstly, the principal component scores of the above two systems were obtained using the principal component analysis method, and then the coupling coordination degree of the above two systems was calculated using the coupling coordination degree model. Finally, the calculated results were taken as proxy variables of the quality of the agricultural economy. The coupling coordination degree model, which can effectively reflect the cooperative effect and overall efficacy among subsystems, has been widely used in the empirical research on the level of coupling and coordination development among multi-systems in recent years [34]. The higher the coupling degree is, the more obvious the coupling relationship between the two subsystems is. The steps are as follows:

① Coupling calculation:

$$C = \sqrt{\frac{U_1 U_2}{\left(\frac{U_1+U_2}{2}\right)^2}} = \frac{2\sqrt{U_1 U_2}}{U_1 + U_2} \tag{2}$$

In Formula (2), U_1 represents the high-efficiency comprehensive evaluation score, while U_2 represents the fair evaluation score. The coupling degree C ∈ [0, 1] represents the coupling value regarding efficiency and fairness. The larger the coupling value is, the higher the efficiency and fairness, which leads toward orderly development.

② Coordination degree calculation:

$$T = \alpha U_1 + \beta U_2. \tag{3}$$

In Formula (3), T is the coordination index of an efficient and fair system, and α and β are the weight coefficients; $\alpha + \beta = 1$. Considering the fact that China's economy is turning toward high-quality development, we should pay attention to efficiency and emphasize fairness at the same time, so equal weight assignment is used.

③ Calculating the coupling degree:

$$D = \sqrt{C \times T} \tag{4}$$

In Formula (4), D is the value of the coupling coordination degree of an efficient and fair system, and the range of the value is [0, 1]. The higher the value is, the higher the degree of coupling and coordination between the two systems is.

(2) Independent variable: Factor misallocation (F_{mis}): The measurement of factor misallocation draws on previous research results [12]. Assuming that the regional production function satisfies the Cobb–Douglas (C–D) form, the relative misallocation coefficients between capital and labor are calculated using Joseph-Louis Lagrange multiplication, based on the profit maximization premise. The formulas for these are as follows:

$$\gamma_{Ki} = \left(\frac{K_i}{K}\right) \Big/ \left(\frac{s_i \beta_{Ki}}{\beta_K}\right) \tag{5}$$

$$\gamma_{Li} = \left(\frac{L_i}{L}\right) \Big/ \left(\frac{s_i \beta_{Li}}{\beta_L}\right) \tag{6}$$

In Formulas (5) and (6), γ_{Ki} and γ_{Li} represent the capital relative misallocation coefficient and labor relative misallocation coefficient, respectively, of prefecture-level city i. K_i is the agricultural capital stock of prefecture-level city i, measured using the perpetual inventory method; the depreciation rates of each prefecture-level city are based on the values of their respective provinces, and the provincial depreciation rates refer to the research results of Zong and Liao (2014) [35]. L_i is the labor force quantity of prefecture-level city i, $K = \sum_{i=1}^{154} K_i$ and $L = \sum_{i=1}^{154} L_i$. S_i represents the proportion of agricultural output in the main production area of prefecture-level city i. β_{Ki} and β_{Li} represent the capital and labor elasticity, respectively, of prefecture-level city i, and are estimated using a variable coefficient panel model based on the C–D production function with constant returns to scale, $\beta_K = \sum_{i=1}^{154} s_i \beta_{Ki}$ and $\beta_L = \sum_{i=1}^{154} s_i \beta_{Li}$.

The two equations mentioned above take the regional average as a reference against which to measure the factor misallocation and ignore incomplete substitution between factors. Therefore, based on previous studies [24], we introduce incomplete substitution between factors into the model in this paper, and construct the factor misallocation coefficient to reflect the degree of capital misallocation relative to labor in major grain-producing regions of prefecture-level cities.

$$F_{\text{mis}} = \left| \frac{\gamma_{Ki}}{\gamma_{Li}} - 1 \right| \tag{7}$$

In Formula (7), when F_{mis} is equal to zero, there is no factor misallocation. The farther F_{mis} is from zero, the higher the degree of factor misallocation.

(3) Control variables: In order to reduce the problem of model estimation errors caused by missing variables, the following control variables are added to the econometric model:

Economic Development Level (P_{gdp}): According to the growth pole theory, the level of regional economic development will lead to the formation of local growth pole, promoting high-quality economic development. In this paper, we took the per capita GDPs of prefecture-level cities to measure the levels of regional economic development.

Mechanization level (M_{ech}): The promotion of mechanized agriculture is an important catalyst with which to guide the high-quality development of agriculture [36]. The mechanized agriculture level is measured by the total agricultural machinery power per unit area sown.

Urbanization level (U_{rban}): On the one hand, the level of urbanization can promote the high-quality development of the agricultural economy by absorbing the rural surplus labor force, realizing agricultural scale management, and raising agricultural production efficiency. On the other hand, it may also absorb too much agricultural capital, land, and other production factors through its own developmental advantages, which then restrain improvements in the level of high-quality development of the agricultural economy. Its action direction and intensity depend on the comparison of the two actions. In this article, we use the proportion of the urban population to the total population as the proxy variable for urbanization, and the data for cities where urban population data are missing are replaced with non-agricultural population data.

Level of industrialization ($I_{ndustry}$): the development of industrialization has improved agricultural production efficiency and continues to increase the demand for primary agricultural products, thereby affecting the high-quality development of the agricultural economy. In this paper, we use the secondary sector of the value-added economy as a percentage of regional GDP.

Financial support for agriculture (F_{sup}): On the one hand, financial support for agriculture can help to improve agricultural infrastructure, raise the level of agricultural science and technology, and train farmers' vocational skills. On the other hand, it is also possible to narrow the urban–rural gap by increasing farmers' access to financial loans, transferring agricultural labor, and other means, thereby affecting the high-quality development of the agricultural economy [37]. In this paper, we use the ratio of the expenditure of agriculture, forestry, and water affairs to the total financial expenditure in prefecture-level cities as its proxy index.

Agri-industrial agglomeration (A_{gria}): agri-industrial agglomeration is conducive to promoting large-scale land management, improving agricultural production efficiency, reducing agricultural production costs, and promoting the transformation of traditional agriculture into modern agriculture; it is an important variable for realizing the high-quality development of the agricultural economy.

(4) Moderator variables: Agricultural industrial upgrading (U_{pgrade}): Upgrading the agricultural industry is an important supporting force for promoting high-quality agricultural development [38]. According to the Cluck theorem, we use the proportion of the total output value of agriculture, forestry, animal husbandry, and fishery services to measure it in this paper.

Advances in agricultural science and technology (T_{ech}): The improvements in high-quality agricultural economic development cannot be separated from the support of technology. Based on Qin (2022) [24], the agricultural production function is used to measure the progress of agricultural science and technology. Let the agricultural production function with constant returns to scale be $Y_t = A_t k_{1t}^{\beta_1} k_{2t}^{\beta_2} k_{3t}^{\beta_3} k_{4t}^{\beta_4}$; among them, Y_t is the total output value of agriculture, forestry, animal husbandry, and fishery (constant price in 2004), K_{it} is the acreage sown by crops, the workers in the primary industry, the total power of agricultural machinery, and the pure quantity of agricultural fertilizer, β_i is the contribution rate, and A_t is an indicator of agricultural scientific and technological progress.

The descriptive statistics of each variable are shown in Table 2. We can find that the degree of data dispersion is relatively low, and we can proceed to the next step of analysis.

Table 2. Variable indicators and descriptive statistics.

Variable Type	Symbols	Sample	Mean	S.D.
Dependent variable	$HQ_{economic}$	2618	0.40	0.09
Independent variable	F_{mis}	2618	0.82	1.24
Control variables	P_{gdp}	2618	38,219.45	30,191.22
	M_{ech}	2618	0.63	0.32
	U_{rban}	2618	47.97	13.65
	$I_{ndustry}$	2618	0.48	0.11
	F_{sup}	2618	0.02	0.02
	Agr_{ia}	2618	1.56	0.86
Moderator variables	U_{pgrade}	2618	0.04	0.04
	T_{ech}	2618	0.52	0.13

4. Results

4.1. Dynamic Evolution of Factor Misallocation

As can be seen from Figure 1, first of all, the distribution of the main peaks on the left side of the curve shows that the degree of factor misallocation in most cities is relatively light, and the central position of the curve as a whole shows a fluctuating trend of moving to the left, indicating that the level of agricultural factor misallocation in prefecture-level cities has been decreasing during the studied period. The average value of agricultural factor misallocation in prefecture-level cities has decreased, from 0.92 in 2004 to 0.80 in 2020, with an average annual decrease of 0.82%. Secondly, with the passage of time, the peak height of the curve shows a fluctuating trend of rising first, then falling and rising as a whole, and the coverage width of the curve continues to shrink, changing from wide peak to peak, which means that cities with relatively heavy factor misallocation in the sample period began to optimize the local allocation of agricultural factors, so that the allocation of agricultural production factors became continuously optimized, and the absolute difference of factor misallocation between cities has been continuously reduced. Thirdly, the curve tail on the right side continues to thicken, indicating that the number of cities with high values of factor misallocation has increased and the difference from the average level has been expanding. Finally, during the whole studied period, the distribution of factor misallocation in prefecture-level cities always maintained the shape of one main peak and several ridges on the right side as auxiliary peaks, but the height difference between the side peaks and the main peaks was large, indicating that the factor misallocation of 154 prefecture-level cities still has a certain gradient effect, showing a weak multi-polarization trend. It is not difficult to understand that, although the factor allocation of prefecture-level cities has been continuously optimized with the steady progress of factor marketization reform—in view of the obvious heterogeneity of the economic development level, government support, marketization level, industrial development level, and other factors affecting the factor allocation in different regions and cities—in the short term, cities with high degrees of factor misallocation have difficulty catching up with cities with low degrees of factor misallocation, and the gap between the two is likely to continue to widen for a certain period of time.

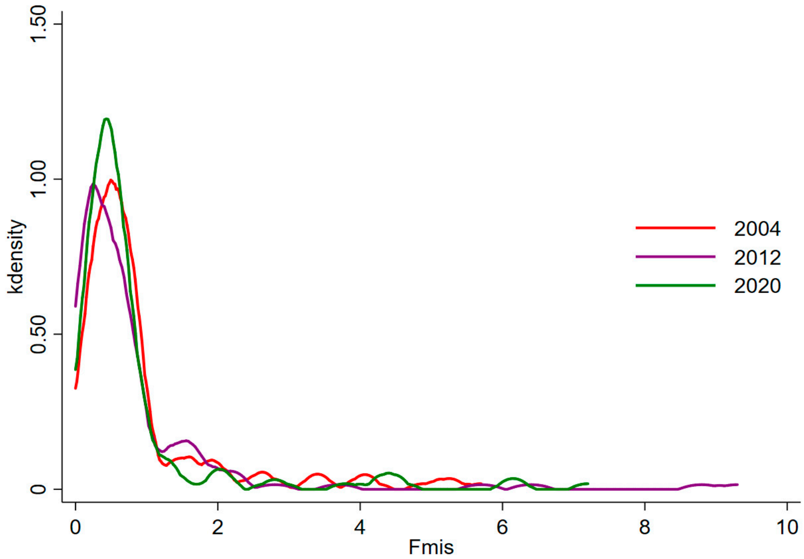

Figure 1. Kernel density map of factor misallocation from 2004 to 2020.

In conclusion, during the studied period, the degree of factor misallocation in the main grain-producing areas decreased, the degree of overall misallocation was relatively light, and the difference between cities and regions was constantly narrowing, but the difference between cities and the average values of high factor misallocation was expanding and the polarization was obvious.

4.2. Dynamic Evolution of High-Quality Agricultural Economy

As can be seen from Figure 2, firstly, the central position of the curve from 2004 to 2020 is always below 0.5. It is almost unchanged in the earlier period of the sample, and the right-shift trend in the later period of the sample shows that the level of high-quality agricultural economic development in prefecture-level cities is relatively low and keeps a slow developmental trend in the initial year, and then increases rapidly in the following year, which is consistent with the research conclusion of Zhang et al. (2021) [39]. Since modern economic growth theory focuses mainly on efficiency and not enough on equity [40], and for a large agricultural country, when the level of economic development is low, ensuring an adequate supply of agricultural products through improvements in efficiency is a necessary condition for maintaining food security [41], so the coupling and coordination degrees of efficiency and fairness in the processes of agricultural development in the main production areas are relatively low. However, with China's economic focus changing from high-speed development to high-quality development, the level of high-quality agricultural economic development also rose, from 0.37 in 2004 to 0.45 in 2020, with an average annual growth rate of 1.29%; in particular, after the 19th National Congress of the Communist Party of China clearly pointed out in 2017 that the economy has turned toward high-quality development, the high-quality development of the agricultural economy rapidly improved, at an average annual growth rate of 3.84%. Secondly, the height of the wave crest as a whole showed an evolutionary trend of first falling and then rising, gradually changing from a broad peak to a sharp peak, and the coverage width of the curve was reduced. This shows that, after leading for a period of time, the development speed of the cities with a higher quality of agricultural development during the sample period decreased, and the prefecture-level cities with lower levels of high-quality agricultural development began to make efforts to optimize the coordination of fairness and efficiency in the process of local agricultural development, making use of late-developing advantages and gradually catching up with the prefecture-level cities with higher levels of development. Finally, the absolute difference in the high-quality development level of agriculture between cities shows the trend of first expanding and then narrowing. Thirdly, the curve tail on the right side is constantly thinning, which indicates that the difference between high-quality agricultural economy development and average-level development was reduced. Finally, in terms of the number of curved peaks, the kernel density curve transitions, from a single peak to a double peak, with a clear bimodal distribution in 2020 but a large height difference between the lateral and main peaks, indicates that the high-quality development of agriculture in this year has the polarization characteristic, and the extensibility of the distribution on the left and right sides of the curve in this year was reduced, implying that high-quality agricultural economic development changed from diffusion to convergence.

In short, although the high-quality development of the agricultural economy in most cities is still low, the overall trend is improving, the spatial difference is shrinking, and the overall development level is changing from diffusion to convergence.

4.3. Spatial Inspection and Selection

(1) Space autocorrelation test

The global Moran's index of agricultural economic quality and factor misallocation in prefecture-level cities was calculated using Stata16.0 software. The detailed results were placed in Table 3. The results indicate that there is a significant positive spatial correlation between high-quality agricultural economy and factor misallocation, making it suitable to use spatial econometric models.

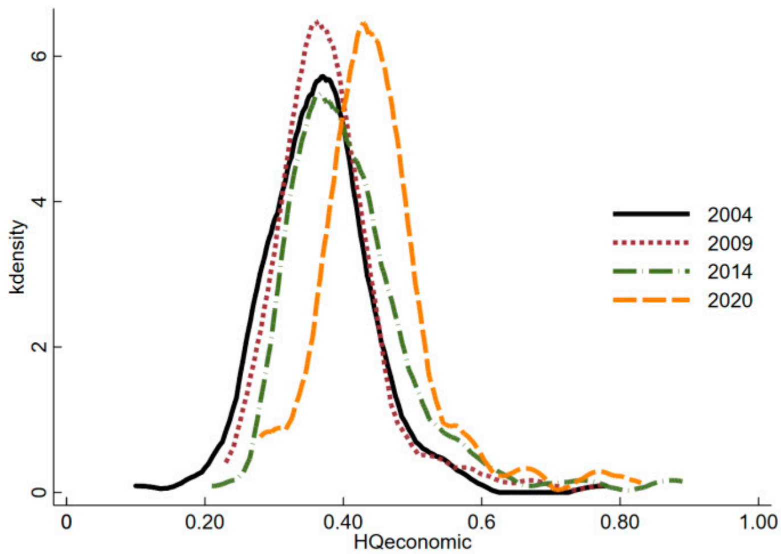

Figure 2. Kernel density map of high-quality agricultural economic development from 2004 to 2020.

Table 3. The overall Moran's index of high-quality agricultural economy and factor misallocation in prefecture-level cities.

Year	Geographical Distance Weight				Economic Geography Weight			
	$HQ_{economic}$		F_{mis}		$HQ_{economic}$		F_{mis}	
	I	p	I	p	I	p	I	p
2004	0.121	0.000	0.016	0.020	0.117	0.000	0.019	0.008
2005	0.142	0.000	0.007	0.148	0.134	0.000	0.019	0.008
2006	0.145	0.000	0.007	0.165	0.140	0.000	0.025	0.001
2007	0.155	0.000	0.015	0.023	0.143	0.000	0.034	0.000
2008	0.184	0.000	0.019	0.007	0.162	0.000	0.041	0.000
2009	0.170	0.000	0.023	0.002	0.136	0.000	0.052	0.000
2010	0.166	0.000	0.023	0.001	0.133	0.000	0.054	0.000
2011	0.187	0.000	0.026	0.001	0.149	0.000	0.057	0.000
2012	0.198	0.000	0.025	0.001	0.156	0.000	0.055	0.000
2013	0.200	0.000	0.026	0.000	0.158	0.000	0.057	0.000
2014	0.210	0.000	0.030	0.000	0.172	0.000	0.063	0.000
2015	0.213	0.000	0.035	0.000	0.168	0.000	0.071	0.000
2016	0.174	0.000	0.039	0.000	0.135	0.000	0.076	0.000
2017	0.157	0.000	0.048	0.000	0.115	0.000	0.091	0.000
2018	0.163	0.000	0.048	0.000	0.121	0.000	0.088	0.000
2019	0.155	0.000	0.046	0.000	0.114	0.000	0.078	0.000
2020	0.125	0.000	0.042	0.000	0.090	0.000	0.064	0.000

(2) Model selection

The specific form of the spatial econometric model needs to be tested before the regression analysis can be performed. According to Table 4, both the traditional and RLM statistics pass the significance test with at least 10%, which indicates that the Spatial Durbin Model (SDM) should be chosen, according to Elhorst (2010) [42]. The results of the Wald and LR tests once again demonstrated the rationality of choosing the SDM model. The Hausman test indicates that we should choose an SDM model with fixed effects for this article. The SDM model under fixed effect includes three forms: the time-fixed effect, the space-fixed effect, and the space–time-fixed effect. By comparison, we found that most of the variables in the time-fixed effect model passed the significance test, and the direction of action of the core explanatory variables was more in line with the expectation; thus, the Spatial Durbin model with time-fixed effects was chosen as the benchmark model for analysis.

Table 4. Space metering model test.

Test Indicator	Statistical Value	*p*-Value
LM-error	418.77	0.000
LM-lag	3.28	0.027
Robust LM-error	422.20	0.000
Robust LM-lag	3.75	0.053
Wald-lag	57.69	0.000
Wald-error	74.53	0.000
LR-lag	57.06	0.000
LR-error	73.51	0.000
Hausman	1168.750	0.000

4.4. Benchmark Regression

On the basis of the model test in the above section, and to avoid the effect of heteroscedasticity, the spatial Durbin model with the time-fixed effect was selected to analyze the impact of factor misallocation on the quality of the agricultural economy in prefecture-level cities; in real regression, all the absolute variables were treated using a logarithm. The results are shown in Table 5.

Table 5. Results of baseline regression.

Variable	F_{mis}	P_{gdp}	M_{ech}	U_{rban}	F_{sup}	$I_{ndustry}$	Agr_{ia}
Main	0.0064 (1.279)	0.0577 *** (13.452)	−0.0492 *** (−10.730)	0.0033 *** (25.000)	−0.4930 *** (−4.126)	−0.0022 (−1.158)	0.0953 *** (35.042)
W*x*	−0.1350 ** (−2.105)	0.2530 *** (3.764)	−0.2950 *** (−4.066)	0.0078 *** (4.789)	6.6880 *** (4.127)	−0.1480 *** (−5.106)	−0.0143 (−0.420)
Direct effect	0.0075 (1.468)	0.0562 *** (13.538)	−0.0473 *** (−10.394)	0.0032 *** (24.869)	−0.5350 *** (−4.715)	−0.0010 (−0.556)	0.0957 *** (36.217)
Indirect effect	−0.0837 ** (−2.214)	0.1320 *** (2.991)	−0.1550 *** (−3.476)	0.0033 *** (3.620)	4.1680 *** (3.986)	−0.0861 *** (−4.996)	−0.0467 ** (−2.530)
Total effect	−0.0762 ** (−2.010)	0.1882 *** (4.228)	−0.2023 *** (−4.454)	0.0065 *** (7.383)	3.6330 *** (3.432)	−0.0871 *** (−4.954)	0.0490 *** (2.685)
ρ				−0.7020 *** (−4.104)			
sigma^2				0.0043 *** (36.052)			
R-squared				0.2587			
Log-likelihood				3417.6956			
N				2618			

Note: ** $p < 0.05$, and *** $p < 0.01$, *t* values in parentheses.

Table 5 shows that the spatial autoregressive coefficient ρ of high-quality agricultural economy is significantly negative at the level of 1%, indicating that the improvement in the level of high-quality development of the local agricultural economy has a significant negative impact on the agricultural development of adjacent areas. On the one hand, it proves the rationality and necessity of incorporating the spatial effect into the econometric model, and it also shows that a siphon effect exists in the process of high-quality agricultural economic development in prefecture-level cities. That is to say, a city with a high level of agricultural economic development will use its own advantages to attract production factors that promote the development of local agriculture, but this has a negative impact on the agricultural development of adjacent cities. Because the estimated coefficients of SDM are biased and cannot be interpreted as a marginal effect [33], the regression results only provide a preliminary judgement on the action direction of each factor. Therefore, it is necessary to further decompose the total effect.

(1) The direct effect coefficient of factor misallocation is 0.0075, but this is not statistically significant. The positive effect may be due to the moderate misallocation of production factors, which can help local agriculture to mobilize and allocate resources and resist the siphon effect of adjacent cities on local agricultural production factors; this is helpful to

the development of local agriculture in a short time, but its direction and intensity are not obvious because it violates the law of markets. The coefficient of spillover effect is −0.0837 passed the 5% significance test, which indicated that local factor misallocation inhibited the high-quality development of the agricultural economy in adjacent cities. The reason for this may be that there is a zero-sum game in political promotion, and the comparison with the performance of adjacent governments at the same level is an important factor in evaluating the promotion of officials [43]; therefore, in the process of promoting local agricultural development and competing for agricultural resources, local governments have incentive to promote local agricultural development through market segmentation and even to produce beggar-thy-neighbor competition. This makes it impossible for the adjacent cities to adjust and optimize the production factors through the market rules, which results in a negative influence of the factor misallocation on high-quality agricultural economic development in the adjacent cities. Thus far, Hypothesis 1 has been partially verified.

(2) The direct effect of the economic development level was 0.0562, and the spillover effect was 0.1320; both passed the 1% significance level test. This shows that an improvement in economic development level will promote high-quality agricultural economic development locally and in adjacent cities. A higher level of regional economic development can not only provide sufficient financial support and technical equipment for agricultural development and increase the efficiency of agricultural production, but also narrow the consumption gap between urban and rural residents [44] by improving the efficiency of agricultural production while maintaining fair distribution. The improvements in the economic development levels of adjacent cities can play a radiative role in the development of local agriculture through the diffusion effect.

(3) The direct effect and spillover effect of the mechanization level were significantly negative, at the 1% level. This indicates that the level of mechanization will hinder improvement in the high-quality development of the agricultural economy locally and in adjacent cities. The main reason for this is that the level of agricultural mechanization in China is relatively low compared with those of developed countries, which has become an important crux restricting the construction of modern agriculture and the process of agricultural modernization [45]. On the other hand, the cross-region operation of agricultural machinery mainly takes place between the different latitudes with time differences, while the agricultural production of the adjacent cities is mostly carried out at the same time; therefore, improvement at the local agricultural mechanization level cannot promote high-quality development of the agricultural economy in adjacent cities.

(4) The direct and indirect effects of urbanization are significantly positive at the level of 1%, indicating that improvements in the level of urbanization can promote improvement in high-quality agricultural economic development locally and in adjacent cities. The improvement in the level of urbanization can provide technical, market, and financial support for agriculture and then promote improvements in the high-quality development of the agricultural economy.

(5) The improvement in the level of financial support for agriculture has restrained improvements in the high-quality development of local agricultural economies. The reason for this is that the main grain-producing areas bear the important task of ensuring national food security, and their financial investment in agricultural support tends to focus on the quantity rather than the quality of agricultural output [46]. The spillover effect is significantly positive, indicating that the improvement in local financial support toward agriculture has promoted the high-quality development of the agricultural economy in adjacent cities.

(6) The improvement in local industrialization will restrain improvements in the high-quality development of the agricultural economy in adjacent cities. The development of industrialization cannot be separated from agricultural land resources or labor resources, and the agricultural sector needs to increase production capacity to meet its demand for raw materials. When the local government cannot provide the necessary conditions for the development of industrialization, it will absorb the relevant factors of production from the

neighboring regions based on its own developmental advantages; furthermore, the current level of coordinated development between workers and farmers is still relatively low. Therefore, the rapid development of local industrialization has inhibited improvements in the high-quality developmental level of the agricultural economy in neighboring cities.

(7) The direct effect (indirect effect) of agricultural industrial agglomeration is significantly positive (negative) at the level of 1%, indicating that agricultural industrial agglomeration promotes improvements in the high-quality development of local agricultural economies, which is not conducive to improvements in the high-quality development of agricultural economies in neighboring cities. The main reason for this is that local agri-industry agglomeration reduces the production cost and transaction cost of agriculture by improving the division of labor and professional cooperation, and promotes the expansion of agricultural scale, thus generating economies of scale. However, the continuous gathering of industries leads to the siphon effect, which continuously absorbs the agricultural production factor from neighboring cities and reduces the high-quality development of the agricultural economy.

4.5. Robustness and Endogenetic Treatment

This section tests the robustness of the results of the benchmark regression part from the following aspects, and the specific results were placed in Table 6.

Table 6. Results of robustness and endogenesis.

Variable	(1)	(2)	(3)	(4)	(5)
$HQ_{economic\text{t-1}}$				0.4580 *** (66.377)	
$W \times HQ_{economic\text{t-1}}$				0.5000 *** (2.731)	
F_{mis}	0.0053 (1.056)	0.0078 (1.595)	0.0044 (0.825)	0.0062 (0.525)	0.0053 (1.070)
Agr_{stru}					0.0641 *** (8.032)
$W \times F_{mis}$	−0.1240 ** (−1.973)	−0.1330 ** (−2.107)	−0.1490 ** (−2.196)	−0.1260 *** (−5.625)	−0.1080 * (−1.647)
$W \times Agr_{stru}$					−0.0626 (−0.658)
ρ	−0.4970 *** (−2.940)	−0.6860 *** (−4.028)	−0.6210 *** (−3.476)	−2.6580 *** (−16.522)	−0.6630 *** (−3.904)
$sigma^2$	0.0043 *** (36.182)	0.0042 *** (36.058)	0.0043 *** (33.889)	0.0006 *** (38.587)	0.0042 *** (36.065)
R-squared	0.2632	0.2587	0.2389	0.2353	0.2579
N	2618	2618	2310	2464	2618

Note: * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$, t values in parentheses, same in Tables 7 and 8.

(1) Robustness test

Changing the weight: The spatial weight matrix is the basic element of the spatial econometrics model, and different weight settings may affect the stability of the model estimation. In the above section, the spatial weights are constructed based on the spatial geographic distance to analyze the related variables. To avoid the impact of selection bias in the spatial weight matrix on the model results, further considering the spatial correlation between the economy and distance between cities, an economic geography weight matrix was constructed to test the robustness of the previous results. The results were placed in column (1) of Table 6. We can see that, under different spatial weights, the direction of city-level factor misallocation on the high-quality development of the agricultural economy has not fundamentally changed; only the magnitude of the coefficient is different. Hence, the results of the benchmark regression are robust.

Tail reduction processing: In order to reduce the influence of variable outliers on the empirical results and to depict the relationship between factor misallocation and high-quality agricultural economic development more truthfully, the dependent variable and the core explanatory variable are shrunk by 1% quantile; the results of re-regressions were placed in column (2) of Table 6. We found that, after excluding outliers, the spatial lag term of factor misallocation is still significantly negative, which further proves the robustness of the benchmark regression results.

Adjusting the time window: China announced the cancellation of agricultural tax in 2006, which not only reduced the burden on farmers and improved their enthusiasm for agricultural production, but also provided strong policy support for the high-quality development of the agricultural economy. Therefore, the samples after 2006 were selected for re-regression, and the specific results were placed in column (3) of Table 6. We found that, after adjusting the time window, the action direction of the core explanatory variables remained highly consistent with the benchmark regression results.

(2) Endogenetic treatment

The existence of endogeneity destroys the consistency of parameter estimation. This section deals with the possible existence of endogeneity in the model from the following two aspects.

In order to mitigate the causality between independent variables and dependent variables, the time and space lag variables of dependent variables were added to the baseline model, and the dynamic spatial Durbin model was used to re-estimate. As shown in column (4) of Table 6, the time lag indicates that there is time inertia in the high-quality development of the agricultural economy. From the time–space lag term, we can see that high-quality agricultural economic development in the last period of adjacent cities has a positive impact on the high-quality development of the local agricultural economy in the current period. The spatial lag coefficient of the independent variables was significantly negative, at the 1% level, and smaller than that of the baseline regression, indicating that the static spatial Durbin model overestimated the impact of factor misallocation on high-quality agricultural economic development. The reason for this is that the first-order lag term of the explained variable can separate the potential factors (such as institutional environment, economic policy, etc.) that affect the high-quality development of the agricultural economy from the spatial factors, correcting for bias in the static space Durbin model. After considering the endogeneity, the direction of the core explanatory variables was consistent with the results of the baseline regression.

A missing variable is an important cause of endogenesis. In order to alleviate the possible endogeneity of the model, the important variable agricultural planting structure (*Agrstru*) was added. By 2022, the grain output of our country achieved '19 successive abundant', which has laid a solid foundation for promoting the high-quality development of the agricultural economy, but, at the same time, there is also an awkward situation in which the production, inventory, and import volumes all increase simultaneously. On the other hand, the supplies of water and land resources in China are increasingly tight, while the consumption structure of residents is constantly upgrading. Therefore, adjusting the agricultural planting structure has become a practical choice toward promoting high-quality agricultural development. Based on the agricultural planting structure setting by Luo and Qiu (2018) [47], the proportion of grain-crop-planting area to crop-planting area was measured. The specific regression results are placed in column (5) of Table 6. We found that the adjustment of agricultural planting structure can promote improvement in the high-quality development of local agricultural economies, but the impact on adjacent cities is not significant. After adding the new variable, the action direction of element misallocation is still consistent with the benchmark regression results.

In conclusion, the relationship between the dependent variable and independent variable remained unchanged after treatment for robustness and endogenesis, but the significance is different, which fully shows that the empirical results in the above section are robust and reliable.

4.6. Heterogeneity Analysis

In the above analysis, the effect of factor misallocation on the high-quality development of the agricultural economy was investigated from the perspective of the full sample, and the effect was confirmed using multiple robustness tests. However, it is worth noting that, due to factor misallocation and the constant changes in time and space of high-quality agricultural economic development, the influence of the former on the latter may have asymmetric effects under different conditions; the discussion of such situations helps to form differentiated policy orientations. In order to achieve the above purposes, we will conduct sub-sample tests in this section on the bases of geographical location, high-quality agricultural economic development, and differences in factor allocation; the specific results are placed in Table 7.

Table 7. Heterogeneity Test results.

Category	Geographic Heterogeneity		Heterogeneity of Development Level		Heterogeneity of Factor Allocation	
	(1)	(2)	(3)	(4)	(5)	(6)
	Northern	Southern	High Level	Low Level	Government Led	Market Led
Direct effect	−0.0146 ** (−2.147)	−0.0067 (−0.736)	−0.0268 *** (−3.116)	0.0111 *** (2.581)	0.0084 (1.327)	0.0029 (0.349)
Indirect effect	−0.1040 ** (−2.549)	0.0013 (0.030)	0.0904 (1.594)	0.0010 (0.046)	−0.0605 * (−1.670)	−0.1110 (−1.314)
Total effect	−0.1186 *** (−2.865)	−0.0054 (−0.116)	0.0636 (1.350)	0.0121 (0.543)	−0.0521 (−1.426)	−0.1080 (−1.271)
Control variable	Control					
N	1326	1292	714	1904	1540	1078

(1) Geographic location heterogeneity: To verify whether there is spatial heterogeneity in the impact of factor misallocation on the high-quality development of the agricultural economy, the samples were grouped by south and north, the provinces of Hebei, Inner Mongolia, Heilongjiang, Jilin, Liaoning, Shandong, and Henan are classified as northern regions, with the rest classified as the south. The samples from different regions were re-estimated, and the results are placed in columns (1) and (2) of Table 7. In terms of the decomposition effects, factor misallocation inhibits the quality of agricultural economic development in northern China and has a significant negative spatial spillover effect, while it has no significant effect on the development of the agricultural economy in southern China; this may be related to the relatively low level of factor misallocation in the south.

(2) Heterogeneity of developmental level: Scholars have found that the high-quality development of agriculture is inseparable from the rational allocation of agricultural production factors [48]. Will the direction and intensity of factor misallocation change with differing levels of agricultural economic development? To verify this, we based this segment of the article on the hot spot analysis module of ArcGIS10.8 and used the natural discontinuity method to divide the annual average of high-quality agricultural economic development into two levels: hot spots and cold spots. Hot spots represent high-level areas of agricultural economic development, while cold spots represent low-level areas of development. The regression results for each sample are presented in columns (3) and (4) of the table below. From the perspective of various decomposition effects, there is a significant inhibitory effect of factor misallocation on agricultural economic development in high-level areas. The main reason for this is that most cities with higher levels of agricultural development belong to areas with higher levels of factor misallocation, which significantly inhibits local agricultural development. There is a promoting effect on the agricultural development of low-level areas. According to the law of factor flow, areas with lower levels of agricultural development will have production factors flowing toward areas with

higher levels of agricultural development. However, the main grain-producing areas bear the heavy responsibility of ensuring national food security. To protect local agricultural development, local governments tend to adopt market segmentation to restrict the flow of agricultural production factors, adjusting and allocating local agricultural production resources through moderate factor misallocation in order to promote local agricultural development.

(3) Heterogeneity of factor allocation: Accelerating the reform of the rural factor market is a necessary condition toward promoting the level of agricultural modernization [49]. Since the Third Plenary Session of the 18th CPC Central Committee in 2013, the main body of production factor allocation is gradually yielding from the government to the market. Has the impact of factor misallocation on agricultural development changed before and after the reform? With regard to this question, we divide the samples in this section with 2013 as the boundary and test the impacts of factor market allocation on agricultural development before and after it. The results are placed in columns (5) and (6) of Table 7. From the coefficient of each decomposition effect, before the factor market (government-led) reform, local factor misallocation had a significant negative impact on the agricultural development of adjacent cities. The main reason for this was that the segmentation of the factor market led to production factors that could not be fully transferred according to market rules, and the production factors could not be adjusted and allocated through the free flow of factors between cities. However, after the factor market (market-led) reform, although the factor misallocation still had a negative impact, it had no statistical significance, indicating that the factor market reform improved the efficiency of resource allocation, and restrained the hindering effect of factor misallocation on improvements in high-quality agricultural economic development.

To summarize, the impact of factor misallocation on the high-quality development of the agricultural economy shows different characteristics with the change in time and space. Therefore, Hypothesis 1 has been further validated.

4.7. Inspection of Channel Mechanism

We consecutively introduced the interactive terms of agricultural industrial upgrading, agricultural science and technological progress, and factor misallocation to explore the effect path of factor misallocation on the high-quality development of the agricultural economy. Because the benchmark regression segment found that the impact of factor misallocation on the high-quality development of the agricultural economy only had a negative spatial spillover effect, if the result of the interactive term was significantly positive, it would show that the upgrading of agricultural industry and the progress of agricultural science and technology can effectively alleviate the negative spillover effect of factor misallocation on agricultural development.

The interactive term of factor misallocation and agricultural industrial upgrading ($F_{mis} \times U_{pgrade}$) was introduced into the model for re-regression, and the specific results were placed in column (1) of Table 8. We found that the spatial lag coefficient of the intersection term was 6.2150 and significantly positive at the level of 1%, which preliminarily confirms the role of the upgrading of agricultural industrial structures in alleviating factor misallocation. From the perspective of the decomposition effect, the spillover effect of the multiplicative term passed the 5% significance level test, indicating that agricultural industrial upgrading can effectively adjust the negative impact of factor misallocation on the high-quality development of the agricultural economy in adjacent cities. In this paper, in order to test the moderating effects of agricultural science and technological progress, we further introduce the interaction between factor misallocation and agricultural science and technological progress ($F_{mis} \times T_{ech}$) for re-regression, and the specific results are placed in column (2) of Table 8. We found that the spatial lag coefficient of the interaction term is 1.5310, and the spillover effect coefficient is 1.3380, which passed the significance level test, thus proving that the progress of agricultural science and technology can effectively adjust the negative impact of local factor misallocation on the high-quality development of the agricultural economy in neighboring cities.

Table 8. Mechanism Test of Factor Misallocation on Quality of Agricultural Economy.

Independent Variable	Dependent Variable: *HQeconomic*					
		(1)			(2)	
F_{mis}		0.0047 (0.922)			−0.0075 ** (−2.256)	
U_{pgrade}		−0.3050 *** (−7.373)				
$F_{mis} \times U_{pgrade}$		0.2100 (1.144)				
T_{ech}					−0.2370 *** (−44.303)	
$F_{mis} \times T_{ech}$					0.5150 *** (56.444)	
W × F_{mis}		−0.0894 (−1.390)			0.1500 (0.777)	
W × U_{pgrade}		0.5550 (0.961)				
W × $F_{mis} \times U_{pgrade}$		6.2150 *** (2.614)				
W × T_{ech}					−0.7590 ** (−2.467)	
W × $F_{mis} \times T_{ech}$					1.5310 *** (3.195)	
Category		$F_{mis} \times U_{pgrade}$			$F_{mis} \times T_{ech}$	
Decomposition of intersection terms	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
	0.1970	4.3020 **	4.4990 ***	0.5150 ***	1.3380 *	1.8530 **
	(1.126)	(2.499)	(2.584)	(54.827)	(1.858)	(2.562)
Control variable				Control		
ρ		−0.499 *** (−2.952)			−0.2080 (−0.844)	
$sigma^2$		0.0042 *** (36.183)			0.0018 *** (36.177)	
N		2618			2618	

In summary, it can be seen that, in the process of factor misallocation affecting the high-quality development of the agricultural economy, agricultural industrial upgrading and technological progress can effectively alleviate the adverse effects of local factor misallocation on the high-quality development of the agricultural economy in adjacent cities. At this point, Hypotheses 2 and 3 have been fully validated.

4.8. Nonlinear Discussion

In order to further test the nonlinear impact of factor misallocation on the high-quality development of the agricultural economy, we took the upgrading of the agricultural industry and the progress of agricultural science and technology as threshold variables in this paper and verified them using the panel threshold model proposed by Hansen (1999) [50]. Due to the lack of mature methods with which to combine spatial econometric models with panel threshold models [51], a panel threshold model with dual-fixed individual and time points was adopted for analysis based on previous research. The specific threshold model settings are as follows:

$$y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 x_{it} \cdot I(q_{it} \leq \gamma) + \beta_3 x_{it} \cdot I(q_{it} > \gamma) + \mu_i + \varepsilon_{it} \quad (8)$$

In Formula (8), y_{it} is the dependent variable for the high-quality development of the agricultural economy, and i and t represent individuals and years, respectively. X_{it} is the control variable, consistent with the benchmark regression model. x_{it} is the core explanatory variable, namely factor misallocation. q_{it} is the threshold variable, which refers to agricultural industrial upgrading and the progress of agricultural technology. γ is the threshold value, $I(\cdot)$ is the indicative function, μ_i is an unobserved feature of the individual, and ε_{it} is a random perturbation term.

We used Hansen's (1999) [48] research approach as a reference against which to test the existence of threshold effects in the model, while determining the number and value of thresholds. Table 9 shows the test results of the threshold effect. Using Stata16.0 statistical software, we obtained the p-value corresponding to the test statistic through repeated

(300 times) sampling. It can be seen that, when the agricultural industry is upgraded to a threshold variable, there is a single threshold effect, with a threshold value of 0.02, which passes the 5% significance level test. When agricultural technological progress is a threshold variable, there is a double threshold effect, with threshold values of 0.37 and 0.90, both of which pass the 1% significance level test.

Table 9. Threshold Effect Test and Threshold Values.

Threshold Variable	Model Checking	*F* Value	*p* Value	Critical Value			BS	Threshold Estimate	95% Confidence Interval
				1%	5%	10%			
Agricultural industrial upgrading	Single threshold	23.90	0.0900	37.94	29.12	22.30	300	0.02	(0.0100, 0.0300)
Agricultural scientific and technological progress	Single threshold	394.62	0.0000	46.15	33.98	25.40	300	0.37	(0.3506, 0.3716)
	Double threshold	212.07	0.0000	45.75	33.54	29.23	300	0.90	(0.8754, 0.9282)

According to the principle of the threshold model, the threshold estimate is the value of γ corresponding to the likelihood ratio statistic approaching zero. Figure 3 shows the likelihood ratio function of the threshold variable, with Figure 3a showing the likelihood ratio function of agricultural industrial upgrading as the threshold variable, and the other two showing the likelihood ratio function of agricultural technological progress as the threshold variable, among them, Figure 3b showing the likelihood ratio function of the first threshold of agricultural technological progress, and Figure 3c showing the likelihood ratio function of the second threshold of agricultural technological progress. The red dashed line in the figure represents the critical value of LR at the 5% significance level, which is 7.35. The areas below the dashed line constitute a 95% confidence interval for the threshold value. Since the critical value is significantly greater than the minimum value of LR statistics, it is considered that the above threshold values are true and effective.

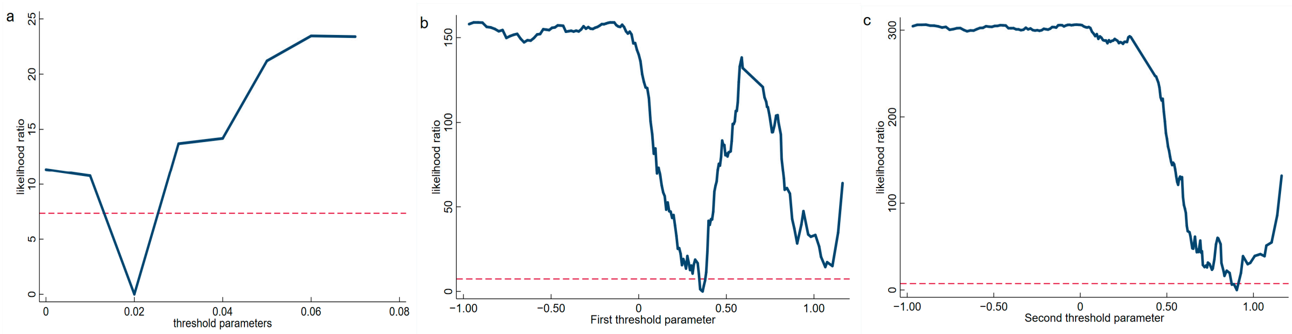

Figure 3. Threshold Variable Likelihood Ratio function diagram.

After determining the threshold value, we further used Stata16.0 statistical software to obtain the regression results of the panel threshold model (Table 10). From Table 10, it can be seen that, when agricultural industrial upgrading is set as the threshold variable, there is a significant difference in the impacts of factor misallocation on the high-quality development of the agricultural economy. Specifically, when the agricultural industrial upgrade is below the threshold value of 0.02, the coefficient of factor misallocation is 0.0147, which passes the 1% significance level test. When the agricultural industrial upgrade is above the threshold value of 0.02, the regression coefficient of factor misallocation is 0.0044, which does not have statistical significance, and the coefficient value significantly decreases. With the optimization and upgrading of the agricultural industry, the impact of factor misallocation on high-quality agricultural economic development constantly weakens. The reason for this is that the local governments in the main production areas bear the important task of promoting agricultural development and ensuring national food security. When the developmental level of the agricultural industry is low, due to its relatively weak industrial foundation and competitiveness, according to the infant industry theory, the local government will protect the development of the local agricultural industry by dividing the market. At this point, moderate factor misallocation can help local governments to adjust and allocate agricultural resources within the region, thus helping them to resist the siphon effect of other cities on local agricultural production factors, and further promoting improvements in the high-quality development of the agricultural economy. With the continuous development of the agricultural industry, the allocation efficiency of agricultural production factors within the region continues to improve [52], the degree of factor misallocation continues to decrease, and the impacts on the high-quality development of the agricultural economy are no longer significant.

Table 10. Parameter estimation results of panel threshold model.

Variable	Coefficient	*t*-Value	Variable	Coefficient	*t*-Value
P_{gdp}	0.0765 ***	(14.406)	P_{gdp}	0.0661 ***	(13.734)
M_{ech}	−0.0177 ***	(−3.559)	M_{ech}	−0.0126 ***	(−2.820)
U_{rban}	−0.0000	(−0.393)	U_{rban}	0.0002 **	(2.000)
F_{sup}	−1.2950 ***	(−16.655)	F_{sup}	−0.8720 ***	(−12.058)
$I_{ndustry}$	−0.0025 ***	(−13.475)	$I_{ndustry}$	−0.0021 ***	(−12.378)
Agr_{ia}	0.0483 ***	(21.106)	Agr_{ia}	0.0412 ***	(19.632)
$F_{mis}\cdot I\ (U_{pgrade} \leq 0.02)$	0.0147 ***	(3.383)	$F_{mis}\cdot I\ (T_{ech} \leq 0.37)$	−0.0054	(−1.388)
$F_{mis}\cdot I\ (U_{pgrade} > 0.02)$	0.0044	(0.995)	$F_{mis}\cdot I\ (0.3646 < T_{ech} \leq 0.90)$	0.0299 ***	(7.395)
			$F_{mis}\cdot I\ (T_{ech} > 0.90)$	0.0906 ***	(17.221)
Constant	−0.2910 ***	(−6.395)	*C*	−0.2000 ***	(−4.832)
N	2618		*N*	2618	

Note: ** $p < 0.05$, and *** $p < 0.01$, t values in parentheses.

When the progress of agricultural technology is used as a threshold variable, there is a significant difference in the impacts of factor misallocation on the high-quality development of the agricultural economy. Specifically, when the progress of agricultural technology is below the threshold value of 0.37, the regression coefficient of factor misallocation is negative, but not significant. Conversely, when agricultural technological progress falls between the threshold values of 0.37 and 0.90, the regression coefficient of factor misallocation is significantly positive, at the 1% level. When the progress of agricultural technology exceeds the threshold value of 0.90, the regression coefficient of factor misallocation further increases and passes the 1% significance level test. The reason for this is that, when agricultural scientific and technological progress is below the threshold, the existence of factor misallocation reduces agricultural total factor productivity and agricultural output, widens the income gap among residents [53], and has a negative impact on the high-quality development of the agricultural economy. At this time, although the level of agricultural science and technology is relatively low, it still plays an important role in improving agricultural production efficiency and promoting farmers' income to some extent, under the combined effects of the above two variables, although the direction of factor misallocation in the high-quality development of the agricultural economy is negative, it no longer has statistical significance. As the level of agricultural technology further improves and crosses the threshold, there is a significant positive correlation between factor misallocation and high-quality agricultural economic development, and the intensity of the effect continues to increase. This is not in line with expectations. On the one hand, the possible reason for this is that, although China's agriculture has been constantly changing toward high-quality development, the concept of relying on factor input to promote agricultural development is still difficult to change, due to the inertia of the original technical support system and agricultural and rural working mechanisms [54]. Agricultural labor released by agricultural scientific and technological progress, represented by labor-saving technology, cannot be transferred quickly in the short term, still stuck in the agricultural sector for agricultural production activities. Although there is a misallocation between capital and labor production factors, a large proportion of the investment in production factors can still promote improvements in the high-quality development of the agricultural economy. On the other hand, the reason may actually be that, with the continuous improvements in agricultural technology and the gradual decrease in factor misallocation issues, the positive promoting effects of agricultural technological progress on high-quality agricultural economic development has far exceeded its negative impacts. Therefore, with improvements in agricultural technology, factor misallocation has a promoting effect on the high-quality development of the agricultural economy. So far, Hypothesis 1 has been fully validated.

5. Discussion

Our main aim in this paper was to reveal the spatial effects and nonlinear effects of factor misallocation on the development of a high-quality agricultural economy. We found that factor misallocation inhibited the improvement of a high-quality development level of the agricultural economy in adjacent cities, but this inhibition can be alleviated in the adjustment of agricultural industry upgrading and agricultural science and technology progress. This is consistent with the previous study of the impact of factor misallocation on agricultural development. For example, based on the data of prefecture-level cities in the major grain-producing areas of northeast China, Qin (2022) [55] found that with the optimization and upgrading of the agricultural industry and the continuous improvement of the level of agricultural science and technology, the negative impact of capital misallocation on agricultural output is continuously weakened [55]. Based on the panel data at the provincial level in China, Lei et al. (2023) found that the impact of capital misallocation and labor misallocation on China's agricultural green total factor productivity has a spatial effect [56]. As expected, our empirical results found that the impact of factor misallocation on the high-quality development of the agricultural economy in adjacent cities was significantly negative at the level of 1%, and this negative impact could be continuously weakened with the upgrading of agricultural industry and the progress of agricultural science and technology. Our conclusions are in general agreement with those of the above-mentioned scholars. Different from previous studies, we found that agricultural science and technology progress strengthened the positive impact of factor misallocation on the high-quality development of the local agricultural economy. On the one hand, the possible reason is that the agricultural labor force released by the progress of agricultural science and technology represented by labor-saving technology cannot be transferred out of the agricultural sector in a short time due to the influence of the system and mechanism (Xie and Lv, 2020) [57]. At this time, although there is a misallocation in agricultural production factors, the perception of producers' promoting agricultural development through factor investment has not been completely changed (Li, 2017) [54]; therefore, the input of a large number of production factors can still promote the improvement of the high-quality development of the agricultural economy. On the other hand, due to the long-term misallocation of agricultural science and technology resources in China (Yang and Ding, 2019) [20], the agricultural science and technology progress of prefecture-level cities failed to effectively adjust the impact of factor misallocation on the high-quality development of the agricultural economy.

Notably, we further analyze the nonlinear effect of factor misallocation on the high-quality development of the agricultural economy. Previous studies based on the macro field show that the factor allocation needs to be in a reasonable range to play a promoting role (Tu, 2017) [58], and only excessive factor misallocation could affect economic development (Wang and Zhao, 2022) [29]. Whether it shows the same features in agriculture remains to be further verified. Based on empirical test of the threshold model, we found that the effect of factor misallocation on the development of a high-quality agricultural economy has a significant nonlinear feature as agricultural science and technology develop.

We base our study in this paper on data at the prefecture level. Compared with the analysis at the provincial level, its spatial scope is relatively small, so the results can provide a valuable theoretical reference for municipal governments at the prefecture level to formulate factor allocation policies. However, this article also has some flaws. The limitation of this manuscript is that it only analyzes the impact of factor misallocation on high-quality agricultural economic development from an economic perspective. Although it accurately portrays high-quality development of the agricultural economy of prefecture-level cities in the main grain-producing areas and analyzes the impact of factor misallocation on it, according to the multifunctional theory of agriculture, in addition to economic functions, agriculture has different functions, such as ecological and social functions. In the future, we should continue to collect data in terms of ecological function or social function in order to study the high-quality development of agriculture in prefecture-level cities in major grain-producing regions, and further analyze the effect of factor misallocation on the high-quality development of agriculture from different perspectives.

6. Conclusions and Inspiration

Based on the panel data from 154 prefecture-level cities in 13 major grain-producing regions in China from 2004 to 2020, we used the coupling coordination model to measure the level of high-quality development of the agricultural economy; analyzed its spatiotemporal evolutionary characteristics; and analyzed the spillover effect, mechanisms, and nonlinear relationships of factor misallocation on the high-quality development of the agricultural economy, based on the econometric model. The specific conclusions we reached in this paper are as follows:

(1) The degree of factor misallocation in prefecture-level cities is relatively light, the overall trend is declining, and the differences between prefecture-level cities are narrowing. Although the high-quality development of the agricultural economy is constantly improving, it is generally in a low-locked state. As time goes on, its spatial differences continue to shrink, with the overall trend transitioning from diffusion to convergence.

(2) There is a significant negative spatial spillover effect of factor misallocation on the high-quality development of the agricultural economy, while the impact on local agricultural development is not significant. With differences in time and space, the impacts of factor misallocation on the high-quality development of the agricultural economy also show significant spatiotemporal heterogeneity.

(3) In the process of factor misallocation inhibiting improvements in high-quality agricultural economic development in adjacent cities, there is a significant moderating effect of agricultural industrial upgrading and agricultural technological progress, and the impacts of factor misallocation on the high-quality development of the agricultural economy have nonlinear characteristics.

Based on our research conclusions, the following suggestions are posited: Firstly, starting from the relevance of the factor market, we should jointly cultivate the agricultural production factor market, thereby improving the institutional system to promote the free flow of factors, giving full play to the resource endowment advantages of major grain-producing areas, building a rural idle resource information-sharing platform based on data technology, and promoting the sharing of idle resources such as "agricultural land, homestead, agricultural machinery, labor and agricultural products" in adjacent areas. We should aim to improve the agricultural socialized service system, establish an agricultural service industry alliance, form a rapid response system for agricultural services, and improve the efficiency of factor allocation.

Secondly, expanding the market space of agricultural factors and leading the optimization and upgrading of agricultural industrial structures would allow prefecture-level cities in major grain-producing areas to extend the agricultural industry chain by cultivating advantageous and characteristic industries. At the same time, we should strengthen exchanges and cooperation among provinces and cities within the main production areas, build a "point-line-area" regional cooperation mechanism, form an industrial agglomeration effect, promote the efficient flow of agricultural production factors among regions, and promote the optimization and upgrading of industrial structures.

Finally, "science and technology + digital" enables coordinated improvements in economic and environmental benefits in major grain-producing areas. Although the grain production in the main production areas has continuously improved, it has not led to a decline in high-quality development of agricultural ecology, which reflects that the coordination and unification of economic benefits and ecological benefits can be achieved through the process of agricultural modernization. Major grain-producing areas need to take advantage of the new opportunities created by the digital economy to change the input structure of traditional factors, iteratively upgrade to the "Internet + agricultural services + green technology" mode, and quickly change the traditional mode of agricultural production.

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