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Does urbanization undermine agricultural sustainability? Evidence from China

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Abstract

This study aims to explore the relationship between urbanization and agricultural development in China, focusing on the mechanisms through which urbanization influences agricultural sustainability. It investigates the role of urbanization in promoting agricultural development through resource agglomeration, technological advancement, and market demand expansion. Using panel data from 31 Chinese provinces between 2007 and 2021, this study applies the entropy method to construct comprehensive evaluation indices for agricultural environments and resources. Bidirectional fixed effects, mediation effect, and moderation effect models are employed to analyze the influence of urbanization on agricultural development systematically. The study finds that urbanization significantly promotes agricultural development by enhancing resource agglomeration, technological advancement, and expanding market demand. Benchmark regression results indicate that a 1% increase in urbanization raises the agricultural environment and resource development indices by 0.351 and 0.374, respectively. Income level partially mediates the relationship between urbanization and agricultural development, as urbanization optimizes resource allocation by increasing farmers' incomes, indirectly driving agricultural modernization. Regional innovation capacity positively moderates the urbanization-agriculture relationship, with high-innovation regions amplifying urbanization's benefits through technology diffusion and institutional optimization. Urbanization plays a crucial role in agricultural development, contributing to resource optimization, income enhancement, and technological innovation. The study underscores the importance of innovation and income level improvements in maximizing the benefits of urbanization for agriculture.

Keywords: Agricultural sustainable development, Entropy method, Urbanization.

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Institutional Review Board Statement: This study involving human participants was conducted by ethical standards and received approval from the Institutional Review Board (IRB) of Chinese institutions. All participants provided informed consent before participation, and their anonymity and confidentiality were strictly maintained throughout the research process. The study adhered to the principles outlined in the Declaration of Helsinki and complied with relevant local and international ethical guidelines for human subject research.
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1. Introduction

Since China's reform and opening up in 1978, the process of urbanization has accelerated significantly. The proportion of the urban population has jumped from 17.9% in 1978 to 63.9% in 2021 [1], forming a unique dual pattern of "spatial expansion" and "population migration." Statistics show that the average annual growth rate of the built-up area of cities between 2000 and 2020 was 5.3%, equivalent to the size of 2,000 new standard soccer fields every year, with the formation of a continuous urban belt along the eastern coast and a mono-core expansion of provincial capitals in central and western China. Population mobility is characterized by a continuous large-scale movement, and the total number of migrant workers in 2021 is nearly 300 million, of which 170 million are working across provinces. The new generation of rural migrant workers has shifted their field of employment to the service industry, and the Yangtze River Delta and Pearl River Delta have absorbed more than half of the cross-provincial labor force. While this development model has brought about economies of scale, it has also led to a significant gap between the household urbanization rate (45.4%) and the urbanization rate of the resident population (64.7%). In the face of this challenge, the government has promoted coordinated urban-rural development through the New Urbanization Plan (2014-2020) and the Rural Revitalization Strategy (2018-2022). Figure 1 shows that urban expansion and agricultural mechanization levels have increased in tandem since 2010, and the power of agricultural machinery has continued to grow, both to cope with the pressure of arable land loss and to create conditions for the development of modern agriculture.

Currently, urbanization is shifting from scale expansion to quality improvement, focusing on solving key issues such as the citizenship of the agricultural transfer population and the intensive use of urban space.

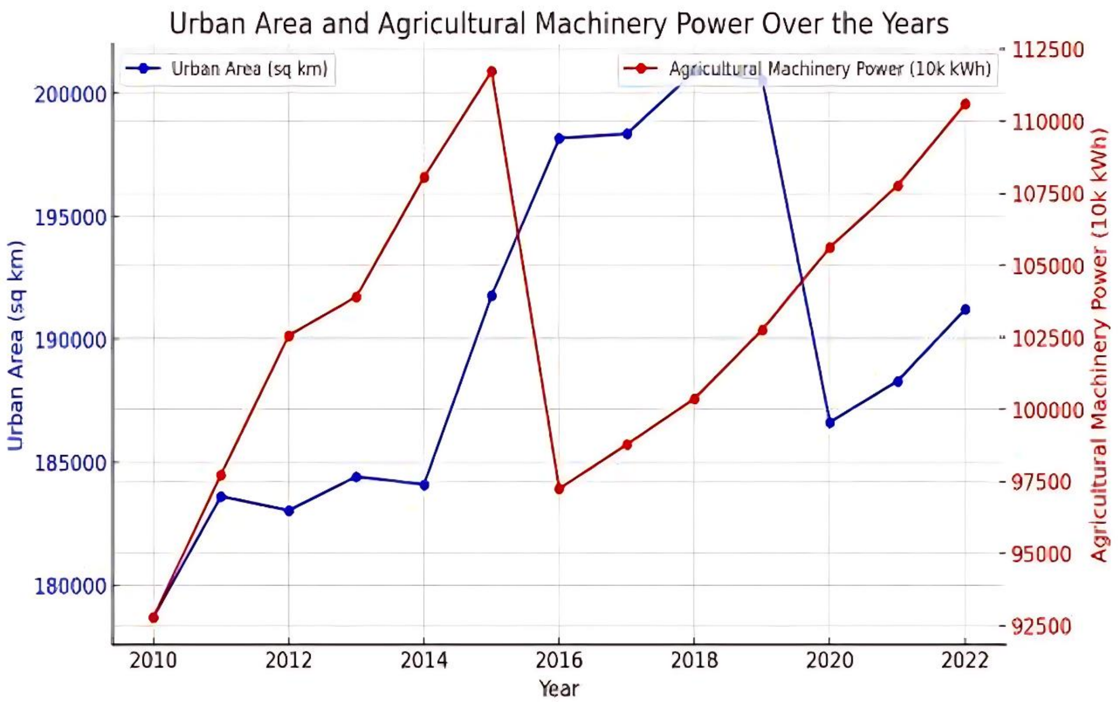

Figure 1.
Relationship between urbanization and agricultural development in China.

China's urbanization process has profoundly affected sustainable agricultural development. Data show that between 2000 and 2020, the country's arable land decreased by 6.2%, with economically active areas such as the Yangtze River Delta and Pearl River Delta alone accounting for nearly 40% of the total loss, directly threatening the foundation of food security [2]. The structural change of the labor force is also significant. In 2020, more than 40% of agricultural workers were over 55 years old, and nearly half of them were women, which makes the question of "who is going to farm the land" a real problem [1]. Environmental pressures cannot be ignored, with the maximum depth of ground subsidence in the Beijing-Tianjin-Hebei region due to over-exploitation of groundwater reaching 3.2 meters, and nearly a quarter of the arable land in the Yangtze River Basin being at risk of heavy metal pollution [3]. The urbanization process has also given rise to opportunities for agricultural transformation. Urban consumption upgrading has driven an average annual growth of 6.5% in the agricultural products processing industry, and the scale of new industries such as prepared vegetables has exceeded a trillion dollars. Policy innovation continues to make an impact, with the "three zones and three lines" control system guarding 1.8 billion mu of arable land red line. In 2020, a special action for arable land protection was initiated, reclaiming 1.2 million mu of farmland. Deqing, Zhejiang Province, and other places have realized 60% of farmland plant protection by drones through digital technology, and more than 3,000 professional managers cultivated in Changzhou, Sichuan Province, are changing the traditional farming mode.

A multi-pronged approach is needed to realize coordinated development of urban and rural areas: establishing a compensation mechanism for arable land protection to break the contradiction between "preserving food and building cities," cultivating new types of professional farmers to alleviate the manpower gap, and developing smart agriculture to improve production efficiency. The "land voucher" system in Foshan, Guangdong Province, has revitalized 32,000 mu of idle land, and the 300 digital farm demonstration sites in Jiangsu Province have achieved a 20% reduction in pesticides and a 15% increase in yields. These practices show that systematic institutional innovation can balance the dual demands of urbanization and agricultural modernization and provide sustainable solutions for food security and ecological protection.

2. Literature Review

2.1. Literature review

The interaction between rapid urbanization and agricultural transformation in China has become a focus of interdisciplinary research. Existing studies have revealed that this process has profoundly shaped the pattern of sustainable agricultural development through the triple path of reconfiguration of production factors, intensification of ecological constraints, and diffusion of technological innovation.

At the factor allocation level, land deforming and labor force transfer constitute fundamental constraints. Arable land nationwide declined by 6.2% between 2000 and 2020, with urban expansion contributing 38% [2], and the intensity of land consumption per unit of GDP growth in the Yangtze River Delta region is 2.3 times higher than that of the central and western parts of the country [4]. The trend of labor hollowing out has intensified, with the average age of agricultural workers reaching 55.3 years old in 2020, the proportion of women rising to 47.8%, and the traditional model of intensive farming facing the risk of intergenerational rupture [1]. The labor migration model constructed by Chen et al. [5] shows that for every 1% increase in the county urbanization rate, the area of rice cultivation shrinks by 0.7%, confirming that this confirms the phenomenon of "conjugate loss of people and land".

In terms of environmental constraints, urban expansion triggers compound ecological pressure [6]. Groundwater overexploitation in the Beijing-Tianjin-Hebei region triggers a maxi-mum of 3.2 meters of ground subsidence [5] and 23% of arable land in the Yangtze River Basin is contaminated with heavy metals [3] Studies have confirmed that the intensity of agricultural surface source pollution within the 200-kilometer radiation circle of urban agglomerations is 40-60% higher than that of peripheral regions, highlighting the spatial spillover effect [7]. In this regard, scholars have proposed an optimization framework of "urban metabolism" to construct an urban-rural resource circulation system through material flow analysis [8], but empirical studies are mostly limited to small-scale cases.

Technological innovation is seen as the key to breaking the mold. Precision agriculture technology has improved water and fertilizer efficiency of facility-based agriculture in the Yangtze River Delta by 35% [9], and the digital agriculture platform has cultivated more than 3,200 professional managers in Chongzhou, Sichuan Province, pushing the rate of large-scale land management up to 68%. However, Xu et al. [10] point out that 76% of current agricultural IT projects are concentrated in economically developed regions in the east, with significant technology adoption barriers in the central and western regions. Green technology diffusion is further confronted with a cost-benefit imbalance dilemma, with the internal rate of return (IRR) of photovoltaic (PV) agriculture projects being 2.8 percentage points lower than that of traditional models [4].

The theoretical construction shows a multidimensional breakthrough. The threshold effect model reveals that the elasticity coefficient of arable land loss increases by 2.4 times when the density of urban built-up area exceeds 15% [11]. However, there are three limitations in the existing re-search: first, the cross-scale connection between micro-farmers' decision-making and macro-policy response is insufficient; second, there is a lack of theoretical reconstruction of the change of agricultural production function triggered by digital technology [12] and third, the research on the mechanism of internalization of environmental costs mostly stays at the conceptual level, and lacks an operable institutional design [13].

Future research needs to focus on building a comprehensive analytical framework of "pressure-response-adaptation," and breakthroughs in three dimensions: (1) establishing a full-cost accounting system for agriculture that includes carbon footprints and ecological service values; (2) developing an appropriate diffusion model of technological innovation that is adapted to the smallholder economy; and (3) exploring the path of institutional innovation for the two-way flow of urban and rural factors. This provides a new theoretical perspective for understanding the transformation of "urban-rural symbiosis" with Chinese characteristics.

2.2. Research Hypotheses

Urbanization, as an important symbol of modern social development, is in essence the concentration and transfer of demographic, economic, social, and cultural factors from rural to urban areas. In this process, urbanization not only promotes the development of industry and services but also has a profound impact on agricultural development. The construction of infrastructure, the expansion of market demand, and technological progress in the process of urbanization have all provided strong support for agricultural modernization.

Therefore, we hypothesize that the urbanization process plays a significant role in promoting agricultural development, which is reflected in the improvement of agricultural production efficiency, the optimization of the structure of agricultural products, and the enhancement of the agricultural industry chain. The following research hypotheses:

H_1: The urbanization process has a significant contribution to agricultural development.

Economic activities and population agglomeration in the process of urbanization have provided rural residents with more employment opportunities and sources of income. As farmers' income levels rise, they have more resources and incentives to invest in agricultural production, thereby promoting agricultural development. At the same time, rising income levels also mean that farmers have a greater ability to purchase advanced agricultural production materials and services, further improving agricultural production efficiency. Therefore, we hypothesize that the urbanization process can indirectly enhance the level of agricultural development by optimizing the mediating variable of income level. Based on this, the following hypothesis is proposed:

H_2: The urbanization process can enhance agricultural development by optimizing income levels.

Innovation is an important driving force for socio-economic development, and this is equally true for the agricultural sector. An increase in the level of regional innovation means that the region has made significant progress in technological innovation, management innovation, and institutional innovation. These innovations can not only be directly applied to agricultural production to improve the efficiency and quality of agricultural production but also provide strong support for the optimization and upgrading of the agricultural industry chain. In the process of urbanization, regions with high levels of innovation can make more effective use of the various resources and opportunities brought by urbanization, thus promoting the faster development of agriculture. Therefore, we hypothesize that the regional innovation level plays a significant positive moderating role in the promotion of the urbanization process on agricultural development. Based on this, the following hypotheses are proposed: H3**:** The level of regional innovation plays a significant positive moderating role in the contribution of the urbanization process to agricultural development

3. Research Methodology

Entropy value method is an objective assignment method, mainly based on the degree of difference between the evaluation indicators to determine the weight coefficients, which can effectively avoid the interference of human factors and make the results more objective. Therefore, the entropy value method is chosen to assign weights to the indicators in the comprehensive evaluation model and calculate the level of agricultural environment and agricultural resources in each province and region. The specific measurement process is as follows:

The indicators are first de-quantified (also called normalized) to avoid the effect of the scale as follows:

$$Y_{ij} = \frac{X_{ij} - \min(X_i)}{\max(X_i) - \min(X_i)} \text{ Positive Indicator} \quad (1)$$

$$Y_{ij} = \frac{\max(X_i) - X_{ij}}{\max(X_i) - \min(X_i)} \quad \text{Negative Indicator} \quad (2)$$

$i = 1, ..., n$, $j = 1, ..., m$, Y_{ij} denotes the standardized result of the indicator j, and X_{ij} denotes the initial value of the indicator, and then calculate the variation size of the indicator as follows:

$$\mathrm{P}_{i|j} = \frac{r_{ij}}{\sum_{l=1}^{n} r_{lj}}, \quad i = 1, \dots, n, \quad j = 1, \dots, m \quad (3)$$

After that, find the information entropy of indicator j, E_j, as follows:

$$E_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} P_i \ln(P_i), \quad j = 1, \dots, m \quad (4)$$

The indicator weights are obtained as follows

$$W_j = 1 - \frac{E_j}{\sum_{j=1}^{m}(1 - E_j)}, \quad j = 1, \dots, m \quad (5)$$

The final weighting is calculated to get the final xxx indicator development index (Score) for different cities as follows:

$$\mathrm{Score}_i = \sum_{j=1}^{m} \left(w_j \times Y_{ij} \right), \quad i = 1, \dots, n \quad (6)$$

Table 1.
Agricultural Resources and Agri-Environmental Indicators.

Primary Indicator		Secondary Indicator	Weight
Agricultural Resources	Input of Agricultural Production Factors	Pure usage of chemical fertilizers	0.099
		Usage of agricultural plastic film	0.098
		Rural electricity consumption	0.212
		Agricultural water usage	0.099
	Agricultural Foundation	Total sown area of crops	0.090
		Forest coverage rate	0.065
		Effective irrigated area	0.104
	Labor Force & Mechanization	Agricultural employment population	0.116
		Total agricultural machinery power	0.113
Agricultural Environment	Natural Disasters & Ecological Impact	Affected area (disaster damage)	0.149
		Disaster-stricken area	0.135
		Agricultural ammonia-nitrogen emissions	0.114
		Pesticide usage	0.098
	Environmental Governance & Protection	Area of soil erosion control	0.093
		Energy conservation & environmental expenditure	0.073
	Technology & Policy Support	Agricultural R&D investment	0.275
		General public budget expenditure	0.061

4. Results

4.1. Study Design

4.1.1. Sample Sources

To explore in depth the specific impact of urbanization on agricultural development, this paper selects data covering 31 provinces in China between 2007 and 2021 as the basis of the study. To ensure the scientific accuracy of the study, we adopt the entropy value method to construct a comprehensive agricultural development index system. The data cited in this paper are from the China Statistical Yearbook and the China Agricultural Statistical Yearbook to ensure the authenticity and reliability of the data, and to provide solid data support for analyzing the intrinsic link between urbanization and agricultural development.

4.1.2. Variable Settings

4.1.2.1. Explained Variables

The explanatory variables in this paper are agricultural environment (Y1) and agricultural resources (Y2). This paper selects each indicator (pure use of agricultural fertilizers, use of agricultural plastic film, rural electricity consumption, crop sown area, agricultural water consumption, effective irrigated area, forest coverage, agricultural employment, total power of agricultural machinery) to calculate the total indicator through the entropy method as a measure of the agricultural environment.

Selection of indicators (disaster-affected area, disaster-affected area, agricultural ammonia nitrogen emissions, pesticide use, soil erosion control area, agricultural science and technology inputs, energy conservation and environmental protection expenditures, and general public budget expenditures) as a measure of agricultural resources through the entropy method to measure the total indicators.

4.1.2.2. Explanatory Variables

The explanatory variable in this paper is the urbanization process (urban). This paper uses the proportion of the urban population to the total population in each province as a measure of urbanization. The data come directly from the National Bureau of Statistics and provincial statistical yearbooks, which have official authority. This indicator is chosen because it can truly reflect the process of population transfer from rural to urban areas, and the calculation method is simple, which is to divide the number of permanent urban residents by the total population of a region.

4.1.2.2. Transmission Mechanism Variables

The transmission mechanism variable in this paper is the level of income (REVENUE). This paper uses per capita disposable income for this measure. Urbanization attracts rural labor through non-agricultural employment opportunities, increasing farmers' non-agricultural income (e.g., wage income, etc.), thereby changing the structure of rural household income and resource allocation (e.g., reducing agricultural labor inputs). As urbanization raises incomes, the demand for agricultural products shifts from a "quantity-based" to a "quality-based" approach, which promotes the upgrading of agricultural structures.

4.1.2.3. Regulatory Mechanism Variables

The moderating mechanism variable in this paper is the innovation level (patented). This paper uses the number of invention patent applications for measurement. This is mainly based on the following three considerations: firstly, invention patents have higher technical content and innovation value than utility model and design patents; secondly, patent application data are characterized by openness, accessibility, and verifiability; and lastly, existing studies have shown that the number of invention patents filed is a better reflection of the level of substantive innovation output of enterprises or regions.

4.1.2.4. Control Variables

This paper further selects the following control variables from the perspective of responding to the urbanization process on agricultural development: gross domestic product (GDP), industrial structure (industry), urban-rural income gap (gap), the degree of government intervention (Gov), the level of transportation infrastructure (traffic), the level of social consumption (consumption) The specific definitions of each variable are shown in Table 2.

Table 2.
Definition of Variable.

Variable Type	Variable Name	Variable Symbol	Measurement Method
Explained Variable	Agricultural Environment	Y1	Calculated by the Entropy Method
	Agricultural Resources	Y2	Calculated by the Entropy Method
Explanatory Variable	Urbanization Process	Urban	Urban population as % of total population
Mediating Variable	Income Level	Revenue	Logarithm of per capita disposable income
Moderating Variable	Innovation Level	patent	Number of invention patent applications
Control Variables	Gross Domestic Product	GDP	Logarithm of regional GDP
	Industrial Structure	Industry	Value-added of the tertiary sector / Value-added of the secondary sector
	Urban-Rural Income Gap	Gap	Logarithm of urban-rural income disparity
	Government Intervention	Gov	Local fiscal general budget expenditure as % of GDP
	Transportation Infrastructure	Traffic	Logarithm of highway mileage
	Social Consumption Level	Consume	Ratio of total retail sales of consumer goods to regional GDP

4.2. Model

To verify the theoretical analysis of this paper about the impact of the urbanization process on agricultural development, this paper constructs a two-way stationary model (4-1) for empirical testing.

$$Y_{i,t} = \alpha_0 + \alpha_1 X_{i,t} + \alpha_2 Controls_{i,t} + \sum Year + \sum Pro + \varepsilon \quad (4\text{-}1)$$

Where Y is the explanatory variable of this paper, representing agricultural development; X is the explanatory variable of this paper, representing the urbanization process. Controls stand for all the control variables of this paper. ∑ Year and ∑ Pro are year and province fixed effects, and ε is a random disturbance term. The specific measurement of the above variables is consistent with the aforementioned; details can be seen in the above table.

To test whether income level is the transmission mechanism of the impact of urbanization process on agricultural development, this paper refers to WenZhonglin and Ye (2014), and empirically analyzes it by adopting the mediation effect test model of stepwise regression method, the first step of this mediation effect test model is as shown in the model (1), and the second and the third steps are as shown in the model (2) (3):

$$revenue_{i,t} = \alpha_0 + \alpha_1 X_{i,t} + \alpha_2 Controls_{i,t} + \sum Year + \sum Pro + \varepsilon \quad (4\text{-}2)$$

$$Y_{i,t} = \alpha_0 + \alpha_1 X_{i,t} + \alpha_2 revenue_{i,t} + \alpha_3 Controls_{i,t} + \sum Year + \sum Pro + \varepsilon$$

In this paper, we will test the effect of the urbanization process on the level of income according to the positive, negative, and significance level of the value of the coefficient α_1 of the model (4-2), and thus test whether the level of income is the transmission mechanism of the effect of the urbanization process on agricultural development.

4.3 Analysis of Empirical Results

4.3.1. Descriptive Statistics

The descriptive statistics of the variables used for empirical testing in this paper are shown in Table 3. From the descriptive statistics of the explanatory variable, agricultural environment (Y1), it can be found that the maximum value is 0.474 and the minimum value is 0.007, which shows that the data have a large range of variability in this variable. This variability may reflect the impact of different regions, periods, or agricultural practices on the Agri-environment. The mean value is 0.17. This indicates that, on the whole, the average level of the Agri-environment in the observed sample is at a low level. This may imply that, generally, the quality or state of the Agri-environment is not satisfactory or that the measurements used are more stringent. From the descriptive statistics of the explanatory variable agricultural resources (Y2), it can be found that it has a maximum value of 0.613, a minimum value of 0.011, and a mean value of 0.253.

From the descriptive statistics of the explanatory variable urbanization process (urban), it can be found that its maximum value is 0.896 and its minimum value is 0.215, showing that there is a large range of variation in the agricultural resource variable in the dataset. This variation may stem from differences in the abundance of agricultural resources, resource utilization efficiency, or management strategies in different regions. The mean value is 0.568, which is higher relative to the mean value of 0.17 for the agricultural environment (Y1). This indicates that, on the whole, the average level of agricultural resources in the observed sample is better than that of the agricultural environment. This may imply that, on average, agricultural resources are managed more effectively than agri-environment in terms of their development, conservation, or utilization.

The descriptive statistics of the remaining control variables are consistent with previous studies, and the standard deviation of each variable is at a low level after shrinking the continuous data of all variables up and down by 1%. This indicates that the construction and preprocessing steps for each variable in this paper are appropriate, laying the foundation for the subsequent in-depth empirical analysis.

Table 3.
Descriptive Statistics.

Variable	N	min	max	mean	S. D	p25	p50	p75
Agricultural Environment	465	0.007	0.474	0.170	0.099	0.089	0.169	0.230
Agricultural Resources	465	0.011	0.613	0.253	0.155	0.128	0.243	0.364
Urban	465	0.215	0.896	0.568	0.145	0.473	0.557	0.641
GDP	465	5.841	11.73	9.512	1.076	8.980	9.613	10.24
Industry	465	0.527	5.244	1.268	0.694	0.900	1.119	1.368
Gap	465	0.212	0.674	0.409	0.0960	0.333	0.405	0.468
Gov	465	0.0970	1.354	0.277	0.197	0.175	0.228	0.309
Traffic	465	5.919	12.98	11.36	1.112	10.82	11.64	12.14
Consume	465	0.220	0.504	0.381	0.0560	0.340	0.382	0.418
Patent	465	4.575	13.80	10.24	1.721	9.177	10.45	11.46
Revenue	465	8.214	10.80	9.537	0.530	9.168	9.586	9.884

4.3.2 Correlation Analysis

This study conducts a preliminary examination of the relationship between the variables through model (4-2), and the results of the bivariate correlation coefficient analysis in Table 4 show that the Pearson correlation coefficients of the explanatory variable urbanization process (urban) and the explanatory variables agricultural environment (Y1) and agricultural resources (Y2) are 0.0490 and 0.0450, respectively, which are weakly and positively correlated in a statistically significant way. This finding is consistent with the direction of the initial observation of the impact of FDI on the green total factor productivity of enterprises, but it should be noted that the absolute values of the correlation coefficients are all below 0.05, indicating that the degree of linear association between the variables is more limited. As far as the control variables are concerned, their correlation coefficients with the explanatory variables all pass the statistical test at different significance levels of 1%-10%, confirming that the selection of control variables in the model is both in line with theoretical expectations and statistically necessary. The bivariate correlation coefficients only reflect a simple linear relationship between the variables, failing to control for the effects of other explanatory variables, industry heterogeneity, time trends, and other model-setting factors. Therefore, the validation of theoretical hypotheses based only on the results of bivariate correlation analysis is significantly deficient in methodological rigor. This paper will further validate the theoretical analysis of this paper by analyzing the subsequent empirical results.

Table 4.
Correlation Analysis.

	Agricultural Environment	**Agricultura l Resources**	**Urban**	**GDP**	**Industry**	**Gap**	**Gov**
Agricultural Environment	1						
Agricultural Resources	0.772***	1					
Urban	0.0490	0.0450	1				
GDP	0.649***	0.657***	0.553***	1			
Industry	-0.371***	-0.327***	0.425***	-0.0190	1		
Gap	0.0500	0.177***	0.641***	0.524***	0.219***	1	
Gov	-0.513***	-0.447***	-0.427***	-0.691***	0.156***	-0.233***	1
Traffic	0.674***	0.649***	0.305***	0.843***	-0.387***	0.304***	-0.770***
Consume	-0.0200	0.00400	0.188***	0.300***	0.285***	0.207***	-0.00100
Patent	0.513***	0.526***	0.668***	0.950***	0.083*	0.599***	-0.637***
Revenue	0.102**	0.194***	0.845***	0.680***	0.425***	0.777***	-0.254***
	traffic	consume	patent	revenue			
Traffic	1						
Consume	0.0710	1					
Patent	0.743***	0.365***	1				
Revenue	0.379***	0.334***	0.768***	1			

Note: Spearman's correlation coefficients are disclosed in the table; ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.3.3. Benchmark Regression Tests

The regression results of model (4-1) are shown in Table 5, with columns (1) and (2) demonstrating the regression results after controlling for province and year, respectively, and after adding the control variables. From Table 5, it can be seen that the regression coefficients of the explanatory variable urbanization process (urban) on the explanatory variable agricultural environment (Y1) and the explanatory variable agricultural resources (Y2) are always positive and all of them are significant at 1% significance level, which confirm the research hypothesis of this paper, that is the process of urbanization will have a significant role in promoting agricultural development. As the urbanization process advances, the urban population increases, and the demand for agricultural products grows. This expansion of market demand provides greater impetus for agricultural development and promotes the growth of agricultural production, and urbanization is often accompanied by scientific and technological progress and accelerated information flow. These advanced technologies and management experience can be quickly disseminated to rural areas to improve agricultural production efficiency and optimize resource allocation, thus promoting agricultural development. At the same time, economic growth in the process of urbanization provides more financial support for agriculture. These funds can be used for agricultural research and development, technology promotion, and market development, injecting new vitality into agricultural development.

Table 5.
Regression tests.

Variable	**(1) Agricultural Environment**	**(2) Agricultural Resources**
Urban	0.351***	0.374***
	(2.62)	(3.96)
GDP	0.035	-0.077***
	(1.61)	(-3.14)
Industry	0.040***	-0.025**
	(3.33)	(-2.04)
Gap	0.000	-0.352***
	(0.01)	(-7.44)
Gov	-0.005	-0.028
	(-0.13)	(-0.75)
Traffic	0.016	-0.038***
	(1.39)	(-3.04)
Consume	-0.122**	0.245***
	(-2.42)	(3.67)
Constant	-0.551**	1.287***
	(-2.43)	(5.10)
Observations	465	465
R-squared	0.908	0.956
Province FE	YES	YES
Year FE	YES	YES

4.3.4. Robustness Tests

Removing the impact of the epidemic. As a major global public health event, the COVID-19 epidemic has had far-reaching economic, social, and environmental impacts on all countries. As a major global public health event, the COVID-19 pandemic has had a profound impact on the economy, society, environment, and other aspects of each country. To prevent the possible impact of the COVID-19 pandemic in 2020 from deteriorating the regression results, this paper excludes the sample data after 2020. Although the sample data after 2020 are excluded, the remaining samples are still sufficiently representative and widespread, and the remaining samples are regressed again. The regression results are shown in columns (1) and (2) of the following table, which show that the explanatory variable urbanization process (urban) has a significant impact on the explanatory variables. It can be seen that the regression coefficients of the explanatory variable urbanization process on the explanatory variable agricultural environment (Y1) and the explanatory variable agricultural resources (Y2) are 0.480 and 0.280, respectively, and both are significant at the 1% level. This result proves the robustness of the original regression results. Even after excluding the sample data that may be significantly affected by the epidemic, urbanization still has a significant effect on agricultural development, and this test further confirms our hypothesis.

Table 6.
Robustness Tests.

Variable	(1) Agricultural Environment	(2) Agricultural Resources
Urban	0.480***	0.280***
	(3.54)	(3.13)
GDP	0.017	-0.078***
	(0.70)	(-2.93)
Industry	0.043***	-0.007
	(2.94)	(-0.53)
Gap	-0.035	-0.319***
	(-0.66)	(-5.93)
Gov	0.017	-0.055
	(0.38)	(-1.49)
Traffic	0.010	-0.016
	(0.79)	(-1.50)
Consume	-0.133**	0.224***
	(-2.26)	(4.17)
Constant	-0.359	1.078***
	(-1.40)	(3.82)
Observations	403	403
R-squared	0.916	0.972
Province FE	YES	YES
Year FE	YES	YES

In empirical analyses, the presence of extreme observations may significantly distort parameter estimates through leverage effects, leading to systematic bias in statistical inference. To alleviate this problem, this study adopts the widely recognized two-sided tailing treatment in econometrics, replacing the extreme values outside the 1% quartile at each end of the variable distribution with thresholds at the critical interquartile points to reduce the over-sensitivity of the estimators to outliers, improve the robustness of the model so that the variable distributions converge more closely to the assumption of normality, and satisfy the prerequisite conditions for parametric tests. Therefore, in this paper, the results after shrinking the tails are regressed again.

The regression results are shown in columns (1) and (2) of the Table 7, which indicate that the regression coefficients of the explanatory variable urbanization process (urban) on the explanatory variable agri-environmental (Y1) and the explanatory variable agricultural resources (Y2) are 0.382 and 0.370, respectively, and both are significant at the 1% level. This result is consistent with the regression findings, and this test further confirms our hypothesis.

Table 7.
Robustness Tests.

Variable	**(1)** **Agricultural Environment**	**(2)** **Agricultural Resources**
Urban	0.382***	0.370***
	(2.81)	(3.77)
GDP	-0.003	-0.039
	(-0.13)	(-1.46)
Industry	0.029**	-0.010
	(2.42)	(-0.79)
Gap	-0.039	-0.316***
	(-0.91)	(-6.77)
Gov	-0.015	-0.056
	(-0.34)	(-1.21)
Traffic	0.015	-0.040***
	(1.30)	(-3.05)
Consume	-0.128**	0.234***
	(-2.45)	(3.44)
Constant	-0.162	0.930***
	(-0.71)	(3.49)
Observations	465	465
R-squared	0.910	0.954
Province FE	YES	YES
Year FE	YES	YES

4.3.5. Endogeneity Test

4.3.5.1. Two-Stage Least Squares

To solve other endogeneity problems, such as two-way causality, this paper further tests the regression results of this paper by two-stage least squares.

Regarding the selection of instrumental variables (Tool), this paper takes the lagged period of the explanatory variable urbanization (urban) as the instrumental variable. From the correlation requirement of instrumental variables, the lagged explanatory variable is usually highly correlated with the explanatory variable in the current period. This correlation allows the lagged variable to be used as an effective instrumental variable to replace the current period explanatory variables that may be endogenous, thus improving the accuracy of the model. The lagged explanatory variable is more exogenous than the current period, i.e., it is less likely to be influenced by the current period's explanatory variables. This exogeneity helps to reduce the bias in the model estimation and makes the lagged explanatory variables more reliable.

The regression results of the two-stage least squares method are shown in Table 8. From column (1), we can see that the regression coefficient of the instrumental variable Tool on the explanatory variable urbanization process (urban) is positive and significant at the 1% significance level. From columns (2) and (3), we can see that the regression coefficients of the explanatory variable urbanization process (urban) on the explanatory variables agro-environmental (Y1) and the regression coefficients of the explanatory variable agricultural resources (Y2) are still positive and significant at the 1% level of significance, which proves that the regression results of this paper are not significantly affected by the endogeneity problem.

Table 8.
Endogeneity Test.

Variable	(1) Urban	(2) Agricultural Environment	(3) Agricultural Resources
L.urban	0.552***		
	(7.64)		
GDP	0.028***	0.035*	-0.077***
	(2.59)	(1.70)	(-3.41)
Industry	-0.015***	0.040***	-0.025**
	(-2.87)	(3.72)	(-2.16)
Gap	0.066**	0.000	-0.352***
	(2.17)	(0.01)	(-6.70)
Gov	0.013	-0.005	-0.028
	(0.62)	(-0.11)	(-0.60)
Traffic	-0.002	0.016	-0.038***
	(-0.33)	(1.58)	(-3.40)
Consume	0.097***	-0.122**	0.245***
	(3.65)	(-2.30)	(4.24)
Urban		0.351***	0.374***
		(4.45)	(4.37)
Constant	-0.029	-0.444**	1.375***
	(-0.27)	(-2.38)	(6.81)
Observations	434	465	465
R-squared	0.991	0.908	0.956
Province FE	YES	YES	YES
Year FE	YES	YES	YES

4.3.6. Conduction Mechanism Test

To test whether the level of income is the transmission mechanism of the impact of the urbanization process on agricultural development, this paper tests the model (4-2), and the regression results are shown in Table 9.

From column (1), it can be seen that the regression result of the explanatory variable urbanization process (urban) on the transmission mechanism variable income level (revenue) is positive and significant at the 1% level of significance, which proves that with the advancement of the urbanization process, the mediating variable per capita disposable income will be positively affected as well.

From columns (2) and (3), it can be seen that the explanatory variable urbanization is positive and significant at different levels of significance for both the explanatory variable Agri-environment (Y1) and the explanatory variable Agri-Resources (Y2) after the inclusion of the mediator variable income level. This result proves that the urbanization process still has a significant effect on the impact of agricultural development after adding the mediator variable. Therefore, the transmission mechanism variable income level plays a mediating role in the impact of the urbanization process on agricultural development.

Table 9.
Conduction Mechanism Tests.

Variable	(1) Revenue	(2) Agricultural Environment	(3) Agricultural Resources
Revenue		0.073*	0.072*
		(1.70)	(1.81)
Urban	1.600***	0.234*	0.259**
	(12.37)	(1.65)	(2.34)
GDP	0.191***	0.021	-0.091***
	(6.20)	(0.89)	(-3.47)
Industry	0.059***	0.036***	-0.030**
	(3.21)	(2.92)	(-2.30)
Gap	0.035	-0.002	-0.355***
	(0.50)	(-0.06)	(-7.53)
Gov	0.122	-0.014	-0.037
	(1.45)	(-0.36)	(-0.99)
Traffic	0.046***	0.013	-0.041***
	(2.62)	(1.03)	(-3.19)
Consume	0.010	-0.123**	0.244***
	(0.15)	(-2.47)	(3.69)
Constant	6.161***	-1.004***	0.845***
	(20.63)	(-3.06)	(2.63)
Observations	465	465	465
R-squared	0.994	0.909	0.956
Province FE	YES	YES	YES
Year FE	YES	YES	YES

4.3.7. Regulatory Mechanism Test

To test whether the moderating variable innovation level (patent) is a moderating variable of the impact of the urbanization process on agricultural development, this paper constructs the following model to test, and the regression results are shown in Table 10.

$$Y_{i,t} = \alpha_0 + \alpha_1 X_{i,t} + \alpha_1 patent_{i,t} + \alpha_2 patent * urban + \alpha_2 Controls_{i,t} + \sum Year + \sum Pro + \varepsilon$$

In this paper, according to the above model, in the regression to add the moderating variable and moderating variable and the explanatory variable of the urbanization process (urban) interaction term, Urban patent and test again, the regression results are shown in Table 10.

From the regression results, it can be seen that the interaction term Urban patent is positive and significant at the 1% and 5% levels for both the explanatory variable Agricultural Environment (Y1) and the explanatory variable Agricultural Resources (Y2), which shows that the moderator variable Innovation Level (patent) plays a moderating role in the impact of the urbanization process on agricultural development.

Table 10.
Regulatory Mechanisms.

Variable	(1) Agricultural Environment	(2) Agricultural Resources
Urban	-0.148	0.050
	(-0.81)	(0.29)
Patent	-0.041***	-0.005
	(-5.26)	(-0.49)
Urban*patent	0.055***	0.031**
	(4.11)	(2.02)
GDP	0.065***	-0.075***
	(2.89)	(-2.97)
Industry	0.028**	-0.030**
	(2.33)	(-2.39)
Gap	-0.018	-0.361***
	(-0.45)	(-7.34)
Gov	0.060	0.014
	(1.30)	(0.35)
Traffic	0.026**	-0.035***
	(2.20)	(-2.67)
Consume	-0.114**	0.262***
	(-2.33)	(3.93)
Constant	-0.575***	1.275***
	(-2.65)	(5.16)
Observations	465	465
R-squared	0.917	0.957
Province FE	YES	YES
Year FE	YES	YES

5. Conclusions

This study takes the data of China's provinces and districts between 2007 and 2021 as the research basis. With the help of the entropy value method, it systematically explores the specific impact of the urbanization process on agricultural development. It is found that the urbanization process has a significant positive impact on the level of agricultural development. As urbanization advances, agricultural development is enhanced accordingly, which is mainly due to the resource agglomeration effect, technological progress, and the expansion of market demand brought about by urbanization. This study confirms that urbanization is not only a process of social and economic structural transformation but also an important force to promote agricultural modernization.

Income levels play a partial mediating role in the impact of urbanization on agricultural development. Urbanization, by improving farmers' income levels, has in turn contributed to agricultural development. This suggests that urbanization not only directly contributes to agricultural productivity but also indirectly contributes to sustained agricultural development by improving farmers' incomes. This finding provides a new perspective for understanding the dynamic relationship between urbanization and agricultural development.

In addition, the level of regional innovation plays a significant moderating role in the positive impact of urbanization on agricultural development. Increased regional innovation capacity can enhance the driving effect of urbanization on agricultural development, reflecting the key role of innovation in agricultural development. Regions with high levels of innovation can make more effective use of the opportunities presented by urbanization to improve the efficiency and quality of agricultural production through technological and model innovation.

In summary, this study reveals the intrinsic links between the urbanization process, income levels, and agricultural development, and highlights the important role of regional innovation levels in promoting agricultural modernization. These findings not only enhance our understanding of the relationship between urbanization and agricultural development but also provide a scientific basis for relevant policy formulation, which can help guide practice and promote the coordinated development of agriculture and cities.

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