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# The Impact of Urban–Rural Integration on Food Security: Evidence from Provincial Panel Data in China

**Xiaofu Chen * and Guoxin Yu ***

College of Economics and Management, Xinjiang Agricultural University, Urumqi 830052, China
* Correspondence: 320200076@xjau.edu.cn (X.C.); ygx@xjau.edu.cn (G.Y.)

**Abstract:** Food security is pivotal for national sustainable development. This study utilizes panel data from 31 Chinese provinces spanning from 1990 to 2021 to construct distinct indicator systems for urban–rural integration and food security. The entropy method is employed to assess levels of urban–rural integration and food security, with their inter-relationship examined through a fixed-effects model. Additionally, this study conducts rigorous robustness and endogeneity tests, alongside comprehensive heterogeneity analyses across various dimensions and regions. The findings underscore the significant role of urban–rural integration in enhancing food security, particularly within spatial, social, and economic dimensions, albeit encountering challenges in ecological integration. Moreover, the impact of urban–rural integration on food security manifests differently across diverse food-producing regions, exhibiting notable advantages in primary production and distribution hubs while being negligible in balanced regions. These results accentuate the critical necessity for refining urban–rural integration strategies to bolster food security. Consequently, in formulating agricultural regional policies, careful consideration of resource allocation and the developmental stages of each region is imperative to ensure food security and promote sustainable agricultural practices.

**Keywords:** urban–rural integration; food security; sustainable



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## 1. Introduction

Food security is fundamentally linked to human well-being, acting as a crucial safeguard for national economic development and playing a direct role in ensuring peace and stability [1]. As we look to the future, the imperative of maintaining food security becomes a global priority, essential for achieving various Millennium Development Goals [2,3]. According to the "2018 World Urbanization Prospects" report, by the mid-21st century, approximately two-thirds (68%) of the world's population will reside in urban areas, with a projected increase of 2.5 billion in the global urban population by 2050, nearly 90% of which will occur in the developing regions of Asia and Africa [4]. This urban concentration, along with ongoing expansion, poses significant challenges, including a shrinking rural workforce, diminishing arable land, environmental degradation, and compromised food security. The rapid pace of urbanization challenges the development of sustainable production and existing consumption models, necessitating targeted initiatives to manage the increased food consumption of urban populations; enhance urban dietary patterns in response to shifts in food demand, primarily through the efficient reallocation of agricultural resources; and maintain essential interactions between urban and rural areas in developing countries.

The realm of food security, marked by inherent complexity and dynamism, is influenced by a confluence of factors, including global pandemics, geopolitical strife, and climatic volatility, which have introduced challenges on an unprecedented scale [5,6]. In China, significant advances have been achieved in food production, supply chains, and agricultural economic development. Notably, China currently supports 22% of the global populace whilst possessing only 7% of the planet's arable land [7]. For fourteen consecutive years, China's per capita food availability has exceeded the globally recognized safety threshold of 400 kg per year, marking a crucial milestone in achieving grain self-sufficiency and the absolute security of staple foods. Despite these advances, a substantial demographic base continues to drive significant food demand, further intensified through the processes of urbanization and rapid economic growth, thereby increasing food requirements across both urban and rural sectors. Enhancements in urban–rural dynamics have facilitated resource distribution; however, disparities in resource allocation continue to pose risks to food security. The promotion of urban–rural integration strategies aims to optimize resource allocation efficiency, thereby reinforcing food security paradigms. The advances in agricultural technology have significantly increased food production levels; however, challenges such as land scarcity, workforce attrition, and an aging demographic persist [8,9]. Ensuring a stable and sufficient food supply remains critical [10]. Addressing the basic nutritional needs of the population will underpin food security. The historical data from the years 1949 to 2021 demonstrate the effective maintenance of per capita food consumption for urban and rural residents, with the food supply–demand ratio rising from 1.05 in 1949 to 3.68. As shown in Figure 1, as the trajectory of per capita food production approaches its peak, showing only a marginal decline, and with the diversification of the food supply leading to a reduction in per capita food demand, China is compelled to recalibrate its food security strategy to address the emerging challenges and shifts in paradigms.

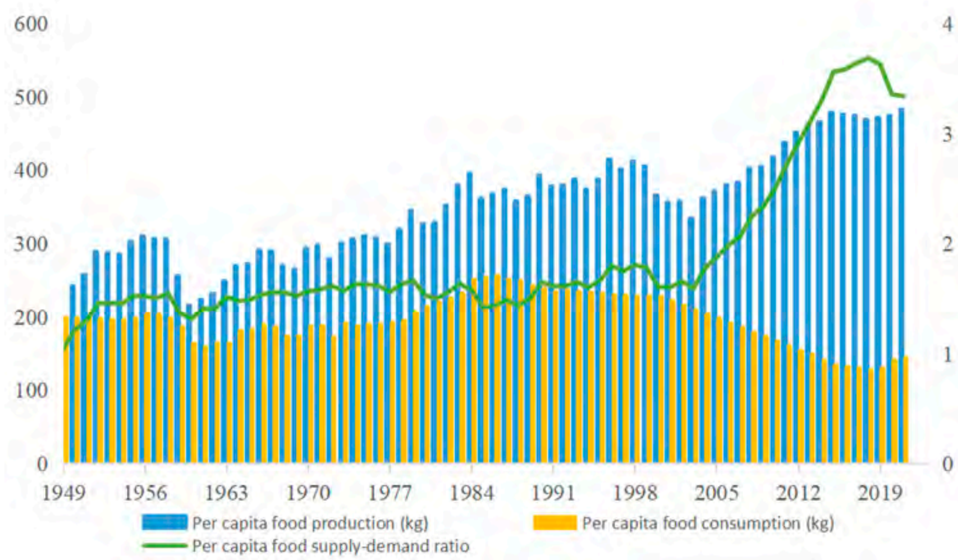


**Figure 1.** The per capita food supply–demand change chart for Chinese residents from 1949 to 2021.

The critical role of food security in national development is undeniable. In this evolving context, both macro- and micro-environmental factors affecting food security are continuously changing. On the supply side, the food sector faces challenges such as rising costs, scarcity of critical factors, and diminishing sustainability [11]. Concurrently, diversified needs have emerged on the demand side, alongside calls for higher quality and quantity. China is at a crucial juncture in its urban–rural transition, characterized by rapid urbanization and industrialization, leading to increased food demands and pressures on agricultural resources. Scholars have explored these dynamics from various angles, with some focusing on quantitative aspects arguing that urbanization not only exacerbates food security challenges, but also limits food production capacity [12,13]. Others, whilst emphasizing the quality of food demand, have suggested that urbanization leads to environmental issues like land degradation, indirectly affecting food security quality [14–16]. Furthermore, some scholars have asserted that urbanization alleviates agricultural employment pressures and, through the introduction of initial urban capital, enhances agricultural technology, funding, and talent, thus promoting the modernization of agriculture and rural areas [17,18].

Urbanization, as a critical stage in rapid socio-economic development within a specific historical period, results in diminishing marginal utility. As urbanization accelerates, rural development lags, highlighting urban-rural integration as a strategic imperative for national development. Urban-rural integration aims not only to bridge the urban-rural divide and improve rural residents' living standards, but also to protect the rural ecological environment, preserve rural culture, and promote mutual prosperity in both urban and rural areas. The implementation of an urban–rural integration strategy is poised to increase investment in rural areas, upgrade rural infrastructure, with a focus on conserving and restoring the rural ecological environment [19], strengthening of rural environmental governance, and the enhancement of rural living standards. Additionally, this strategy revitalizes resource elements, attracting more entrepreneurs and business operators back to the agricultural sector, and thereby reinforcing food security.

In conclusion, within the intricate and evolving international and domestic contexts, ensuring food security remains a critical concern for China. Despite years of increasing grain production, driven by rapid urbanization, technological advances in agriculture, and rising grain yields, the persistent challenges of declining farmland quality and a diminishing rural workforce persist. Previous research has primarily focused on the impact of urbanization on food security, overlooking the significant relationship between urban-rural integration and food security in transitioning economies. With the growing interconnectedness between urban and rural areas, adopting an integrated approach to urban-rural synergy in food security research becomes imperative [20]. This paper is structured as follows: Section 2 provides a conceptual framework and hypotheses, Sections 3 and 4 represent the Materials and Methods and Results sections, respectively. Section 5 analyzes the results, and Section 6 offers the conclusions and discusses the implications for policy.

## 2. Conceptual Framework and Hypotheses

### 2.1. Food Security Concept

The concept of food security, as initially delineated by the United Nations Food and Agriculture Organization (FAO) in 1974, has undergone substantial evolution, resulting in a nuanced, multi-dimensional perspective [21]. This expansion transcends mere supply concerns to encompass aspects such as economic purchasing power, food safety, and food quality. This is particularly pertinent for China, where significant population numbers and limited cultivable land necessitate a robust strategy centered on domestic food self-sufficiency. Scholars have maintained that the crux of macro food security lies in maintaining the food self-sufficiency rate, achievable only through the enhancement of agricultural technologies, optimization of food production structures, increments in yield levels, and a strategic integration with global food trade [22]. At the meso level, the enhancement of the urban food supply efficiency is pursued through the optimization of supply chains, expansion of distribution channels, and the integration of advanced technological interventions, thus improving food access for urban populations [23]. At the micro level, attention is directed towards the food acquisition challenges confronting low-income groups, tackled through the implementation of food subsidies, regulation of staple food prices, provision of community employment opportunities and living supports, the establishment of community food mutual aid systems, and the promotion of rooftop and community gardening to mitigate food costs, thereby ensuring that low-income groups have and maintain effective access to necessary food resources [24].

The core dimensions of food security are delineated as follows: first, quantity safety, which ensures the adequacy of food production and supply to meet basic population needs and maintains food availability at the urban level; second, quality safety, which focuses on the safety and nutritional values of food to prevent food-related safety incidents and safeguard human health [25]; third, industry safety, which centers on the comprehensive development of the food industry, emphasizing stable production outputs, appropriate variety and nutritional structure, and the continuity and orderliness of supply [26]; fourth, ecological safety, ensuring that food production practices do not detrimentally impact the ecological environment, thereby promoting ecological balance and the advancement of ecological and sustainable agriculture; fifth, economic accessibility, enhancing the financial ability of all community members, particularly the economically disadvantaged, to afford necessary food [27]; and sixth, multifunctionality, which emphasizes that the food industry not only addresses human food needs but also actively extends its ecological and social functions, such as in elder care [28].

In the specific context of China, the food security paradigm has broadened from a traditional focus on quantitative and qualitative food measures to a more expansive view encompassing nutritional safety and the sustainable development of the food sector. This shift reflects a heightened emphasis on consumer upgrading and health needs. This comprehensive approach to food security not only addresses contemporary challenges of demand and supply but also provides strategic guidance for the ongoing enhancement of food security protocols in the future.

### *2.2. Urban–Rural Integration Concept*

Urban–rural integration development surpasses traditional models, embracing a broader spectrum of developmental trajectories that extend beyond mere urban support for rural settings or the rural emulation of urban paradigms. Despite variations in the definitions of urban and rural areas across different countries, the concept of “urbanization” is relatively consistent globally, denoting the transformation from traditional rural societies to modern urban societies [29], a process that is notably characterized by population concentration [30]. As urbanization advances, particularly in developed nations, a clear trend toward population redistribution becomes increasingly apparent.

Urban–rural integration development is not merely equivalent to the urbanization of rural areas. It not only strives to construct a spatial infrastructure connecting urban and rural zones but also accentuates the fundamental requirements and value orientations of urban–rural integration, thereby preventing alienation between the urban and rural environments. At its heart, urban–rural integration seeks to dismantle the traditional binary division between urban and rural areas, fully acknowledging the distinctions in social attributes, functions, and historical roles between cities and rural areas while stressing their equal significance [31].

The integration is facilitated through the complementary amalgamation of advantageous elements from both settings, with cities and rural areas leveraging their respective strengths for mutual supplementation and organic union, achieving a holistic development. This dynamic process relies on the fluid movement of elements between urban and rural areas, fostering complementarity between the industrial and agricultural sectors, transforming the traditional urban–rural dichotomy, and ensuring balanced development across both landscapes [32]. In interactions between urban and rural zones, the organic integration of rural resources underscores the reciprocal exchange and coupling of roles, adapted to specific local conditions and pushing the boundaries of urban–rural distinctions beyond conventional administrative frameworks.

The effective integration of advantageous resources between urban and rural areas is not simply a matter of urban support for rural areas but a bidirectional fusion of strengths, effectively driving concurrent progress in both rural revitalization and urbanization. Urban–rural integration development includes various facets, such as multidimensional strategies for industrial integration between urban and rural areas, primarily manifesting in the interconnectedness between sectors, in particular, in the symbiotic relationship between industry and agriculture. This structure prioritizes agriculture in rural settings while urban populations remain more concentrated, ideal for the nascent phases of industrial and agricultural development [33].

Additionally, the balanced distribution of populations between urban and rural areas mitigates the contemporary urban challenges, particularly those associated with environmental, housing, and health issues that stem from urban population density. The process of achieving adaptive complementarity between urban and rural lifestyles hinges on the mutual adaptation of functions and statuses between cities and rural areas, a process that is not inherently spontaneous [34]. Urban–rural integration further facilitates the optimal blend of natural, economic, spatial, and human elements, creating a symbiotic community characterized by mutual permeation, close connections, functional complementarity, and shared benefits [35]. Based on this foundation, the concept of urban–rural integration development is defined as the organic integration and coordinated development between cities and rural areas in domains such as spatial structures, functional systems, institutional mechanisms, cultural forms, and ecological environments [36].

### 2.3. The Role of Urban–Rural Integration in Strengthening Food Security

The integration of urban and rural areas is widely recognized as a pivotal trend in China's modernization [36], indicating a shift towards more rational and sophisticated structural improvements [37]. Urban–rural integration primarily aims to facilitate the smooth and orderly flow, as well as the equitable allocation, of resources. It also seeks to establish a unified national market and integrate resource markets to ensure fair distribution across urban and rural regions [38]. This is crucial for bolstering food security. Despite the prevailing dual urban–rural framework, there is a notable emphasis on the intensive input of resources to drive rapid socio-economic advancement. However, as the urban–rural gap widens, policies favoring urban areas have negatively impacted agricultural profitability. There has been a significant evolution in agricultural development, transitioning from solely addressing poverty and basic needs to generating initial capital for urbanization and industrialization to now focusing on the inherent qualities of food provision [39].

Urban–rural integration is increasingly recognized as a critical trend in China's modernization trajectory [36], signaling a move towards more rational and sophisticated structural reforms [37]. The fundamental aim of this process is to promote the orderly and equitable flow and distribution of resources. Moreover, urban–rural integration seeks to create a unified national market and consolidate resource markets, ensuring the fair allocation of resources across both urban and rural areas [38], which is essential for bolstering food security. Despite the ongoing dual urban–rural structure that heavily invests resources to expedite socio-economic progress, the expanding urban–rural divide and urban-biased policies have detrimentally impacted agricultural profitability. Agricultural development has experienced significant shifts, evolving from merely addressing poverty and basic needs to generating initial capital for urbanization and industrialization, and currently focusing on enhancing the intrinsic quality of food supply [39]. In this new development phase, strategies to ensure food security need to not only emphasize regional disparities but also rigorously assess the distinct impacts of urban–rural integration across various dimensions. Therefore, food security measures should be tailored based on the degree of urban–rural integration within different regions and dimensions, ensuring a targeted and effective approach.

Based on the aforementioned analysis, this paper proposes the following hypotheses:

**Hypothesis 1.** *The integration of urban and rural areas, facilitated by the organic convergence of agricultural and urban development, enhances the assurance of food security.*

Core-periphery theory suggests that food security increasingly displays pronounced regional characteristics [40,41]. The variability in urban–rural integration levels across different regions necessitates adjustments in food security strategies, highlighting the importance of focusing on regional disparities in this new development phase. Tailored strategies, based on urban–rural integration levels, are essential for ensuring food security, acknowledging that integration impacts food security differently across various dimensions. Consequently, this paper introduces additional hypotheses:

**Hypothesis 2.** *The impact of urban–rural integration on food security varies across various dimensions.*

**Hypothesis 3.** *The impact of urban–rural integration on food security varies across different regions.*

The interplay and evolution of urban and rural areas are fundamentally connected to national food security, significantly affecting the well-being of millions. Urban–rural integration is crucial for both optimal resource distribution and as a strategic method to secure food safety and promote sustainable agricultural growth. Facing the limitations and uniqueness of resources, an in-depth exploration of the dynamic relationship between urban–rural integration and food security is critical. This research endeavors to bridge the gaps in current studies and offer a scientific foundation for policy formulation through the analysis of comprehensive panel data from 31 provinces in China, excluding Hong Kong, Macau, and Taiwan. To clarify the relationship between urban–rural integration and food security, this study constructs a methodological flowchart, as illustrated in Figure 2.

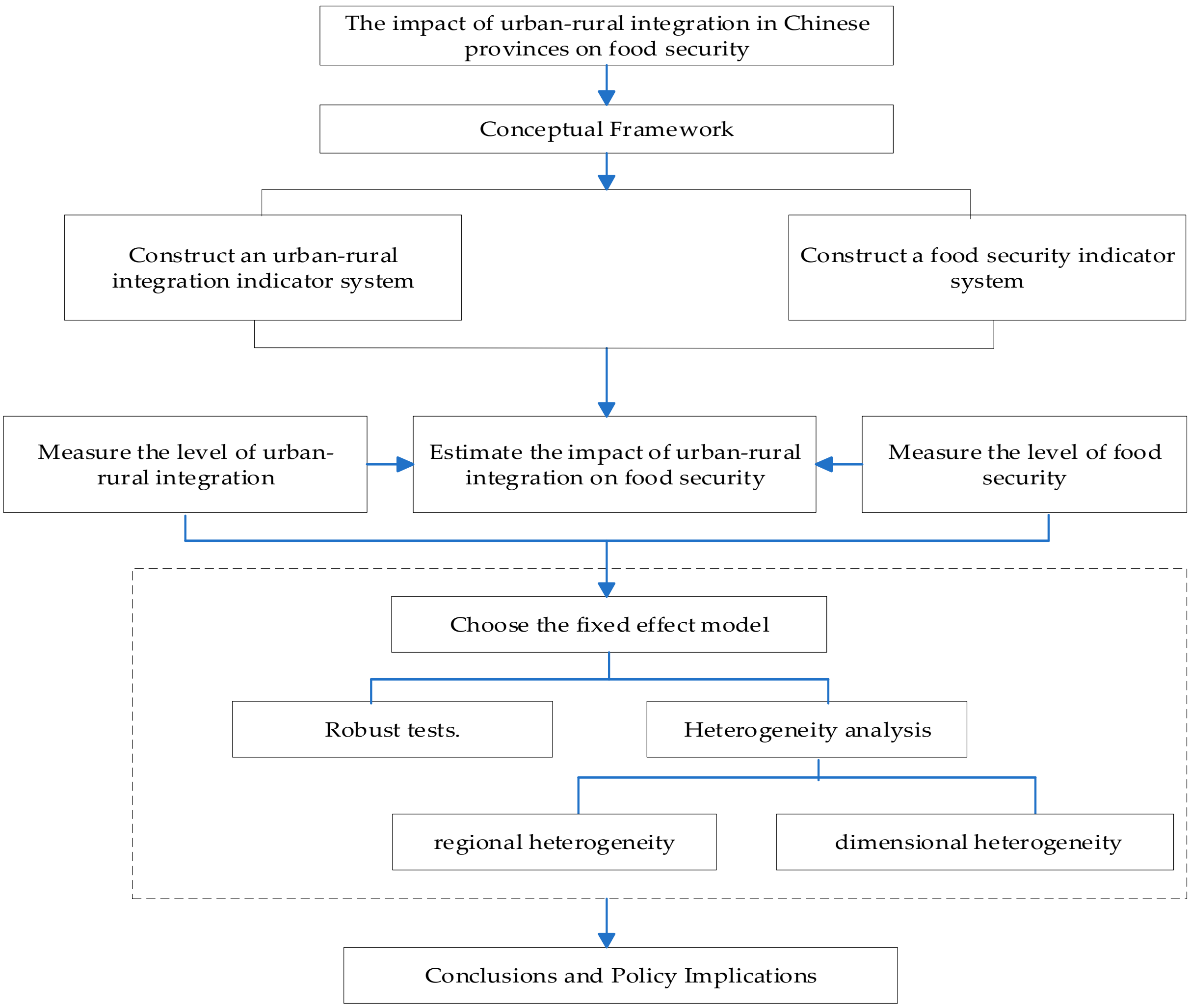


**Figure 2.** A flowchart of the methods employed in this study.

## 3. Materials and Methods

### *3.1. Materials*

Data Source

This study undertook an analysis of panel data encompassing 31 Chinese provinces (excluding Hong Kong, Macao, and Taiwan) in the period 1990 to 2021. The data sources primarily included the China Statistical Yearbook, the China Urban Statistical Yearbook, the China Rural Statistical Yearbook, the China Household Survey Yearbook, the China Energy Statistical Yearbook, the China Population and Employment Statistics Yearbook, and provincial statistical yearbooks. To address missing values in the dataset, a non-parametric approach utilizing the random forest algorithm within the framework of machine learning was employed for the process of data imputation. This method leverages known variables as predictors and constructs a random forest model with the target variable containing missing values, thereby predicting these missing values. Random forest is recognized as one of the most advanced methods for data imputation, offering substantial reliability and precision. It is widely utilized in machine learning, surpassing traditional methods such as mean imputation, mode imputation, regression imputation, and k-nearest neighbors (KNN) imputation in terms of accuracy and reliability.

### *3.2. Variable Selection*

The food security level was identified as the critical variable for analysis. Given the multifaceted nature of food security, accurately measuring it presents a considerable challenge [42]. This study adopts a comprehensive approach, recognized by scholars both within China and internationally, that employs multiple perspectives and dimensions to systematically evaluate food security levels across China's provinces. Through the integration of systematic and scientific methods and the consideration of economic, societal, and ecological factors, this paper endeavors to present a nuanced depiction of food security's characteristics and extent. Drawing from seminal research on availability, stability, accessibility, and sustainability, it defines 18 distinct indicators within the following seven key categories: the quantity and quality of security, economic infrastructure, transport systems, variability analysis, resource allocation, and ecological management [43–46].

This results in the construction of a food security evaluation system tailored to China's unique characteristics, as illustrated in Table 1. It underscores the significance of ensuring access to basic nutritional needs and a healthy diet, improving disposable income and food acquisition conditions, analyzing price volatility and production, and advocating for sustainable resource use and ecological stewardship. Employing these indicators, this research constructed a detailed food security level assessment system, quantified it using the entropy method, and visually presents the results in a bubble chart, as shown in Figure 3.

**Table 1.** The food security level indicator system.

| Primary Index | Secondary Index | Three-Level Index | Direction |
|---|---|---|---|
| Supply levels | Quantity Security | Food Production (Z1) | + |
| | | Farmland Area (Z2) | + |
| | | Per Capita Grain Possession (Z3) | + |
| | Quality Security | Affected Area (Z4) | − |
| | | Pesticide Usage (Z5) | − |
| | | Agricultural Plastic Film Usage (Z6) | − |
| | | Effective Fertilizer Usage (Z7) | − |
| Accessibility | Economic Foundation | Per Capita GDP (Z8) | + |
| | | Rural Resident Per Capita Disposable Income (Z9) | + |
| | Transportation Facilities | Railway Density (Z10) | + |
| | | Road Density (Z11) | + |
| Stability | Fluctuations | Coefficient of Grain Production Fluctuation (Z12) | − |
| | | Coefficient of Grain Consumption Price Fluctuation (Z13) | − |
| Sustainability | Resource Input | National Financial Expenditure on Agriculture (Z14) | + |
| | | Per Capita Arable Land Area (Z15) | + |
| | | Effective Irrigated Area of Farmland (Z16) | + |
| | Ecological Governance | Drainage Area (Z17) | + |
| | | Soil Erosion Control Area (Z18) | + |

Note 1: The grain-related indicators represent the combined data for cereals, legumes, and root crops. Note 2: In the table, a '+' symbol signifies a higher index, which corresponds to a more favorable condition for ensuring food security, whereas a '−' symbol indicates a lower index, which is also advantageous for ensuring food security.

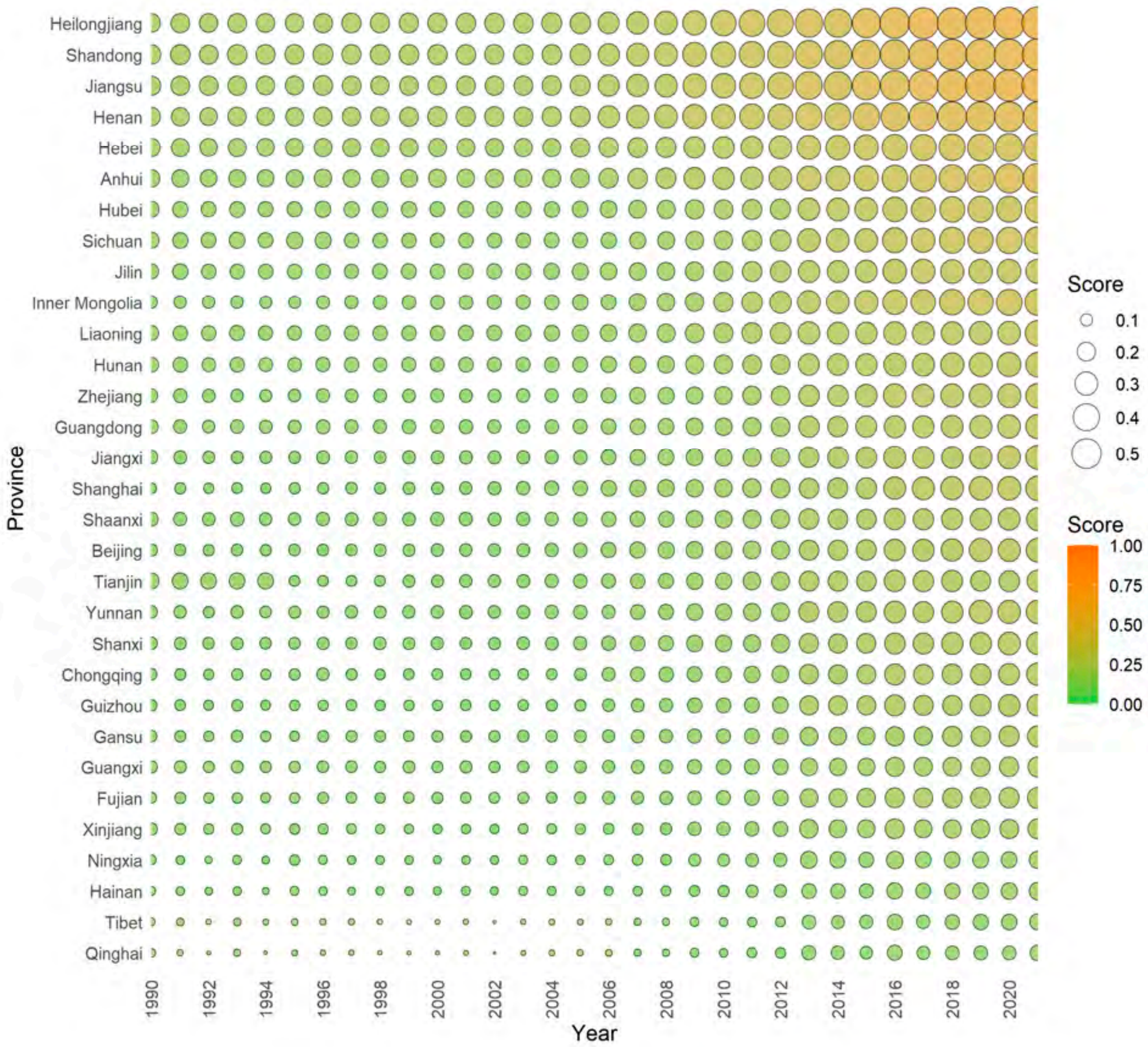


**Figure 3.** Bubble chart of food security levels across 31 provinces from 1990 to 2021.

For the establishment of the food security indicator system, we specifically focused on the computational methods for indicators z10–z13, as outlined in Table 1. Enhanced accessibility, particularly through the improvements in the rail transit system, significantly boosts the spatial efficiency and quality of grain distribution, facilitating the seamless transportation from production to consumption areas. A robust transportation infrastructure and systems play a pivotal role in enabling the unrestricted movement of production factors, optimizing spatial economic layouts, and fostering shared prosperity. Consequently, through a comparative analysis of the total mileage of roads and railways with the area ratios of various provinces, railway density (Z10) and road density (Z11) emerge as critical indicators for assessing the grain circulation capacity [47]. Regarding stability, fluctuations in grain supply and consumption prices, driven by market dynamics, have a notable impact on residents' living standards. Therefore, the grain supply volatility coefficient (Z12) and the grain consumption price index volatility (Z13) were chosen as specific indicators to evaluate market fluctuations. Utilizing a five-year average method to forecast trends in production volume and grain consumption price indices, we derived the respective volatility coefficients [48]. The remaining indicators, Z1–Z9 and Z14–Z18, were extracted directly from Section 3.1 and underwent brief processing. As these indicators were extensively utilized in related scholarly research [45,46], this study does not delve further into their evaluation.

The explanatory variable chosen is the level of urban–rural integration. To comprehensively reflect this level across various Chinese provinces, this study primarily draws on the research of scholars such as Zhou et al. [49], Shu et al. [50], and Liu et al. [51]. Utilizing four dimensions—urban–rural spatial integration, economic integration, social integration, and ecological integration—a set of 22 indicators was established, covering 16 aspects including spatial aggregation level, spatial connectivity efficiency, digitalization level, population density, economic conditions, industrial structure, employment situation, resident income, consumer spending, technological progress, education inclusivity, material foundation, pursuit of cultural life, healthcare, vegetation greening, and energy consumption. The objective was to construct a multidimensional evaluation index system that comprehensively reflects the actual level of urban–rural integration in China [52–54]. Through the comprehensive assessment of these indicators, it becomes possible to accurately reflect the differences and development situations of the urban–rural integration level across different provinces in China.

The spatial dimensions of urban-rural integration are of paramount importance in the current research. This study primarily relies on the methodologies utilized by scholars such as Zhou et al. [55] and Shu et al. [50]. Urban-rural spatial integration encompasses several pivotal components, namely the spatial agglomeration level, spatial accessibility efficiency, digitalization level, and population density. The spatial agglomeration level, measured using the urbanization rate, is an important indicator for assessing the urbanization process, reflecting the differences in rural-urban development and the level of urbanization. Spatial accessibility efficiency is evaluated using indicators such as passenger turnover, cargo turnover, and private car ownership, which measure the convenience and efficacy of urban-rural transportation, thereby shedding light on the dynamics of material exchange between urban and rural areas. The digitalization level is measured through metrics like the ratio of urban-rural mobile phone usage, reflecting the extent of information technology integration and digital development in urban and rural areas. The population density indicators, such as the urban-rural population density ratio, yield valuable insights into the distribution of the population between urban and rural areas and the extent of population concentration.

The economic dimension of urban-rural integration is a multifaceted concept that encompasses various aspects, including economic status, industrial structure, employment dynamics, residents' financial profiles, and technological advances. Drawing primarily on the methodologies of esteemed scholars such as Zhou et al. [55], Zhou et al. [49], and Shi et al. [56], this dimension was meticulously examined. Economic status was evaluated through indicators such as the proportion of non-agricultural output to agricultural output, which elucidates the disparities and developmental stages of urban and rural economic frameworks. The industrial structure was scrutinized using metrics like the dualistic coefficient, shedding light on the disparities in urban and rural industrial formations and the equilibrium of industrial progress. The employment dynamics were assessed through indicators such as the urban unemployment registration rate, the ratio of non-agricultural employment to agricultural employment, and the ratio of the average number of dependents per labor force member in urban and rural areas, revealing the discrepancies in employment scenarios and the distribution of job opportunities between urban and rural sectors. The financial profiles of residents were examined using metrics such as the ratio of per capita disposable income of urban and rural residents, which highlights the income gap and the extent of income inequality between these populations. Furthermore, residents' consumption patterns were analyzed through metrics such as the ratio of per capita consumption expenditure of urban and rural residents, providing insights into the disparities in living standards and consumption structures between urban and rural communities. Lastly, technological progress was gauged using metrics such as the level of agricultural mechanization, reflecting the degree of modernization in the agricultural sector.

The social dimension of urban-rural integration encompasses various facets, drawing primarily on the methodologies of esteemed scholars such as Zhao et al. [57] and Yang et al. [36]. This dimension was delineated into aspects including universal access to education, material life security, cultural pursuits, and healthcare. Universal access to education was evaluated through indicators such as the comparison of rural and urban education levels, enabling the assessment of disparities in educational resources and the degree of educational inclusiveness between urban and rural areas. Material life security was assessed using metrics like the ratio of per capita housing area between urban and rural residents, which reflects the differences in housing conditions and the level of material life security between these populations. Cultural pursuits were examined through considering the ratio of family spending on cultural, educational, and entertainment activities for urban and rural residents, allowing for an evaluation of differences in cultural education and entertainment consumption between the two groups. Healthcare was gauged through indicators such as the ratio of per capita healthcare expenditure between urban and rural residents, offering insights into the disparities in healthcare resources and the level of healthcare between urban and rural areas.

The ecological dimension of urban-rural integration, as elucidated by scholars like Haq et al. [58] and Chun-sheng et al. [59] encompasses various facets, notably urban and rural vegetation greening and energy consumption. Vegetation greening entails assessing the environmental disparities between urban and rural regions, as well as the degree of ecological conservation, through indicators such as per capita green space area and forest coverage rate. Similarly, energy consumption analysis, including metrics like the proportion of urban and rural electricity usage, offers insights into the divergence in energy utilization and consumption levels between urban and rural locales.

In selecting these specific indicators, we considered the following key factors: firstly, academic reference—the particular study draws upon crucial research methodologies employed by scholars in the dimensions of spatial, economic, social, and ecological integration of urban and rural areas, adopting their research findings. Secondly, comprehensiveness—the chosen indicators cover multiple aspects of urban-rural integration, such as spatial characteristics, economic structures, social development, and ecological environment, fully reflecting the complexity and diversity of urban-rural integration. Additionally, comparability—the selected indicators are easily comparable, aiding in assessing differences, changes, and trends in urban-rural development to guide policy formulation and decision-making. Finally, practicality—these indicators objectively measure key aspects of the urban-rural integration process, providing crucial reference points for assessing the status of urban-rural development and formulating development plans. Integrating these factors, we have selected these specific indicators to evaluate various aspects of urban-rural integration, aiming to deepen our understanding of the current state of urban and rural development and to promote comprehensive and balanced progress in urban-rural integration.

Consequently, the aforementioned indicators were selected to construct an evaluation index system for the level of urban–rural integration, as depicted in Table 2. The entropy method was employed to measure this level of integration, with the measurement results further visualized using a heatmap, as illustrated in Figure 4.

Based on an examination of the pertinent literature, this study identifies a set of control variables: government intervention, trade dependence on agricultural products, the dependency of agriculture on water resources, the average annual temperature, and the structure of the industry. The definitions for these variables are provided in Table 3. In the context of government intervention, it is notable that China is navigating through a transitional phase, with its market system exhibiting a lower level of maturity relative to that of developed nations. Consequently, judicious government intervention is deemed critical for the sustenance of food security. Typically, government interventions propel economic growth via specific institutional frameworks. Liu et al. [54] observed a pervasive trend across developing countries where fiscal allocations are disproportionately skewed towards urban areas, thereby endowing urban dwellers with a social welfare advantage over their rural counterparts, and fostering a disparity in development between urban and rural regions. Such fiscal practices could hinder the equitable distribution of resources based on market demands, leading to discrepancies in resource allocation across sectors. The further research of Han et al. [60] indicated that excessive government regulation incrementally exacerbates the misalignment of resources among sectors. Nonetheless, the government's implementation of price support policies and agricultural subsidies has played a significant role in bolstering food security [61]. Accordingly, this paper utilizes the ratio of governmental fiscal expenditure on agriculture to the total fiscal expenditure as a gauge of the government's capacity to influence agricultural practices [62].

**Table 2.** Urban–rural integration level indicator system.

| Primary Index | Secondary Index | Three-Level Index | Index Calculation Method | Direction |
|---|---|---|---|---|
| Spatial Dimension | Spatial Agglomeration Level | Urbanization Rate (B1) | Urban population/Total population | + |
| | Spatial Smoothness Efficiency | Passenger Turnover Volume (B2) | Passenger volume (in ten thousand person-km) | + |
| | | Freight Turnover Volume (B3) | Freight volume (in ten thousand ton-km) | + |
| | | Private Car Ownership (B4) | Private car ownership/Total population | + |
| | Digitization Level | Urban and Rural Mobile Phone Usage Ratio (B5) | Urban mobile phone users/Rural mobile phone users | − |
| | Population Density | Urban and Rural Population Density Ratio (B6) | Rural population density/Urban population density | + |
| Economic Dimension | Economic Conditions | Non-agricultural Output Value Proportion (B7) | GDP of secondary and tertiary industry/GDP of primary industry | + |
| | Industrial Structure | Gini Coefficient (B8) | Output value of primary industry/Number of employees in primary industry)/(Output value of secondary and tertiary industry/Number of employees in secondary and tertiary industry) | + |
| | Employment Structure | Proportion of Non-agricultural Employment to Agricultural Employment (B9) | Employees in secondary and tertiary industry/employees in primary industry | + |
| | | Urban Unemployment Registration Rate (B10) | Registered urban unemployed/(Urban employed + Registered urban unemployed) | − |
| | | Urban and Rural Average Labor Burden Person Ratio (B11) | Average number of dependents per urban worker/Average number of dependents per rural worker | − |
| | Resident Income | Urban and Rural Per Capita Income Ratio (B12) | Per capita annual disposable income of urban households/Per capita annual net income of rural residents | − |
| | Resident Consumption | Urban and Rural Per Capita Family Consumption Ratio (B13) | Per capita household expenditure in cities/Per capita household expenditure in rural areas | − |
| | | Urban and Rural Engel Coefficient Ratio (B14) | Urban Engel coefficient/Rural Engel coefficient | + |
| | Technological Progress | Level of Agricultural Mechanization (B15) | Total agricultural machinery power/Total cultivated area | + |

**Table 2.** *Cont.*

| Primary Index | Secondary Index | Three-Level Index | Index Calculation Method | Direction |
|---|---|---|---|---|
| Social Dimension | Inclusive Education | Comparison of Rural Education Level to Urban Education Level (B16) | Illiterate and semi-literate population ratio aged 15 and above in rural areas/Illiterate and semi-literate population ratio aged 15 and above in urban areas | + |
| | Material Basis | Urban and Rural Per Capita Housing Area Ratio (B17) | Urban housing area/Rural housing area | + |
| | Pursuit of cultural life | Urban and Rural Per Capita Expenditure on Culture, Education, and Recreation Ratio (B18) | Urban household spending on culture, education, and entertainment/Rural household spending on culture, education, and entertainment | − |
| | Healthcare | Urban and Rural Per Capita Medical Expenditure Ratio (B19) | Per capita medical and healthcare expenditure in cities/Per capita medical and healthcare expenditure in rural areas | − |
| Ecological Dimension | Vegetation Greening | Forest Coverage Rate (B20) | Forest area/Land area | + |
| | | Per Capita Green Area (B21) | Urban public green space area/Non-agricultural population in urban areas | + |
| | Energy Consumption | Electricity Consumption (B22) | Ratio of urban and rural electricity consumption | − |

Note: In the table, the symbol "+" signifies that an increase in the index corresponds to greater facilitation of urban–rural integration. Conversely, the symbol "−" denotes that a decrease in the index is more conducive to promoting urban–rural integration.

Trade dependence on agricultural products: As market openness expands, the international grain market presents import-related risks. The research of Zhu et al. [63] indicated a notable transition in China's grain self-sufficiency, which decreased from 97.9% in 2001 to 86% in 2019, highlighting an increased reliance on international markets for grain supply. This study measures agricultural trade dependence through the ratio of the value of agricultural imports and exports to the added value of the agricultural sector [64].

Agriculture's dependence on water resources: Advances in agricultural production face significant hurdles due to the scarcity and uneven distribution of water resources. These disparities result in acute water shortages in certain areas, considerably constraining agricultural output. This challenge is exacerbated by the northward migration of food production [65], further emphasizing the concerns over water scarcity. Therefore, the adaptability and flexibility of the agricultural system in addressing water shortages are crucial for maintaining food security [66].

The average annual temperature: The escalating concerns surrounding global warming and its ramifications on food security [67] underscore the pivotal role of temperature fluctuations in food production. These fluctuations, integral to plant growth, not only influence crop production but are also critical in ensuring food security. The importance of maintaining optimal temperature variations for food production and safety is paramount [68]. The studies of Schlenker et al. [69] and Hatfield et al. [70] highlighted the profound effects of temperature shifts on the growth cycles and yields of crops, emphasizing the necessity for governmental and agricultural bodies to diligently monitor these trends and implement strategic measures to uphold the continuity and safety of food production.

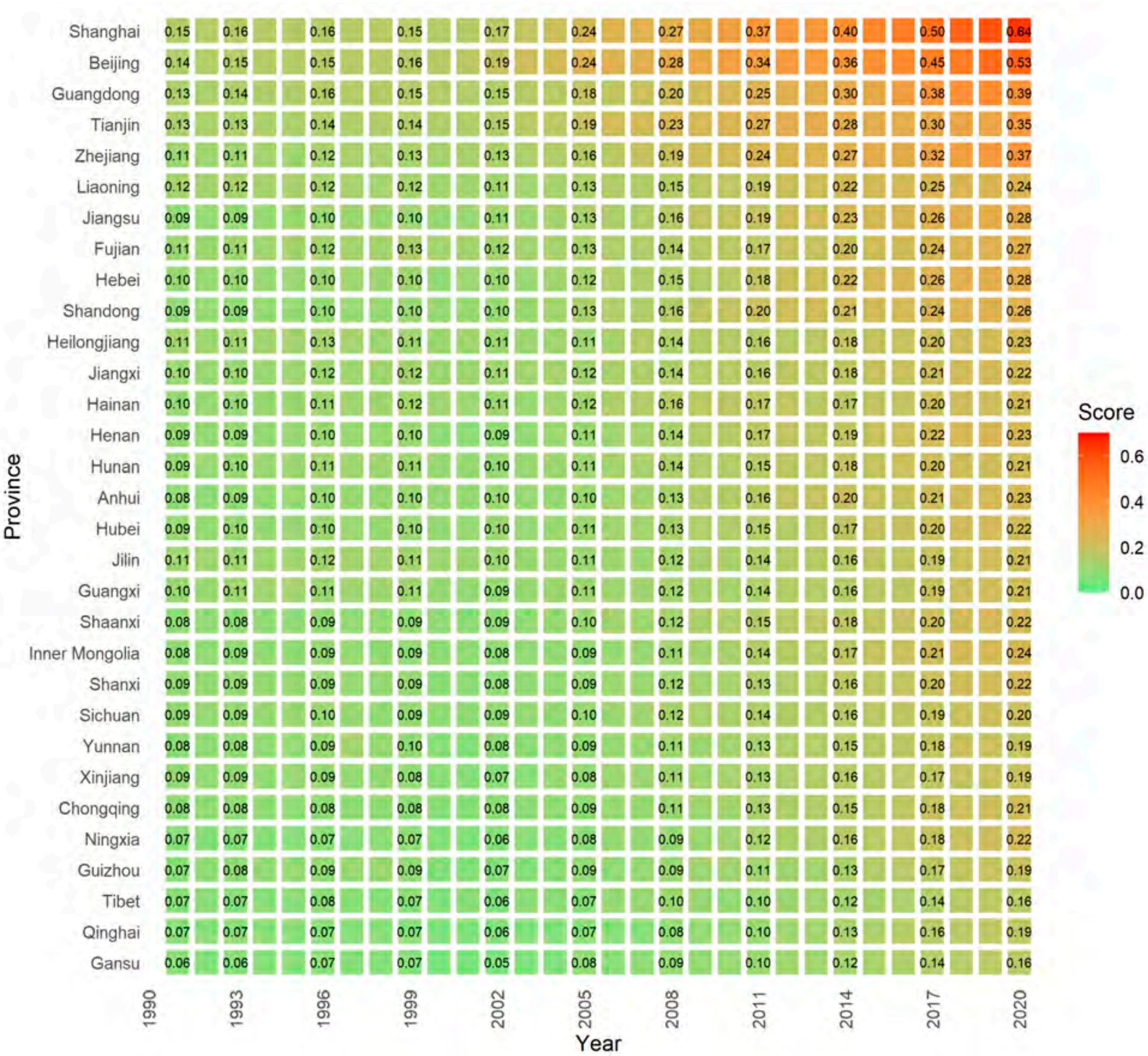


**Figure 4.** Heat map of the level of urban–rural integration across 31 provinces from 1990 to 2021.

The industrial structure profoundly shapes the modernization trajectory inherent in the Chinese model. Its dynamic adaptation plays a pivotal role in transitioning economic growth away from reliance on factor-intensive inputs towards optimizing factor-distribution efficiency. These adjustments facilitate resource reallocation, directing them towards sectors that demonstrate higher productivity. In response to the distinct dual economic structure that exists between urban and rural areas, many developing nations have prioritized strategies emphasizing industrial or heavy industrial development. These strategies involve reallocating resources from rural settings to foster primary capital accumulation. As economic development progresses, global trends indicate a shift towards industrialization, accompanied by changes in industrial structure and a reduction in the size of the agricultural sector [71]. Consequently, this study employs the ratio of added value in the primary industry to the region's GDP as a metric for assessing industrial structure.

Table 3 delineates the symbols, essential definitions, and methodologies for computing the dependent, independent, and control variables. Table 4 offers a comprehensive statistical overview of these variables, including the symbols, sample sizes, means, standard deviations, and the range of values. A calculation of the Pearson correlation coefficient among the key variables reveals a significantly positive correlation between urban–rural integration and food security, aligning with the predictions of extant theoretical frameworks.

Additionally, the correlation coefficients between variables in the model uniformly fall below 0.6. The variance inflation factor (VIF) for the urban–rural integration core variable registers at 2.00, significantly under the threshold of 10, suggesting minimal concerns of multicollinearity (the variance inflation factor (VIF) test indicates that there is no severe multicollinearity issue among all variables).

**Table 3.** Variable definitions.

| Type | Variable Name | Symbol | Calculation Method |
|---|---|---|---|
| Dependent variable | Food security level | food | Food security levels of each province calculated based on the entropy method annually |
| Explanatory variable | Urban–rural integration level | Integration | Urban–rural integration levels of each province calculated based on the entropy method annually |
| Control variable | Government intervention | Government | The proportion of government fiscal expenditure on agriculture to total fiscal expenditure to measure government intervention in agriculture |
| | Dependence on agricultural trade | Trade | Proportion of total agricultural import and export volume to agricultural value added |
| | Dependence on agricultural water resources | Resources | Proportion of agricultural water use to total water consumption |
| | Annual average temperature | Temperature | Average temperature calculated by summing up the temperatures of each month throughout the year and dividing by 12 |
| | Industrial structure | Structure | Proportion of the combined value added of the secondary and tertiary industries to GDP |

**Table 4.** Descriptive statistics of variables.

| Variable Name | Symbol | Obs. | Mean | Min | Max | SD | VIF |
|---|---|---|---|---|---|---|---|
| Food security level | food | 992 | 0.182 | 0.042 | 0.580 | 0.105 | -- |
| Urban–rural integration level | Integration | 992 | 0.149 | 0.053 | 0.694 | 0.078 | 2.00 |
| Government intervention | Government | 992 | 0.074 | 0.003 | 1.383 | 0.097 | 1.97 |
| Dependence on agricultural trade | Trade | 992 | 0.305 | 0.002 | 7.672 | 0.744 | 1.84 |
| Dependence on agricultural water resources | Resources | 992 | 0.634 | 0.069 | 0.979 | 0.169 | 1.46 |
| Annual average temperature | Temperature | 992 | 14.303 | 4.300 | 25.800 | 5.056 | 1.23 |
| Industrial structure | Structure | 992 | 0.840 | 0.491 | 1.023 | 0.096 | 1.19 |

Source: computed by Stata 16.0.

### *3.3. Methods*

#### 3.3.1. Entropy Method

This study employs the entropy method to assign appropriate weights to the indicators across various dimensions, thereby comprehensively assessing the levels of urban–rural integration and food security. By calculating the contribution of uncertainty factors within the system, this method ascertains the optimal weights for each indicator. In contrast to methods such as expert review and the analytic hierarchy process, the entropy method minimizes human interference and provides a more comprehensive and accurate reflection of the practical utility of information entropy. Consequently, the entropy method is utilized to independently evaluate the levels of urban–rural integration and food security. The specific mathematical expressions are detailed below.

$$Z'_{ijt} = (Z_{ijt} - \text{min}Z_{ijt})/(\text{max}Z_{ijt} - \text{min}Z_{ijt}) \tag{1}$$

$$Z'_{ijt} = (\text{max}Z_{ijt} - Z_{ijt})/(\text{max}Z_{ijt} - \text{min}Z_{ijt}) \tag{2}$$

Equations (1) and (2) normalize the positive and negative indicators for both the urban–rural integration and food security index systems, respectively.

$$P_{ijt} = \frac{Z_{ijt}}{\sum\limits_{t=1}^{n}\sum\limits_{i=1}^{m} Z_{ijt}} \tag{3}$$

Equation (3) indicates that under the $j$th indicator, the weight for the $t$ th year in region $i$ is set to $P_{ijt}$.

$$E_j = -K\sum_{t=1}^{n}\sum_{i=1}^{m} P_{ijt} ln(P_{ijt}) \tag{4}$$

Equation (4) indicates that $E_j$ represents the entropy value of project $j$. To ensure $(0 \leq E_j \leq 1)$, where $K = 1/\ln(n \times m)$.

$$W_j = \frac{1 - E_j}{\sum\limits_{j=1}^{r} 1 - E_j} \tag{5}$$

Formula (5) indicates that the weight of project $j$ is $W_j$.

$$food_{it} = P_{ijt} \times W_j \tag{6}$$

Formula (6) represents the food security level of region $i$ in year $t$, denoted by $food_{it}$. Similarly, urban–rural integration levels can be calculated using the above-mentioned method, indicated by $integration_{it}$.

3.3.2. Model Construction

This study employs a fixed-effects model to examine the influence of urban–rural integration levels on food security.

$$food_{it} = e_0 + e_1 integration_{it} + \sum\nolimits_j^5 e_2 controls_{i,t} + \mu_i + \lambda_t + \varepsilon_{it} \tag{7}$$

In this model, $i$ and $t$ denote the province and year, respectively; $food_{it}$ serves as the dependent variable, signifying the multidimensional food security level for province $i$ in year $t$. The variable $integration_{it}$ measures the urban–rural integration, the primary explanatory variable, indicating the integration level for province $i$ in year $t$. The model also includes controls, which are a set of variables influencing food security. Additionally, $\mu_i$, $\lambda_t$, and $\varepsilon_{it}$ represent the unobservable individual effects of the province, fixed time effects, and random disturbances.

Initially, an Ordinary Least Squares (OLS) regression is performed using Stata 16.0 to assess the effects of urban–rural integration on food security. To minimize heteroscedasticity, all variables undergo a logarithmic transformation prior to regression analysis, resulting in the conversion of Equation (1) into Equation (2).

$$Infood_{it} = e_0 + e_1 lnintegration_{it} + \sum\nolimits_{\text{j}}^5 e_2 lncontrols_{i,t} + \mu_i + \lambda_t + \varepsilon_{it} \tag{8}$$

## 4. Results

### *4.1. Analysis of Urban–Rural Integration and Food Security Measurement Results*

4.1.1. Analysis of Food Security Measurement Results

Figure 3 illustrates the levels of food security across China's 31 provinces (excluding Hong Kong, Macau, and Taiwan) from 1990 to 2021, highlighting a consistent enhancement in food security across the provinces. Key grain-producing regions such as Heilongjiang, Henan, and Shandong remain pivotal in ensuring food security despite approaching saturation in their capacity. Leveraging their abundant resources, these primary production areas have efficiently supplied food to major consumption centers, fostering a synergy of regional strengths. Concurrently with economic progress, the focal point of food security is gradually shifting northward, with Xinjiang, Shanxi, and Qinghai emerging as critical hubs for food reserve capabilities, demonstrating significant potential. Although primary consumption areas display low self-sufficiency, their economic influence and robust infrastructure support reliance on primary production regions and trade to ensure food security. Advancements in transportation, technology, and digitalization are steadily enhancing food supply capabilities, underscoring the importance of maintaining regional food security equilibrium as a fundamental aspect of revising the national food security strategy.

#### 4.1.2. Analysis of Urban–Rural Integration Measurement Results

Figure 4 illustrates the levels of urban–rural integration across China's 31 provinces (excluding Hong Kong, Macau, and Taiwan) from 1990 to 2021, providing a clear visual representation. Analyzing the urban–rural integration data visually permits an intuitive understanding of the disparities in integration levels among provinces, highlighting significant variations. For instance, developed regions such as Beijing, Shanghai, Guangdong, Zhejiang, and Jiangsu consistently demonstrate high levels of urban–rural integration, reflecting their advanced economic development, comprehensive urbanization, and effective integration of urban and rural public services. In contrast, less developed areas such as Guangxi, Guizhou, Yunnan, Xinjiang, and Tibet present substantial opportunities for improving their urban–rural integration.

### *4.2. Results of Baseline Regression*

Utilizing stepwise regression, Table 5 presents the benchmark regression results on the impact of urban–rural integration on food security, revealing a significantly positive effect across models (1–6), indicating statistical significance. The progressive inclusion of control variables and the specific control for year or province fixed effects in models (2–6) confirm that urban–rural integration significantly enhances food security at the 1% significance level. Notably, the findings in column (6) elucidate that each unit increase in urban–rural integration level corresponds to a 0.154 increase in food security level, highlighting the beneficial role of urban–rural integration in strengthening food security. Moreover, the incorporation of relevant control variables demonstrates meaningful adjustments in the coefficient of urban–rural integration level, maintaining a robust positive correlation and refining the model's fit. This refinement enables a more precise assessment of the impact on the dependent variable, consistent with the expectations of statistical regression analysis. Early indications from these results validate the effectiveness of enhancing urban–rural integration level in advancing food security. Examining model (6) to analyze the influence of control variables on food security across provinces reveals a significant positive impact of government intervention, as evidenced by an estimated coefficient of 0.0396 that surpasses the 1% significance threshold. This underscores the crucial role of government intervention in strengthening food security, particularly through bolstering the macro institutional framework for food, implementing price subsidies to stimulate grain production [61], and improving the operational mechanism of macro food security to navigate market uncertainties and accommodate changes in food supply capacity [72]. Conversely, the estimated coefficient of $-0.0188$ for agricultural trade dependence confirms a detrimental effect on food security, highlighting the necessity of imports to bridge the gap in domestic crop planting areas to achieve agricultural product supply–demand equilibrium in China. The reliance on imports, coupled with international regulatory constraints, volatility in international grain prices, and complex global dynamics, poses challenges to domestic food security. In response to the persistent decline in self-sufficiency rates, enhancing food self-sufficiency emerges as a fundamental strategy for safeguarding food safety [73]. Additionally, the negative impact of agriculture's dependence on water resources, with an estimated coefficient of 0.0585, underscores water resources as a critical constraint on the sustainable development of food security.

**Table 5.** The results of baseline regression analysis.

| Variables | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|---|---|---|---|---|---|---|
| lnintegration | 0.184 *** | 0.176 *** | 0.193 *** | 0.160 *** | 0.158 *** | 0.154 *** |
| | (0.0285) | (0.0282) | (0.0285) | (0.0299) | (0.0299) | (0.0301) |
| lngovernment | | 0.0350 *** | 0.0402 *** | 0.0394 *** | 0.0395 *** | 0.0396 *** |
| | | (0.00776) | (0.00786) | (0.00782) | (0.00782) | (0.00782) |
| lntrade | | | −0.0193 *** | −0.0183 *** | −0.0176 *** | −0.0188 *** |
| | | | (0.00571) | (0.00568) | (0.00572) | (0.00585) |
| lnresources | | | | −0.0611 *** | −0.0603 *** | −0.0585 *** |
| | | | | (0.0173) | (0.0173) | (0.0174) |
| lntemperature | | | | | 0.0495 | 0.0502 |
| | | | | | (0.0456) | (0.0456) |
| lnstructure | | | | | | –0.0434 |
| | | | | | | (0.0412) |
| CConstant | −1.707 *** | −1.673 *** | −1.647 *** | −1.753 *** | −1.882 *** | −1.909 *** |
| | (0.0684) | (0.0681) | (0.0682) | (0.0741) | (0.140) | (0.142) |
| Fixed Year | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed Province | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 992 | 992 | 992 | 992 | 992 | 992 |
| R2 | 0.9823 | 0.9827 | 0.9829 | 0.9832 | 0.9832 | 0.9832 |

Note: standard error in parentheses. *** indicate significance at the 10%, 5%, and 1% levels, respectively.

In essence, the regression analysis highlights the positive impact of urban–rural integration on food security, bolstered with effective government interventions. Conversely, agricultural trade dependence and reliance on water resources negatively affect food security, posing significant constraints. The analysis suggests that average annual temperature and industrial structure have minimal influence on food security. While climate change does impact agricultural yield and regional food security, variations in global or regional average temperatures may not be as significant as specific climatic extreme events, such as droughts and floods [74,75]. Additionally, in economically advanced regions, the direct effect of industrial structure on food self-sufficiency is limited, as trade can compensate for local production deficits.

### *4.3. Robustness Test*

The benchmark regression analysis highlighted the positive impact of urban–rural integration on food security. To validate the reliability of these findings, this study conducted a robustness check by reassessing both the dependent and independent variables. Employing global principal component analysis, this study aimed to strengthen the robustness and accuracy of the benchmark results, mitigating potential biases arising from measurement indicators and selection of estimation methods. The model's robustness was tested by re-estimating and substituting the independent and core variables. As shown in Table 6, although the coefficients varied in magnitude, their direction and significance remained consistent with the initial results, thereby affirming the robustness and bolstering the credibility of the benchmark findings.

**Table 6.** Robustness check of replacing variables.

| Variables | Model 1: Replace the Explained Variables. | Model 2: Replace the Explanatory Variables. |
|---|---|---|
| lnintegration | 0.188 *** | 0.314 *** |
| | (0.0498) | (0.0111) |
| Constant | −1.807 *** | −1.981 *** |
| | (0.221) | (0.257) |
| Control variable | Yes | Yes |
| Fixed Year | Yes | Yes |
| Fixed Province | Yes | Yes |
| Observations | 992 | 992 |
| R2 | 0.961 | 0.896 |

Note: standard error in parentheses. *** indicate significance at the 10%, 5%, and 1% levels, respectively.

### *4.4. Endogeneity Test*

This study employed two strategies to address endogeneity concerns. Initially, it adopted the methodology proposed by Zhang et al. [76], among others, which involves lagging the explanatory variables by one period to effectively deal with reverse causality in time series data. As demonstrated in Model 1 of Table 7, a one-period lag in urban–rural integration levels continues to exert a significant positive influence on food security. Additionally, following the approach advocated by Blundell et al. [77], the generalized method of moments (GMM) was utilized for estimation. As shown in Model 2 of Table 7, with an AR (1) less than 0.1 and AR (2) greater than 0.1, this indicates a substantial mitigation of the endogeneity issue. The results of the Sargan test further confirm the adequacy of the model specification.

**Table 7.** Endogeneity test results.

| Variables | Model 1: Explanatory Variables Lag by One Stage | Model 2:SYS-GMM |
|---|---|---|
| lnintegration (−1) | 0.127 *** | |
| | (0.0305) | |
| lnfood (−1) | | 0.613 *** |
| | | (0.0105) |
| lnfood (−2) | | 0.231 *** |
| | | (0.00949) |
| lnintegration | | 0.222 *** |
| | | (0.0109) |
| Constant | −2.115 *** | 0.156 *** |
| | (0.231) | (0.0160) |
| Control variable | Yes | Yes |
| Observations | 961 | 930 |
| R2 | 0.984 | |
| AR (1) | | 0.0004 |
| AR (2) | | 0.6325 |
| Sargan | | 1.000 |

Note 1: standard error in parentheses. *** indicate significance at the 5% and 1% levels, respectively. Note 2: "lnintegration (−1)" denotes the variable lagged by one period. "lnfood (−1), lnfood (−2)" indicate the variable lagged by one and two periods, respectively.

### *4.5. Heterogeneity Analysis*

#### 4.5.1. Dimensional Heterogeneity Analysis

To elucidate the multidimensional impacts of urban–rural integration on food security, this study systematically explored its spatial, economic, social, and ecological facets to assess their varied effects on food security levels. The dimensions of urban–rural integration were quantified using the entropy method, facilitating subsequent regression analyses on food security. The results (see Table 8) demonstrate that integration within spatial, economic, and social realms significantly enhances food security at a 1% statistical level, while the ecological dimension exhibits a notable negative impact at a 5% statistical level, with a correlation coefficient of −0.0998. Hence, urban–rural integration exerts a beneficial influence on food security in spatial, economic, and social contexts; however, it may detrimentally affect food security within the ecological scope.

**Table 8.** Dimensional heterogeneity analysis test results.

| Variables | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Spatial dimension | 0.530 *** (0.0091) | | | |
| Economic dimension | | 0.0679 *** (0.0193) | | |
| Social dimension | | | 0.206 *** (0.0583) | |
| Ecological dimension | | | | −0.0998 ** (0.0420) |
| Constant | −0.772 *** (0.166) | −1.858 *** (0.130) | −1.211 *** (0.138) | −1.522 *** (0.115) |
| Control variable | Yes | Yes | Yes | Yes |
| Fixed Year | Yes | Yes | Yes | Yes |
| Fixed Province | Yes | Yes | Yes | Yes |
| Observations | 992 | 992 | 992 | 992 |
| R-squared | 0.958 | 0.983 | 0.532 | 0.529 |

Note: standard error in parentheses. ** and *** indicate significance at the 5% and 1% levels, respectively.

#### 4.5.2. Regional Heterogeneity Analysis

The economic components, industrial frameworks, resource endowments, and conditions for agricultural production exhibit substantial variability across China's regions, potentially leading to regional differences in the impact of urban–rural integration on food security. As urban–rural integration progresses, its effects on food security also diverge. Drawing on prior research, this study classifies China (excluding Hong Kong, Macao, and Taiwan) into 13 primary grain-producing provinces (Heilongjiang, Inner Mongolia, Jilin, Liaoning, Henan, Hebei, Shandong, Jiangsu, Anhui, Hubei, Hunan, Jiangxi, Sichuan), 7 main sales provinces (Beijing, Tianjin, Shanghai, Guangdong, Zhejiang, Fujian, Hainan), and 11 generally balanced provinces (Gansu, Xinjiang, Shanxi, Qinghai, Ningxia, Yunnan, Shaanxi, Guizhou, Guangxi, Chongqing, Tibet) [78] to thoroughly examine the specific effects of urban–rural integration on food security within these regions. The findings reveal that urban–rural integration significantly bolsters food security in both the main producing and selling provinces, especially in the producing areas where the degree of urban–rural integration has a more pronounced beneficial effect on food security. This underscores the critical importance of enhancing urban–rural integration levels to ensure food security, particularly via the interest linkage mechanism established between production and sales areas. While high urban–rural integration in major sales provinces may reduce food production due to population concentration and urban land expansion, it aids in improving resource allocation efficiency and the rational planning and optimization of infrastructure [11,79]. In the balanced provinces, the positive influence of urban–rural integration on food security is relatively minor, with a regression coefficient of 0.0799, which does not reach the threshold of statistical significance, suggesting a limited impact. This further highlights the need for creating region-specific urban–rural integration strategies tailored to local characteristics to effectively boost food security. These results are presented in Table 9.

**Table 9.** The inspection results based on the classification of food production regions.

| Variables | Model 1: Food Main Production Area | Model 2: Food Main Sales Area | Model 2: Food Balanced Area |
|---|---|---|---|
| lnintegration | 0.438 *** | 0.369 *** | 0.0799 |
| Constant | −0.577 ** | −2.975 *** | −1.906 *** |
| | (0.235) | (0.808) | (0.177) |
| Fixed Year | Yes | Yes | Yes |
| Fixed Province | Yes | Yes | Yes |
| Observations | 416 | 224 | 352 |
| R-squared | 0.715 | 0.967 | 0.985 |

Note: standard error in parentheses. ** and *** indicate significance at the 5%, and 1% levels, respectively.

## 5. Discussion

The integration of urban and rural development in China significantly impacts food security. This study examines the effects of urban–rural integration on food security and discovers a substantial positive correlation between the level of urban–rural integration development and food security, highlighting the importance of this trend in safeguarding food security. According to Mitra's research, urban–rural integration substantially mitigates the risk of food insecurity. Additionally, the enhancement of urban–rural integration fosters inclusive economic growth, linking rural agricultural production to urban markets. This advancement generates non-agricultural business and employment opportunities within the food supply chain across rural, suburban, and urban areas, while also facilitating urban technological support and investment in rural farms [80]. Prior research has indicated that urban–rural integration is pivotal for developing countries to achieve a mature urbanization process. The implementation of an integrated urban–rural development model has notably decreased land fragmentation due to rural land release and population decline, benefiting large-scale agricultural development and environmental protection and advancing multidimensional food security [81]. This research offers a novel perspective on the nexus between urban–rural relations and food security, which is of paramount policy relevance for regions globally experiencing rapid urbanization. However, extant studies have so far failed to develop a comprehensive urban–rural integration index system for an in-depth examination of its correlation with food security, showing a gap in the empirical analysis. This paper corroborates, via economic model analysis, that urban–rural integration enhances food security levels, thereby substantiating Hypothesis 1.

Secondly, this study delved into the complexities and variabilities of the impact of urban–rural integration on food security across multiple dimensions. A comprehensive review of urban–rural integration across spatial, economic, social, and ecological dimensions reveals that it positively influences food security levels in spatial, economic, and social aspects. However, it potentially exerts a suppressive effect in the ecological dimension. The existing research highlights the significant ecological costs associated with increasing population density in developing countries, shifts toward higher-quality dietary habits, and the continuously rising demand for food production [82]. The augmentation of environmental constraints—such as agricultural non-point source pollution, soil quality degradation, groundwater over-extraction, land desertification, and soil erosion—severely limits the resources available for food production [83]. The substantial dependence of agricultural production on natural resources like water, soil, and climate not only aggravates resource scarcity and distributional imbalance but also further impacts food security [84]. Additionally, some scientists have noted that the intensification and industrialization of food production methods, developed to meet food demands, are increasingly harming the environment, posing future risks of reduced food production due to environmental degradation [85]. In the long term, China's food security and ecological safety exhibit clear vulnerability traits. While the implementation of urban–rural integration strategies has promoted food production and security to some extent, it has also intensified ecological environmental pressure, presenting new challenges for the sustainability of food security.

Therefore, this study emphasizes the need for a balanced consideration of food security and ecological safety during urban–rural integration, highlighting the dual importance of both aspects. To achieve sustained growth in food production and the sustainable development of the ecological environment, adopting diversified strategies to address ecological constraints and enhance food security capabilities is particularly crucial. Hypothesis 2, which posits that different dimensions of urban–rural integration variably affect food security levels, has been validated.

Thirdly, the accelerated economic growth in southeast China's coastal provinces has attracted a substantial population influx, altering the food security risk profile and introducing new challenges to regional food security [86]. This study delves into the impact of urban–rural integration on various grain-producing regions, noting the effects of regional background disparities and shifts in the industrial structure on agricultural development directions across provinces. It highlights the variance in suitability for grain production and the roles that different regions play within the grain production cycle. A thorough analysis of urban–rural integration across grain-producing, main consumption, and balanced areas shows the significant promotion of grain production and consumption regions. However, its influence on food security in balanced areas, predominantly situated in economically disadvantaged regions undergoing transition, is minimal. In these areas, agriculture, an essential economic backbone, faces pressures of modernization and upgrading, yet urban–rural integration has not yet been fully effective due to substantial labor retention in agriculture and low technological and industrial integration. The reliance on intensive inputs of natural resources and labor, combined with sluggish urbanization and industrialization, limits the enhancement of agricultural efficiency and food security levels. With China transitioning into a "new normal" economic phase and shifting the grain production focus northward, there is an emphasis on extending cultivated land, especially encouraged by national farmland policies and the effects of land acquisition and compensation policies [87], favoring expansion into less developed regions that are rich in land resources [88,89]. These findings underscore the necessity of devising targeted strategies and measures based on regional specifics to optimize the benefits of urban–rural integration and to foster sustainable growth in the agricultural industry. Concurrently, the findings call for a focus on and research of additional factors influencing the agricultural sector to ensure urban–rural integration strategies effectively mitigate potential challenges, offering practical recommendations for food security's enduring development.

The limitations of this paper are principally manifested in several key areas. First, while selecting evaluation indicators for urban–rural integration and food security, this study referenced a broad range of distinguished domestic and international scholarly articles and chose widely acknowledged and established indicators. However, these selected indicators might have inherent limitations due to the availability and complexity of data pertaining to urban–rural integration and food security. Second, leveraging relevant research and opting for a fixed-effects model for analysis, this study investigated the facilitative role of urban–rural integration in enhancing food security. However, due to space constraints, this study did not conduct comparisons between regression models and other models nor examine the suitability and cost-effectiveness of various research methodologies, potentially compromising this study's rigor. Third, the data utilized in this research originate from China's statistical databases, focusing on China's 31 provinces (excluding Hong Kong, Macao, and Taiwan). Consequently, the findings and recommendations may predominantly be applicable to China. Despite this, this paper posits that urban–rural integration introduces a novel perspective for the transformation of the agricultural food system towards achieving sustainable development goals, catalyzing reforms across different facets of the global agricultural food system. This situation presents both challenges and opportunities for ensuring accessible and nutritious diets for everyone. Thus, for other countries with access to pertinent data, the analytical framework and methodologies of this paper retain their applicability and can be tailored to assess the effects of urban–rural integration on food security in varying contexts. Fourth, owing to challenges in data collection, this research did not explore the influence of urban–rural integration on food security at the county level, which could offer more comprehensive insights if investigated.

## 6. Conclusions and Policy Implications

### *6.1. Conclusions*

Food security remains a critical global concern, evolving in concept yet steadfast in its mission to meet the nutritional and health needs of the global population. This research utilized data from 31 Chinese provinces (excluding Hong Kong, Macau, and Taiwan) between 1990 and 2021, employing a fixed-effects model complemented by extensive robustness tests to scrutinize the influence and mechanisms of urban–rural integration on food security. The findings affirm that enhancing urban–rural integration significantly strengthens food security, highlighting its crucial role in meeting these needs. This assertion is supported with robust evidence, upheld across various variable substitutions, estimation techniques, and instrumental variable approaches. Additionally, this study discovered that while urban–rural integration fosters food security across spatial, social, and economic dimensions, its amalgamation within ecological dimensions might slightly impede food security. Differential regional impacts highlight that urban–rural integration markedly benefits food security in primary production and consumption zones, yet its effects in balanced regions appear more attenuated. This delineates the nuanced relationship between urban–rural integration's efficacy and a region's developmental stage, accentuating the need to tailor integration strategies to regional specifics and developmental phases.

Beyond recognizing the pivotal role of urban–rural integration in food security, this study emphasizes the importance of considering regional nuances in strategic planning. Future policy initiatives should prioritize addressing regional disparities, leveraging agricultural comparative advantages to promote both food security and sustainable agricultural development. This requires strategically harnessing regional agricultural strengths in policy formulation. As a result of the variations in resources, developmental stages, and market scopes, agricultural development across China is expected to diverge significantly. Notably, strategies for food production and distribution—ranging from large-scale centralization to small-scale dispersion—will shape the future layout of agricultural regions. Therefore, developing policies around food production functional zones, essential agricultural product protection areas, and specialized agricultural product advantage zones is crucial to align with these emerging trends.

### *6.2. Policy Implications*

#### 6.2.1. Strategic Approaches to Enhancing Food Security via Urban–Rural Integration

In China, the advancement of urban-rural integration is significantly reshaping the landscape of food production and security, introducing new challenges and opportunities. This process not only enhances production efficiency and optimizes resource allocation but also exerts a profound impact on market dynamics and policy frameworks. To effectively adapt to these changes and safeguard food security, it is imperative to refine and regionalize existing policies. Specifically, urban-rural integration augments the mobility of land, capital, and human resources, promoting optimal resource distribution across a broader geographic area. For instance, leveraging the technological and capital advantages of the eastern coastal regions through technology transfer has the potential to significantly enhance agricultural productivity in the western and central regions, thereby mitigating regional development disparities.

Moreover, the reform of rural land systems, which involves reducing land transfer costs and promoting the concentration of land management rights among more efficient farmers, not only improves land utilization rates but also fosters scale operations, directly influencing food production and the sustainability of agricultural development. Additionally, crafting differentiated policies tailored to the unique resource endowments and developmental levels of various provinces is essential; for example, southern provinces might prioritize innovating rice cultivation technologies and managing water resources, while northern provinces may focus on enhancing the efficiency of wheat and maize cultivation and improving drought resistance techniques.

Investments in public services and infrastructure, particularly in education, healthcare, and transportation, not only enhance the quality of life for rural residents but also foster the accumulation of human capital, crucial for enhancing agricultural labor productivity. Concurrently, the promotion of ecological agriculture and green production technologies—such as reducing the use of chemical fertilizers and pesticides, implementing crop rotation, and practicing conservation tillage—contributes to maintaining soil health and ensuring the sustainability of food production.

Through the establishment of robust regional collaboration mechanisms to facilitate resource sharing and policy coordination, regions can develop specialty agricultural products based on their strengths, achieving geographical complementarity in food production, and thereby enhancing the national food security network. These specific strategies must be meticulously tailored for balancing areas, main production areas, and main sales areas, according to their respective food security goals.

Balanced Area: Within the framework of urban-rural integration, the primary function of the balanced area is to regulate food supply and demand and stabilize market prices. To this end, enhancing infrastructure development, particularly in transportation and storage facilities, is crucial to bolster its capacity for effective food regulation and transportation. Moreover, developing a refined market mechanism, such as introducing electronic trading platforms and information services, is vital for increasing market transparency and operational efficiency. Additionally, establishing risk management and compensation mechanisms, including price insurance and disaster relief funds, is imperative for mitigating the impacts of natural disasters and market fluctuations.

Main Production Areas: As a pivotal region for food production, the main production area should concentrate on boosting yield and production efficiency. Promoting cutting-edge agricultural technologies, such as smart farming systems and precision irrigation, is the key to improving the efficiency of land and water resource use. Furthermore, through the establishment of agricultural technology training centers to enhance the skills and quality of agricultural labor, farmers' adaptability to and proficiency with new technologies can be significantly improved. Implementing sustainable agricultural practices, such as ecological farming and organic cultivation, not only protects the environment but also boosts the long-term productivity of the land.

Main Sales Area: Typically located in densely populated urban areas, the food security strategy of the main sales area should emphasize enhancing the efficiency of the supply chain and ensuring food safety. Strengthening the food safety regulation system to ensure compliance with safety standards at all stages of the food supply chain is crucial. Optimizing logistics and distribution networks to minimize food losses during transportation and storage is also essential. Furthermore, raising consumer awareness about the origins and methods of food production through education and public outreach is crucial to fostering the demand for high-quality, sustainable food products.

Through these targeted policy adjustments and strategic measures, urban-rural integration not only addresses current challenges but also provides enduring support for future food security. Specific strategies for each region will ensure a balanced integration of food production, supply, and consumption, creating a robust, multi-layered food security protection network. The implementation of these measures will not only effectively tackle the challenges posed by urban-rural integration but also lay a solid foundation for the long-term stability of food security.

#### 6.2.2. Comprehensively Understand the Relationship between Urban–Rural Integration and Food Security, Effectively Balancing Interests and Resolving Conflicts

Comprehensively understanding the intricate relationship between urban–rural integration and food security and effectively managing their interdependency are essential for ensuring national food security and promoting harmonious urban–rural development. In the current phase of urban–rural integration, the declining rural population is a predictable trend, emphasizing the need to bridge the gap towards mature urbanization. This situation highlights the inherent tension between urban expansion and the preservation of land resources vital for food security.

Advancing towards attaining a state of mature urbanization necessitates a scientifically based and comprehensive urban and rural land-use plan, which must include strict restrictions against the disorderly expansion of urban construction zones. Such urbanization planning should be customized to meet specific local needs while strictly safeguarding arable land boundaries to ensure the stability of existing agricultural fields. Urbanization efforts ought to extend beyond mere expansion, incorporating the more efficient utilization and planning of land resources. A critical aspect of this process is the refinement of policy management to fairly balance the usage and compensation of arable land during urban development phases, thus moderating the intensity of urbanization to ensure both high-quality urban space development and the sustainability of food production. Fundamentally, urban–rural integration requires strategic investments in food production infrastructure to support the scaling of production, optimization of cropping patterns, and advancement of agricultural technologies, thereby streamlining agricultural operations. Encouraging technological innovation in food production through active financial and tax incentives is crucial for accelerating advancements in agricultural techniques and assisting farmers in expanding their operations through orderly land rights' transfers, thus optimizing land usage and unleashing its full potential. In promoting integrated growth across the various dimensions of urban–rural integration, it is essential, firstly, to enhance spatial concentration, foster industrial diversification, and maximize scale benefits to establish a core–periphery structure. Improved infrastructure boosts food accessibility, effectively overcoming geographical barriers and forming an integrated supply chain. Secondly, from an economic standpoint, urban–rural integration should strengthen policies that encourage urban support for rural and agricultural progress, enhancing the symbiotic relationship between agricultural and non-agricultural sectors. This involves channeling social capital into the food production sector, supporting modernization, extending agricultural value chains, and ensuring effective connectivity throughout the food production process. Thirdly, in the social sphere, easing residency restrictions and enhancing welfare benefits for the children of non-agricultural workers can help bridge urban–rural divides and better integrate rural labor into urban employment. Providing more robust support for food producers through enhanced training, technology dissemination, and increased subsidy incentives is also vital. Fourthly, in the ecological dimension, achieving a balance between urban–rural integration and environmental conservation presents a fundamental challenge to food security. Maintaining a healthy ecological environment is crucial for sustainable food security, necessitating government intervention to navigate the complex relationship between ecological health and food production in the face of evolving environmental challenges.

The impact of urban–rural integration on national food security is multifaceted and operates across various dimensions and levels, shaped by dynamic interactions among diverse forces. For developing countries, transitioning from a dichotomous urban–rural paradigm to the establishment of a modernized state, as exemplified in the Chinese model, and achieving collective prosperity, is an imperative trajectory.

This study offers an in-depth analysis of the impacts of urban-rural integration on food security, aiming to ensure the scientific validity and reliability of its conclusions. Despite these efforts, this research faces limitations due to constraints such as data availability. Primarily, this study leverages provincial panel data from 1990 to 2021, and the indicators used to measure urban-rural integration require further enhancement. These indicators, spanning spatial, economic, social, and ecological dimensions, are limited in scope due to data constraints. Similarly, the food security assessment system employs 18 basic indicators across four dimensions—availability, access, sustainability, and stability—to reflect food security levels comprehensively. However, the diversity of these indicators is limited by data availability and provincial data discrepancies, despite rigorous efforts to collect and refine data. Furthermore, this study's focus could benefit from greater refinement. It currently relies heavily on provincial panel data, potentially leading to conclusions with a weak micro-level foundation. While this research summarizes macro-level trends using provincial data, the lack of micro-level support hampers the accuracy of its conclusions. The attempts to gather county- and municipal-level data to analyze the relationship between urban-rural integration and food security were hindered by significant data shortages and inconsistencies in indicators, restricting this research to a provincial scope. Looking ahead, it is crucial to improve data availability and conduct more detailed micro-level studies to identify patterns at municipal and county levels, integrating cross-level research methods to further clarify the impact of urban-rural integration on food security. Lastly, it is important to acknowledge that the factors affecting food security are complex and multidimensional. Urban-rural integration is just one of many factors influencing food security, and future research should continue to explore and expand on further, diverse factors in this area.

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## References

1. Lv, F.; Deng, L.; Zhang, Z.; Wang, Z.; Wu, Q.; Qiao, J. Multiscale analysis of factors affecting food security in China, 1980–2017. *Environ. Sci. Pollut. Res.* **2022**, *29*, 6511–6525. [CrossRef]
2. Filippini, R.; Mazzocchi, C.; Corsi, S. The contribution of Urban Food Policies toward food security in developing and developed countries: A network analysis approach. *Sustain. Cities Soc.* **2019**, *47*, 101506. [CrossRef]
3. Godfray, H.C.J.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Nisbett, N.; Pretty, J.; Robinson, S.; Toulmin, C.; Whiteley, R. The future of the global food system. *Philos. Trans. R. Soc. B Biol. Sci.* **2010**, *365*, 2769–2777. [CrossRef] [PubMed]
4. ESA, U. *World Urbanization Prospects the 2018 Revision Methodology*; United Nations: New York, NY, USA, 2018.
5. Myers, S.S.; Smith, M.R.; Guth, S.; Golden, C.D.; Vaitla, B.; Mueller, N.D.; Dangour, A.D.; Huybers, P. Climate change and global food systems: Potential impacts on food security and undernutrition. *Annu. Rev. Public Health* **2017**, *38*, 259–277. [CrossRef] [PubMed]
6. Paudel, D.; Neupane, R.C.; Sigdel, S.; Poudel, P.; Khanal, A.R. COVID-19 pandemic, climate change, and conflicts on agriculture: A trio of challenges to global food security. *Sustainability* **2023**, *15*, 8280. [CrossRef]
7. Chen, M.; Liu, W.; Lu, D. Challenges and the way forward in China's new-type urbanization. *Land Use Policy* **2016**, *55*, 334–339.
8. Zeng, Q.; Chen, X. Identification of urban-rural integration types in China–an unsupervised machine learning approach. *China Agric. Econ. Rev.* **2023**, *15*, 400–415. [CrossRef]
9. Zhang, X.; Hu, L.; Yu, X. Farmland Leasing, misallocation Reduction, and agricultural total factor Productivity: Insights from rice production in China. *Food Policy* **2023**, *119*, 102518. [CrossRef]
10. Long, H.; Ge, D.; Zhang, Y.; Tu, S.; Qu, Y.; Ma, L. Changing man-land interrelations in China's farming area under urbanization and its implications for food security. *J. Environ. Manag.* **2018**, *209*, 440–451. [CrossRef]
11. Satterthwaite, D.; McGranahan, G.; Tacoli, C. Urbanization and its implications for food and farming. *Philos. Trans. R. Soc. B Biol. Sci.* **2010**, *365*, 2809–2820. [CrossRef]
12. Barthel, S.; Isendahl, C.; Vis, B.N.; Drescher, A.; Evans, D.L.; van Timmeren, A. Global urbanization and food production in direct competition for land: Leverage places to mitigate impacts on SDG2 and on the Earth System. *Anthr. Rev.* **2019**, *6*, 71–97. [CrossRef]
13. Liu, Y.; Zhou, Y. Reflections on China's food security and land use policy under rapid urbanization. *Land Use Policy* **2021**, *109*, 105699. [CrossRef]
14. Chen, J. Rapid urbanization in China: A real challenge to soil protection and food security. *Catena* **2007**, *69*, 1–15. [CrossRef]

15. Chen, X.; Liu, C.; Yu, X. Urbanization, economic development, and ecological environment: Evidence from provincial panel data in China. *Sustainability* **2022**, *14*, 1124. [CrossRef]
16. Song, W.; Deng, X. Effects of urbanization-induced cultivated land loss on ecosystem services in the North China Plain. *Energies* **2015**, *8*, 5678–5693. [CrossRef]
17. Li, Y.; Jia, L.; Wu, W.; Yan, J.; Liu, Y. Urbanization for rural sustainability–Rethinking China's urbanization strategy. *J. Clean. Prod.* **2018**, *178*, 580–586. [CrossRef]
18. Sakketa, T.G. Urbanisation and rural development in sub-Saharan Africa: A review of pathways and impacts. *Res. Glob.* **2023**, *6*, 100133. [CrossRef]
19. Zhong, S.; Wang, M.; Zhu, Y.; Chen, Z.; Huang, X. Urban expansion and the urban–rural income gap: Empirical evidence from China. *Cities* **2022**, *129*, 103831. [CrossRef]
20. UNICEF. *The State of Food Security and Nutrition in the World 2023*; UNICEF: Geneva, Switzerland, 2023.
21. Moscatelli, S.; El Bilali, H.; Gamboni, M.; Capone, R. Towards sustainable food systems: A holistic, interdisciplinary and systemic approach. *Agrofor* **2016**, *1*, 103–112. [CrossRef]
22. Song, H. Food demand-supply balance and state food safety. *J. Nanjing Agric. Univ* **2016**, *16*, 1–11.
23. Ge, H.; Gray, R.; Nolan, J. Agricultural supply chain optimization and complexity: A comparison of analytic vs simulated solutions and policies. *Int. J. Prod. Econ.* **2015**, *159*, 208–220. [CrossRef]
24. Christensen, G.; Bronchetti, E.T. Local food prices and the purchasing power of SNAP benefits. *Food Policy* **2020**, *95*, 101937. [CrossRef]
25. Li, X.; Lyu, X. Judgment of China's Food Security Situation at the Present Stage: Pay Equal Attention to Quantity and Quality. *Issues Agric. Econ.* **2021**, *11*, 31–44.
26. Tagtow, A.; Roberts, S. Cultivating resilience: A food system blueprint that advances the health of Iowans, farms and communities. *Elkhart Iowa Food Syst. Counc.* **2011**, *12*, 194–253.
27. Burchi, F.; De Muro, P. From food availability to nutritional capabilities: Advancing food security analysis. *Food Policy* **2016**, *60*, 10–19. [CrossRef]
28. Zhou, Y.; Wang, S.; Yan, B. The structure, evolution and prospect of food system in China. *Issues Agric. Econ.* **2022**, *505*, 100–113.
29. Henderson, J.V. Urbanization and growth. In *Handbook of Economic Growth*; Elsevier: Amsterdam, The Netherlands, 2005; Volume 1, pp. 1543–1591.
30. Jian, X.; Huang, K. Empirical analysis and forecast of the level and speed of urbanization in China. *Econ. Res. J.* **2010**, *3*, 28–39.
31. Zhou, J.; Zou, W.; Qin, F. Review of Urban-Rural Multi-Dimensional Integration and Influencing Factors in China Based on the Concept of Equivalence. *Geogr. Res.* **2020**, *39*, 1836–1851.
32. De, Z.; Jia-ling, Q.; Wen-yu, Z. Review of urban-rural integration evaluation: Connotation identification, theoretical analysis, and system reconstruction. *J. Nat. Resour.* **2021**, *36*, 2634–2651.
33. Chen, M.; Zhou, Y.; Huang, X.; Ye, C. The integration of new-type urbanization and rural revitalization strategies in China: Origin, reality and future trends. *Land* **2021**, *10*, 207. [CrossRef]
34. Fang, C. On integrated urban and rural development. *J. Geogr. Sci.* **2022**, *32*, 1411–1426. [CrossRef]
35. Ma, L.; Liu, S.; Fang, F.; Che, X.; Chen, M. Evaluation of urban-rural difference and integration based on quality of life. *Sustain. Cities Soc.* **2020**, *54*, 101877. [CrossRef]
36. Yang, Y.; Bao, W.; Wang, Y.; Liu, Y. Measurement of urban-rural integration level and its spatial differentiation in China in the new century. *Habitat Int.* **2021**, *117*, 102420. [CrossRef]
37. Liu, Y. Strategic Objectives and Regional Orientation of Urban–Rural Transformation in China. In *Urban-Rural Transformation Geography*; Sustainable Development Goals Series; Springer Singapore: Singapore, 2021; pp. 137–183.
38. Hu, Z.; Song, G.; Hu, Z.; Zhang, B.; Lin, T. How to promote the balanced development of urban and rural China? Evidences from reallocating idle rural residential land of Zhejiang province, China. *PLoS ONE* **2023**, *18*, e0287820. [CrossRef]
39. Zoomers, A.; Van Noorloos, F.; Otsuki, K.; Steel, G.; Van Westen, G. The rush for land in an urbanizing world: From land grabbing toward developing safe, resilient, and sustainable cities and landscapes. *World Dev.* **2017**, *92*, 242–252. [CrossRef]
40. Fujita, M.; Krugman, P.R.; Venables, A. *The Spatial Economy: Cities, Regions, and International Trade*; MIT Press: Cambridge, MA, USA, 2001.
41. Borgatti, S.P.; Everett, M.G. Models of core/periphery structures. *Soc. Netw.* **2000**, *21*, 375–395. [CrossRef]
42. Vaitla, B.; Coates, J.; Glaeser, L.; Hillbruner, C.; Biswal, P.; Maxwell, D. The measurement of household food security: Correlation and latent variable analysis of alternative indicators in a large multi-country dataset. *Food Policy* **2017**, *68*, 193–205. [CrossRef]
43. Leroy, J.L.; Ruel, M.; Frongillo, E.A.; Harris, J.; Ballard, T.J. Measuring the food access dimension of food security: A critical review and mapping of indicators. *Food Nutr. Bull.* **2015**, *36*, 167–195. [CrossRef]
44. Smyth, S.J.; Phillips, P.W.; Kerr, W.A. Food security and the evaluation of risk. *Glob. Food Secur.* **2015**, *4*, 16–23. [CrossRef]
45. Wang, G.; Lu, T.; Zhou, Q. Comprehensive Evaluation of Food Security in China: 1978–2010. *J. Shanghai Adm. Inst.* **2013**, *14*, 64–73.
46. Zhang, Y.; Lu, X. A comprehensive evaluation of food security in china and its obstacle factors. *Int. J. Environ. Res. Public Health* **2022**, *20*, 451. [CrossRef] [PubMed]
47. Wen, Y.; Zhang, M.; Yu, F. A study on the resource reallocation effect of China's transportation infrastructure. *Econ. Res. J.* **2022**, *1*, 155–171.

48. Zhang, X.; Bao, J.; Xu, S. Research on the Evaluation of China's Food Security Based on Entropy Weight Topsis Model. *Chin. J. Agric. Resour. Reg. Plan* **2023**, *44*, 35–44.
49. Zhou, J.; Qin, F.; Liu, J.; Zhu, G.; Zou, W. Measurement, spatial-temporal evolution and influencing mechanism of urban-rural integration level in China from a multidimensional perspective. *China Popul. Resour. Environ.* **2019**, *29*, 166–176.
50. Shu, J.; Zhou, J.; Chen, Y.; Liu, C. Spatial Evolution Characteristics of China's Provincial Digital Economy and Its Urban-rural Integration Effect. *Econ. Geogr* **2022**, *42*, 104–111.
51. Liu, M.; Lu, F. Study on the influence of factor mismatch on urban-rural integration development: Evidence from Chinese provincial panel data. *J. Agrotech. Econ.* **2019**, *2*, 33–46.
52. Liu, C.; Zhang, Z. From town-country integration to urban-rural integration: New thinking on the relationship between urban and rural areas. *Sci. Geogr. Sin.* **2018**, *38*, 1624–1633.
53. Rao, C.; Gao, Y. Evaluation mechanism design for the development level of urban-rural integration based on an improved TOPSIS method. *Mathematics* **2022**, *10*, 380. [CrossRef]
54. Liu, Y.; Long, C. Urban and rural income gap: Does urban spatial form matter in China? *Sage Open* **2021**, *11*, 21582440211002215. [CrossRef]
55. Zhou, J.; Bai, Y. The time series' fluctuation and regional difference of the urban-rural development integration level in china. *China Ind. Econ.* **2014**, *2*, 5–17.
56. Shi, J.; Duan, K.; Wu, G. The measurement of the urban-rural lntegration development level in the Yangtze River Delta Region and the analysis of its spatio-temporal characteristics. *J. Tongji Univ. Soc. Sci. Ed.* **2022**, *33*, 78–89.
57. Zhao, D.; Chen, N. Research on the measurement of urban-rural integration development level in China. *Explor. Econ. Probl.* **2019**, *12*, 1–28.
58. Haq, S.M.A. Urban green spaces and an integrative approach to sustainable environment. *J. Environ. Prot.* **2011**, *2*, 601–608. [CrossRef]
59. Chun-sheng, Z.; Shu-Wen, N.; Xin, Z. Effects of household energy consumption on environment and its influence factors in rural and urban areas. *Energy Procedia* **2012**, *14*, 805–811. [CrossRef]
60. Han, J.; Zheng, Q. How does government intervention lead to regional resource misallocation—Based on decomposition of misallocation within and between industries. *China Ind. Econ.* **2014**, *11*, 69–81.
61. Yu, X.; Wu, Z.; Zhou, J. The implications of the reform of common agricultural policy in the EU for China: The Relationship between Long-term international grain price fluctuations and domestic agricultural subsidies. *Chin. Rural Econ.* **2017**, *2*, 84–96.
62. Zhang, S.; Zhang, X. Fiscal agricultural expenditures' impact on sustainable agricultural economic development: Dynamic marginal effects and impact mechanism. *PLoS ONE* **2024**, *19*, e0299070. [CrossRef] [PubMed]
63. Zhu, J.; Li, T.; Zang, X. Emerging challenges and coping strategies in China's food security under the High-level Opening Up. *Issues Agric. Econ* **2021**, *1*, 27–40.
64. Cheng, G.; Zhu, M. The path-choosing and policy framework of agriculture implementing global strategy in China. *Reform* **2014**, *27*, 109–123.
65. Liu, X.; Xu, Y.; Sun, S.; Zhao, X.; Wu, P.; Wang, Y. What is the potential to improve food security by restructuring crops in Northwest China? *J. Clean. Prod.* **2022**, *378*, 134620. [CrossRef]
66. Amiraslani, F.; Dragovich, D. Food-energy-water nexus in Iran over the last two centuries: A food secure future? *Energy Nexus* **2023**, *10*, 100189. [CrossRef]
67. Wheeler, T.; Von Braun, J. Climate change impacts on global food security. *Science* **2013**, *341*, 508–513. [CrossRef]
68. Lee, C.-C.; Zeng, M.; Luo, K. How does climate change affect food security? Evidence from China. *Environ. Impact Assess. Rev.* **2024**, *104*, 107324. [CrossRef]
69. Schlenker, W.; Roberts, M.J. Nonlinear temperature effects indicate severe damages to US crop yields under climate change. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 15594–15598. [CrossRef] [PubMed]
70. Hatfield, J.L.; Prueger, J.H. Temperature extremes: Effect on plant growth and development. *Weather Clim. Extrem.* **2015**, *10*, 4–10. [CrossRef]
71. Ye, X.Q. China'sruralareastoward2035: Vision, challenges andstrategies. *Manag. World* **2021**, *37*, 98–112.
72. Li, C.; Sha, Z.; Sun, X.; Jiao, Y. The Effectiveness Assessment of Agricultural Subsidy Policies on Food Security: Evidence from China's Poverty-Stricken Villages. *Int. J. Environ. Res. Public Health* **2022**, *19*, 13797. [CrossRef] [PubMed]
73. Cheng, G.; Zhu, M. The situation and policy framework of Chinese grain macro-control. *Reform* **2013**, *227*, 18–34.
74. Lesk, C.; Rowhani, P.; Ramankutty, N. Influence of extreme weather disasters on global crop production. *Nature* **2016**, *529*, 84–87. [CrossRef]
75. Matiu, M.; Ankerst, D.P.; Menzel, A. Interactions between temperature and drought in global and regional crop yield variability during 1961–2014. *PLoS ONE* **2017**, *12*, e0178339. [CrossRef]
76. Zhang, Z.; Sun, C.; Wang, J. How Can the Digital Economy Promote the Integration of Rural Industries—Taking China as an Example. *Agriculture* **2023**, *13*, 2023. [CrossRef]
77. Blundell, R.; Bond, S. GMM estimation with persistent panel data: An application to production functions. *Econom. Rev.* **2000**, *19*, 321–340. [CrossRef]
78. Long, W.-J.; Fan, S.-G. Building a diversified food supply system with a big food approach. *Res. Agric. Mod.* **2023**, *44*, 233–243.

79. Yang, B.; Zhang, Z.; Wu, H. Detection and attribution of changes in agricultural eco-efficiency within rapid urbanized areas: A case study in the Urban agglomeration in the middle Reaches of Yangtze River, China. *Ecol. Indic.* **2022**, *144*, 109533. [CrossRef]
80. Mitra, P.; Shaw, R.; Sukhwani, V.; Mitra, B.K.; Rahman, M.A.; Deshkar, S.; Sharma, D. Urban–rural partnership framework to enhance food–energy–water security in the post-COVID-19 era. *Int. J. Environ. Res. Public Health* **2021**, *18*, 12493. [CrossRef] [PubMed]
81. Wang, S.; Bai, X.; Zhang, X.; Reis, S.; Chen, D.; Xu, J.; Gu, B. Urbanization can benefit agricultural production with large-scale farming in China. *Nat. Food* **2021**, *2*, 183–191. [CrossRef] [PubMed]
82. Chen, Y.; Fan, S.; Liu, C.; Yu, X. Is there a tradeoff between nature reserves and grain production in China? *Land Use Policy* **2022**, *120*, 106285. [CrossRef]
83. Popp, J.; Pető, K.; Nagy, J. Pesticide productivity and food security. A review. *Agron. Sustain. Dev.* **2013**, *33*, 243–255. [CrossRef]
84. Pawlak, K.; Kołodziejczak, M. The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production. *Sustainability* **2020**, *12*, 5488. [CrossRef]
85. Nellemann, C. *The Environmental Food Crisis: The Environment's Role in Averting Future Food Crises: A UNEP Rapid Response Assessment*; UNEP/Earthprint: Hertfordshire, UK, 2009.
86. Li, F.; Ma, S.; Liu, X. Changing multi-scale spatiotemporal patterns in food security risk in China. *J. Clean. Prod.* **2023**, *384*, 135618.
87. Liu, Y.-S.; Liu, Y.; Guo, L.-Y. Impact of climatic change on agricultural production and response strategies in China. *Chin. J. Eco-Agric.* **2010**, *18*, 905–910. [CrossRef]
88. Liu, Y.; Li, J.; Yang, Y. Strategic adjustment of land use policy under the economic transformation. *Land Use Policy* **2018**, *74*, 5–14. [CrossRef]
89. Chai, J.; Wang, Z.; Yang, J.; Zhang, L. Analysis for spatial-temporal changes of grain production and farmland resource: Evidence from Hubei Province, central China. *J. Clean. Prod.* **2019**, *207*, 474–482. [CrossRef]