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Enhancing Rural Economic Sustainability in China Through Agricultural Socialization Services: A Novel Perspective on Spatial-Temporal Dynamics

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Abstract: Rural economic development faces significant challenges in the context of rapid urbanization and agricultural transformation, particularly in developing countries like China. Agricultural socialization services (ASSs) play a crucial role in promoting rural economic sustainability by enhancing household income and fostering regional development. This study investigates the impact of ASSs on rural economic sustainability in China from both temporal and spatial perspectives, employing the entropy weight method, double fixed effects model, and Spatial Durbin Model. Analyzing panel data from 30 Chinese provinces from 2011 to 2021 reveals significant positive effects of ASSs on rural income, along with spatial spillovers to neighboring regions. The results highlight regional heterogeneity in the impact of ASSs, with the eastern region benefiting from local spillovers, while the central and western regions gain from intensification and scale effects. These findings suggest that policymakers should adopt region-specific ASSs strategies, such as facilitating technology transfer in the eastern regions while leveraging intensification and scale advantages in the central and western regions, to optimize the effectiveness of agricultural support measures. Moreover, the relationship between ASSs and rural income exhibits a non-linear trend across various urbanization stages, implying that ASS policies should be tailored to the specific challenges and opportunities associated with different levels of urbanization to maximize their impact on rural economic sustainability. These findings underscore the importance of optimizing ASSs, tailoring policies to local conditions, and harnessing the role of ASSs in the urbanization process to promote inclusive rural development and foster sustainable rural economic growth.

Keywords: agricultural socialization service; rural income; space spillover; threshold effect; urbanization; rural economic sustainability

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1. Introduction

1.1. Background

Agricultural modernization and rural development pose critical challenges for developing economies, as they strive to balance agricultural efficiency with the interests of smallholder farmers [1,2]. In developing countries, the transformation of traditional agriculture into modern farming systems has emerged as a universal challenge across diverse geographical contexts, from Brazil's agricultural cooperatives to China's agricultural socialization service system and India's farmer-producer organizations [3–5]. Agricultural socialization services (ASSs) involve specialized entities providing comprehensive support to farmers throughout the agricultural production process, from pre-production to post-production stages. In this context, agricultural socialization services involve specialized entities providing various services to farmers throughout the agricultural production process. These services encompass pre-production, production, and post-production stages. For instance, they include technical support, machinery operations, supply of agricultural inputs, pest and disease control, as well as processing and marketing of agricultural products. The primary objective of these services is to enhance agricultural productivity, reduce production costs, and facilitate the integration of smallholder farmers into modern agricultural systems.

Agricultural socialization services (ASSs) have emerged as a crucial pathway to bridge the gap between traditional and modern agriculture [6,7]. These comprehensive services, incorporating technical assistance, mechanization support, information technology integration, and financial mechanisms have demonstrated significant efficacy across diverse contexts. Notably, China's agricultural socialization service system has exhibited substantial advancement, with 900,000 socialized agricultural service suppliers in China providing services for over 107 million hectares of farmland [8]. In essence, ASSs aim to establish a comprehensive support system for farmers, thereby promoting the development of modern agriculture. ASSs provide specialized services to farmers to support and enhance their agricultural activities, ultimately aiming to modernize agriculture and improve the livelihoods of smallholder farmers. ASSs encompass various forms of support provided to farmers through public institutions, cooperatives, and private organizations aimed at enhancing productivity, facilitating resource access, and promoting sustainable agricultural practices.

The motivation for this study arises from the urgent need to improve rural economic sustainability amid rapid urbanization and evolving agricultural practices. Investigating the role of Agricultural Socialization Services (ASSs) in enhancing rural income is essential for developing effective poverty reduction strategies and sustainable development policies, especially in China and other developing nations.

1.2. Objectives

Significant research gaps persist in the extant literature, with substantial implications for the disparities in implementation and overall effectiveness of ASSs. First, while existing research has extensively examined the direct effects of ASSs on productivity and income gap [9,10], the spatial spillover effects across different regions remain inadequately explored, potentially resulting in inefficient service distribution and suboptimal resource allocation [11,12]. However, the current policy landscape often overlooks the importance of spatial dynamics, potentially leading to an overconcentration of services in certain areas while missing opportunities for cross-regional synergies [13].

The relationship between urbanization levels and the effectiveness of ASSs remains poorly understood, with a lack of research on the potential non-linear effects of urbanization on ASS efficacy, which has hindered the development of targeted agricultural support strategies. Secondly, the literature is deficient in a thorough study of this potential non-linear relationship [14]. This gap is particularly significant when emerging nations experience increased urbanization [15]; yet, the moderating impact of this phenomenon on agricultural services is still inadequately comprehended. Third, there is insufficient comprehension of how regional heterogeneity affects the influence of these services on rural household income, potentially resulting in standardized policies that fail to address locality-specific needs and conditions. The lack of comprehensive research on these critical aspects obstructs the formulation of targeted and effective agricultural support policies that are responsive to local contexts and requirements. Studies have shown that the effectiveness of agricultural socialization services (ASSs) varies by region. Lazarova et al. [16] found regional disparities between the infrastructural potential and agricultural sector productivity in rural areas of Bulgaria, suggesting that the provision of ASSs needs to be adapted to local conditions, taking into account the resource endowments and development levels of different regions.

This study uses a broad analytical framework to look at how ASSs affect rural household income in China. It focuses on threshold effects and spatial spillover dynamics to fill in these important research gaps. This study combines institutional economics and spatial analysis to examine the operational mechanisms of ASSs across various contexts. This study specifically examines panel data from 30 Chinese provinces from 2011 to 2021 and uses an entropy weight method to create a structured evaluation framework for agricultural socialization service indicators. Our investigation encompasses three key dimensions: (1) quantifying the direct effect of ASSs on rural residents' income through a comprehensive evaluation framework; (2) examining the spatial spillover effects of these services across different regions utilizing spatial econometric methodologies; and (3) analyzing the threshold effect of urbanization levels on the relationship between ASSs and rural income. This comprehensive analytical approach enables us to capture both the direct and indirect pathways through which ASSs influence rural development.

The remainder of this paper first reviews the relevant literature and presents our methodology, followed by empirical findings, conclusions, and policy recommendations, with a final discussion of limitations and future research directions.

2. Literature Review

2.1. Overview of ASSs

ASSs have become a key driver of sustainable rural development and poverty reduction. Studies show that ASSs, including technical support, market information, and training, can boost production efficiency and farmers' incomes [17]. Birner and Anderson [18] define ASSs as a broad set of organizations that help farmers overcome challenges and improve their livelihoods through knowledge, skills, and technology.

ASSs have evolved from traditional top-down government-led extension models [19] to more participatory approaches that actively engage farmers [20]. The widespread integration of Information and Communication Technologies (ICTs) has revolutionized the provision of Agricultural Support Services. The integration of mobile applications and digital platforms has enabled farmers to access vital information, including market trends, weather predictions, and personalized guidance [21,22]. This technological advancement has markedly increased the reach and effectiveness of Agricultural Support Services, particularly in remote areas, allowing a greater proportion of the rural population to benefit from these offerings.

It is important to recognize that while research and development (R&D) is a component of Agricultural Socialization Services (ASSs), a paradox exists between R&D's emphasis on patent acquisition and its practical application in economic sectors. Zhang et al. [23] found that innovation does not always guarantee the survival of firms in China's high-tech industry, indicating that patent-seeking alone may not suffice for economic success. Griliches [24] also underscored the intricate relationship between R&D, productivity, and economic growth. To ensure that ASSs effectively contribute to rural economic sustainability, it is essential that R&D outcomes are not only patented but also applied effectively in practice.

The ongoing debate about the effectiveness of different ASS models continues to evoke varied opinions among researchers. Some argue that standardized approaches are necessary to ensure consistency and scalability, while others advocate for a focus on localized demand-driven services that address the specific needs of diverse regions. [25]. Policymakers face a complex challenge as they must consider local contexts, the requirements of farmers, and the capabilities of service providers. This thorough examination is crucial for developing and implementing ASS programs aimed at achieving optimal impact and effectiveness [26].

2.2. Impact of ASSs on Rural Household Income and Spatial Spillover Effects

Research has explored the impact of ASSs on rural household income. Grounded in the theory of specialization and division of labor, ASSs have the potential to boost agricultural productivity and profitability by offering specialized services and leveraging economies of scale [27]. Empirical studies substantiate this theory. For example, Chen et al. [28] examined the effects of science and technology services on the agricultural income of rural households in northeastern China, finding significant income increases linked to these services. Similarly, Cunguara and Darnhofer [29] investigated the relationship between advanced agricultural technologies and household income in rural Mozambique, confirming that these technologies positively influence income levels. Additionally, Guo et al. [30] scrutinized the correlation between innovations in science and technology and rural revitalization systems. They highlighted the pivotal role of ASSs in fostering rural development and augmenting household income. Additionally, Qing et al. [9] analyzed the connection between innovations in science and technology and rural revitalization systems, emphasizing the critical role of ASSs in promoting rural development and enhancing household income.

It is essential to recognize the potential drawbacks associated with ASSs. Increased reliance on market mechanisms and the rising costs of these services may adversely affect smallholder farmers. Yang and Liu [31] emphasize that excessive dependence on ASSs can undermine farmers' autonomy and bargaining power, potentially jeopardizing long-term economic benefits. Ivanov et al. [32] found that agricultural enterprises that quickly provide returns on invested capital are more attractive to investors. This suggests that developing ASSs to improve agricultural efficiency and profitability can attract more investment and promote rural economic development. To address these challenges, policy interventions should strike a balance between the expansion of ASSs and initiatives that enhance farmers' skills and resilience in the marketplace.

While considerable research has focused on the direct effects of ASSs on rural household income, their spatial spillover effects remain insufficiently explored. The positive impacts of ASSs often extend beyond administrative boundaries, benefiting neighboring regions through mechanisms such as technology transfer and shared economies. Therefore, conducting a spatial analysis of ASSs is imperative [33].

To account for these spillover effects, the Spatial Durbin Model (SDM) is employed in the empirical analysis. This model incorporates spatial lags of both the dependent variable, rural income, and key explanatory variables, including ASSs and control variables. By explicitly modeling spatial interactions, the SDM quantifies the magnitude of spillover effects in relation to direct effects, yielding valuable insights for policy design.

The spatial dimension of agricultural development is increasingly acknowledged, yet empirical studies examining the spatial spillover effects of ASSs on rural incomes are limited. In their study, Zhang et al. [34] analyzed the influence of agricultural exports on the urban–rural income gap in China, revealing positive spillover effects on adjacent areas.

To formulate effective policies for ASSs, a comprehensive understanding of their spatial dynamics is crucial. This involves recognizing the complex relationships between ASSs and rural development, as well as the spatial dimensions of these interactions. A thorough analysis of the spillover effects of ASSs is vital for developing inclusive policy strategies that foster rural development and alleviate poverty. Incorporating spatial interdependencies into policy frameworks is essential for creating resilient and impactful interventions aimed at enhancing the well-being of rural communities. This approach requires moving beyond simplistic models to account for the intricate network of spatial interactions and their significant influence on rural income generation.

2.3. Non-Linear Effects of ASSs at Different Stages of Urbanization

The relationship between urbanization and the effectiveness of ASSs is complex and multifaceted, yet it remains an under-researched area [12]. As urbanization alters rural demographics and production practices, it may affect the relevance and outcomes of ASSs in nonlinear and unpredictable ways. Understanding these non-linear dynamics is crucial for designing targeted ASS interventions and optimizing their effectiveness in promoting inclusive rural growth across different stages of urbanization.

While studies have addressed the challenges posed by urbanization in developing countries, emphasizing the need for sustainable agricultural practices and adaptations in rural labor markets [15], they have not directly examined the implications for the effectiveness of ASSs. Other research has explored connections between agricultural modernization and ASSs' influence on various economic indicators including green total factor productivity [12], regional economic growth [13], and the significance of socialized services in fostering green agricultural development [14]. Yet, none of these investigations have focused on the potential non-linear effects of ASSs across different stages of urbanization.

Addressing this research gap is crucial for developing evidence-based policies that maximize the benefits of ASSs in the context of rapid urbanization. By examining the non-linear relationship between urbanization and ASS effectiveness, policymakers can design targeted interventions that account for the evolving needs and challenges faced by rural communities at various stages of urbanization. This approach is essential for promoting sustainable agricultural practices, improving rural livelihoods, and fostering inclusive rural development in an increasingly urbanized world.

This study contributes to the literature by addressing research gaps in three key areas. First, it develops a comprehensive analytical framework that integrates institutional economics and spatial analysis to examine the operational mechanisms of ASSs across various contexts. This approach sets our study apart from previous works that have primarily focused on direct effects, enabling us to capture both the direct and indirect pathways through which ASSs influence rural development. Second, it employs spatial econometric techniques to uncover the geographical dynamics and spillover effects of ASSs, demonstrating that benefits extend to neighboring regions and provide insights for optimizing resource allocation. Third, it constructs a threshold model to examine the non-linear relationship between urbanization and ASS effectiveness, identifying critical urbanization levels at which the impact on rural incomes shifts significantly. These findings offer valuable guidance for designing ASS policies in the context of rapid urbanization and evolving agricultural systems, promoting sustainable and inclusive rural growth.

To address this research gap, the study explores the non-linear effects of ASSs on rural household income at different stages of urbanization. By integrating the urbanization perspective, this research provides a more comprehensive understanding of the interaction between ASSs and rural development. The findings will contribute to the formulation of policies that promote sustainable agricultural practices and improve rural livelihoods, taking into account the varying impacts of ASSs as urbanization progresses.

3. Research Design

The study employs the Spatial Durbin Model (SDM) to capture the spatial spillover effects of Agricultural Support Services (ASSs). This model incorporates spatial-lagged terms of the dependent variable (rural income) and key explanatory variables (ASSs and control variables), effectively reflecting the impact of ASSs on the income of neighboring regions. This design not only accounts for the direct effects of ASSs within the region but also reveals their indirect effects in adjacent areas, thereby providing a deeper understanding of the comprehensive impact of ASSs.

3.1. Data Sources

The dataset used in this study covers 30 provinces in China (excluding Hong Kong, Macao, Taiwan, and Tibet) from 2011 to 2021, representing the vast majority of the country's land area, population, and economic activity. The selected provinces, while operating under common national governance and economic systems, capture substantial regional diversity in economic development level, agricultural production characteristics, geography, climate, and policy environment that may influence the dynamics of agricultural socialization services (ASSs) and rural sustainability. This enables the analysis of ASS impacts across varied contexts. These 30 provinces share commonalities in ASS adoption potential, rural economic structure, and development prospects, allowing the study to better reflect ASSs' effects on sustainable rural development. The data are collected from various official statistical yearbooks, including the China Statistical Yearbook, China Rural Statistical Yearbook, China Urban and Rural Construction Statistical Yearbook, China Science and Technology Statistical Yearbook, China Financial Statistical Yearbook, China Industrial Statistical Yearbook, China Water Conservancy Statistical Yearbook, and China Rural Policy and Reform Statistical Yearbook, as well as statistical yearbooks of individual provinces. Some missing values are imputed using linear interpolation. In this study, linear interpolation was chosen as the method for handling missing data due to its appropriateness in the context of agricultural data, which often exhibits seasonal characteristics. This method effectively maintains the continuity of the dataset and reflects seasonal variations. However, it is important to acknowledge that while linear interpolation can provide reasonable estimates, it may not fully eliminate shifts in the data. Therefore, we will discuss the potential implications of using this method and consider alternative approaches in future research.

The consistency and reliability of the data across various sources and years have been meticulously verified to ensure data quality. It is important to note that official statistics might contain measurement errors or reporting biases, which could influence the findings. To evaluate the robustness of the results, sensitivity analyses employing different data sources or imputation techniques could be performed. Table 1 presents the descriptive statistics of the variables used in the analysis.

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
lnINC	330	9.410	0.414	8.361	10.559
ASS	330	0.182	0.108	0.026	0.516
hc	330	7.834	0.616	5.878	9.910
open	330	0.265	0.291	0.008	1.548
agdp	330	2.009	0.945	0.509	6.026
ls	330	0.902	0.054	0.742	1.014
md	330	0.641	0.230	0.264	1.386
urb	330	0.596	0.121	0.350	0.896

3.2. Modeling

3.2.1. Benchmark Regression Model

The benchmark regression model is as follows:

$$\ln INC_{it} = \beta_0 + \beta_1 ASS_{it} + \beta_2 control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where $\ln INC_{it}$ represents the logarithm of rural income in province i in year t; AS_{it} denotes the level of ASSs in province i at year t; and $control_{it}$ represents the control variables that have been commonly used in the prior literature to capture relevant factors influencing rural incomes [35,36]. These include the average education level of rural residents, level of openness to the outside world, level of rural economic development, industrial structure, and machinery density; the fixed effect of province; μ_i and λ_t represent the province and time0fixed effects, respectively; and ε_{it} is the error term.

Theoretically, the fixed effects model controls for time-invariant provincial characteristics that may influence rural income, allowing us to focus on the impact of changes in agricultural socialization service levels on rural income. The province fixed effects control for time-invariant province-specific factors that might affect rural incomes, including geographic location and natural resource endowments. Time-fixed effects account for common shocks or trends that impact all provinces within a specific year, such as changes in national policies or macroeconomic conditions. Fixed effects account for unobserved provincial-level heterogeneity, allowing us to focus on within-province changes in ASSs and rural incomes [37,38].

3.2.2. The Spatial Models

This study examines the spatial spillover effects of ASSs on rural incomes by applying three different spatial econometric models: the Spatial Autoregressive (SAR) model, the Spatial Error Model (SEM), and the Spatial Durbin Model (SDM). These models have been widely applied in various fields to capture spatial dependencies [39,40].

The SAR model captures the direct spatial spillover effects of rural incomes by including a spatial lag term in the dependent variable. The model is expressed as

$$\ln INC_{it} = C + \rho W \ln INC_{it} + \beta_1 ASS_{it} + \beta_2 control_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

The spatial structure of the SAR model is defined by the spatial weight matrix, and W is constructed using the inverse of the geographic distance between provinces, with the diagonal elements set to zero to exclude self-influence. The parameter ρ is the spatial autoregressive coefficient that estimates the magnitude of spatial spillover effects, and $W\ln INC$ represents the spatial lag of the dependent variable $\ln INC$.

The SEM model incorporates spatial dependence within the error term. This acknowledges the possibility that unobserved factors influencing rural incomes in one province may also exert an effect on neighboring provinces. The model takes the following form:

$$\ln INC_{it} = C + \beta_1 ASS_{it} + \beta_2 control_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \varepsilon_{it} = \gamma W \varepsilon_{it} + \mu_{it} \quad (3)$$

where λ_t is the spatial error coefficient and ε_{it} is the spatially autocorrelated error term.

The SDM provides a more comprehensive approach by including both a spatial lag of the dependent variable and spatial lags of the explanatory variables, recognizing that a province's rural incomes may be affected by ASSs and other factors in neighboring provinces. The model is given by

$$\ln INC_{it} = C + \rho W \ln INC_{it} + \beta_1 ASS_{it} + \beta_2 control_{it} + \theta_1 WAS_{it} + \theta_2 Wcontrol_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

where θ_1 and θ_2 are coefficients measuring the spatial spillover effects of ASSs and the control variables, respectively.

The spatial weight matrix W is a crucial element in all three models, representing the spatial structure of the data. The spatial weight matrix W is defined using the inverse of the geographic distance between provinces, with diagonal elements set to zero to eliminate self-influence. This formulation implies that spatially proximate provinces exhibit more substantial spatial interactions. Alternative specifications of W such as contiguity-based or economic distance-based weights could be considered to test the robustness of the results [41,42]. The choice among the SAR, SEM, and SDM depends on the specific spatial processes underlying the data and the research question at hand. The SDM is the most flexible, nesting the SAR and SEM as special cases. Likelihood ratio tests or other model selection criteria can be used to determine the most appropriate specification [43,44].

3.2.3. Threshold Effect Modeling

This study aims to investigate the potential non-linear relationship between ASSs and rural residents' income using a threshold regression model. The threshold regression model allows for the effect of ASSs on rural incomes to vary across different regimes defined by a threshold variable [45,46]. In this analysis, the level of urbanization (urb) serves as the threshold variable, given the anticipated variation in the impact of ASSs based on a province's urbanization stage.

The selection of the urbanization level as the threshold variable is supported by both theoretical underpinnings and empirical evidence. Urbanization acts as a crucial factor driving rural–urban transformation, significantly impacting rural income dynamics and the effectiveness of agricultural support services. Previous studies indicate that the relationship between ASSs and rural incomes may display nonlinear patterns depending on the stage of urbanization.

While other factors like land rights, credit access, and participation in agricultural organizations could also serve as threshold variables, we emphasize urbanization because of its significant role in rural development and its strong connection to agricultural modernization. Nevertheless, we recognize that investigating alternative threshold variables is a valuable area for future research to deepen our understanding of the complex interactions between ASSs and rural incomes.

Several factors rooted in economic theory point to the potential for threshold effects in the relationship between ASSs and rural household incomes. During the initial phases of urbanization, the migration of rural workers to urban centers can lead to a scarcity of agricultural labor, potentially limiting the impact of ASSs on rural income growth [47,48]. Nevertheless, as urbanization advances, the expansion and refinement of ASSs could gather pace, playing a more substantial role in fostering rural income growth. Moreover, the need for and advantages of ASSs likely differ depending on the degree of urbanization. Regions with higher levels of urbanization often have a more technologically advanced and market-oriented agricultural sector, which may require more specialized and streamlined services [49].

The threshold regression model takes the following form:

$$\ln INC_{it} = \beta_0 + \beta_1 urb_{it} \times I(ASS_{it} \leq \gamma_1) + \beta_2 urb_{it} \times I(ASS_{it} > \gamma_1) + \sum \beta_3 control_{it} + \varepsilon_{it} \quad (5)$$

where $I(\bullet)$ is an indicator function that equals one if the condition in parentheses is satisfied and zero otherwise, and γ is the threshold value of urbanization to be estimated. The coefficients β_1 and β_2 capture the effect of ASSs on rural incomes in the low and high urbanization regimes, respectively.

The threshold value γ_1 is estimated endogenously by minimizing the sum of squared residuals from the regression. To test for the statistical significance of the threshold effect, the bootstrap method proposed by Hansen [50] generates asymptotically valid p-values. In this analysis, 1000 bootstrap replications are utilized to obtain precise p-values and critical values for the threshold estimates.

3.3. Selection of Indicators and Data Sources

3.3.1. Explained Variable

Rural residents' income (ln*INC*): rural income is measured by taking the natural logarithm of the per capita disposable income of rural households. This metric is widely used in studies focused on rural development and inequality, as it accurately captures the economic well-being of rural residents [51,52]. Per capita disposable income is a key indicator of rural residents' economic well-being and living standards, as it represents the actual economic resources available to households after accounting for taxes and transfers. Higher per capita disposable income enables rural residents to afford better housing, healthcare, education, and other amenities, thereby improving their overall quality of life. Disposable income, after accounting for taxes and transfers, provides a more precise evaluation of the financial resources accessible to rural households. To minimize the impact of outlier values on our analysis, a logarithmic transformation to the income variable is performed. This transformation not only mitigates the influence of extreme values but also allows for a more nuanced interpretation of the results. Specifically, by transforming the income variable, the resulting coefficients can be interpreted as elasticities.

3.3.2. Explanatory Variable

To assess the scope of ASSs, this study employs a comprehensive index. This index is developed through the entropy weight technique, which allows for a thorough evaluation of ASSs. It encompasses seven key dimensions: services related to agricultural enterprises, mechanization, informatization, infrastructure, technology, finance, and societal/public services. A detailed description of the specific indicators and their assessment methods is presented in Table 2.

Table 2. Indicator system for agricultural socialization services.

Level 1 Indicators	Secondary Indicators	Interpretation of Indicators	Unit (of Measure)	Weights	Expected Effects
Agricultural management services	Proportion of land trusteeship	Ratio of land trust area to sown area	%	0.0294	Positive
	Land productivity of scale operation	Ratio of gross agricultural output to sown area	%	0.0206	Positive
	Proportion of arable land at an appropriate scale	Proportion of farmers operating at an appropriate scale	%	0.0692	positive
Agricultural mechanization services	Number of agricultural mechanization service providers	Number of agricultural mechanization service providers	-	0.0576	Positive
	Area served by agricultural aircraft	Total area of machine-ploughing, machine-irrigation, machine-planting, machine-harvesting, and machine-sowing	Khm^2	0.0373	Positive
	Level of agricultural mechanisation	Total power of agricultural mechanisation	Ten thousand Kilowatts	0.0302	Positive
	Number of agricultural mechanisation service organisations	Number of agricultural mechanisation service organisations	-	0.0473	Positive
	Agricultural aircraft operational area	Agricultural aircraft operational area	Khm^2	0.1171	Positive
	Refined operation area of agricultural machinery	Area of small-scale planting under mechanical refinement	Khm^2	0.0862	Positive
	Number of medium and large tractors	Number of medium and large tractors	10,000 units	0.0527	Positive

Table 2. *Cont.*

Level 1 Indicators	Secondary Indicators	Interpretation of Indicators	Unit (of Measure)	Weights	Expected Effects
Agricultural informatization services	Rural Internet penetration rate	Number of rural Internet broadband accesses	-	0.0437	Positive
	Rural telephone penetration	Rural telephone penetration	%	0.0134	Positive
	Proportion of villages with postal service	Proportion of postal villages in total villages	%	0.0011	Positive
	Length of rural postal delivery routes	Length of rural postal routes	km	0.0191	Positive
Agricultural infrastructure services	Level of rural water construction	Effective irrigated area	hm^2	0.0284	Positive
	Length of rural roads	Length of rural roads	km	0.0374	Positive
	Rural per capita investment in agriculture, forestry and water fixed assets	Per capita investment in fixed assets in agriculture, forestry, and water	Hundred million CNY/person	0.0300	Positive
	Reservoir density	Number of reservoirs	-	0.0459	Positive
	Electricity consumption in rural areas	Rural electricity consumption	Kilowatts	0.0602	Positive
Agricultural technology services	Number of agricultural technicians per 10,000 farmers	R&D personnel per unit of agricultural GDP	Hundred million CNY/person	0.0323	Positive
	Rural human capital	Average years of schooling weighted by education level and region	%	0.0046	Positive
	Agrometeorological observation stations	Number of agrometeorological observation stations	-	0.0124	Positive
Agricultural financial services	Penetration rate of agricultural insurance	Agricultural insurance costs	%	0.0301	Positive
	Proportion of agricultural loans in total loans	Total agriculture-related loans	billion	0.0284	Positive
Agricultural socialized services	Living standards of the rural population	Rural Engel coefficient	%	0.0046	Negative
	Completion of fixed asset investment in rural households	Ratio of completed fixed asset investment in rural households to primary sector output value	%	0.0175	Positive
	Fiscal agricultural expenditure	Local financial expenditure on agriculture, forestry and water affairs	Hundred million CNY	0.0157	Positive
	Level of soil erosion control	Area of soil and water conservation	Km^2	0.0266	Positive

Agricultural Socialization Services (ASSs): ASSs ARE the key explanatory variables in this study, representing the level and quality of agricultural support services provided to farmers. We construct a comprehensive index to measure ASSs using the entropy weight method, which takes into account seven dimensions: agricultural enterprise services, mechanization services, informatization services, infrastructure services, technology services, financial services, and societal/public services. Each dimension is composed of several specific indicators, such as the number of agricultural mechanization service providers, the area served by agricultural aircraft, and the penetration rate of rural internet. The specific indicators and their measurement units are listed in Table 2. Data were sourced from national agricultural databases and local government reports to ensure comprehensive coverage and relevance.

The ASS index captures the multidimensional nature of agricultural support services and their potential impact on rural household income. By considering a wide range of service dimensions, we aim to provide a comprehensive assessment of the role of ASSs in promoting rural economic sustainability. The entropy weight method allows us to objectively assign weights to each indicator based on its information content, ensuring that the index reflects the relative importance of each dimension in explaining the variation in ASSs across regions and over time.

The entropy weight method, an objective weighting technique frequently used in research, assigns weights to each indicator based on its information entropy [53,54]. Indicators exhibiting higher variability across provinces and years receive greater weights, as they are deemed to contain more information. By utilizing the entropy weight method, subjectivity in weight assignment is minimized, making it a popular choice for constructing composite indices in numerous studies [55,56].

Each aspect of ASSs included in the index has the potential to influence rural incomes through various channels. For instance, agricultural business services may improve market access, while technology services can enhance productivity. Financial services provide farmers with access to credit and insurance, and infrastructure services create an enabling environment for agricultural growth.

The multidimensional ASS index developed in this study accounts for the diverse pathways through which ASSs can impact rural incomes, including enhancing agricultural productivity, improving market access, and offering technical and financial assistance to farmers. However, it is important to acknowledge the limitations of the index construction process, such as potential subjectivity in indicator selection and data constraints.

3.3.3. Control Variables

The selection of control variables is theoretically grounded in an extended Cobb-Douglas production function framework, where rural income (INC) is conceptualized as a function of agricultural socialization services (ASSs) and other key production factors: INC = f(ASS, K, L, H, T). This framework incorporates the capital input (K), labor input (L), human capital (H), and technology level (T). Based on this theoretical foundation, we include several control variables that capture different aspects of the production function.

In addition to the core explanatory variable of Agricultural Socialization Services (ASSs), this study incorporates a set of control variables commonly used in the literature to capture other factors influencing rural incomes [57]. The selection of these variables is guided by theoretical considerations and the previous empirical literature. These control variables can be grouped into three main categories: human capital, economic openness, and structural transformation.

These control variables not only fit well within the theoretical framework but also highlight the intricate interactions among various factors influencing rural income. For example, education level enhances the capacity for technology adoption in conjunction with ASSs, while openness promotes both technology diffusion and market access. Additionally, the industrial structure variables demonstrate how changes in structure can influence the effectiveness of ASSs in fostering rural income growth.

Human capital is included, measured by the average years of schooling of rural residents, weighted by education level and regional population. Theoretical and empirical research has consistently highlighted human capital as a crucial driver of income growth [58,59]. Education is a key determinant of individual productivity and earning potential. Regions with higher levels of human capital are expected to have higher rural incomes, ceteris paribus. This approach allows us to account for regional disparities in educational quality, as the weighting scheme gives more importance to higher levels of education and adjusts for differences in population size across regions;

The level of openness to the outside world (open) is calculated as the ratio of total import and export volume to regional GDP. Trade and investment openness can influence rural incomes through multiple pathways, including the expansion of market opportunities for agricultural products, facilitation of technology spillovers, and attraction of foreign direct investment [60,61]. Exposure to international trade can affect rural incomes through multiple channels, such as altering the relative prices of agricultural products, facilitating technology transfer, and attracting foreign investment;

The structural shift of the economy from agriculture to industry and services can significantly impact rural incomes [62]. Variables capturing structural transformation are considered. Two control variables are included to capture this effect: the level of rural economic development (agdp), measured by the per capita gross output value of agriculture, forestry, animal husbandry, and fishery in rural areas; and the industrial structure (ls), measured by the share of secondary and tertiary industries in regional GDP. Both factors can influence rural income growth through multiple channels. As labor shifts from agriculture to industry and services, it often leads to higher economic returns. The development of non-agricultural industries in rural areas creates employment opportunities, allowing rural residents to earn higher wage income. Structural transformation is also accompanied by advancements in agricultural technology, enhancing productivity;

The agricultural mechanization level, represented by machinery density (total power of agricultural machinery per cultivated land area), is included, proxied by machinery density (md), which is calculated as the total power of agricultural machinery per unit of cultivated land area. Agricultural mechanization can increase productivity and efficiency, contributing to higher rural incomes [63]. The agricultural mechanization level is included as a control variable because it can significantly impact rural incomes by enhancing agricultural productivity and altering labor requirements. The adoption of machinery in agricultural production allows farmers to cultivate larger areas of land more efficiently, leading to increased output and economies of scale. Mechanization also reduces the labor intensity of agricultural tasks, freeing up labor for off-farm employment opportunities that often provide higher returns. Moreover, the use of machinery can improve the timeliness and precision of agricultural operations, leading to better crop management and higher yields. By boosting productivity and facilitating labor reallocation, agricultural mechanization can contribute to income growth in rural households.

The selection of control variables in this study is guided by theoretical foundations and prior empirical evidence. While our analysis accounts for a range of control variables, limitations in data availability and unobservable factors prevent complete control for all influencing variables. To further augment our findings, future research could investigate the impact of additional determinants on rural incomes, such as infrastructure development, governance effectiveness, and community engagement.

3.3.4. Threshold Variables

The urbanization level (urb), calculated as the proportion of the urban population, captures the degree of urbanization. This variable's impact on the relationship between ASSs and rural incomes is indirect, affecting agricultural production, ASS demand, and rural labor dynamics [15,64]. Urbanization is a complex process that can fundamentally reshape the socioeconomic fabric of rural areas. As such, the impact of ASSs on rural incomes may exhibit non-linearities across different stages of urbanization. To capture these potential threshold effects, this study employs a panel threshold regression model, with urbanization level serving as the threshold variable. The theoretical rationale for considering urbanization as a threshold variable is twofold. First, during the initial stages of urbanization, the outflow of agricultural labor to urban sectors can lead to rising labor costs and labor shortages in rural areas. This may limit the capacity of ASSs to drive rural income growth. Second, as urbanization progresses, the demand for specialized high-quality ASSs may increase as agricultural production becomes more technology- and capital-intensive.

The choice of urbanization level as a threshold variable is supported by established theoretical frameworks and previous empirical research [65], which indicate a nonlinear relationship between ASSs and rural incomes across varying urbanization stages. Therefore, the urbanization level is incorporated as a threshold variable to capture any non-linear relationships. Analyzing these dynamics will allow for a better understanding of the ASS–rural income relationship.

3.4. Spatial Model and Weight Matrix Selection

To analyze the spatial effects more effectively, we utilized a Spatial Durbin Model. This model incorporates spatial interactions among provinces, seeking to capture both direct and indirect effects.

A weight matrix based on geographic distance was employed to quantify the spatial relationships. This approach is widely utilized in spatial econometrics to reflect the degree of interaction between different regions based on their geographical proximity.

The choice of a geographic distance-based weight matrix was made to capture the spatial relationships between provinces effectively. However, we acknowledge that factors such as economic ties and political relationships may also influence spatial interactions. Future research could explore these alternative weight specifications to enhance our understanding of spatial dynamics in rural development.

4. Empirical Analysis

4.1. Benchmark Regressions and Robustness Tests

The benchmark regression and robustness test results, summarized in Table 3, reveal a strong positive relationship between ASSs and rural income. The double fixed-effects model (Column 2) yields a coefficient of 0.183 for ASSs, statistically significant at the 1% level, suggesting that enhancements in service quality and efficiency can substantially boost rural household earnings. Specifically, a one-unit increase in the level of ASSs is associated with an 18.3% increase in rural residents' income, ceteris paribus. In this context, a one-unit increase in agricultural social services (ASSs) refers to a one standard deviation improvement in the comprehensive ASS index, constructed using the entropy weight method as described in Section 3.3.2. This improvement can be achieved through various strategies, such as enhancing the quality and accessibility of agricultural extension services, increasing the availability of agricultural machinery and technology, or expanding rural financial services. Therefore, the findings indicate that targeted investments and policies focused on strengthening specific aspects of ASSs could significantly benefit rural incomes. This result confirms the established positive effect of agricultural support services on rural household welfare and aligns with previous studies [66]. This result carries profound economic implications for narrowing China's entrenched urban–rural income disparity [67]. Investing in the growth and improvement in ASSs may prove to be a potent approach for fostering rural development and mitigating poverty. Nevertheless, the efficacy of these services likely depends on a range of factors, including implementation quality, beneficiary targeting, and concurrent investments in rural infrastructure and human capital [68]. The analysis of regional heterogeneity indicates that the impact of agricultural social services (ASSs) on rural incomes differs across China's eastern, central, and western regions. Policymakers should prioritize investments in ASSs in areas with lower levels of these services, particularly in central and western provinces where spillover effects are likely to be more significant. By targeting regions with greater income disparities and underdeveloped ASSs, these investments can effectively promote inclusive rural growth and alleviate poverty.

The analysis of control variables in the panel regression reveals several important trends. Firstly, there is a significant positive relationship between the education level of rural residents and their income. A coefficient of 0.020, which is statistically significant at the 1% level, indicates that enhancing educational attainment in rural areas can lead to increased income levels. Vocational training programs focused on agricultural skills and technology are vital for rural residents to effectively use agricultural social services (ASSs). Investments in formal education, particularly in enhancing access and quality of primary and secondary schooling, will also strengthen human capital and support the long-term benefits of ASSs. Combining targeted vocational training with improvements in formal education will likely maximize the income-boosting potential of ASSs. This finding aligns with existing research on the benefits of education in developing countries [69]. Investing in rural education, especially in vocational training and skill development initiatives, can enhance the effectiveness of ASSs by improving human capital among rural residents. This empowerment can help them capitalize on emerging economic opportunities. Additionally, the analysis shows that the degree of openness to external markets has a coefficient of 0.065, which is statistically significant at the 1% level. This indicates that greater openness through trade and foreign investment can broaden market access for agricultural products, thereby fostering growth in rural incomes. However, it is important to note that the advantages of increased openness may not be distributed equitably across the population, and small-scale farmers could face marginalization if not adequately supported to compete in global markets [70]. To mitigate this risk, policymakers should implement targeted subsidies for small-scale farmers, such as input subsidies or price support, to maintain competitiveness. Encouraging the development of agricultural cooperatives can help these farmers achieve economies of scale, strengthen their bargaining power, and improve market access. Furthermore, enhancing access to credit facilities and financial services will enable small-scale farmers to invest in productivity-boosting technologies and manage risks associated with market volatility. Third, the positive and significant coefficient of agricultural machinery density highlights the importance of technological upgrading and modernization in the agricultural sector. Mechanization can improve agricultural productivity and efficiency, freeing up labor for more remunerative non-farm activities. However, the high cost of agricultural machinery and the need for specialized skills may limit the accessibility of mechanization for small-scale farmers, necessitating policies to ensure affordability and provide training and extension services. Shared-use programs that allow farmers to access machinery through cooperatives or rental services can alleviate the financial burden of individual ownership. Public–private partnerships, where the government supports private-sector mechanization services, can enhance accessibility for small-scale farmers. Furthermore, targeted subsidies for purchasing or leasing machinery, along with training in operation and maintenance, can help marginalized farmers overcome adoption barriers.

Table 3. Benchmark regression and robustness test results.

	(1) **lnINC**	**(2)** **lnINC**	**(3)** **lnINC**	**(4)** **lnINC**	**(5)** **lnINC**
ASS	0.171 ***	0.183 ***	0.272 ***	0.280 **	0.241 ***
	(0.061)	(0.063)	(0.091)	(0.116)	(0.071)
hc		0.020 ***	0.121 ***	0.111 ***	0.011
		(0.007)	(0.025)	(0.023)	(0.008)
open		0.065 ***	0.240 ***	0.318 ***	0.037 *
		(0.019)	(0.075)	(0.057)	(0.022)
agdp		0.0004	0.249 ***	0.222 ***	0.017 ***
		(0.005)	(0.012)	(0.015)	(0.005)
ls		−0.086	4.354 ***	4.034 ***	0.185
		(0.149)	(0.258)	(0.309)	(0.166)
md		0.065 ***	0.173 ***	0.176 ***	0.048 ***
		(0.015)	(0.063)	(0.054)	(0.016)
_cons	8.881 ***	8.741 ***	3.810 ***	4.238 ***	8.566 ***
	(0.009)	(0.142)	(0.280)	(0.297)	(0.157)
Year	Yes	Yes			Yes
Province	Yes	Yes			Yes
Number of observations	330	330	330	300	330
Adj.R^2	0.995	0.995	0.737	0.742	0.994

Note: *, **, and *** indicate significance at the level of 10%, 5%, and 1%, respectively.

Three robustness checks were performed to validate the regression results. The findings maintain their significance across all robustness checks, demonstrating their resilience to different model specifications and estimation techniques. Column (3) uses a mixed OLS model for re-regression analysis, and Column (4) lags the core explanatory variable ASSs by one order and uses the instrumental variable method (2SLS) test, which uses the one-year lagged value of ASSs as an instrumental variable. The instrumental variable approach was used to address potential endogeneity issues, such as reverse causality, between agricultural social services (ASSs), and rural incomes. By utilizing lagged values of ASSs as instruments, the goal is to isolate the causal effect of these services on rural economic outcomes, as these lagged values are less likely to be affected by current income levels. This method also reduces potential biases from omitted variables or measurement errors that could simultaneously influence both ASSs and rural incomes. Column (5) shrinks the model; it simplified the model by reducing the number of predictor variables, which helps mitigate potential overfitting and enhances interpretability. This model specification also maintains the significance of the results across all robustness checks, further confirming their reliability. The results remain significant across all robustness tests, indicating the robustness of the findings.

In summary, robustness checks confirm the positive impact of ASSs on rural household income in China, as revealed in the benchmark regression analysis. However, the effectiveness of these services in promoting rural development and reducing poverty likely depends on various factors, including implementation quality, beneficiary targeting, and complementary investments in education, infrastructure, and market access.

4.2. Space Measurement

4.2.1. Spatial Correlation Test

Spatial econometric analysis relies on a spatial weight matrix to model the relationships between spatial units. This study employs the inverse of the geographic distance between provinces to construct the geographic distance weight matrix W, which can be expressed as

$$W_d = 1/d_{ij} \tag{6}$$

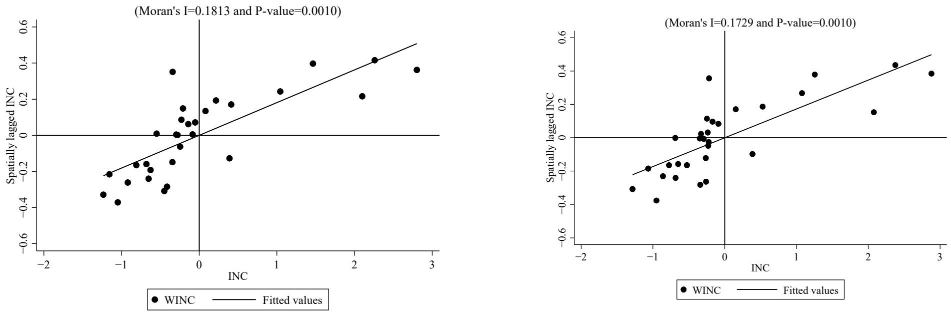
This approach is widely used in spatial econometric studies due to its ability to account for the distance decay effect, where the influence of one spatial unit on another diminishes with increasing distance [71]. However, potential drawbacks associated with this weighting scheme should be noted, such as the assumption of isotropic spatial relationships and the sensitivity to the choice of distance measure [47]. These limitations could potentially lead to an overestimation or underestimation of the true spatial dependence, affecting the accuracy of our results. Future research could explore alternative spatial weight specifications, such as economic distance or transportation network-based weights, to verify the robustness of the results.

Moran's I index, calculated using the spatial geographic distance weight matrix, assesses the spatial auto-correlation of rural residents' incomes in each province. The Geary's C index complements the Moran's I by providing a more localized measure of spatial autocorrelation. While Moran's I captures the overall spatial pattern, Geary's C is more sensitive to differences between neighboring observations. The results, presented in Table 4, show that across the period 2011–2021, statistically significant spatial autocorrelation, as measured by both Moran's I ($p < 0.01$) and Geary's C ($p < 0.01$), was consistently observed. The Moran's I values are greater than 0, and the Geary's C coefficients are less than 1, indicating substantial positive spatial autocorrelation in rural residents' incomes. The consistency between Moran's I and Geary's C results reinforces the evidence of significant spatial clustering in rural income levels across Chinese provinces. This finding highlights the importance of considering spatial dependence when analyzing the impact of agricultural socialization services on rural economic sustainability.

Table 4. Moran Index of Rural Income 2011–2021.

Year	Moran's I	Z	P	Geary's C	Z	P
2011	0.181	6.169	0.000	0.828	−3.511	0.000
2012	0.183	6.209	0.000	0.827	−3.548	0.000
2013	0.185	6.244	0.000	0.827	−3.575	0.000
2014	0.185	6.247	0.000	0.827	−3.577	0.000
2015	0.182	6.178	0.000	0.829	−3.501	0.000
2016	0.179	6.097	0.000	0.833	−3.406	0.000
2017	0.177	6.050	0.000	0.835	−3.355	0.001
2018	0.175	6.014	0.000	0.836	−3.303	0.001
2019	0.174	5.997	0.000	0.836	−3.280	0.001
2020	0.173	5.986	0.000	0.836	−3.273	0.001
2021	0.173	5.969	0.000	0.836	−3.264	0.001

The positive spatial autocorrelation in rural incomes indicates that provinces with similar income levels, whether high or low, tend to cluster spatially, resulting in a concentrated pattern. Figure 1 illustrates this phenomenon using localized Moran's scatter plots of rural incomes for 2011 and 2021, plotted on a global Moran's I basis. Quadrants I and III illustrate "high-high" and "low-low" agglomeration, while the second and fourth quadrants showcase "low-high" and "high-low" agglomeration levels. This spatial clustering, known as the "Matthew effect" or "rich-get-richer" mechanism, refers to the phenomenon where advantaged individuals or groups tend to accumulate further advantages over time, while disadvantaged ones fall further behind, significantly impacting regional inequality and poverty alleviation strategies. Policymakers should consider the spatial clustering of rural incomes when designing and implementing development strategies, as the effectiveness of interventions may be influenced by the spatial context.



(**a**) (**b**)

Figure 1. Moran scatter plot of rural residents' income in 2011 (**a**) and 2021 (**b**).

The spatial autocorrelation of rural incomes can be attributed to various factors, such as market potential, agglomeration economies, and knowledge spillovers. These factors, grounded in economic theory, provide insights into the spatial clustering of rural incomes and the potential channels through which ASSs can generate spatial spillover effects. New economic geography suggests that spatial economic clustering arises from increasing returns to scale, transportation costs, and market size [72]. Furthermore, endogenous growth theory highlights the importance of human capital, innovation, and technological diffusion in creating positive spatial externalities [73]. These theoretical perspectives offer insights into the spatial clustering of rural incomes and the possible channels through which ASSs can generate spatial spillover effects.

Although spatial autocorrelation in rural incomes indicates spatial patterns in economic development, it does not confirm spatial spillovers from ASSs. Further analysis, using models like the Spatial Durbin Model (SDM) that account for spatial lags of both dependent and independent variables, is needed to determine the extent of these spillovers. In conclusion, the spatial correlation test reveals significant spatial autocorrelation in rural residents' incomes across Chinese provinces, indicating the presence of spatial clustering and dependence. This finding underscores the importance of considering the spatial dimension in the analysis of rural development and the evaluation of ASSs.

4.2.2. Model Selection for Spatial Measurement

The results in Table 5 reveal that the model passed both the LM and LR tests, suggesting that the Spatial Durbin Model is the optimal choice for this research. Furthermore, Hausman and Wald tests indicate that a two-way fixed-effects approach is the most fitting for the analysis. As a result, this study employs a two-way fixed-effects Spatial Durbin Model as its primary means of analysis.

Table 5. Results of spatial econometric modeling tests.

Methods	Index	Value	P
LM	Moran's I	21.602	0.000
	LM_error	414.029	0.000
	Robust_LM_error	97.049	0.000
	LM_lag	519.545	0.000
	Robust_LM_lag	202.565	0.000
LR	LR_spatial_lag	61.72	0.000
	LR_spatial_error	73.34	0.000
Husman	FE or RE	18.91	0.002
Wald	Wald_spatial_error	64.8	0.000
	Wald_spatial_error	79.2	0.000

The Spatial Durbin Model was selected because it is the most comprehensive and flexible among the considered spatial models. Unlike the spatial lag and spatial error models, which account for spatial dependence only in the dependent variable or the error term, respectively, the Spatial Durbin

Model captures both the spatial dependence in the dependent variable and the potential spillover effects of the explanatory variables. Moreover, the two-way fixed-effects specification was chosen based on the Hausman and Wald tests, which suggested that it was the most appropriate approach to control for unobserved heterogeneity across provinces and time periods.

4.2.3. Regression Results of the Spatial Durbin Model

Table 6 summarizes the regression findings from the spatial econometric analysis employing the geographic distance weight matrix. Columns (1), (2), and (3) report results for the spatial autoregressive (SAR), spatial error (SEM), and spatial Durbin (SDM) models, respectively. The spatial autoregressive coefficients ρ for both the SAR and SDM, along with the spatial error coefficient λ for the SEM, are statistically significant at the 1% level, which supports the robustness of all three estimation models based on the geographic weight matrix. The results indicate that ASSs have a spatial effect on rural residents' income growth, with spillovers promoting income increases in neighboring areas. The spatial autoregressive coefficients ρ for both the SAR and SDM, along with the spatial error coefficient λ for the SEM, are statistically significant at the 1% level, confirming the robustness of all three estimation models based on the geographic weight matrix. This finding demonstrates that improvements in agricultural socialization levels can create spatial spillover effects, driving income growth for farmers in neighboring regions. This finding confirms that ASSs can significantly increase rural residents' income. Moreover, improvements in agricultural socialization levels can create spatial spillover effects, driving income growth for farmers in neighboring regions.

Table 6. Results of the spatial regression of agricultural socialization services and rural residents' income.

Main	(1) SAR	(2) SEM	(3) SDM	Wx
ASS	0.134 ***	0.104 **	0.120 **	1.851 ***
	(0.052)	(0.053)	(0.049)	(0.310)
hc	0.016 ***	0.014 **	0.018 ***	0.139 ***
	(0.006)	(0.006)	(0.006)	(0.042)
open	0.054 ***	0.047 ***	0.060 ***	0.438 ***
	(0.016)	(0.016)	(0.015)	(0.088)
agdp	−0.001	−0.000	−0.005	−0.013
	(0.004)	(0.004)	(0.004)	(0.026)
ls	−0.094	−0.088	−0.140	−1.386 *
	(0.122)	(0.122)	(0.117)	(0.809)
md	0.054 ***	0.050 ***	0.035 ***	0.101
	(0.012)	(0.012)	(0.012)	(0.064)
ρ	0.795 ***		0.702 ***	
	(0.059)		(0.083)	
λ		0.779 ***		
		(0.065)		
Log-lik	878.774	872.964	909.634	
N	330	330	330	
R^2	0.588	0.367	0.669	

Note: *, **, and *** indicate significance at the level of 10%, 5%, and 1%, respectively.

The "demonstration effect" of ASSs, acting as a model for other regions to follow, contributes to their spatial spillover effects. High-quality ASSs in certain regions set a successful precedent, motivating and directing neighboring areas to adopt similar practices, leading to improved rural incomes across a broader spatial extent. The demonstration effect operates through multiple channels, including the spread of advanced technologies, farmer training initiatives, and the influence of agricultural cooperatives. High-quality ASSs in certain regions set a successful precedent, motivating and directing neighboring areas to adopt similar practices, leading to improved rural incomes across a broader spatial extent.

The inclusion of control variables, selected based on their theoretical relevance and use in the prior literature, provides a more comprehensive understanding of the factors influencing rural income growth and provides supplementary information on the factors influencing rural income growth, offering a more comprehensive understanding. The positive and significant coefficient of human capital (hc) underscores the importance of education and skill development in promoting rural income. Similarly, the positive and significant coefficient of agricultural machinery density (md) indicates that the adoption of advanced agricultural equipment can enhance productivity and contribute to higher rural incomes.

4.2.4. Utility Decomposition of the Spatial Durbin Model

Table 7 illustrates the decomposition of effects arising from the Spatial Durbin Model, highlighting the direct, spillover, and total impacts of ASSs on the income of rural residents. The coefficient for the direct effect, significant at the 1% level, indicates that ASSs can substantially increase income among rural residents in the region through mechanisms such as technological spillovers, economies of scale, and the reallocation of resources [74]. This outcome is consistent with the findings of Chen et al. [28], who demonstrated that science and technology services significantly enhance agricultural income in rural households by fostering innovation, improving efficiency, and increasing the application of modern agricultural techniques.

Table 7. Regression results for direct and indirect effects.

	Direct Effects	Spillover Effects	Total Effect
ASS	0.315 ***	6.650 ***	6.965 ***
	(0.096)	(2.299)	(2.381)
hc	0.033 ***	0.516 **	0.549 **
	(0.010)	(0.224)	(0.233)
open	0.109 ***	1.668 ***	1.777 ***
	(0.024)	(0.596)	(0.616)
agdp	−0.006	−0.060	−0.067
	(0.005)	(0.098)	(0.101)
ls	−0.295 *	−5.208	−5.504
	(0.170)	(3.538)	(3.673)
md	0.049 ***	0.452	0.501
	(0.017)	(0.295)	(0.306)

Note: *, **, and *** indicate significance at the level of 10%, 5%, and 1%, respectively.

Furthermore, the indirect effect coefficient of 6.650, which is statistically significant at the 1% level, highlights the considerable spatial spillover effects that ASSs have on neighboring regions. This spatial diffusion of services transpires through a "demonstration effect", where regions with superior service quality act as models and standards for others to emulate. This effect materializes through various avenues, such as the propagation of advanced technologies, the execution of farmer education initiatives, and the facilitating role of agricultural cooperatives. As a result, successful instances of ASSs motivate and direct adjacent areas to adopt comparable practices, ultimately resulting in a more widespread enhancement of rural incomes across a broader geographical area. Debolini et al. [33] corroborated the existence of spatial spillover effects, illustrating how ASSs facilitate the diffusion of knowledge, technologies, and best practices among regions.

The results from the Spatial Durbin Model indicate a significant positive relationship for the spillover effects, with quantitative results demonstrating that the spillover effects of ASSs are substantially influential compared to the direct effects. This finding underscores the critical role of ASSs in promoting income growth in surrounding rural areas and further validates the importance of interregional interdependence. Through the quantitative analysis of spillover effects, we gain clearer insights into the extent of ASSs' influence across different regions and its contribution to overall rural economic development.

The total effect coefficient of 6.965, which is statistically significant at the 1% level, illustrates the broad influence of ASSs on increasing the income of rural residents in the area. This finding suggests that policies aimed at expanding and improving ASSs, such as increasing investment in agricultural extension services, promoting the adoption of new technologies, and facilitating market access can have a substantial impact on rural incomes and contribute to reducing the urban–rural income gap. Policymakers should prioritize targeted interventions, including subsidies or incentives for smallholder farmers' access to ASSs, infrastructure improvements in underserved areas, and training programs to enhance the capacity of disadvantaged groups to utilize these services.

However, the equitable distribution of these benefits requires further consideration, given potential disparities in access and usage across socioeconomic groups. To address this issue, policymakers should prioritize the implementation of targeted measures to ensure a more equitable distribution of the benefits derived from these services, thereby contributing to the overarching objective of rural revitalization. Furthermore, the government should persistently strengthen ASSs, expand its coverage, and strategically allocate resources to prioritize regions with lower levels of these services, fostering inclusive growth in rural areas.

4.2.5. Robustness Tests of the Spatial Durbin Model

This study employs three distinct robustness tests to ensure the robustness and reliability of the research findings. First, alternative spatial weight matrices are utilized, specifically the economic–geographical nested matrix and the agricultural economic–geographical matrix of agricultural representativeness. The economic–geographical nested matrix is selected to capture the spatial interactions among provinces based on their economic and geographical proximity, while the agricultural economic–geographical matrix emphasizes the agricultural sector. These matrices allow for testing the robustness of the results to different specifications of spatial dependence that consider both economic and agricultural factors. The application of different spatial weight matrices enables the examination of the sensitivity of the results to various specifications of spatial dependence. The economic–geographical nested matrix captures the spatial interactions among provinces based on their economic and geographical proximity, while the agricultural economic–geographical matrix emphasizes the agricultural sector. Second, the dependent variable, rural residents' income (ln*INC*), is lagged by one and two orders to account for the potential delayed impact of ASSs on rural income. This approach addresses the possibility of temporal dynamics in the effects of these services, which may not be immediately observable but manifest over time [5]. Third, municipalities directly under the central government are excluded from the sample due to their distinct characteristics in terms of economic development, population agglomeration, and policy benefits compared to other provinces. This exclusion allows for the assessment of the robustness of the findings to potential outliers or influential observations.

The robustness test results presented in Tables 8 and 9 indicate that the coefficients related to ASSs range from 0.131 to 0.155 and maintain statistical significance at both the 1% and 5% levels across all three tests. This consistency confirms the stability of our findings. The results affirm the robustness of our conclusions, illustrating that the beneficial effects of ASSs on rural residents' income are not influenced by changes in spatial weight matrices, lagged effects, or the removal of municipalities [7].

Table 8. Robustness test of the Spatial Durbin Model.

	Economic Geography Nested Matrix			**Agricultural Economic Geography Matrix**		
	Direct Effect	**Spillover Effect**	**Aggregate Effect**	**Direct Effect**	**Spillover Effect**	**Aggregate Effect**
ASS	0.248 ***	4.627 ***	4.875 ***	0.241 ***	4.030 ***	4.271 ***
	(0.078)	(1.672)	(1.733)	(0.071)	(1.522)	(1.574)
hc	0.028 ***	0.323 **	0.350 **	0.046 ***	0.982 ***	1.028 ***
	(0.008)	(0.141)	(0.148)	(0.014)	(0.371)	(0.384)
open	0.078 ***	0.769 **	0.847 ***	0.119 ***	1.515 **	1.633 **
	(0.018)	(0.311)	(0.322)	(0.026)	(0.676)	(0.698)
agdp	0.001	0.111	0.113	−0.020 ***	−0.416 **	−0.436 **
	(0.005)	(0.072)	(0.075)	(0.008)	(0.211)	(0.218)
ls	0.002	1.300	1.302	−0.155	−3.364	−3.519
	(0.152)	(2.952)	(3.060)	(0.179)	(3.823)	(3.971)
md	0.034 **	0.200	0.234	0.086 ***	1.094 **	1.180 **
	(0.015)	(0.191)	(0.200)	(0.019)	(0.460)	(0.475)

Note: ** and *** indicate significance at the level of 5% and 1%, respectively.

Table 9. Robustness tests.

	SDM		
	First Order Lag	**Lagging Second Order**	**Excluding Municipalities**
ASS	0.155 ***	0.131 **	0.138 **
	(0.051)	(0.055)	(0.063)
W × ASS	1.919 ***	1.682 ***	1.203 ***
	(0.323)	(0.342)	(0.388)
direct effect	0.389 ***	0.377 ***	0.199 ***
	(0.112)	(0.125)	(0.072)
indirect effect	7.800 ***	7.974 **	2.423 **
	(2.812)	(3.167)	(0.960)
aggregate effect	8.189 ***	8.351 **	2.622 ***
	(2.912)	(3.280)	(0.995)
ρ	0.732 ***	0.768 ***	0.465 ***
	(0.076)	(0.067)	(0.130)
Control	YES	YES	YES
Log-lik	894.782	872.820	740.713
N	330	330	286
adj.R^2	0.535	0.135	0.514

Note: ** and *** indicate significance at the level of 5% and 1%, respectively.

Moreover, the robustness checks performed in this study offer significant insights into the inherent traits and consistency of spatial spillover effects. Through the examination of these effects in diverse scenarios, the checks unveil the manner in which ASSs propagate their impact to adjacent rural regions, transcending the mere influence on the intended households. Although the estimated magnitude of the spillover effects may differ based on the selection of spatial weight matrices, their significance and direction are consistently upheld [8]. This suggests that the positive spatial externalities generated by ASSs are a fundamental feature of the system and not contingent upon a specific spatial interaction pattern.

This stability suggests that the positive externalities generated by ASSs are an intrinsic property of the system and not an artifact of the chosen spatial model. Notably, this positive impact persisted even after excluding municipalities directly under central government administration [6], indicating widespread effectiveness in promoting rural development and narrowing regional income disparities.

4.2.6. Regional Heterogeneity Tests

Table 10 illustrates the regression results concerning regional heterogeneity, highlighting marked differences in how ASSs affect rural residents' income across China's eastern, central, and western regions. The analysis reveals notable differences in the effectiveness of ASSs among the various regions. In both the eastern and central regions, the coefficients for ASSs are positive and statistically significant. This indicates that ASSs significantly contribute to increasing the income of rural residents in these areas. In contrast, the results for the western region show insignificant coefficients, suggesting that ASSs do not have a meaningful positive impact on income growth for rural households in this part of the country.

Several factors contribute to the observed regional heterogeneity in ASS impact, including variations in natural resource endowments, stages of economic development, and agricultural infrastructure. These underlying differences shape the effectiveness of ASSs in each region. The effectiveness of ASSs appears contingent upon regional contexts. The eastern and central regions, with their advantageous natural conditions, advanced economies, and robust agricultural sectors, are better positioned to benefit from these services. The western region's comparatively poor natural resources, underdeveloped economy, and weaker agricultural foundations constrain the potential impact of ASSs on rural income growth. Policymakers can harness the benefits of intensification and scale in central and western provinces through targeted interventions. These measures should promote the development of agricultural and machinery cooperatives, optimize agricultural machinery subsidy programs, and improve training for machinery service providers. Region-specific policies can strengthen the role of ASSs in boosting rural income growth by addressing the unique needs and conditions of each area.

Table 10. Regional heterogeneity regression results.

Main	(1) Eastern Part	(1) Central Section	(1) Western Part
ASS	0.281 ***	0.156 *	0.009
	(0.068)	(0.084)	(0.128)
W × ASS	0.152	0.701 ***	1.742 ***
	(0.231)	(0.189)	(0.515)
direct effect	0.435 ***	0.610 ***	1.899 **
	(0.143)	(0.167)	(0.764)
indirect effect	1.790	3.934 ***	16.261 ***
	(1.138)	(1.108)	(5.682)
aggregate effect	2.225 *	4.544 ***	18.160 ***
	(1.268)	(1.255)	(6.442)
ρ	0.810 ***	0.805 ***	0.902 ***
	(0.032)	(0.042)	(0.019)
Control	YES	YES	YES
Log-lik	392.771	254.466	295.326
N	132	99	99
R^2	0.647	0.951	0.795

Note: *, **, and *** indicate significance at the level of 10%, 5%, and 1%, respectively.

Utility decomposition analysis reveals that ASSs generate positive spatial effects within each region. Interestingly, the central and western provinces exhibit stronger positive spatial spillovers on neighboring areas compared to the eastern region. The magnitude of these spillover effects intensifies gradually from east to west. This phenomenon may be explained by the large-scale intensive production services in the central and western regions, which are facilitated by the movement of populations from west to east. The outflow of labor in these regions leads to rising labor costs, creating opportunities for agricultural development in neighboring areas. Intensive agricultural practices in the central and west contribute to effective service delivery and increased farmer incomes in surrounding areas. To enhance technological transfer from the eastern to central and western regions, the establishment of collaborative agricultural technology platforms is recommended.

Policymakers can leverage the benefits of intensification and scale in the central and western provinces by implementing targeted interventions. These measures should focus on fostering the growth of agricultural and machinery cooperatives, optimizing agricultural machinery subsidy programs, and enhancing training initiatives for agricultural machinery service providers. Region-specific policies can enhance the role of ASSs in promoting rural income growth. This requires addressing the unique needs and conditions of each area. To facilitate technological transfer from east to central and western regions, establishing collaborative agricultural technology platforms is recommended. Furthermore, incentivizing investment from eastern enterprises in the central and western regions and bolstering agricultural talent development are crucial strategies.

The implications of this research are substantial for comprehending the heterogeneous effects of ASSs across regions and for formulating region-specific agricultural support strategies. Agricultural issues are highly regional in nature, requiring targeted policies based on the resource endowments and development stages of different areas. By revealing the heterogeneous impact of ASSs across regions, this research provides important guidance for promoting agricultural modernization and reducing regional disparities in a locally adapted manner.

In conclusion, the spatial correlation test indicates significant spatial autocorrelation in rural residents' incomes across Chinese provinces, highlighting spatial clustering and dependence. The Spatial Durbin Model further shows that agricultural social services (ASSs) generate substantial positive spillover effects on rural incomes in neighboring regions. These findings emphasize the need to incorporate spatial dimensions in the analysis of rural development and the evaluation of ASSs. Policymakers should capitalize on these spatial spillovers by strategically investing in ASSs at key locations, as the benefits can extend to broader areas, fostering more balanced and inclusive rural growth.

4.3. Threshold Regression Models

This study utilizes the urbanization level as a threshold variable to explore the potential non-linear effects of ASSs on rural household income. The threshold regression analysis, summarized in Table 11, uncovers an intricate interplay between urbanization and ASS effectiveness in fostering income growth, with varying impacts observed across different stages of urbanization.

Table 11. Threshold effect regression results.

urb	lnINC
ASS × I (Th ≤ 0.3878)	−1.049 **
	(0.516)
ASS × I (0.3878 < Th < 0.4348)	1.111 ***
	(0.317)
ASS × I (Th ≥ 0.4348)	1.699 ***
	(0.240)
_cons	3.296 ***
	(0.481)
Control	YES
N	330
R^2	0.920

Note: ** and *** indicate significance at the level of 5% and 1%, respectively.

When the urbanization level is below the first threshold of 0.3878, ASSs appear to exert a negative effect on rural income growth. This finding can be attributed to the large-scale transfer of rural labor, particularly young and middle-aged individuals, to urban areas during the early stages of urbanization, leading to severe rural aging and hindering rural income growth. Population mobility and rural development theories offer a lens to comprehend how labor migration influences agricultural production and rural household incomes [75]. Taylor et al. (2003) [76] discovered that the relocation of rural workers can diminish agricultural productivity. The disruption of the rural workforce due to urbanization is a significant factor contributing to the negative impact of ASSs on income growth in less urbanized regions. This disruption likely results in a population that lacks the necessary skills and knowledge for modern efficient agricultural practices. Both theoretical frameworks and empirical findings support this conclusion.

Once urbanization surpasses a critical threshold, it signifies a shift in which ASSs begin to positively influence rural incomes. This change is primarily driven by the expansion and enhancement of ASSs. Their contributions to income growth are varied, including improved technology dissemination, better access to market information, and increased availability of financial services. Building on the research of Anderson and Feder (2004) [19], our study emphasizes the importance of these services in increasing agricultural productivity and elevating rural living standards. As urbanization advances, the quality and scope of these services improve, resulting in a more significant positive impact on rural incomes.

Beyond a second urbanization threshold of 0.4348, the beneficial effects of ASSs on rural income markedly increased. This increase is driven by the modernization and commercialization of agriculture in highly urbanized areas, which intensifies the demand for specialized ASSs. This trend aligns with agricultural modernization theory, which posits that more developed agricultural economies experience productivity gains that lead to higher rural incomes.

Regression threshold analysis provides policymakers with a strategic framework that underscores the necessity of developing localized ASS intervention strategies tailored to regional economic conditions and unique developmental characteristics. This strategy should focus on fostering sustainable rural income growth. Policymakers must account for varying urbanization levels across areas. In less urbanized regions, ASSs should prioritize overcoming challenges such as rural labor shortages and an aging population. Encouraging the adoption of labor-saving technologies can address these concerns, along with ensuring the inclusion of older farmers in agricultural activities. By aligning ASSs with the specific needs of each region, it can more effectively enhance rural incomes and sustainability. In more urbanized areas, the goal of ASSs should be to assist smallholder farmers in integrating into modern agricultural value chains. Effective strategies may involve offering targeted services such as quality certification, brand enhancement, and establishing market connections. Tailoring ASS interventions to the specific needs and challenges faced by rural communities at various stages of urbanization can amplify the role of ASSs in boosting rural income.

By employing new structural economics as an interpretive framework, this study explores the nuanced interactions between ASSs and rural income dynamics. This framework highlights the importance of exploiting regional comparative advantages and fostering agricultural sector upgrading [77]. In low-urbanized stages, ASSs should capitalize on the comparative advantages of agriculture, promoting large-scale and standardized agricultural operations to improve efficiency and productivity. As regions become more urbanized, ASSs should prioritize the cultivation of new agricultural business entities, develop high-value-added urban agriculture, and strengthen the integration with secondary and tertiary industries. The deployment of ASSs can trigger a transformation in the rural economy, driving sustained income growth for rural residents and regional development.

5. Conclusions and Recommendations

5.1. Conclusions

This study analyzes the effect of ASSs on rural household income in China, focusing on threshold effects and spatial spillovers. The empirical findings yield several key conclusions with significant practical implications.

Firstly, the benchmark regression analysis, coupled with robustness checks, shows a strong and positive relationship between ASSs and rural household income. The results suggest that an increase in ASSs leads to higher income levels for rural residents, which can significantly improve their living standards and contribute to poverty reduction in rural areas. A one-unit increase in the level of agricultural social services (ASSs) is associated with an 18.3% rise in rural residents' income, holding other factors constant. This finding has significant economic implications for reducing China's persistent urban–rural income disparity. Investing in the expansion and enhancement of ASSs may serve as an effective strategy for promoting rural development and alleviating poverty.

Secondly, the spatial econometric analysis uncovers notable spillover effects of ASSs on neighboring regions. The Spatial Durbin Model (SDM) indicates a total effect coefficient of 6.965, meaning that the benefits of ASSs extend to promote rural income growth in a broader spatial area. This finding implies that investing in ASSs in one region can positively impact the economic well-being of rural households in surrounding areas, leading to an average per capita income increase of CNY 6965. These spillover effects enhance the overall effectiveness of ASS interventions and emphasize the importance of considering the spatial aspects of rural development.

Thirdly, the analysis reveals significant regional disparities in the effectiveness of ASSs. In the eastern and central regions, the effects are positive and statistically significant. However, in the western region, the impact is not statistically significant. This difference can be attributed to variations in natural resources, economic development stages, and agricultural infrastructure. The eastern and central provinces of China typically benefit from more favorable agricultural conditions, such as fertile soils and abundant water resources. In the western region, arid landscapes and mountainous terrain present substantial challenges to agricultural productivity. In contrast, the eastern and central regions benefit from more advanced economic development and superior agricultural infrastructure, including effective irrigation systems and transportation networks, which facilitate the implementation of ASSs. This infrastructure supports the adoption of new technologies, improves market access, and enhances service delivery. Conversely, the harsher environmental conditions and less developed infrastructure in the western region may limit the capacity of ASSs to improve rural incomes. This disparity underscores the necessity of adapting ASS promotion strategies to local contexts, ensuring that investments and interventions are specifically designed to tackle the unique challenges faced by each region.

Fourthly, threshold regression analysis indicates that the relationship between urbanization and the impact of ASSs on rural income is non-linear. In less developed areas, early stages of urbanization disrupt the rural workforce, resulting in a negative association with ASSs. However, as urbanization progresses, the improvement in ASS quality and focus positively influences rural income. Policymakers should recognize these varying effects and adjust their interventions accordingly. In less urbanized regions, ASSs should focus on addressing challenges such as rural labor shortages and an aging population. Encouraging the adoption of labor-saving technologies and facilitating the participation of older farmers in agricultural activities can effectively address these issues.

This study explores the intricate relationship between ASSs and rural household income in China, considering threshold effects, spatial spillovers, and regional variations. The findings provide essential insights for policymakers aiming to enhance ASSs to alleviate poverty and reduce inequality. To maximize the contribution of ASSs to rural prosperity and equitable development, it is vital to leverage spatial spillovers and adjust strategies in response to the non-linear effects of urbanization.

5.2. Recommendations

First, a comprehensive strategy is essential for enhancing ASSs. Expanding the scope of ASSs to encompass a wide range of services will increase their value to farmers. Furthermore, developing a diverse network of service providers, including private sector actors, government agencies, and NGOs, can improve service delivery. To incentivize their participation, policymakers should consider targeted subsidies, tax breaks, and capacity-building initiatives. Research suggests that this integrated approach creates an environment conducive to adopting specialized technologically advanced farming techniques, ultimately elevating the incomes of farm households. To maximize the impact on rural development, this strategy should be complemented by investments in rural education, vocational training, and robust agricultural research and development initiatives. Second, it should strengthen rural knowledge systems and vocational education. Successful models, such as the Farmer Field School approach and the use of information and communication technologies (ICTs) in agricultural extension services, demonstrate the potential of these investments. For example, the Food and Agriculture Organization (FAO) has successfully implemented Farmer Field Schools in numerous countries, promoting experiential learning and knowledge sharing among farmers. This should be conducted alongside promoting increased openness and investment in agricultural research and development, while simultaneously promoting greater openness and investment in agricultural research and development.

Second, to optimize the role of ASSs in boosting rural incomes, policymakers should promote inter-agency collaboration and employ strategic fiscal policies. The empirical findings demonstrate notable regional differences in the impact of ASSs. Specifically, the eastern and central regions show positive and statistically significant effects. These results indicate that allocating ASS resources to these areas may generate the highest returns in rural income growth. Targeted tax incentives for rural social services, in conjunction with a well-coordinated effort among government agencies, will strengthen the effectiveness of ASSs and foster rural income generation. This approach is consistent with the broader goals of high-quality development. The empirical analysis underscores the significant positive impact of these services on rural incomes, highlighting the importance of a comprehensive policy approach.

Third, given the significant spatial spillover effects of Agricultural Support Services (ASSs) identified in this study, policies should aim to maximize the positive externalities associated with ASS investments. The spatial econometric analysis indicates that the benefits of ASSs extend beyond the immediate region, contributing to rural income growth in neighboring areas. Policymakers can take advantage of these spillover effects by strategically locating ASS centers in areas that benefit multiple communities. This approach should include fostering inter-regional cooperation and knowledge sharing, as well as enhancing transportation and communication infrastructure to facilitate the distribution of ASS benefits.

Fourth, to effectively address the regional variations in how ASSs influence rural incomes, it is essential for policymakers to adopt customized strategies that are suited to local contexts. The empirical results reveal significant regional disparities in the effectiveness of ASSs, driven by differences in resource endowments, economic structures, and institutional contexts. In the central and western provinces, promoting the growth of agricultural cooperatives and machinery-sharing arrangements can help overcome the challenges of small-scale farming and limited access to modern technologies. Establishing collaborative agricultural technology platforms can facilitate knowledge transfer from the eastern region, where ASSs are more advanced. Policymakers should use these empirical insights to inform the design of ASS policies that are tailored to the specific needs and conditions of each region. In the east, efforts should focus on consolidating ASS resources, facilitating technology transfer to the central and western regions, and setting strategic benchmarks. Meanwhile, the central and western regions should leverage their advantages in intensification and scale, capitalizing on the synergies between technology and scale effects. Empirical evidence highlights the potential for these regions to reap spillover benefits through targeted intensification and scaling efforts.

Fifth, policymakers should acknowledge the non-linear relationship between urbanization and the influence of ASSs on rural incomes. Tailoring ASS interventions to various stages of urbanization is essential due to the non-linear relationship between urbanization and the effectiveness of ASSs. The threshold regression analysis indicates that the impact of ASSs on rural incomes varies notably across different urbanization stages. In less urbanized regions, ASSs may negatively affect rural income because of labor shortages, while in more urbanized areas, ASSs tend to have a significantly positive impact. These findings highlight the necessity of customizing ASS policies to address the unique challenges and opportunities presented by varying levels of urbanization. In regions with lower urbanization, policies should focus on mitigating issues related to labor scarcity and an aging population. Conversely, in more urbanized areas, the emphasis should be on integrating smallholder farmers into modern agricultural value chains and promoting high-value agricultural activities. Policymakers should also prioritize the provision of ASSs in peri-urban areas, where the potential for agricultural modernization and market integration is highest.

6. Limitations and Future Research Directions

While this study advances our comprehension of the influence of ASSs on Chinese rural household income, it is important to acknowledge the limitations of focusing solely on urbanization as a threshold variable. Other factors, such as education levels, market access, and agricultural technology adoption, may also moderate the effectiveness of ASSs on rural income. Future research should explore these alternative threshold variables to provide a more nuanced understanding of the dynamics at play. Further investigation is warranted. Future research employing micro-level household data would provide more nuanced insights into the mechanisms underlying ASSs' impact. However, accessing and analyzing such data in rural regions can be challenging due to issues related to data availability, quality, and comparability. Collaborating with local stakeholders, such as agricultural cooperatives and extension services, can help overcome these challenges. Innovative data collection methods, such as mobile phone surveys and remote sensing, can also be used to gather high-resolution data in resource-constrained settings. Moreover, the generalizability of these findings to other developing countries requires careful consideration, given variations in land tenure systems, market structures, and institutional contexts. While certain aspects of ASSs, such as the importance of technological adoption and capacity building, may be universally applicable, regional differences are likely to arise. For instance, China's unique land tenure system, characterized by collective ownership and household responsibility, may influence the effectiveness of ASSs in ways that differ from other countries with private land ownership, such as India and Brazil. Similarly, the level of government support for ASSs and the strength of agricultural cooperatives may vary across countries, affecting the implementation and impact of these services. Comparative cross-national studies are needed to identify the common challenges and success factors for ASSs in different contexts. Other factors besides urbanization, such as land rights, credit access, and participation in agricultural organizations, may moderate the effectiveness of ASSs. Examining these could provide a more nuanced picture of when ASSs can substantially benefit rural livelihoods. Despite its insights, the study leaves important avenues for future work to address its limitations and expand our understanding of how ASSs can promote sustainable rural development. It is also important to acknowledge the inherent limitations of linear regression, such as its sensitivity to model specification and assumptions. Future research could explore alternative approaches, including instrumental variables and panel data methods, to establish more robust causal inferences.

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