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# How can rural agriculture-industry-services integration help narrow the urban-rural income gap? Evidence from China

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Rural revitalization hinges on the rural agriculture-industry-services (AIS) integration and urban-rural coordinated development, with improved market-oriented allocation of rural factors serving as a key economic lever for advancing both. Based on national panel data from 2009 to 2022, our analysis suggests that rural AIS integration exerts a positive income-increasing effect on rural residents. Further quantile regression reveals that rural AIS integration exhibits a stronger positive association with farmers' income growth at higher income quantiles. Both the dynamic System GMM and the difference GMM indicate that the rural AIS integration can narrow the urban-rural income gap. Non-farm employment plays a partial mediating role in the impact of rural AIS integration on reducing the income gap. The threshold model test results reveal that the income-increasing effect of the rural AIS integration showed an inverted U-shaped marginal convergence trend with the increase of urbanization rate. Therefore, deepening the reform of the rural land system, exploring multifunctional agriculture for higher non-farm employment, enriching the financial and fiscal support, and advancing phased coordination between urbanization and rural AIS integration are appropriate choices to promote the rural AIS integration, which aims to narrow the urban-rural income gap by creating new pathways to increase rural residents' property income, operating income and wage income. The findings enrich the theoretical foundation for understanding how the rural AIS integration boosts residents' income and narrows the urban-rural gap, with two specific contributions: first, clarifying that its marginal income-increasing effect is more pronounced across higher quantiles of rural income distribution; second, deriving policy implications for leveraging urbanization's non-linear impact to strengthen this effect.

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## Introduction

Since its reform and opening up, China's agricultural development and rural livelihoods have undergone distinct phased changes. In the early stages of reform and opening up, the implementation of the household contract responsibility system resolved the problem of how rural areas could achieve development. Undoubtedly, this policy innovation and institutional reform in this period greatly enhanced the labor productivity of the primary industry, and the management autonomy and enthusiasm of agricultural producers significantly improved. Data from the National Bureau of Statistics of China demonstrates that, in 2005, the added value of the primary industry increased by 202% over 1980, and the income of rural residents increased by 365% during the same period. With the widening of the urban-rural development gap and the income disparity between urban and rural residents, which increased from 2.5 in 1980 to 3.08 in 2005, the New Rural Construction was proposed, which aimed to promote the overall urban-rural development, marking the beginning of a rapid development track for rural residents' income. Consequently, the real income of rural residents increased by 182% from 2005 to 2017, and the per capita disposable income gap between urban and rural residents decreased from 3.08 to 2.71 over the same period. In 2017, implementing a rural revitalization strategy was proposed to promote integrated urban-rural development and achieve better development of agriculture and rural areas. Clearly, the pursuit of rural revitalization is inseparable from the rural agriculture-industry-services (AIS) integration (hereafter referred to as "rural AIS integration") and urban-rural integrated development: the former consolidates the endogenous foundation for rural development, while the latter facilitates the two-way, independent, and orderly flow of urban-rural factors. From a long-term perspective, improving the market-oriented allocation efficiency of rural factors is undoubtedly an important economic lever for promoting the rural AIS integration and the urban-rural integration, and for advancing rural revitalization. Scholars have conducted multi-dimensional studies on these themes. By reviewing the research process and development practice of urban-rural integration at home (Jin et al., 2019; Liu, 2020) and abroad (Xiao and Du, 2015; Lu, 2016; Li, 2019; Chen and Jiang, 2024), it can be seen that the smooth transition from the divided rural-urban dual structure to the unitary rural-urban integration structure was a systematic and long-term process, which was influenced not only by economic reasons articulated by classic economic theories (Luo and Liu, 2021), but also by institutional reasons that have been formed over a long history in different regions (Development Research Center of the State Council et al. Ye and Xu, 2014; Dong, 2019).

Over more than four decades of sustained rapid urban-rural economic development since reform and opening up, China has entered a critical phase for advancing integrated urban-rural development, narrowing the urban-rural development gap, and promoting rural revitalization. Nevertheless, narrowing the urban-rural income gap remains one of the most intractable and critical objectives in the pursuit of rural revitalization. Against this backdrop, studying whether rural AIS integration can narrow the urban-rural income gap, whether it exacerbates or alleviates rural internal inequality, and how to rationally advance urbanization to enhance its income-boosting effects holds substantial theoretical and practical significance. Further, rural AIS integration faces prominent constraints, including limited room for industrial convergence, underdeveloped value-added potential in agricultural supply chains, barriers to bidirectional urban-rural factor mobility, and shortages of rural human capital. Accordingly, theoretically and empirically clarifying the policy orientation of rural AIS integration, identifying the key mechanisms

underlying its heterogeneous, mediating, and non-linear effects, and proposing actionable measures for its advancement are of urgent practical relevance to promoting rural revitalization and achieving urban-rural common prosperity.

## Literature review and theoretical mechanism

**Literature review.** The rural AIS integration refers to the process in which the primary industry (agriculture) realizes resource sharing, complementary advantages, and extension of the value chain towards the secondary industry (industry) and tertiary industry (services) through the integration of factor resources, technology penetration, collaboration of market organization, and management innovation. This type of integration helps enhance the application of technology in agriculture, tap the functional diversity of agriculture, improve the added value of agriculture, and thus promote the growth of the rural economy and farmers' income. Around rural AIS integration, the existing literature can be broadly categorized into three streams: the rationale behind integration, the outcome assessment of integration, and the methods of integration.

The integration of the primary, secondary, and tertiary industries in rural areas mainly involves the constraints of diminishing marginal productivity of agricultural inputs (Ye, 2021), varying degrees of industrial decline and population outflow in rural areas, and recognition of multifunctionality in agricultural systems (Hodbod et al., 2016). With the reduction in rural population due to industrialization and urbanization, some rural areas have experienced industrial decline and hollowing out (Li and Wang, 2020; Qu et al., 2021; Zhang et al., 2024). Meanwhile, leisure attributes, traditional cultural values, geographical ecological functions, and village heritage protection hidden in the agricultural sector have not been fully recognized and exploited. Thus, agricultural sustainable development has not only failed to keep abreast of industrialization and urbanization but has also been negatively impacted by industrial structure evolution. Therefore, China's agricultural modernization should adopt a new approach centered on the AIS integration. The market-oriented reform of rural areas, the diffusion of emerging technologies, the growing demand for agricultural multifunctionality, and the potential inflow of industrial and commercial capital have laid a foundation for the subsequent integrated development of rural AIS integration (Zhang, 2015).

Second, studies on the economic effects of rural AIS integration are primarily empirical, utilizing various econometric methods and data sources. Based on provincial-level macro data, Li and Ran (2019) used the Least Squares Dummy Variable estimation method and empirically concluded that rural industrial integration development directly narrows the urban-rural income gap, with promoting rural economic growth and accelerating urbanization as two indirect channels. Ge et al. (2022), employing the system Generalized Method of Moments (GMM) method, empirically found that rural AIS integration can promote household consumption by narrowing the income gap between urban and rural residents. At the microdata level, Guo and Zhang (2023) used data from China Family Panel Studies to construct a rural AIS integration evaluation index system comprising nine specific indicators measuring integration behavior and performance. Their empirical analysis showed that this integration narrows income disparities within rural areas by increasing the wage income and operating income of rural households. Huang et al. (2023) constructed a difference-in-differences approach to empirically analyze panel data from 287 prefecture-level cities and discovered that developing rural tourism helps narrow the urban-rural income gap overall. As one of the physical

manifestations of rural AIS integration, the pilot policy for integrated rural complexes effectively increases rural residents' income and narrows the urban-rural income gap (Shi and Xu, 2023). In terms of the driving forces, the income inequality-reducing effects of rural AIS integration include different functioning mechanisms or channels. The expansion of the contracted land transfer scale, as a key driving force, helps narrow the income gap (Tan et al., 2025). The study of Qi et al. (2025) also identifies the mediating effect of moderate-scale land operation, as well as the threshold effects of the digital economy development and business environment optimization in narrowing this disparity. Agricultural technological innovation serves as a fundamental driver for narrowing urban-rural income gaps through interconnected pathways of employment structure optimization, factor allocation improvement, and production efficiency enhancement (Liao et al., 2025). The optimization of employment structures among low-income groups serves as the primary transmission channel through which rural AIS integration generates income-boosting effects and reduces income disparities (Zhu et al., 2022). Other factors include vertical integration of agricultural supply chains and cultivation of new agricultural business models (Shi and Xu, 2023).

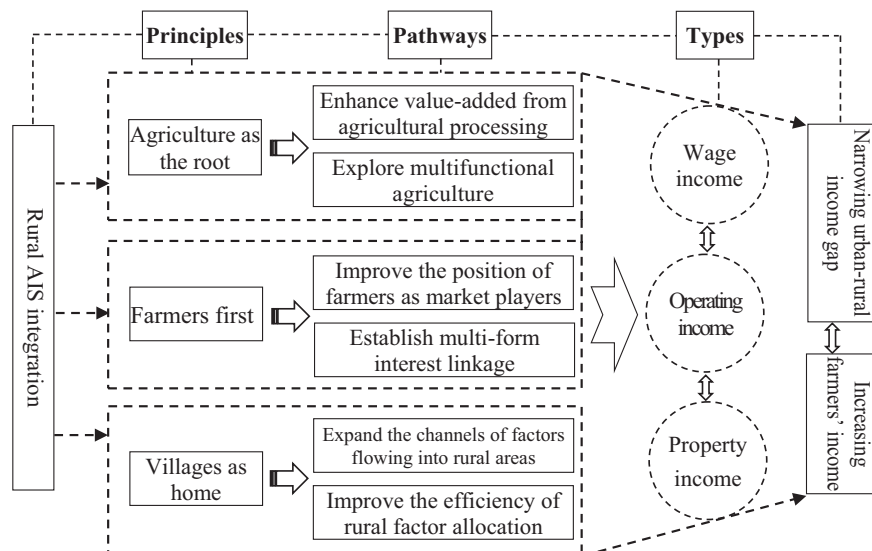
Empirical research on the rural AIS integration inevitably requires the establishment of a comprehensive indicator system. The existing literature measures the rural AIS integration from the following dimensions: expansion of the agricultural chain, multifunctional agriculture, integration of agricultural technology, urban-rural integration, and performance of the integration (Ge et al., 2022; Li and Peng, 2023; Guo and Zhang, 2023; Li et al., 2024). Totally, there is no consensus in the literature on the construction of evaluation indicators for the development level of rural AIS integration. The difficulty lies partly in the incomplete and discontinuous micro and macro data reflecting the integration of these industries and partly in the challenge of accurately measuring and expressing the additive and multiplicative effects that may exist in rural AIS integration. Generally, the development level of rural AIS integration in China is relatively low, with large fluctuations and unclear economic growth effects, mainly due to the insufficient flow of rural factors and financial services, as well as the weak competitiveness of new agricultural business entities (Kuang and Xiao, 2022). Nevertheless, increasing farmers' income remains the core goal of rural revitalization, and rural AIS integration can better leverage the value-added potential of agriculture and rural areas, enabling rural residents to more effectively utilize local factor endowments and thereby gain broader employment opportunities for diversified income.

Third, in research on how to achieve rural AIS integration, scholars have used diverse research methods and put forward a variety of path choices. Regarding the types of integration that have emerged in China, studies have distinguished between industrial recombination integration (e.g., the integration of planting and aquaculture), industrial extension integration (e.g., the processing industry of agricultural products), cross-industry integration (e.g., leisure agriculture), and industrial penetration integration (such as rural e-commerce) (Yu, 2020). From the perspective of organizational and management forms, compared with traditional vertical integrated agricultural management forms such as "leading enterprises + farmers" and "leading enterprises + cooperatives + farmers," agricultural industrialization complexes and integrated rural complexes that have received policy support have closer organizational forms and a more significant scope of economy (Wang and Yu, 2019). The essence lies in the internalization of the inter-industry division of labor, which is the process and result of the transformation of inter-industry division of labor into intra-industry division of labor (Su et al., 2016). Additionally, studies have focused on the driving

mechanisms (Wang et al., 2023) and model innovation of rural AIS integration (Nakata and Ogata, 2023; Verdouw et al., 2010; Knutson and Cropp, 2013), factor mobility and marketization (Cai and Chen, 2018; Feng and Wang, 2020; Zhang and Chen, 2020), and the positive impact of the digital economy on rural AIS integration (Ge et al., 2022; Zhang et al., 2023). Development practices in developed countries offer valuable insights for reference. Rural AIS integration in Europe was denoted as multifunctional agriculture (Hodbod et al., 2016). During the 1950s–1970s, as European industrialization and urbanization advanced, recognition of agriculture's multiple values and functions emerged. In the 1980s, with the onset of environmental issues and unbalanced rural development, Europe began to prioritize agricultural sustainability and comprehensive rural development. Since the 1990s, the European Union has formulated relevant policies, such as reforms to the Common Agricultural Policy (CAP) (Koester and Bale, 1990; Skogstad and Verdun, 2009), to support the development of agricultural multifunctionality, with a particular focus on rural tourism, local food networks, and agricultural innovation. Drawing on the "Sixth Industry" theory and policy framework (Imamura, 2010), Japan and South Korea have adopted a series of policy instruments, including legislative safeguards, streamlined institutional mechanisms, and financial support. These measures aimed to facilitate the inflow of external capital and talent, expand agricultural product exports, increase the share of farmers' non-agricultural income, improve rural living environments, and enhance rural welfare levels, thereby establishing a rural industry integration system encompassing processing, circulation, exports, tourism, and services (Cao, 2018; Cui and Park, 2019).

In summary, existing studies have explored the economic drivers underlying rural AIS integration and analyzed its income-increasing mechanisms and role in narrowing the urban-rural income gap from multiple dimensions, providing valuable insights for our research. However, while rural AIS integration generally exhibits a positive income-increasing effect, two critical questions remain under-explored: first, does this effect exhibit heterogeneity across different income distributions? Second, will promoting rural AIS integration widen or narrow the internal income gap among rural residents? These questions have received limited attention in the existing literature. If rural AIS integration tends to widen the internal income gap, investigating the underlying mechanisms will yield significant policy insights. Furthermore, while existing studies have examined the potential mediating and moderating roles of urbanization, they lack non-linear analysis that incorporates urbanization as a threshold variable. Urbanization has improved the return on factor resources in both urban and rural areas. However, will excessive urbanization modify the income-increasing mechanism of rural AIS integration due to the resource siphon effect? Investigating this question will facilitate the formulation of income growth paths tailored to regions with different urbanization levels.

**Theoretical mechanism.** Rural AIS integration is inherently linked to the autonomous bidirectional flow of urban-rural factors and is designed to further facilitate such flow. It relies on the input of urban factor resources while seeking to break constraints on the mobility of inherent rural production factors and dismantle the closed rural property rights structure. Rural AIS integration centers on strengthening the long-term mechanism for farmers' income growth through the additive and multiplicative effects of the "Sixth Industry" (Imamura, 2010), with broader objectives of exploring the value addition of multifunctional agriculture, addressing imbalances and inadequacies in



**Fig. 1 The income-increasing mechanisms and pathways of rural AIS integration.** This figure illustrates the key mechanisms and pathways through which rural AIS integration raises farmers' income. Enhancing the added value of the agricultural industrial chain and developing multifunctional agriculture reflect the fundamental role of agriculture; improving farmers' market bargaining power and establishing multi-form interest linkage mechanisms ensure that farmers' economic interests are prioritized in the process of rural AIS integration; and expanding rural factor inflows and improving allocation efficiency form the endogenous driving force for steadily advancing rural revitalization. These pathways jointly increase farmers' operating, wage, and property income, thereby narrowing the urban-rural income gap.

urban-rural development, and ultimately advancing the modernization of agriculture and rural regions.

*Direct income-increasing effect of rural AIS integration.* First, rural AIS integration is oriented toward expanding multifunctional agriculture, which encompasses broader productive, environmental, and consumption-related values. In stages where agricultural development foundations are underdeveloped, agriculture primarily fulfills the role of ensuring national food security. However, as the development foundations of agriculture and rural areas are continuously consolidated and shifts occur in societal lifestyle preferences, multifunctional agriculture has gradually gained prominence. Cultivating rural characteristic industries, advancing agricultural product processing and distribution, developing rural leisure tourism, expanding rural services, and fostering rural information industries can thus boost farmers' wages and operating income. Integrating planting and breeding based on existing agricultural activities, introducing large-scale operations and agricultural technologies, and developing agricultural product processing, storage, and distribution chains can enhance agricultural value addition and farmers' income levels. Leveraging rural areas' resource endowment advantages to develop recreational fishing, camping, ecological tourism experiences, and e-commerce enables the conversion of agricultural multifunctionality into novel income-generating channels for farmers.

Second, multifunctional agriculture can offer more non-farm employment opportunities and strengthen farmers' status as market participants. This status encompasses two core dimensions: first, farmers gain new employment opportunities as primary beneficiaries of rural AIS integration; second, farmers have complete control over the factors and resources they possess and retain the capacity for independent negotiation during rural AIS integration processes. These two dimensions are complementary. Consequently, the diverse interest coordination mechanisms under rural AIS integration become more flexible, autonomous, diversified, and market-efficient. In the long term,

this enhances farmers' market-oriented operational awareness, capabilities, and resilience to market risks, which contributes to enhancing the potential for sustained growth of rural households' incomes.

Third, the unbalanced development of urban and rural factor markets constitutes the economic root cause of rural areas lagging behind their urban counterparts. Behind this phenomenon lie critical institutional constraints, notably including the rural land system and the household registration (Hukou) system. Specifically, the rural land system, by defining property rights and transferability, fundamentally shapes the weak incentive structures and feasible pathways for capital investment in rural areas. Concurrently, the household registration (Hukou) system, by tying core social benefits to registered residency, substantially creates notable barriers to cross-regional mobility of human capital. Owing to disparities in factor returns and the inefficient market allocation of urban and rural factor resources, far more factors have flowed into urban areas than into rural regions. To guide additional factor resources toward rural areas, reforming the rural land system to reduce property rights constraints and strengthen the industrial carrier role of rural AIS integration is critical. For inflowing factor resources to take root, the emergence of corresponding agricultural industries is necessary, alongside the guarantee of reasonable market-based investment returns. Deepening the integrated reform of urban and rural factors facilitates the bidirectional equal exchange and orderly autonomous flow of urban and rural factors, which expands the breadth and depth of rural AIS integration and ultimately advances farmers' income growth and rural revitalization. Specific mechanisms and pathways are shown in Fig. 1.

*Convergence effect of rural AIS integration on the urban-rural income gap.* Rural AIS integration is an advanced form of internal division of labor among different industrial entities and represents an upgrade and expansion of agricultural industrialization, which has brought greater benefits to agriculture, rural areas, and farmers compared to traditional agricultural industrialization (Su

et al., 2016), thereby gradually narrowing the urban-rural income gap. Over the past four decades of reform and opening up, the urban-rural income gap in China has generally experienced a process of first rising and then declining. Since 2007, the urban-rural income gap has been continuously narrowing to 2.45 in 2022, which has probably benefited from the integration process of the rural AIS over the corresponding period.

First, the environmental and consumption-related values in rural areas are conducive to attracting urban residents for leisure, tourism, and consumption. These emerging business forms and supply models can achieve “industry nurturing agriculture and cities supporting rural areas,” and narrow the urban-rural income gap. The 1694 beautiful leisure villages released by China’s Ministry of Agriculture and Rural Affairs are a tangible reflection of agricultural and rural areas’ multifunctionality. The data for 2022 indicated that China’s rural leisure tourism revenue exceeded 700 billion yuan, employment remained above 11 million, and nearly 9 million farming households benefited from its development (Deng, 2023, as cited in Yan, 2023). In parallel, the 7780 Taobao Villages identified by the Alibaba Research Institute serve as key platforms for direct sales of local characteristic agricultural products to households nationwide, which enable urban residents to access fresh, high-quality agricultural products efficiently while directly boosting farmers’ sales income. Shortened sales chains have substantially increased farmers’ direct earnings and mitigated the issue in the “leading enterprises + farmers” organizational model, where farmers gain insufficient benefits at the production stage while sales-stage profits accrue to external parties. This model not only channels urban residents’ spending on rural products to rural areas but also allows farmers to secure higher returns from both production and sales stages, aligning with the value chain upgrading postulated by the smile curve theory and thereby contributing to narrowing the urban-rural income gap.

Second, the in-depth development of rural AIS integration is inherently dependent on the flow of urban resources to rural areas. The inflow of factors can foster additional new agricultural market entities linking the secondary and tertiary industries, and shape diverse mechanisms for rural industrial integration via industrial, value, interest, talent, and data chains (Feng and Wang, 2020). In the post-productivist stage, rural areas’ environmental and consumption-related values, such as esthetic, recreational, and leisure attributes, have become increasingly prominent. Urban residents’ growing preference for rural lifestyles facilitates factor inflows and consumption in rural areas. The increased flow of urban factor resources into rural areas can not only enhance rural factor endowments, boost rural factor returns, and gradually narrow the urban-rural gap in factor returns, but also increase farmers’ property income facilitated by rural land system reforms. Furthermore, it can expand the value addition of rural industries through AIS integration projects, thereby narrowing the urban-rural income gap. The inflow of urban talents into rural areas generates human capital spillover effects: enhancing farmers’ skills and entrepreneurial capacities, which in turn strengthens their ability to achieve sustainable income growth and fundamentally mitigates the intergenerational transmission of the urban-rural income gap. Local leading enterprises can also form a two-way empowerment dynamic with external cooperative entities, realizing added value in rural characteristic industries via cross-sectoral resource and service integration (Zhang et al., 2022). Under such conditions, the multi-dimensional interactions and transmission pathways between urban and rural areas enhance and deepen the level of urban-rural integration, thereby narrowing the urban-rural income gap.

While rural AIS integration theoretically generates direct income-increasing effects, these effects may exhibit heterogeneity across the rural income distribution. Specifically, high-income households, endowed with greater human, physical, and social capital, are better positioned to seize high-return opportunities arising from AIS integration. In contrast, low-income households face constraints from limited resources and unequal access to training programs or market networks, leading to weaker marginal gains. This hypothesized heterogeneity, driven by initial endowment gaps and opportunity inequality, remains to be empirically verified, with implications for whether AIS integration alleviates or exacerbates rural internal income disparities.

## Methods and variable description

### Model specification

*Dynamic panel model.* According to the statistical interpretation of disposable income by the National Bureau of Statistics of China, the disposable income of residents in China comprises four components: wage income, net business income, net property income, and net transfer income. The diversity of income sources is the foundation of the dynamic continuity of residents’ disposable income in China. Among these sources, the relative stability of wage income and the growth potential of net operating income in the context of economic development are significant factors affecting the dynamic continuity of income. Furthermore, benefiting from the implementation of targeted poverty alleviation and rural revitalization policies, which have brought more transfer income, the growth rate of per capita disposable income of rural residents in China has continued to outpace that of urban residents, leading to a gradual narrowing of the urban-rural income gap. Therefore, this study posits that the growth of rural residents’ disposable income and the overall urban-rural income gap exhibit dynamic continuity. Consequently, a dynamic panel model was employed to test and identify the impact of the integration level of rural industries on residents’ disposable income and the urban-rural income gap. The specific model was constructed as follows:

$$\ln rurd_{it} = \alpha_0 + \alpha_1 \ln rurd_{i,t-1} + \alpha_2 \text{aisin}_{it} + \sum_j \delta_j \text{con}_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (1)$$

$$\text{ingap}_{it} = \beta_0 + \beta_1 \text{ingap}_{i,t-1} + \beta_2 \text{aisin}_{it} + \sum_j \delta_j \text{con}_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (2)$$

In Eqs. (1) and (2), the subscript  $i$  denotes the provincial region,  $t$  represents the year,  $\ln rurd_{it}$  (rural residents’ disposable income) represents the natural logarithm of the disposable income of rural residents in region  $i$  in year  $t$ ,  $\ln rurd_{i,t-1}$  represents the natural logarithm of the disposable income of rural residents in region  $i$  in year  $t - 1$ ,  $\text{ingap}_{it}$  represents the urban-rural income gap in region  $i$  in year  $t$ ,  $\text{ingap}_{i,t-1}$  represents the urban-rural income gap in region  $i$  in year  $t - 1$ ,  $\text{aisin}$  (rural AIS integration) is the level of integrated development of the rural AIS calculated using the entropy method;  $\text{con}$  represents a series of control variables that may affect the explained variable;  $\mu_i$  and  $\nu_t$  represent individual and time effects respectively; and  $\varepsilon_{it}$  represents the random error term.

It should be noted that, following the research by Blundell and Bond (1998), the GMM is instrumental in addressing unobserved individual heterogeneity, omitted variable bias, and potential endogeneity issues. Furthermore, to mitigate the risk of reverse causality between rural AIS integration and the dependent variable, which could lead to endogeneity in the model, the study employed a two-step System GMM for estimation.

*Mediating effect model.* To identify the mechanism through which rural AIS integration exerts an impact on rural residents' income and the urban-rural income gap, we adopt rural non-farm employment (nonfarm) as the mediating variable for verification. The model specification is as follows:

$$\ln rurdi_{it} = \rho_0 + \rho_1 aisin_{it} + \rho_2 nonfarm_{it} + \sum_j \delta_j con_{it} + \mu_i + v_t + \varepsilon_{it} \quad (3)$$

$$ingap_{it} = \rho_0 + \rho_1 aisin_{it} + \rho_2 nonfarm_{it} + \sum_j \delta_j con_{it} + \mu_i + v_t + \varepsilon_{it} \quad (4)$$

In Eqs. (3) and (4), the non-farm employment structure is calculated as: Non-farm employment structure = (Total rural employment – Employment in the primary industry)/Total rural employment

*Threshold model.* To further investigate the possible non-linear relationship between rural AIS integration and rural residents' income, based on Hansen's (1999) research, this study also employed the degree of urbanization as a threshold variable to characterize this relationship. Therefore, the following threshold regression model was constructed:

$$\begin{aligned} \ln rurdi_{it} = & \theta_0 + \theta_1 aisin_{it} I(urban_{it} \leq \gamma_1) + \theta_2 aisin_{it} I(\gamma_1 < urban_{it} \leq \gamma_2) \\ & + \theta_3 aisin_{it} I(urban_{it} > \gamma_2) + \sum_j \delta_j con_{it} + \varepsilon_{it} \end{aligned} \quad (5)$$

In the model, urban is the threshold variable; aisin is the explanatory variable; and I(.) is the indicator function, which equals 1 if the condition within the parentheses is met, and 0 otherwise.  $\gamma_1 \sim \gamma_2$  represents the estimated threshold value, and  $\theta_1 \sim \theta_3$  denotes the impact coefficients of the explanatory variable for different intervals of the threshold variable.

**Variable selection and data processing**

*Explained variable.* The explained variables are rural residents' disposable income (lnrurdi) and the urban-rural residents' income gap (ingap). Here, the disposable income of rural residents is deflated according to the 2009 CPI of rural residents in provincial regions (and the 2009 CPI of all residents for Beijing, Shanghai, Tianjin, and Chongqing) to obtain real income. The urban-rural residents' income gap is expressed by dividing the disposable income of urban residents by that of rural residents.

*Core explanatory variable.* The core explanatory variable is the comprehensive development level of the rural AIS integration. The index system for that was constructed by referring to the studies of Li and Ran (2019), Yu (2020), and Ge et al. (2022), as shown in Table 1.

- (1) *Reconstruction of primary industry.* Rural AIS integration still relies on agriculture. Consolidating agricultural foundations requires technical penetration of the primary industry to improve the application level of agricultural science and technology. Moderately scaled operations should be carried out to leverage the advantages of agricultural cooperative economies. Therefore, focusing on the modernization of agriculture and considering positive practices in the restructuring process of China's agriculture, the number of farmers' specialized cooperatives per 10,000 rural residents was used here to represent the effectiveness of the cooperative economy, and the proportion of the amount of agricultural plastic film required for plastic greenhouses to the total sown area of crops was used to indicate the progress made in facility agriculture.

**Table 1 The comprehensive index system of rural AIS integration.**

First-level index	Specific index	Computing method	Weight	Attribute
Reconstruction of primary industry	Cooperative economy	Number of farmers' specialized cooperatives per 10,000 rural residents (pieces)	11.37%	Positive
	Facility agriculture	Agricultural plastic film usage/Total sown area of crops (tons/ha)	13.07	Positive
Combination of primary and secondary industries	Agricultural product processing	Operating income of agricultural processing industry/value added of primary industry	22.52%	Positive
	Agricultural mechanization	Total power of agricultural machinery/cultivated land area (million kilowatts/thousand hectares)	6.45%	Positive
Integration of primary and tertiary industries	Agricultural service	Output value of agriculture, forestry, animal husbandry, and fishery professional and auxiliary activities/added value of primary industry	8.20%	Positive
	E-commerce and leisure agriculture	Number of Taobao villages and beautiful leisure villages/number of administrative villages	38.39%	Positive

- (2) *Combination of primary and secondary industries.* Developing the agricultural product processing industry is an inevitable requirement for extending the industrial chains and value chains of primary agricultural products. Owing to the severe homogeneity of primary agricultural products and the greater influence of the law of diminishing marginal utility, it is challenging to increase their market prices. Developing distinctive agricultural product-processing industries can enhance the differentiation of agricultural products, extend their shelf life, and increase their added value. The indicator for agricultural product processing was represented by the proportion of the operating income of the agricultural product processing industry to the value-added of the primary industry. Specifically, the operating income of the agricultural product processing industry was the sum of the revenues from ten sub-industries, including the manufacturing of agricultural and sideline food products; food manufacturing; beverage and refined tea manufacturing; tobacco manufacturing; textiles; leather, fur, and feather products and footwear; wood processing and wood, bamboo, rattan, palm, and straw product manufacturing; furniture manufacturing; paper and paper products manufacturing; and rubber and plastic product manufacturing. The second specific index is agricultural mechanization, primarily because the application of industrial technology in agriculture has significantly improved agricultural productivity and provided industrial technical support for moderately scaled operations. Agricultural mechanization is conducive to the development of agricultural modernization and green agriculture. From an economic perspective, mechanization reduces labor costs in agriculture and promotes the integration of value chains between agriculture and industry. For instance, agricultural machinery manufacturing has become a supporting industry for agriculture, forming an “agro-industry” system. From a social perspective, mechanization has transformed the structure of rural labor: the released labor force has accelerated the urbanization process and raised the development level of rural service industries.
- (3) *Integration of primary and tertiary industries.* Professional and auxiliary activities in agriculture, forestry, animal husbandry, and fishing encompass a range of service activities that are directly related to agricultural production. These include agricultural technology guidance and training, services provided by agricultural machinery cooperatives, distribution services for agricultural supplies, agricultural finance and information services, and services to protect agricultural resources and the environment. These activities, which fall under the tertiary industry in China’s statistical classification, provide necessary support for agricultural production by helping to improve agricultural production efficiency and the added value of agricultural products, and promoting the sustainable development of agriculture. Therefore, the proportion of the output value of professional and auxiliary activities in agriculture, forestry, animal husbandry, and fishing to the added value of the primary industry was used. E-commerce and leisure agriculture are key components of rural AIS integration, fully reflecting the characteristics and requirements of livability, business suitability, and rural tourism from the perspective of the integration of primary and tertiary industries. Due to the serious lack of income data for leisure agriculture and rural tourism across provinces since 2020, this representative indicator had to be discarded. Instead, data on “Beautiful Leisure Villages” released by the Ministry of Agriculture and Rural Affairs of

China were used as a substitute for the leisure agriculture component, while data on “Taobao Villages” released by the Ali Research Institute were employed to represent the rural e-commerce component. The proportion of the cumulative number of the two indexes in the administrative villages of China represents the degree of integration of leisure agriculture and e-commerce. Once the above indicators were determined, the entropy method was used to measure the weight of each indicator (as shown in Table 1) and then to compute the comprehensive development level of rural AIS integration across provincial regions. The entropy weight method was selected for its objectivity in determining indicator weights, as it relies on the inherent information within the data. This avoids the subjectivity inherent in expert weighting or arbitrary equal weighting schemes. Given that the specific calculation steps of the entropy method have been detailed in numerous existing studies, they need not be elaborated on here.

*Control variables.* Following the research conclusions of Huang et al. (2021), Su et al. (2019), and You (2023), the urbanization rate (urban), degree of internationalization of agricultural products (inter), per capita capital accumulation level (rpcap), rural human capital (hucap), degree of rural policy intervention (polic) and level of financial service support (fiser), which are closely related to farmers’ income growth and narrowing the urban-rural income gap, were selected as control variables in this study. The urbanization rate, which may affect urban-rural integration, is also included in the control variables as a threshold variable. The specific explanations are as follows: (1) Urbanization rate. It is expressed as the proportion of the urban population to the number of permanent residents in each provincial region. Generally, the higher the rate of urbanization, the more opportunities rural residents have for gainful employment. (2) Degree of internationalization of agricultural products. This is in terms of the proportion of agricultural exports to the added value of the primary industry in each provincial region during the same period. The greater the proportion, the higher the degree of internationalization of agricultural products in the region, as the export of agricultural products directly reflects the role of foreign demand in the growth of farmers’ income. (3) Per capita capital accumulation. The per capita capital accumulation level of rural residents is reflected in the ratio of rural household fixed asset investment to the rural population. According to the economic growth theory, with an increase in per capita capital, the faster the level of economic development, the higher the improvement in the per capita living standard. (4) Rural human capital. It is expressed by the average years of schooling of the rural population above the age of 6 in each provincial region. In general, the more years of education there are, the greater the potential for long-term income growth. (5) Degree of rural policy intervention. It is expressed by the proportion of fiscal expenditure on agriculture, forestry, and water in the added value of agriculture, forestry, husbandry, and fishery in each provincial region. The greater the proportion, the greater the degree and ability of government policy intervention in the rural economy. (6) Level of financial service support. This is expressed as the ratio of the balance of agriculture-related loans to the GDP of each provincial region. The greater the proportion, the greater is the degree of financial service support for the rural economy.

**Data sources and descriptive statistics.** The models selected panel data from 30 provinces, autonomous regions, and municipalities of China from 2009 to 2022 for analysis. Among them, the data for specialized agricultural cooperatives are from the

**Table 2 Descriptive statistics of relevant variables.**

Variable symbol	Meaning	Mean value	Standard deviation	Minimum value	Maximum value	Sample size
Inrurdi	Rural disposable income	9.157	0.431	8.082	10.266	420
ingap	Income gap	2.612	0.397	1.827	3.952	420
theil	Income theil	0.091	0.042	0.017	0.230	420
aisin	AIS integration	0.146	0.085	0.034	0.608	420
nonfarm	Rural non-farm employment	0.418	0.212	0.005	0.906	420
urban	Urbanization	0.589	0.127	0.299	0.896	420
inter	Agricultural product trade	0.128	0.235	0.004	1.843	420
rpcap	Rural per capita capital	0.163	0.073	0.006	0.487	420
hucap(year)	Rural human capital	7.810	0.634	5.878	10.115	420
polic	Policy support	0.482	0.750	0.105	5.001	420
fiser	Rural financial service support	0.392	0.184	0.044	0.915	420

annual *Statistical Report of China's Rural Operation and Management*, the annual *Statistical Report of China's Rural Cooperative Economy*, and the annual *Statistical Report of China's Rural Policy and Reform*. The operating income data of the agricultural processing industry are from the annual *China Industry Statistical Yearbook*, and the balance data of agriculture-related loans are from *China Rural Financial Services Report* over the years. The export data for agricultural products are from the *China Agricultural Yearbook* and the *China Agricultural Products Import and Export Monthly Statistical Report* on the website of the Ministry of Commerce. The per capita education data of rural residents are from the annual *China Population and Employment Statistical Yearbook*, and the fixed asset investment of rural households is from the annual *China Rural Statistical Yearbook*. Other indicators were derived from the *China Statistical Yearbook* and the *Statistical Yearbook* of each province (municipalities and autonomous regions). For the five missing values for the operating income of the agricultural processing industry in four provinces, interpolation was performed using mean or adjacent-average methods. The price index variables in the sample were deflated with 2009 as the base year to eliminate the impact of price changes, and the natural logarithm was used to reduce the impact of heteroscedasticity on non-proportional variables. Table 2 presents the descriptive statistics of these variables.

**Result analysis**

**Results for the income effect.** The appropriateness and rationality of the model estimation method were assessed using Arellano-Bond's AR root test and the Hansen over-identification test. The system GMM estimation allows for first-order autocorrelation but should not exhibit second-order autocorrelation. The corresponding results are reported in Column (1) of Table 3. The *P* value of the AR(1) statistic rejects the null hypothesis of no autocorrelation in the error term at the 5% significance level, indicating the presence of first-order autocorrelation in the model's error term; the *P* value of the AR(2) statistic is 0.344, which accepts the null hypothesis at the 5% significance level, suggesting that there is no second-order autocorrelation in the model. The *P* value of the Hansen over-identification test is 0.267, indicating that the instrumental variables are uncorrelated with the error term and that there is no over-identification issue. The test results suggest that the current model is relatively reasonable and effective.

The estimation results show that the coefficient of the first-order lagged term of rural residents' disposable income is positive at the 1% significance level, indicating that the income status in the previous period has a positive impact on the current period. This suggests that income growth has clear continuity and characteristics of path dependence, which also indicates the

**Table 3 Estimation results of the impact of rural AIS integration on residents' income.**

Variables	System GMM (1)	25% quantile (2)	50% quantile (3)	75% quantile (4)
Inrurdi <sub>-1</sub>	0.874*** (0.023)			
aisin	0.260*** (0.100)	0.781** (0.332)	0.856*** (0.176)	0.909*** (0.172)
urban	0.441*** (0.122)	4.504*** (0.263)	4.436*** (0.139)	4.388*** (0.136)
inter	-0.087** (0.041)	-0.224 (0.036)	-0.233* (0.122)	-0.239** (0.119)
rpcap	0.164*** (0.054)	0.298* (0.179)	0.256*** (0.095)	0.226** (0.093)
hucap	-0.061*** (0.017)	0.091* (0.054)	0.091*** (0.029)	0.092*** (0.028)
polic	-0.001 (0.010)	0.139*** (0.036)	0.118*** (0.019)	0.103*** (0.019)
fiser	-0.117*** (0.044)	0.090 (0.119)	0.040 (0.063)	0.004 (0.062)
constant	1.439*** (0.182)			
AR(1) z value	-4.23			
( <i>P</i> value)	(0.000)			
AR(2) z value	0.95			
( <i>P</i> value)	(0.344)			
Hansen test	15.67			
statistic	(0.267)			
( <i>P</i> value)				
Instruments	22			
Observations	420	420	420	420

Robust standard error is indicated in parentheses. \*\*\*, \*\*, and \* indicate significance at the 1%, 5%, and 10% levels, respectively. The same applies to the following tables.

necessity of using a dynamic panel model. The coefficient of the core explanatory variable *aisin* is also significantly positive, indicating that rural AIS integration has a significant income-increasing effect on rural residents. The possible reasons are as follows: rural AIS integration promoted the application of agricultural production technology, expanded the sales range of agricultural products, tapped the potential of leisure agriculture and rural tourism, and increased the productive and consumptive value of agriculture, thereby increasing farmers' operating income. Additionally, rural AIS integration has strengthened farmers' positions as market players and increased their wage income through various forms of interest linkage mechanisms. Meanwhile, the inflow of urban elements not only improved the allocation efficiency of rural factor resources but also increased farmers' property income. Control variables are not the focus of this study and will not be detailed, but the coefficient of the

**Table 4 Estimation results of the impact of rural AIS integration on the urban-rural income gap.**

Variables	System GMM (1) ingap		Difference GMM (2) ingap		System GMM (3) theil	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
ingap <sub>-1</sub>	0.630***	0.106	0.642***	0.078	0.572***	0.098
theil <sub>-1</sub>						
aisin	-0.474***	0.183	-0.443**	0.203	-0.029**	0.014
urban	-0.664**	0.305	-0.943***	0.278	-0.123***	0.038
inter	0.141*	0.0729	0.086*	0.052	0.013**	0.005
rpcap	0.111	0.200	0.030	0.181	0.003***	0.001
hucap	-0.044	0.061	-0.019	0.034	-0.000	0.002
polic	0.071*	0.036	0.022*	0.012	0.003***	0.001
fiser	0.128	0.098	0.321***	0.116	0.008	0.007
constant	1.613**	0.740			0.107***	0.032
AR(1) z value (P value)	-2.36 (0.018)		-3.08 (0.002)		-1.79 (0.073)	
AR(2) z value (P value)	-0.65 (0.515)		-1.40 (0.160)		-1.31 (0.189)	
Hansen test (P value)	27.18 (0.165)		25.39 (0.148)		23.19 (0.143)	
Instruments	30		27		26	
Observations	420	420	420	420	420	

urbanization rate, used as a threshold variable in the following text, is significantly positive, indicating that the process of urbanization also had a significant promoting effect on farmers' income. This is because urbanization development could provide more and better job opportunities for migrant workers, thereby significantly improving their incomes.

As quantile regression not only reveals the associational trends and variations of rural AIS integration with rural residents' income but also exhibits strong robustness to outliers, non-normality of the dependent variable, and heteroscedasticity, we further performed quantile regression on Model (1) to enhance the overall robustness of our analytical results. Specifically, three representative quantiles (25th, 50th, and 75th percentiles) were selected for the analysis. The regression results are shown in Columns (2)–(4) of Table 3. The results indicate that the estimated coefficients of the three sub-points of 25, 50, and 75% are 0.781, 0.865, and 0.909, respectively, showing a clear increasing trend, and all the coefficients passed the significance level test. This suggests that with an increase in rural residents' income, the marginal income effect of the AIS integration becomes more pronounced. The reasons are as follows: (1) With the increase in rural residents' income, the productive and consumptive values of rural areas are more likely to be valued and maintained, and the requirements for living, working, and traveling have gradually increased. The attractiveness and factor absorption capacity of rural areas would be enhanced because of the construction of beautiful and leisurely rural areas; (2) With the increase of urban residents' income, the leisure consumption function of rural areas has been highlighted and reflected, and the demand for short-term travel and weekend holiday leisure has gradually increased. Thus, space for urban residents and other factors flowing into rural areas would be opened up, and the channels for rural income increase would be strengthened. To mitigate the subjectivity in the selection of quantile points, sensitivity tests using other different quantiles also yield consistent results.

**Results for the convergence effect.** To assess the impact of rural AIS integration on narrowing the urban-rural income gap, we employed both system GMM and difference GMM estimators. A series of diagnostic tests were conducted to validate the reliability

of these estimators. The AR(1) test indicates the presence of first-order serial correlation, the AR(2) test shows no evidence of second-order serial correlation, and the Hansen test verifies that the instrumental variables are not plagued by over-identification. Collectively, these results validate the reasonableness and appropriateness of utilizing both system GMM and difference GMM for our estimations. As shown in Table 4, the coefficient for rural AIS integration is negative and statistically significant. This finding suggests that greater integration is associated with a reduction in the income gap. A potential mechanism is that AIS integration helps alter the traditional one-way flow of labor, capital, technology, and other factor resources to urban areas. By mitigating rural factor endowment shortages and improving the returns to factor combinations in rural sectors, this process can contribute to narrowing the urban-rural income disparity. Currently, as multifunctional agriculture gains more recognition and preference, an increasing number of urban residents are engaging in leisure tourism, fishing, camping, and family-oriented picking and shopping in rural areas. This has led to a significant increase in urban residents' consumption expenditure on agricultural products and leisure experiences in rural areas, which in turn narrows the urban-rural income gap.

Meanwhile, to ensure the reliable stability of the empirical results, difference GMM and the Theil index of urban-rural income were employed to supplement the test of the impact of rural AIS integration on narrowing the urban-rural income gap, with the calculation method of the Theil index of urban-rural income referable to the descriptions in existing literature. As shown in Columns (2) and (3) of Table 4, the coefficient of the core explanatory variable *aisin* remains significantly negative, which indicates that rural AIS integration has a convergence effect on the urban-rural income gap. Additionally, using the Theil index as an alternative explained variable for income gap (*ingap*) further validates the robustness of the convergence effect, thus supporting the robustness of the results from Model (2).

**Mediating effect of non-farm employment.** Rural AIS integration can boost rural residents' income and narrow the urban-rural income gap by promoting non-farm employment. To verify this

**Table 5 Test results of the mediating effect of non-farm employment structure.**

Variables	(1)Inrurdi	(2)nonfarm	(3)Inrurdi	(4)ingap	(5)ingap
aisin	1.960*** (0.193)	0.528*** (0.166)	1.873*** (0.194)	-0.644** (0.257)	-0.520** (0.258)
nonfarm			0.165*** (0.057)		-0.235*** (0.076)
control variables	control	control	control	control	control
constant	6.760*** (0.201)	0.465*** (0.172)	6.683*** (0.201)	4.266*** (0.268)	4.375*** (0.267)
N	420	420	420	420	420
Sobel test			0.087** (0.041)		-0.124** (0.056)
Mediating effect			0.087** (0.041)		-0.124** (0.056)
Direct effect			1.873*** (0.194)		-0.520** (0.258)
Total effect			1.960*** (0.193)		-0.644** (0.257)

**Table 6 Test results for the number of thresholds.**

Threshold type	F stat	Prob	Critical value		
			1%	5%	10%
Single	121.46	0.0000	63.6131	47.3474	37.3938
Double	52.63	0.0100	50.5381	35.2682	30.5945
Triple	16.73	0.8400	84.3587	69.7324	61.7379

**Table 7 Double threshold estimation results and confidence intervals.**

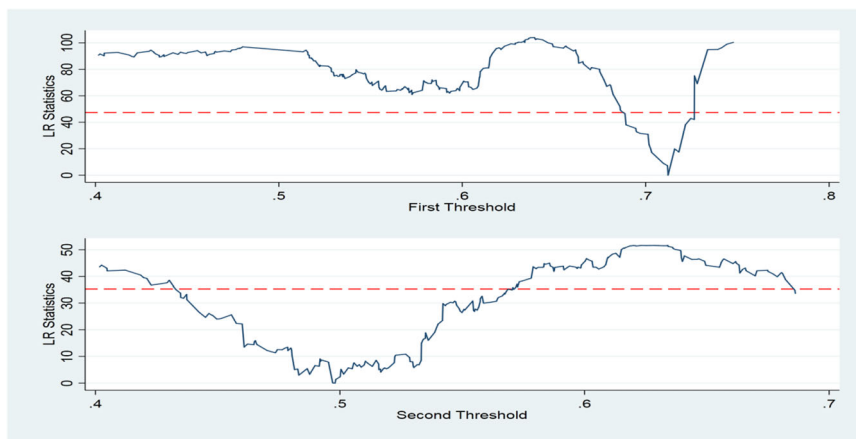
Threshold type	Threshold	95% confidence interval
Th-21	0.7122	(0.7107, 0.7158)
Th-22	0.4980	(0.4963, 0.4983)

mechanism, we adopt the rural non-farm employment structure as the mediating variable. The results are presented in Table 5. Columns (2) and (3) show positive and significant coefficients for both rural AIS integration and non-farm employment, indicating that rural AIS integration improves the rural non-farm employment structure, increases the proportion of the rural non-farm employed population, and thereby enhances rural residents' income through diversified income channels. Meanwhile, the coefficients of rural AIS integration and non-farm employment in Columns (4) and (5) are both negative and significant, suggesting that both factors contribute to narrowing the urban-rural income gap. Specifically, non-farm employment plays a partial mediating role, explaining 19.3% of the total impact of rural AIS integration on reducing the urban-rural income gap, which indicates that the mediating effect of the non-farm employment structure is relatively prominent. The underlying economic logic is as follows: through rural AIS integration, rural households break away from their original single income source and diversify their income structures on the basis of acquiring new professional skills. Moreover, the wage income and operating income derived from rural AIS integration are generally higher than the income from land cultivation, which exerts a significant positive effect on narrowing the urban-rural income gap.

**Threshold effect of urbanization.** Urbanization can affect rural AIS integration through factor allocation, market connection, and technological penetration. Different levels of urbanization development may have a non-linear role on the income effect of rural AIS integration. Surpassing a certain level of urban concentration possibly alters the mechanisms of factor flow and industrial spillovers between urban and rural areas. Therefore, it was necessary to determine whether there was a threshold effect and the number of thresholds needed to determine the final form of

the threshold regression model. To this end, the “Bootstrap” method with 500 repetitions was employed for testing, and the test results of threshold effect and threshold estimates are shown in Tables 6 and 7. Table 6 indicates that the *P* values of the *F*-statistics for the single- and double-threshold models reject the null hypotheses of “no threshold” and “only one threshold” at the 1% significance level, respectively. However, the *P* value for the triple threshold model fails to reject the null hypothesis of “only two thresholds” at the 10% significance level, suggesting that, with the help of the likelihood ratio (LR) function diagram (Fig. 2), the model exhibits characteristics of a double threshold. Table 7 presents the corresponding double-threshold estimates and confidence intervals.

After determining the number of thresholds and their specific estimates, the coefficients of the threshold model can be estimated according to Eq. (5). The results in Table 8 show that, across all identified threshold intervals, rural AIS integration is positively associated with increases in farmers' income, and this pattern is consistent with the findings from our earlier empirical analysis. Furthermore, an inverted U-shaped relationship between the effect of rural AIS integration and the urbanization rate is empirically identified. As the urbanization rate threshold increases from 49.8 to 71.22%, the coefficient of rural AIS integration becomes larger, indicating that the income effect of rural AIS integration exhibits marginal enhancement. After the threshold reaches 71.22%, this marginal growth effect then begins to decline. A possible reason for this is that an excessively high level of urbanization would absorb more factor resources into cities than otherwise, thereby reducing the agglomeration effect of these resources in rural areas. In particular, a reduction in the number of individuals with higher human capital would greatly weaken the internal dynamism and sustainability of rural development.



**Fig. 2 Estimated double thresholds and likelihood ratio (LR) function plot.** The likelihood ratio (LR) function plot in Fig. 2 clearly illustrates that the LR statistics at the identified threshold values fall below the corresponding critical values, with the decisive drop in the LR statistic to zero at the estimated threshold values.

**Table 8 Estimation results of the double threshold regression model.**

Variables	Coefficient	Standard error
aisin (urban $\leq \gamma_1$ )	3.012***	0.346
aisin ( $\gamma_1 < \text{urban} \leq \gamma_2$ )	4.384***	0.260
aisin (urban $> \gamma_2$ )	2.706***	0.178
inter	-0.913***	0.128
rpcap	0.528***	0.153
hucap	0.341***	0.034
polic	0.038	0.024
fiser	0.562***	0.092
constant	5.746***	0.250
R <sup>2</sup>	0.855	
F Stat	26.77	

**Discussion.** The preceding dynamic system GMM results reveal a statistically significant conditional causal effect of rural AIS integration on farmers’ income growth and narrowing the urban-rural income gap. These findings are consistent with and complement the results of existing empirical studies (Guo and Zhang, 2023; Shi and Xu, 2023), thereby enhancing the credibility of the observed associations. However, our panel quantile regression reveals a crucial nuance: the marginal income-increasing effect of rural AIS integration is more pronounced at higher quantiles of rural residents’ income. This finding, by revealing characteristics across the income distribution, extends related research by indicating that the benefits of integrated development are not evenly distributed among the rural population. Theoretically, this can be explained by the inequality of opportunity and initial endowment effects (Roemer, 1998; Zhu, 2025; Yang and Sun, 2024). Higher-income rural households may often possess more capital, social connections, and better access to market information, enabling them to more effectively seize new opportunities created by rural AIS integration. This finding implies that without accompanying pro-poor policies, the rural AIS integration may inadvertently exacerbate rural internal inequality while increasing average incomes.

Second, based on the results of system GMM and difference GMM estimations, this study demonstrates that the rural AIS integration helps narrow the urban-rural income gap, which is consistent with the findings of Li and Ran (2019) and Ge et al.

(2022). The convergence effect we identified supports the theoretical expectation that improved rural factor allocation efficiency and policy support from the perspective of rural AIS integration can promote a more balanced distribution of economic benefits. Notably, this effect is deeply rooted in China’s dual identity as a transitional economy and an emerging market, which shapes unique urban-rural dynamics distinct from developed economies (Dai et al., 2025). China’s profound structural transformation from agriculture to high-productivity sectors, accompanied by technology diffusion and factor flow (Dai et al., 2025), enables rural AIS integration to break urban-rural segmentation, facilitate factor mobility, and link rural areas to urban technology and capital spillovers, thereby reinforcing the gap-narrowing effect.

Third, the partial mediating role of non-farm employment underscores that rural AIS integration narrows the urban-rural income gap through optimizing the rural non-farm employment structure. Theoretically, AIS integration fosters factor inflows to rural areas, directly improving resource allocation efficiency. Practically, it extends agricultural value chains through processing industries, creates labor demand via cultural-tourism development and supporting infrastructure investment, and shortens production-supply cycles through e-commerce platforms. Rural households acquire new vocational skills amid this transformation, shifting from single agricultural income to diversified sources such as wage income from AIS-related jobs and operating income from rural businesses. Since these non-farm incomes typically exceed traditional farming income, the improved income structure and elevated income levels directly mitigate urban-rural income disparities, validating the critical mediating channel of non-farm employment.

Fourth, the study reveals the non-linear role of urbanization level. It finds an inverted U-shaped relationship between the income-increasing effect of rural AIS integration and the urbanization rate, a pattern consistent with the theory of economic structure transformation and the law of diminishing marginal returns to factors. Underlying this is likely the shifting balance between “complementarity” and “competitiveness” in urban-rural dynamics. In the early and middle stages of urbanization, urbanization brings market demand, capital, and technology to rural areas, promoting the development of formats such as agricultural product processing, rural tourism, and large-scale land operation. This shifts farmers’ income from a single agricultural source to a diversified portfolio, and the significant

complementary factors strongly enhance the income effect of integration. However, when urbanization reaches a certain level, the “siphon effect” of cities will lead to the outflow of rural factor resources. Concurrently, urban industrial upgrading will raise skill requirements for the rural workforce, and urban consumption will shift towards high-end markets, reducing the competitiveness of traditional rural integrated formats. These competitive factors cause the income-increasing effect of the integration to weaken.

Nevertheless, this study has limitations that merit future exploration. First, provincial-level data may mask heterogeneous effects at the city or county level. Future research could use more granular data. Second, while this study focuses on the overall impact of the rural AIS integration, future work could compare the effects of different integration models. Third, further investigation into the interaction between integration and institutional reforms, such as land system and rural finance within China’s dual identity context, would be valuable.

### Conclusions and policy implications

**Conclusions.** This study empirically examines the impact of rural AIS integration on rural residents’ income growth and the urban-rural income gap using Chinese provincial panel data, with an emphasis on dynamic effects and non-linear relationships. The core findings are as follows: (1) rural AIS integration exerts a positive direct income-increasing effect on rural residents’ income growth, and the marginal strength of this positive association is more pronounced at higher income quantiles. (2) Both the dynamic system GMM and difference GMM estimations reveal that the integration narrows the urban-rural income gap, demonstrating a convergence effect on income distribution. (3) Non-farm employment plays a partial mediating role, explaining 19.3% of the total impact of rural AIS integration on reducing the urban-rural income gap. (4) The threshold model test results reveal that the income-increasing effect of the rural AIS integration showed an inverted U-shaped marginal convergence trend with the increase of the urbanization rate.

**Policy implications.** First, deepening the reform of China’s rural land system provides institutional safeguards for the rural areas to absorb more external resources. Currently, due to the segmentation of the urban and rural land market in China and the more closed rights of rural land than urban land, the flow of capital, labor, land, information, and technology is much more autonomous and efficient in cities than in rural areas, creating certain institutional barriers for attracting more factor resources for rural AIS integration. Therefore, efforts should be made to extend the circulation scope of contracted land management rights, and liberalize the transfer of use rights of collectively-owned rural homesteads, which will reduce the restrictions of property rights constraints on factor input, and promote the two-way, autonomous, and orderly flow of urban and rural factors. At the institutional level, consideration could be given to establishing a feedback mechanism that channels proceeds from the “Linkage Between Urban Construction Land Increase and Rural Construction Land Decrease” policy back to rural communities. At the industrial level, encouraging the development of new agribusiness entities such as family farms and farmer cooperatives, supported by enabling policies, may help advance diverse business formats under the “agriculture plus” model.

Second, supporting the development of multifunctional agriculture could contribute to higher levels of rural non-farm employment and a broader diversification of farmers’ income sources. By leveraging local resource endowments, it would be valuable to foster the growth of businesses well-aligned with multifunctional agriculture, such as deep processing of

agricultural products, rural eco-cultural and wellness tourism, which can help absorb rural labor into non-farm roles near their local communities. Encouraging entities like family farms and farmer cooperatives to engage in agricultural product grading, packaging, and branding would further promote the extension of the agricultural value chain. Rural vocational training focused on non-agricultural skills represents an important pathway to enhance non-farm employment. Therefore, providing farmers with practical skills training in areas such as agricultural product processing, e-commerce operations, and cultural tourism services should be considered. Simultaneously, establishing job information matching mechanisms could help lower the transition barriers for rural workers shifting from agriculture to non-farm industries. Meanwhile, developing new models such as rural live-streaming e-commerce and direct sales from production sites can enhance the added value of agricultural products while creating more operating and wage income opportunities.

Third, enriching and strengthening the financial and fiscal support for rural AIS integration. Fiscal subsidies can be used to increase skill training for small-scale farmers, focusing on enhancing their ability to participate in the industrial chain division of labor in the AIS integration. Policy incentives should be enhanced to guide the flow of talents, social investment, and digital technologies toward rural areas. Within the framework of policies and regulations, appropriate institutional arrangements should be established, allowing investors who are not members of collective organizations to join new rural cooperatives, and providing flexible market-oriented organizational structures and financial arrangements (Knutson and Cropp, 2013). Meanwhile, financial institutions should be encouraged to develop credit products tailored to rural AIS integration, such as industrial chain finance and mortgage loans for homestay operation rights. The downward penetration of digital technologies can be leveraged to enhance the capacity of financial services to support rural AIS integration in the process of urbanization.

Fourth, the phased coordinated development of urbanization and rural AIS integration deserves careful consideration. During the early stages of urbanization, the focus should be on improving the connectivity of urban and rural infrastructure, including upgrading the quality of rural roads, developing cold chain logistics, and building digital villages etc., embedding rural characteristic industrial chains into the layout of urbanized areas, and leveraging the advantages of urban service industries to develop integrated formats such as rural health and wellness, and study tour programs. This will enable the urbanization process to serve as an incubator for rural projects integrating the rural industries, thereby absorbing rural labor and strengthening the fundamental role of the AIS integration in driving income growth. After the urbanization rate crosses the threshold, it is necessary to guard against rural “hollowing out” caused by excessive concentration of factors in cities. Efforts should be directed toward deepening the linkage between urban consumer markets and rural production ends, such as order-based agriculture and rural e-commerce, thereby reshaping the marginal effects of income growth through rural AIS integration.

### Data availability

The data that support the findings of this study were found in the officially published yearbooks and government websites such as <https://data.stats.gov.cn/index.htm> etc.

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### Author contributions

Chenyou Wang: funding acquisition, project management, conceptualization, methodology, validation, formal analysis, data curation, and writing—original draft; Yamin Du: validation, data curation, software, and writing—review and editing.

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The authors declare no competing interests.

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### Additional information

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