

Article

Rural E-Commerce and Income Inequality: Evidence from China

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Abstract: Common prosperity is the fundamental driving force of rural revitalization, as well as the foundation for achieving sustainable economic development. The e-commerce to the countryside policy has energized the rural economy, helping to improve household economic resilience and reduce income stratification, thereby promoting the inclusive and sustainable development of the digital economy. Drawing on panel data collected from rural fixed observation points in Henan Province during 2009–2022, this study employs a staggered difference-in-differences (DID) approach to evaluate the impact of China's e-commerce to the countryside policy on farmers' income and income inequality. The empirical results reveal that the rural e-commerce policy significantly increases farmers' income while mitigating income inequality. The underlying mechanisms function through three synergistic pathways: industrial structural upgrading, manifested through tri-sector integration driven by rural enterprise development; factor allocation restructuring, evidenced by productivity gains from optimized labor–capital reallocation; and enhanced market inclusion through digital technology empowerment that lowers participation barriers. Heterogeneity analysis indicates that the e-commerce to the countryside policy exhibits pro-poor characteristics, with its income-enhancing and equalizing effects being particularly pronounced in agricultural areas, traditional villages, county-level civilized villages, underdeveloped regions, registered poverty-stricken villages, and households with low human, physical, and financial capital endowments. These findings confirm the inclusive development efficacy of rural e-commerce among vulnerable populations. Consequently, the study provides a replicable policy implementation framework for achieving common prosperity objectives.

Keywords: rural e-commerce; income inequality; rural revitalization; common prosperity



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1. Introduction

China's transition toward high-quality development reveals a sustainability paradox: while aggregate household income growth aligns with economic sustainability targets, persistent multidimensional disparities in urban–rural, interregional, and cross-group income distribution undermine social sustainability imperatives [1]. Under the enduring urban–rural dual structure, rural residents' income growth has consistently lagged behind their urban counterparts. These structural imbalances manifest as compounded differentiation patterns that contravene the United Nations Sustainable Development Goals (SDGs), particularly Goal 10 (Reduced Inequalities). As per National Bureau of Statistics data, the urban–rural per capita disposable income ratio persisted at 2.45 in 2022, highlighting systemic inequities in development outcomes. At the regional level, coastal provinces in

eastern China have accelerated industrial upgrading by capitalizing on the first-mover advantages of the digital economy, while central and western rural areas remain constrained by traditional factor allocation mechanisms. This structural constraint has led to a compromised capacity for income growth [2]. Even more worryingly, the income gap within rural areas is widening. Particularly vulnerable groups, including low-skilled laborers and smallholder farmers, face dual challenges: technological marginalization manifested in the digital divide and skill obsolescence exacerbated by rapid technological transformation [3]. Rural e-commerce provides employment opportunities for disadvantaged groups and increases their off-farm income, such as low-skilled labors and women, who rely on farming and selling grain for their income, thus contributing to narrowing the income gap within rural groups. In this context, it is of great theoretical and practical significance to examine the income effect of rural e-commerce policy for achieving the goal of rural revitalization and common prosperity. This study provides evidence that the rural e-commerce policy helps alleviate income inequality within rural groups, explores new explanations to clarify its underlying mechanisms, provides a basis for assessing the long-term dynamic effects of rural e-commerce policy, and examines heterogeneity across groups with different endowments and regions.

As a flagship initiative under China's 14th Five-Year Plan, the Digital Rural Development Strategy seeks to transform rural productivity and production relations through digital technology, thereby advancing the common prosperity agenda. Following the Ministry of Commerce's launch of the Comprehensive Demonstration Counties for E-commerce in Rural Areas program in 2014 (Henceforth the rural e-commerce policy), implementation has expanded to 1500 counties with over 158,000 village-level service stations established nationwide. Official statistics indicate that rural e-commerce transactions reached CNY 2.5 trillion in 2023, marking a 13-fold increase from 2014 levels, while online agricultural product sales surged to CNY 587.03 billion, representing a fivefold growth from 2014 figures. Notably, the specialized "832 Platform" facilitated over CNY 50 billion in agricultural product sales across 832 formerly impoverished counties by 2023, effectively supporting 3.2 million households in sustaining poverty eradication outcomes. On the one hand, this digital transformation has catalyzed a fundamental transition from production-oriented to market-driven rural economies, enabling the digital reorganization of production factors, including land, labor, and data resources. The emergence of innovative models such as sharing economy models and livestream commerce has empowered traditional agricultural producers to overcome geographical barriers and access national markets [4]. Crucially, the decentralized architecture of digital empowerment creates opportunities for low-capital groups to obtain equitable access to industrial value chains [5], thereby integrating equity enhancement mechanisms within efficiency improvements and establishing a vital pathway toward achieving common prosperity.

On the other hand, reducing income inequality within rural groups contributes to achieving the Sustainable Development Goals. First, reducing the income gap between agricultural producers can contribute directly to SDG1 (no poverty) and SDG2 (zero hunger): by providing more equitable access to resources (e.g., land, finance, and technology) to small-scale farmers and marginalized groups, their productivity and market participation can be increased. Second, this process contributes to SDG8 (decent work and economic growth), as income redistribution policies and fair-trade practices stabilize rural employment, increase the resilience of the overall agricultural economy, and avoid the over-concentration of resources in a few advantaged groups. In addition, reducing inequality contributes to SDG5 (gender equality), as improving the economic status of women producers in agriculture, who often face systemic income discrimination, can enhance women's autonomy and social participation. Finally, increased social inclusiveness contributes to SDG10 (reduced

inequalities) and SDG16 (peace, justice, and strong institutions) by reducing economic conflicts and social fragmentation, building more stable rural communities, and providing a social foundation for sustainable development.

The existing literature has yielded multidimensional research results on the economic effects of e-commerce, primarily encompassing the following aspects. The first is the driving mechanism of e-commerce for economic growth. Empirical studies confirm that e-commerce stimulates regional economic development through transaction cost reduction, market coverage expansion, and resource allocation optimization [6,7], particularly in rural contexts where platforms enhance agricultural producer surplus via streamlined distribution channels [8]. Second, e-commerce's structural impacts on income distribution. While some scholars identify exacerbation of digital divides through skill-based technology adoption disparities that favor high-capacity groups [9,10], others emphasize its role in creating low-barrier entrepreneurship opportunities that mitigate traditional market entry barriers for resource-constrained populations [11]. Third, industrial transformation and value chain upgrading are driven by e-commerce. Academic investigations reveal its catalytic role in agricultural supply chain modernization, fostering innovative models, including contract farming and customized production systems [12], while simultaneously reshaping the value distribution pattern of the industrial chain through data element embedding [13]. Fourth, regional heterogeneity in policy effectiveness. Comparative analyses demonstrate amplified demonstration effects in infrastructure-deficient regions, though spatial disparities in governance capacity may constrain policy dividend realization [14]. Fifth, e-commerce's social capital synergies. Platform ecosystems activate rural social networks through digital community building, enhancing agricultural risk mitigation capabilities, while algorithmic reputation systems improve transactional trust mechanisms [15].

The existing literature offers theoretical frameworks for understanding income determinants and inequality, which can be systematically categorized as follows. First, the differential impacts of human capital accumulation. Schultz's human capital theory establishes education and skill acquisition as drivers of productivity-enhanced income growth [16], while accumulation identifies educational return heterogeneity across socioeconomic strata [17], wherein skill premiums may amplify income divergence. Second, the dual role of physical capital and financial inclusion. Piketty's capital accumulation framework demonstrates wealth concentration's self-reinforcing distributional effects [18], whereas Banerjee and Duflo's findings reveal how financial exclusion perpetuates poverty cycles through constrained economic mobility [19]. Third, the dualistic distributional consequences of technological advancement. Acemoglu and Autor's skill-biased technological change hypothesis posits wage polarization through low-skill job displacement [20], contrasting with Bresnahan et al.'s evidence of digital technologies democratizing market access and disrupting traditional rent-seeking structures [21]. Fourth, institutional and policy-mediated redistribution mechanisms. North's institutional economics underscores property rights systems as fundamental to factor allocation efficiency [22], complemented by empirical evidence showing land rights reforms enhance farmer incomes through asset collateralization activation [23], and regional poverty alleviation programs effectively mitigate inequality via redistributive policy instruments [24]. Fifth, structural transformation dynamics. The Kuznets curve hypothesis postulates inverted U-shaped inequality patterns during industrialization [25], contrasted with contemporary findings suggesting service sector expansion exacerbates wage disparities through high-skill service premia [26]. Sixth, social networks and the ability to participate in markets. Granovetter's embeddedness theory elucidates the role of social capital in opportunity acquisition [27], while Sen's capability approach framework identifies market participation barriers [28], including informational asymmetries and technological exclusion, as systemic inhibitors of the in-

come potential of disadvantaged groups. Collectively, these theoretical constructs form the analytical foundation for income determination studies.

Current research examining the income effects of rural e-commerce policy reveals three principal limitations. First, academic consensus remains elusive regarding e-commerce's inequality impacts, with mechanistic pathways requiring further elucidation. Scholarly perspectives diverge significantly: while some demonstrate poverty alleviation effects through rural e-commerce penetration [29], others document widening intra-rural income gaps [30,31]. Existing mechanistic analyses predominantly focus on information accessibility, non-agricultural employment, and social capital activation [32–34], with limited exploration of structural dimensions, including industrial reorganization, property rights reform, and technology adoption thresholds. Second, the dynamic and continuous tracking of research data is lacking, and the research method needs to be improved. The most empirical analysis is based on cross-sectional data, short-term, discontinuous panel data, and the least squares method, which makes it difficult to capture the time series evolution law of policy effects and lacks consideration of endogeneity problems, resulting in a bias in the long-term evaluation of policy effects. Third, the heterogeneity investigation needs to be further improved. The existing research focuses on heterogeneity analysis from the perspectives of region, age, digital literacy, and education level and ignores the differences in farmers' capital endowment and rural characteristics, which makes it difficult to verify the inclusiveness and accuracy of policies effectively.

This study fills these gaps in the following three ways. First, theoretical mechanism innovation. Developing a tripartite transmission mechanism encompassing industrial structure optimization, factor allocation reorganization, and farmer market participation systematically elucidates the synergistic pathways through which digital economy integration drives rural transformation. This theoretical framework offers systematic explanations for achieving common prosperity through digital technology-enabled development. Second, refinement of data methodology. Utilizing longitudinal tracking data (2009–2022) from rural fixed observation points in Henan Province, we implement a staggered difference-in-differences (DID) design to isolate and quantify the dynamic cumulative effects of policy interventions. This methodological advancement enables a rigorous assessment of governmental programs' sustained impacts. Third, multidimensional heterogeneity analysis. This study systematically evaluates policy effect variations across (1) household capital endowment (human, physical, and financial capital endowments), (2) rural typological characteristics (agricultural zones, traditional villages, and county-level civilized villages), and (3) regional development levels (less-developed areas and nationally designated poverty villages). These multidimensional investigations generate empirically grounded insights for formulating context-sensitive policies and enhancing targeting precision in fiscal resource allocation.

2. Research Hypotheses

Common prosperity represents the central value orientation and fundamental objective of agricultural modernization. This developmental paradigm requires not only technological innovation to elevate production efficiency, but also the creation of inclusive growth mechanisms [35]. The modernization process unfolds through dual pathways: (1) transforming inefficient, traditional smallholder economies through scale expansion and digital technology diffusion, thereby establishing new income generation channels; (2) advancing institutional innovations involving land system reform, cooperative organization development, and inclusive service provision, restructuring factor distribution patterns to address polarization risks associated with technological displacement. This synergy activates market mechanisms to unlock growth potential and bridges capability gaps via

targeted policy instruments [36]. The subsequent analysis systematically examines the policy's dual income-equity effects through three analytical dimensions: industrial structure optimization, factor allocation restructuring, and market participation enhancement, as conceptualized in Figure 1.

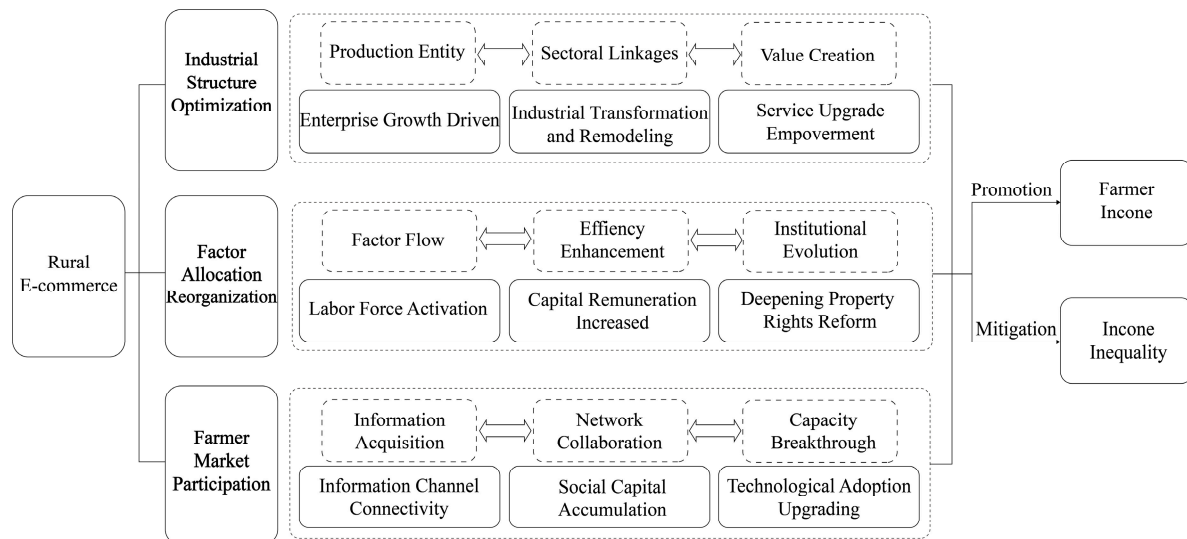


Figure 1. Theoretical analysis framework.

2.1. Industrial Structure Optimization Mechanism

2.1.1. Rural E-Commerce Policy and Industrial Structure Optimization

The rural e-commerce policy promotes the evolution of industrial structure in the direction of high value-added and diversification by systematically reconfiguring the organizational form of rural industries, and the influence channels can be summarized in three aspects. First, the growth of rural enterprises is the basic driving force for the optimization of industrial structure. The e-commerce platform activates rural entrepreneurial vitality by reducing transaction costs and broadening market coverage, which promotes small- and medium-sized enterprises to form a cluster effect in production, processing, logistics, and other links [37]. The expansion of the number of enterprises and the improvement of scale not only increase the density of the local economy but also strengthen the industrial linkage through knowledge spillover and technology diffusion, thus enhancing the resilience of the regional economy. Second, industrial transformation is the core path of structural upgrading, and traditional agriculture has accelerated its extension to secondary and tertiary industries under the penetration of e-commerce. For example, primary agricultural products enter the deep processing chain through e-commerce channels or directly connect to end consumers, promoting the transformation of the industrial chain from single production to “production–processing–service” integration [38]. This vertical integration not only extends the value chain but also enhances total factor productivity through the refinement of the division of labor. Third, service upgrading and empowerment are the continuous guarantee of structural optimization. The e-commerce ecosystem has generated demand for supporting services such as warehousing, logistics, and finance, which has led to a significant increase in the proportion of the tertiary industry [39]. The professional development of the service industry reduces transaction friction and optimizes factor matching efficiency, providing synergistic support for agriculture and manufacturing, and ultimately forming a modernized industrial system for the integration of the three industries.

2.1.2. Industrial Structure Optimization and Income

The optimization of the industrial structure creates a systematic boost to the income of farm households through a variety of channels, including three main aspects. First, Rural enterprise clusters create a large number of processing, operation, logistics, and other jobs, so that farmers can shift from traditional agricultural labor to wage employment, and their income structure shifts from agricultural production relying on natural risks to stable labor compensation [40]. Second, value-added income sharing of the industrial chain enhances operating income. With the extension of the industrial structure to high value-added links, farmers obtain a share of the profits from processing and circulation by participating in the e-commerce marketing of agricultural products, brand building, after-sales service, and other links [41]. For example, the e-commerce premium for specialty agricultural products enables producers to break through the wholesale price constraints of origin and directly capture consumer surplus. Third, the spillover effect of the service industry reduces production costs. Improvement of the logistics system to reduce the loss rate of agricultural products, financial support to ease the liquidity constraints, and the application of digital technology to improve the efficiency of management. This service industry support indirectly reduces the production and operation costs of farmers, expanding the net income space [42]. Together, these three mechanisms promote a shift in total farm household income from single-farm dependence to a diversified and compound growth model. To sum up, this paper puts forward hypothesis 1a:

Hypothesis 1a. *The rural e-commerce policy improves farmers' income by optimizing industrial structure.*

2.1.3. Industrial Structure Optimization and Income Inequality

The optimization of industrial structure suppresses the widening of the intra-rural income gap through structural adjustment, and its equalizing effect is reflected in a threefold path. First, equalization of employment opportunities weakens the impact of human capital differences. Labor-intensive service industries and small- and medium-sized enterprises provide standardized jobs for low-skilled labor, reduce the weight of individual differences in education and technical ability on income, and enable disadvantaged groups to obtain stable compensation through manual labor [43]. Second, the redistribution of industrial chain income compensates for the competitive disadvantages of small farmers. Differences in resource endowments such as land size and production tools in traditional agriculture led to income differentiation, while the extension of secondary and tertiary industries driven by e-commerce provides small farmers with opportunities for non-farm participation [44], such as obtaining non-land-dependent income through sub-processing and subcontracting logistics, which partially offsets the impact of unequal resource appropriation. Third, the universality of public services narrows the ability gap. The e-commerce supporting service system (e.g., standardized quality control training, promotion of digital tools) has the attribute of quasi-public goods, and its low-cost access characteristics enable marginal farmers to break through the constraints of intangible resources, such as information and technology [45], and narrow the productivity gap with large-scale operators. This structural level of inclusive improvement has effectively curbed the widening of the intra-rural income gap. Therefore, Hypothesis 1b is proposed:

Hypothesis 1b. *The rural e-commerce policy mitigates income inequality among farming households by optimizing industrial structure.*

2.2. Factor Allocation Reorganization Mechanism

2.2.1. Rural E-Commerce Policy and Factor Allocation Reorganization

The rural e-commerce policy reconfigures the logic of factor combination of rural economic activities by optimizing the allocation efficiency of production factors and the distribution of benefits, and its core driving force is reflected in three progressive levels. First, the cross-sectoral flow of labor factors accelerates the release of human capital value. E-commerce has created logistics, customer service, operation, and other non-farm positions for agricultural surplus labor to provide employment channels, promoting their shift from low-value-added traditional agricultural production to a high-productivity service industry [46]. This process, through the job conversion, directly enhances the labor compensation rate. Second, the mechanism of increasing capital compensation improves labor returns through market efficiency improvement. E-commerce platforms enable farmers to sell their products at higher prices with the same labor input by reducing intermediate circulation links [47], expanding the sales radius, and enhancing price transparency, thus realizing the value enhancement of output per unit of labor time. Third, the property rights reform of land elements stimulates the efficiency of asset allocation. The e-commerce-driven demand for scale has prompted the development of the market for the transfer of agricultural land management rights, and the concentration of land to highly operationally efficient subjects, releasing the potential for rental income from idle land while forcing the land management system to evolve in the direction of flexibility in the right of use [48].

2.2.2. Factor Allocation Reorganization and Income

Factor allocation reorganization systematically expands the space for farm household income growth through higher rates of return and improved portfolio efficiency of factors of production. First, the wage premium effect of non-farm employment of labor is significant. The economic value of farm households' labor time increases significantly due to productivity differences after they shift from the agricultural sector to e-commerce-related services. For example, the income per unit of time of logistics and distribution workers is generally higher than that of traditional farming, and the increased stability of employment further reduces the risk of income fluctuations [49]. Second, the capital compensation efficiency mechanism reshapes the distribution pattern of labor returns. E-commerce channels shorten the supply chain, so that farmers with the same production labor input, due to the terminal selling price increase, circulation loss reduction, and better price conditions [50]. For example, the direct connection of live e-commerce to consumers can skip the wholesaler's profit sharing, and the income conversion efficiency of labor has risen significantly. Third, the asset value-added effect of land transfer creates property income. After farmers rent out their land management rights, they can not only obtain stable cash flow through rental income but release their labor force from land bondage to engage in high-paying non-agricultural work, forming a composite income-generating model of "rental income plus labor remuneration" [51]. In summary, we propose Hypothesis 2a:

Hypothesis 2a. *The rural e-commerce policy increases farmers' income by restructuring factor allocation.*

2.2.3. Factor Allocation Reorganization and Income Inequality

Factor allocation restructuring effectively mitigates intra-rural income divergence by optimizing the inclusiveness of the distribution of factor returns. First, the inclusiveness of non-farm employment opportunities reduces the marginal impact of endowment differences. The lower skill thresholds of e-commerce service industry jobs provide equalized income-generating channels for farm households with weaker initial endowments, such as education level and social capital, weakening the role of individual heterogeneity in

determining income [44]. For example, the compensation of logistics sorting and packaging positions relies mainly on labor time input rather than technical differences, narrowing the wage gap between different groups. Second, the universal character of capital remuneration enhancement suppresses the market segmentation effect. The e-commerce platform operates through a standardized access mechanism, so that small farmers and large operators can participate in market transactions on similar terms, the pricing of labor results from the traditional intermediary to the producer part of the transfer, and disadvantaged groups with the same labor intensity of earnings growth more equitable [52]. Third, the development of the land transfer market promotes the rebalancing of asset returns. Farmers without farming capacity can obtain rental income through land transfer, complementing the efficiency gains of large-scale operators. This process guarantees land output efficiency while realizing the transformation of asset returns from a “possession-oriented” to a “use efficiency-oriented” distribution model. This process guarantees land output efficiency while realizing the transformation of asset income from “possession-oriented” to “use efficiency-oriented” distribution mode [53]. Therefore, this study introduces hypothesis 2b:

Hypothesis 2b. *The rural e-commerce policy reduces income inequality among farming households by restructuring factor allocation.*

2.3. Farmer Market Participation Mechanism

2.3.1. Rural E-Commerce Policy and Farmer Market Participation

The rural e-commerce policy systematically reduces the threshold of market participation and reconfigures the economic behavior pattern of farmers, promoting their transformation from traditional production subjects to modern market subjects, and its mechanism can be summarized in three key dimensions. First, the information channel changes the information base of farmers’ decision-making. E-commerce platform through real-time price data, demand dynamics tracking, and consumer portrait analysis, breaking the constraints of geospatial information dissemination, so that farmers can optimize production plans based on market signals [54]. For example, with the help of the platform’s consumption trend prediction function, farmers can adjust the planting structure in advance to match the demand for high-value-added categories, significantly reducing the waste of resources caused by the mismatch between supply and demand. Second, social capital accumulation enhances market bargaining power. The e-commerce ecology has spawned cooperatives, industry alliances, and other organizational forms through collective purchasing, co-branding operations, and other collaborative models to form economies of scale [55]. This networked collaboration not only reduces individual transaction costs, but also enhances product premiums by sharing logistics resources and building a common quality certification system, thus strengthening the negotiating position downstream of the supply chain. Third, technology adoption and upgrading promote the production management of an intergenerational leap. E-commerce competition has forced farmers to introduce smart storage systems, live broadcasting equipment, and other digital tools, and to adopt modern agricultural technologies such as precision irrigation and organic planting, shifting from experience-dependent production to data-driven decision-making. Such technological empowerment has helped farmers establish differentiated competitiveness in dimensions such as product quality and responsiveness, thereby embedding themselves more deeply into the modern value chain system [56].

2.3.2. Farmer Market Participation and Income

The improvement of farmers’ market participation achieves a structural breakthrough in income growth through a multidimensional synergistic mechanism, which is driven by three types of complementary pathways. First, improved information access efficiency

optimizes resource allocation decisions. Real-time market data enables farmers to accurately identify high-value crop varieties and choose the optimal time to sell according to price fluctuation patterns, thus maximizing sales revenue under the same yield [57]. At the same time, improved demand forecasting significantly reduces the risk of slow-moving crops, which directly reduces wastage costs and improves net income. Second, social network collaboration creates both cost savings and value-added effects. Farmers collectively bargain through cooperatives to reduce the unit cost of agricultural procurement and logistics services; co-branding operations break through homogeneous competition through differentiated positioning to obtain higher premiums in the terminal market [58]. Third, the productivity leap driven by technology adoption creates a sustainable revenue stream. Intelligent agricultural equipment shortens the production cycle and improves the efficiency of the yield; for example, the environmental control system can extend the supply cycle of fruits and vegetables to realize staggered seasonal sales at high prices; quality traceability technology establishes consumer trust through authentication marking, so that the products can obtain quality premium [59]. The synergy of information optimization, collaborative efficiency gains, and technological innovation is driving the transformation of farm incomes from extensive to intensive growth. Therefore, Hypothesis 3a is formulated:

Hypothesis 3a. *The rural e-commerce policy increases farmers' income by enhancing farmers' market participation.*

2.3.3. Farmer Market Participation and Income Inequality

The deepening of market participation suppresses the trend of widening income disparities among farm households through inclusive improvements, and its equalizing effect is realized through three transmission paths. First, information transparency dissolves the traditional information monopoly advantage. The standardized interface of e-commerce platforms enables marginal farmers to have equal access to cross-regional market price information, weakening the determinative role of geographic location and social networks on information accessibility [60]. For example, farmers in remote areas can check the national price index through a unified platform, and their pricing strategies are no longer restricted by the information manipulation of local intermediaries, thus enhancing their bargaining autonomy. Second, social network embedding compensates for differences in resource endowments. By joining e-commerce cooperatives to share infrastructure such as cold chain logistics and marketing channels, disadvantaged farmers break through the individual capital constraints on market entry [61]. The collective action model enables small-scale producers to participate in high-value-added markets in a cost-sharing manner, such as jointly leasing sorting equipment to reduce the cost of single-product processing and narrowing the competitive disadvantage with large-scale operators. Third, the inclusive nature of technology diffusion promotes capacity convergence. The digital tools provided by e-commerce platforms (e.g., intelligent product selection algorithms, online training courses) have low-threshold characteristics, so that technology adoption no longer relies on high capital investment or complex skill reserves. Smallholders gradually narrow the productivity gap with large-scale operators through incremental technological improvements, thereby weakening the long-term impact of initial resource inequality on income distribution [62]. By reducing heterogeneity in the conditions of market participation, this triple mechanism promotes a more inclusive evolution of income distribution patterns. In summary, this paper develops Hypothesis 3b:

Hypothesis 3b. *The rural e-commerce policy reduces income inequality among farming households by enhancing farmers' market participation.*

3. Research Design

3.1. Data

This study utilizes longitudinal data from the Henan Province Rural Fixed Observation Point Survey, which is obtained from the Henan Province Department of Agriculture and Rural Affairs and includes 16 administrative villages strategically distributed across diverse administrative divisions (Figure 2). The sampling framework covers all prefecture-level cities in Henan Province with the exclusion of Xinxiang and Jiaozuo. Established in 1984 with authorization from the Secretariat of the CPC Central Committee, the National Rural Fixed Observation Point Survey System has been operational since 1986. The China Rural Fixed Observation Points (CRFOP) is an authoritative and continuous rural socio-economic survey system, which obtains dynamic and continuous data at the rural grassroots through a long-term tracking survey of fixed and unchanging rural villages and farmers. Limited by the availability of data, this paper only uses the data of Henan Province for research.

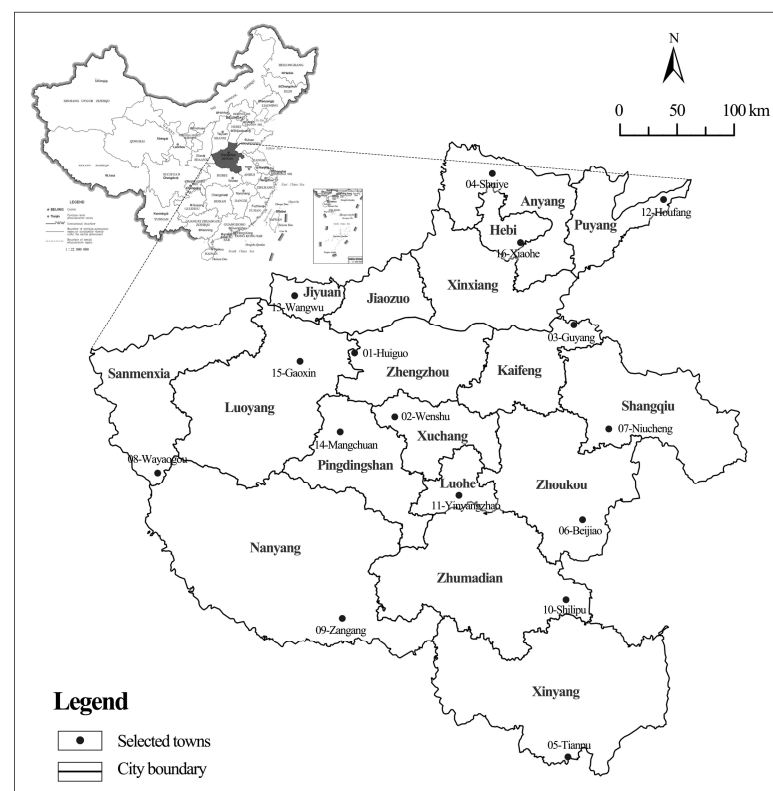


Figure 2. Geographical distribution of rural fixed observation points in Henan Province.

As an important core area of agricultural production in China, Henan Province has multiple attributes such as ballast for food security, an experimental field for agricultural transformation, a contradictory body for urban–rural integration, etc., and the achievements and challenges of its agricultural development present the common problems of China’s agricultural modernization in three dimensions. These tripartite characteristics of agricultural development collectively embody the paradoxical realities of China’s agricultural modernization. Selecting Henan Province as a case study enables both mechanism discovery through typical case analysis and policy implications for national strategies, offering unique academic and practical value. Using the latest survey data, this study examines the income effects of rural e-commerce policy to provide an empirical basis for addressing income inequality and promoting common prosperity.

This study establishes 2009–2022 as the study period based on three methodological considerations. First, the standardization was achieved in China’s rural economic statistical system after 2008, ensuring consistency in core variables, including household income, non-agricultural employment, and adoption of digital technology. Second, the 2022 endpoint encompasses the complete policy cycle before and after implementation. Third, incorporating COVID-19 pandemic data (2020–2022) enables the assessment of digital technologies’ risk mitigation capacity against exogenous shocks.

The list of e-commerce into Rural Areas Comprehensive Demonstration Counties was sourced from China’s Ministry of Commerce portal, with treatment assignment determined through geographic coding matching between farmer locations and demonstration counties. After data cleaning and organizing, the final dataset yielded 13,923 valid observations (7939 treatment and 5984 control observations).

3.2. Variables Description

3.2.1. Core Explanatory Variable

The rural e-commerce policy (Ecommerce) is the core explanatory variable. The program, Comprehensive Demonstration Counties for E-commerce in Rural Areas, is one of the core policies that promote the development of a rural digital economy and rural revitalization. Initiated in 2014, this administrative intervention introduced structural innovations in tri-level (county–township–village) service system architecture, facilitated bidirectional circulation channels for agricultural product outflows and industrial product inflows, and has proven instrumental in stimulating rural employment opportunities while enhancing household income levels. Methodologically, the list of demonstration counties published every year from 2014 to 2021 is matched with the counties where the sample farmers are located, and if the farmer’s county belongs to the demonstration counties, a value of 1 is assigned; otherwise, the value is 0. Specifically, we obtain the list of E-commerce into Rural Areas Comprehensive Demonstration Counties from the official website of the Ministry of Commerce of China, which provides the county names and administrative division codes that are included in the demonstration counties each year in detail. The data of Rural Fixed Observation Points in Henan Province include the specific village names, county names, and administrative division codes of 16 rural fixed observation points. We use county administrative division codes for matching to identify counties that were affected by the rural e-commerce policy and those that were not.

3.2.2. Dependent Variable

Total household income (Totincome) and income inequality (Inequality) are dependent variables. Total household income is measured by the logarithm of the total annual household income plus one. Income inequality is measured by the relative deprivation index of income calculated by the Kakwani index. For analytical robustness, supplementary specifications incorporating household per capita income and per capita income inequality index are used for testing. The larger the value of the Kakwani index is, the higher the degree of income inequality is, and the more unfavorable it is to achieve common prosperity. The computational formula for income inequality measurement is expressed as:

$$Inequality_f = \frac{1}{n\pi_M} \sum_{j=f+1}^n (m_j - m_f) = \eta_{m_f}^* \frac{\pi_{m_f}^* - m_f}{\pi_M} \quad (1)$$

where $Inequality_f$ denotes the degree of income inequality of farm household f relative to other farm households in the sample and belongs to $[0,1]$. According to the total household income in descending order, f denotes the f th farmer in the sample, whose income is m_f ; j denotes the j th farmer, whose income is m_j ; n is the total number of samples; M is

a vector of incomes, and there are $M = (m_1, m_2, \dots, m_n)$; π_M is the sample mean of the total household incomes; $\eta_{m_f}^*$ is the ratio of the number of samples with total household incomes exceeding m_f to the total samples; and $\pi_{m_f}^*$ is the mean of the samples with total household incomes exceeding m_f .

In the mechanism analysis section, this paper uses rural firms (Firm), industrial structure (Revshare), industrial transformation (Indrate), nonfarm employment (Nonfarm), nonfarm income (Nfarminc), farmland transferred out (Landout), farmland transferred in (Landin), information capital (Inform), social capital (Social), and technology adoption (Internet) as dependent variables to examine the theoretical mechanisms by which digital technology affects farm income and income inequality.

3.2.3. Control Variables

Considering that the gender, age, occupation, education level, and health status of farmers, as well as the economic strength of the household itself and the number of labor force may affect the income and income inequality, we include control variables in the benchmark regression to mitigate the endogeneity problem caused by omitted variables. For example, the income of male, younger, engaged in non-agricultural labor, highly educated, and healthy farmers is usually higher. The higher the proportion of these members in the family is, the higher the total household income will be, thus affecting the income inequality within rural areas. Meanwhile, whether a household has a car, whether it is a village cadre household, cultivated land area, house area, and family size determine the original economic base of the household. And families with cars, village cadres, families with large houses, and families with much labor force usually have higher incomes, and the gap between other households and them is also larger, thus affecting income and income inequality.

To exclude the interference of other factors on the regression results, the individual and family characteristic variables are selected to control with reference to the existing research [63,64]. Individual control variables include gender (Igender), age (Iage), occupational category (Ijob), education level (Ieduc), and health status (Ihealth). Household control variables include whether there is a car (Fcar), whether there is a village cadre household (Fcadre), cultivated land area (Farea), house area (Fhouse), and household size (Flabor). For the analysis of village collective, per capita income (Aveinc), total population (Popular), total income (Totinc), total expenditure (Totexp), total assets (Asset), and total liabilities (Debt) are selected as control variables.

The descriptive statistics of the main variables are shown in Table 1, and the definitions of variables are shown in Appendix A (Table A1).

Table 1. Variables descriptive statistics.

Variables Type	Variable Meaning	Variable	N	Mean	S.D.
Independent Variable	Rural E-Commerce Policy	Ecommerce	13,923	0.241	0.428
	Total Income	Totincome	13,923	10.305	0.993
	Income Inequality	Inequality	13,923	0.464	0.252
Control Variable	Gender	Igender	13,923	1.072	0.259
	Age	Iage	13,923	59.252	11.499
	Profession	Ijob	13,923	3.516	4.739
	Education	Ieduc	13,923	7.281	2.481
	Health Status	Ihealth	13,923	1.917	1.147
	Automobile	Fcar	13,923	0.148	0.355
	Cadre	Fcadre	13,923	0.038	0.192
	Cropland Area	Farea	13,923	1.561	1.297

Table 1. Cont.

Variables Type	Variable Meaning	Variable	N	Mean	S.D.
Mechanism Variable	House Area	Fhouse	13,923	3.911	0.861
	Family Size	Flabor	13,923	2.442	1.290
	Per Capita Income	Aveinc	224	8.782	0.693
	Total Population	Popular	224	7.555	0.582
	Total Expenditure	Totexp	224	7.435	3.012
	Total Assets	Asset	224	7.675	2.299
	Total Liability	Debt	224	9.420	2.923
	Firm Number	Firm	224	0.188	0.528
	Industrial Transformation	Revshare	224	0.502	0.034
	Service Upgrade	Indrate	224	1.035	0.350
	Non-Farm Employment	Nonfarm	13,923	0.328	0.469
	Non-Farm Income	Nfarminc	13,923	0.843	0.208
	Farmland Transferred Out	Landout	13,923	0.582	2.394
	Farmland Transferred In	Landin	13,923	0.608	3.082
	Information Capital	Inform	13,923	3.230	0.697
Heterogeneity Variable	Social Capital	Social	13,923	6.443	1.988
	Technology Adoption	Internet	13,923	0.352	0.478
	Human Capital	Heduc	13,923	0.665	0.472
	Physical Capital	Hconsum	13,923	0.499	0.500
	Financial Capital	Hdepo	13,923	0.423	0.494
	Agricultural Area	Argiarea	13,923	0.823	0.382
	Traditional Village	Conven	13,923	0.269	0.444
	Civilized Village	Civili	13,923	0.392	0.488
	Poor Village	Needy	13,923	0.375	0.484
	Economic Level	Undevel	13,923	0.380	0.485

Note: Some variables are at the village level, such as village characteristic variables and the number of enterprises, so the number of samples is 224; that is, 14 years of data from 16 administrative villages. The control variables and mechanism variables at the village level are mainly used to test the mechanism of industrial structure optimization.

3.3. Model Setting

This paper uses the staggered difference-in-differences method to investigate the impact of e-commerce policy on farmers' income and income inequality, and the specification is constructed as follows:

$$Income_{ft} = \alpha + \beta \cdot Ecommerce_{ct} + Controls'_{ft} \gamma + \delta_f + \delta_t + \varepsilon_{ft} \quad (2)$$

where f denotes farmer, t denotes year, and c denotes county. The dependent variables $Income_{ft}$ denote the total household income and income inequality of farmer f in year t . The core explanatory variable $Ecommerce_{ct}$ indicates whether county c where the farmer is located belongs to the list of Comprehensive Demonstration Counties for E-commerce in Rural Areas in year t . If the list of demonstration counties includes county c in year t , the value of this year and subsequent years is 1; otherwise, it is 0. $Controls$ denote the control variables for the characteristics of farmers and households, including gender, age, occupational category, education level, health status, whether there is a car, whether there is a village cadre household, cultivated land area, house area, and household size. δ_f and δ_t denote farmer fixed effects and year fixed effects, respectively. ε_{ft} is the error term. Standard error is clustered at the farmer level.

Then, to test the mechanism at the farmer level, we conduct mechanism tests with a similar specification, as follows:

$$M_{ft} = \alpha + \beta \cdot Ecommerce_{ct} + Controls'_{ft} \gamma + \delta_f + \delta_t + \varepsilon_{ft} \quad (3)$$

where M denotes the mechanism variables. It should be noted that the mechanism here only includes the reorganization of factor allocation and the market participation of farmers.

In addition, when verifying the industrial structure optimization mechanism, this paper conducts a similar regression at the village collective dimension, and the specification is constructed as follows:

$$Village_{vt} = \alpha + \beta \cdot Ecommerce_{ct} + Controls'_{vt} \gamma + \delta_v + \delta_t + \varepsilon_{vt} \quad (4)$$

where v denotes village. The dependent variable $Village_{vt}$ represents the number of collective enterprises established, the proportion of the income of the secondary industry and the tertiary industry, and the ratio of the income of the tertiary industry to the secondary industry in village v in year t . Control variables include village per capita disposable income, total population, total expenditure, total assets, and total liabilities; controlling for both village and year fixed effects, standard errors are clustered at the village. It is used to examine the promotion effect of the implementation of e-commerce to the countryside project on rural industrial upgrading and to provide empirical evidence for revealing the internal mechanism of e-commerce to the countryside policy affecting farmers' income and income inequality.

4. Empirical Results

4.1. Baseline Results

The results of the benchmark regression on the impact of e-commerce on rural areas policy to farmers' income and income inequality are shown in Table 2. Columns (1) and (3) do not include control variables, and the e-commerce to the countryside policy significantly increases farm household income and mitigates farm household income inequality. Columns (2) and (4) add control variables to the regression, and the results show that the implementation of e-commerce to the countryside program increases farm household income by 12.2% and reduces farm household income inequality by 2.6%. As the core of China's rural revitalization strategy, the e-commerce to the countryside policy plays an important role in raising the income of rural residents, narrowing the income gap within the countryside, and achieving the goal of common prosperity.

Among the control variables, females and the middle-aged and the elderly inhibit the increase in income, while households with a car and households with a large labor force contribute to the increase in total income; females, the middle-aged and the elderly, and households with a large house size increase income inequality, while households without a car and households with a small labor force alleviate income inequality. In other words, the increase in the number of laborers in the household can increase the total income of the household, but also further aggravate the income inequality. In addition, the house area is positively associated with income inequality, while the relationship with income is not statistically significant. The possible reason is that the larger the house area is, the better the economic foundation of the family is, so the larger the gap between ordinary families and these families is, the higher the income inequality is. But the house area does not directly affect income. This suggests that, to raise the incomes of rural residents and reduce income inequality, policy efforts should be focused on improving the employment and incomes of women and the middle-aged and elderly, precisely empowering vulnerable groups and promoting structural redistribution of wealth to realize synergies between efficiency and equity.

Table 2. Benchmark regression results.

Variable	(1)	(2)	(3)	(4)
	Totincome	Totincome	Inequality	Inequality
Ecommerce	0.122 *** (0.034)	0.122 *** (0.031)	−0.025 *** (0.008)	−0.026 *** (0.008)
Igender		−0.165 ** (0.068)		0.028 * (0.015)
Iage		−0.012 *** (0.002)		0.003 *** (0.000)
Ijob		−0.000 (0.003)		−0.000 (0.001)
Ieduc		−0.004 (0.008)		0.003 (0.002)
Ihealth		−0.022 (0.014)		0.005 (0.004)
Fcar		0.096 *** (0.029)		−0.024 *** (0.007)
Fcadre		0.019 (0.053)		0.002 (0.014)
Farea		0.003 (0.011)		−0.001 (0.002)
Fhouse		−0.018 (0.011)		0.006 * (0.003)
Flabor		0.126 *** (0.010)		−0.034 *** (0.002)
Constant	10.275 *** (0.008)	10.986 *** (0.170)	0.471 *** (0.002)	0.317 *** (0.041)
Farmer FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	13,894	13,894	13,894	13,894
R ²	0.623	0.643	0.653	0.673

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Values in parentheses are standard errors.

4.2. Test of Parallel Trends

In this paper, the event study method is used to test for parallel trends:

$$Income_{ft} = \alpha + \sum_{k=-7}^7 \beta_k Ecommerce_{ct}^k + Controls'_{ft} \gamma + \delta_f + \delta_t + \varepsilon_{ft} \quad (5)$$

where the dummy variable $Ecommerce_{ct}^k$ indicates whether the farmer's county c is in the k years before, the current year, and the k years after being included in the list of demonstration counties. Considering the sample interval, the value range of k is set to $[-7, 7]$, and the year before the farmer's county is included in the list of demonstration counties is used as the base period. The parallel trend hypothesis holds if there is no significant difference in the total household income and income inequality of farmers in demonstration counties (treatment group) relative to farmers in non-demonstration counties (control group) before they were included in the list of demonstration counties.

Estimates of β_k at the 95% significance level are shown in panel (a) of Figure 3. The figure shows the dynamic effects of the e-commerce to rural areas policy on income levels and income inequality, respectively. It can be seen that before the implementation of the "Comprehensive Demonstration of E-commerce in Rural Areas" program, the impact of the policy of e-commerce to the countryside on the total income of farmers and income inequality was not significant, while after the implementation of the policy, the income level of farmers increased significantly, the degree of income inequality decreased significantly, and the effect of the implementation of the policy has gradually increased over time.

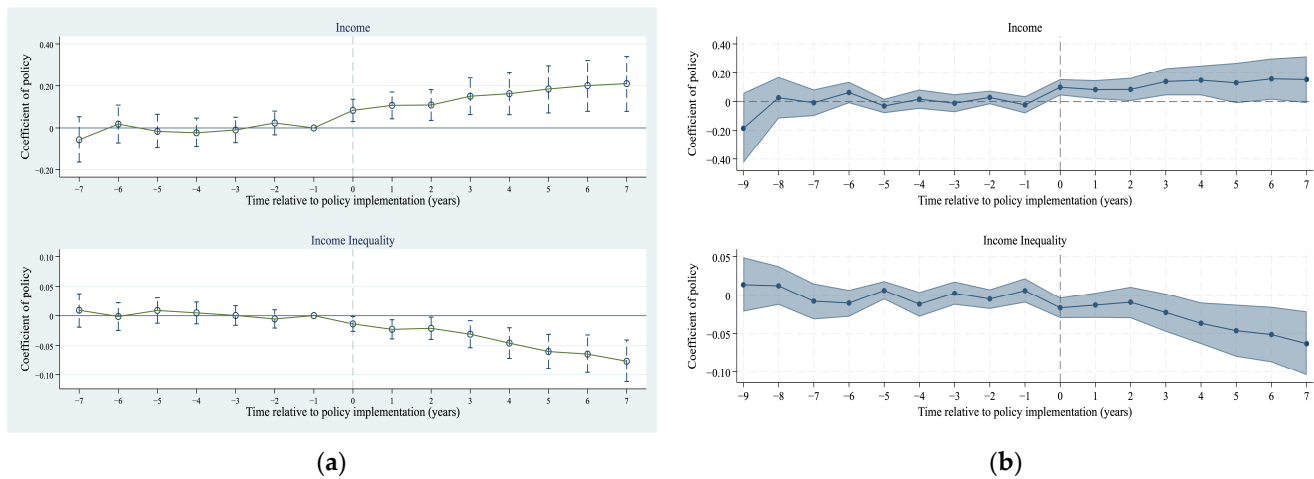


Figure 3. (a) Parallel trend test; (b) heterogeneous DID estimation.

This paper examines heterogeneous treatment effects. The estimation results of the multi-period double-difference method may be biased due to the heterogeneous treatment condition [65]. In this regard, this paper adopts the method proposed by Callaway and Sant’Anna to estimate the treatment effect of the e-commerce to the countryside policy, and the dynamic estimation results are shown in panel (b) of Figure 3. Post-implementation analysis shows significant farm income growth alongside substantial inequality reduction. This demonstrates the digital economy’s role in advancing common prosperity.

4.3. Robustness Test

4.3.1. Replacement of the Dependent Variable

To exclude the interference of household size on the estimation results, the regression is conducted by replacing the total income with the per capita income of the household, and at the same time, the per capita income inequality index is calculated by using the Formula (1), to examine the impact of the e-commerce to the countryside policy on the per capita income of the household and income inequality, and the estimation results are shown in the columns (1) and (2) of Table 3. The results show that the implementation of e-commerce to the countryside policy significantly boosts the per capita income of rural households and suppresses income inequality, confirming the robustness of the benchmark results.

Table 3. Robustness test results.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Replacement of the Dependent Variable		Exclusion of “Broadband China” Policy		Exclusion of “Smart City” Policy	
	Totincome	Inequality	Totincome	Inequality	Totincome	Inequality
Ecommerce	0.115 *** (0.031)	−0.034 *** (0.008)	0.124 *** (0.032)	−0.028 *** (0.008)	0.111 *** (0.031)	−0.022 *** (0.008)
Broadband			−0.015 (0.047)	0.006 (0.012)		
Smartcity					−0.125 *** (0.041)	0.047 *** (0.010)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Farmer FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	13,894	13,894	13,894	13,894	13,894	13,894
R ²	0.506	0.544	0.643	0.673	0.644	0.674

Notes: *** $p < 0.01$. Values in parentheses are standard errors.

4.3.2. Exclusion of Other Policy Effects

Since other policies may affect the income and income inequality of farm households during the sample period, the “Broadband China” demonstration city was implemented in 2014, and the national “smart city” pilot began in 2012. To exclude the influence of omitted variables on the regression results, this paper controls for “Broadband China” and “Smart City” in the benchmark regression, and the regression results are shown in columns (3)–(6) of Table 3. The results show that the benchmark results are still robust after excluding the effects of other policies.

4.3.3. Instrumental Variable

To address potential endogeneity concerns, we employ the topography of the county in which the village is located as an instrumental variable (IV) following Kolko’s methodology [66]. Elevated village topography increases the costs of installing/maintaining network infrastructure, logistics facilities, and e-commerce services, thereby constraining rural e-commerce development and satisfying the relevance condition. As an exogenous geographic characteristic, county topography exerts no causal influence on farmers’ income levels or distribution patterns, fulfilling the exclusion restriction. Table 4 presents the results for the two-stage least squares (2SLS). The first-stage results show that there is a significant negative correlation between village topography and the e-commerce policy in the village, and the second-stage results indicate that the e-commerce policy in the countryside significantly improves the income of farm households and alleviates the income inequality, which is in line with the benchmark results. The value of the Kleibergen-Paap rk Wald F statistic indicates that there is no weak instrumental variable, and the value of the Kleibergen-Paap rk LM statistic indicates that there is no unidentifiable and the instrumental variable is selected reasonably.

Table 4. Instrumental variable results.

Variable	(1)	(2)	(3)
	Ecommerce	Totincome	Inequality
Ecommerce		0.494 *** (0.118)	−0.154 *** (0.029)
IV	−0.151 *** (0.008)		
Controls	Yes	Yes	Yes
Farmer FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	13,894	13,894	13,894
Kleibergen-Paap rk Wald F Statistic		343.692 ***	
Kleibergen-Paap rk LM Statistic		141.266 ***	

Notes: *** $p < 0.01$. Values in parentheses are standard errors.

4.3.4. Placebo Test

Unobservable factors might influence farm household income and income distribution, potentially introducing estimation bias. Specifically, we use a random sampling method; the same number of counties in the sample are randomly selected as the treatment group, and the year of policy implementation is randomly generated to re-estimate the baseline model and the process is repeated 1000 times, and the kernel density plots of the estimated coefficients are obtained as shown in Figure 4. The estimated coefficients of the randomly generated treatment group are distributed around the value of 0, and the true coefficient estimates (dashed line in the figure) are not within the range of this coefficient,

indicating that the regression results in this paper still hold after excluding the influence of unobservable factors.

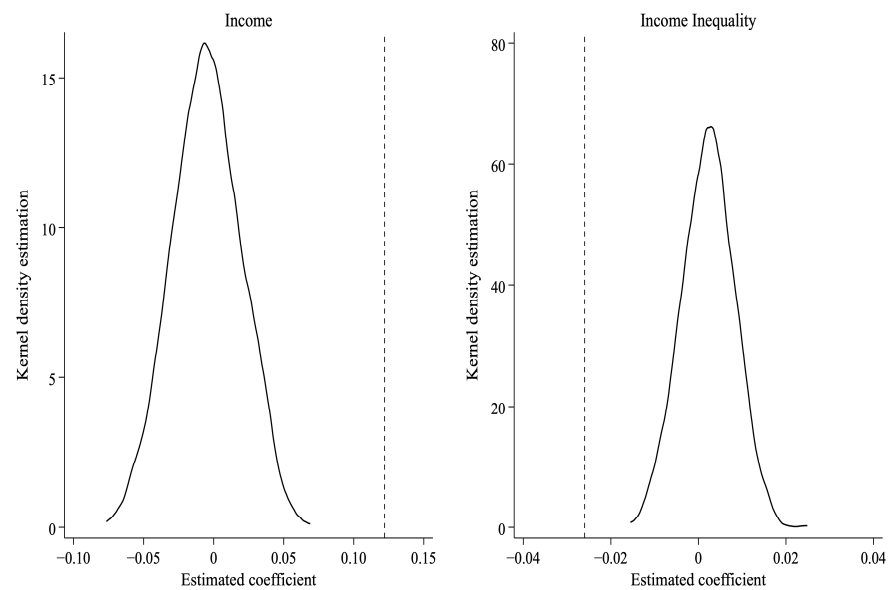


Figure 4. Placebo test. The dashed line represents the baseline regression estimates.

5. Heterogeneous Effects

The e-commerce to the countryside policy helps to increase farm household income and alleviate income inequality, but the impact on farm households with different characteristics may differ. Considering that farmers' capital endowment [67], village characteristics [68], and economic level [69] may affect the implementation effect of the e-commerce policy to the countryside, this paper examines the impact of e-commerce to the countryside policy on farmers with different characteristics from the heterogeneous perspectives of human capital, physical capital, financial capital, agricultural areas, traditional villages, civilized villages at county level and above, economically developed degree, and poverty-stricken villages with documented cards, etc.

5.1. Capital Endowment

5.1.1. Human Capital

Human capital is measured by farmers' education level [70], and farmers with more than 6 years of education are regarded as high human capital and assigned a value of 1, and vice versa, a value of 0. The results of the test for heterogeneity of human capital are shown in columns (1) and (2) of Table 5, which show that for farmers with low human capital, the policy of e-commerce to the countryside has a greater role in boosting incomes, and a greater role in income inequality mitigating effect is also stronger. This is mainly due to the fact that high human capital farmers have already achieved market integration through traditional paths, and the marginal gains from their technology adoption are relatively limited, while low human capital farmers have a larger gap between their original education level and their market participation ability, the e-commerce to the countryside policy significantly reduces the requirement for complex skills through standardized digital tools, which enables the low human capital group to access the modern market at a lower cost of learning [71].

Table 5. Capital endowment heterogeneity.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Totincome	Inequality	Totincome	Inequality	Totincome	Inequality
Ecommerce × Heduc	−0.111 ** (0.051)	0.028 ** (0.013)				
Heduc	−0.086 (0.057)	0.026 * (0.015)				
Ecommerce × Hconsum			−0.178 *** (0.042)	0.021 ** (0.010)		
Hconsum			0.445 *** (0.026)	−0.124 *** (0.005)		
Ecommerce × Hdepo					−0.131 *** (0.048)	0.025 ** (0.013)
Hdepo					0.221 *** (0.027)	−0.071 *** (0.007)
Ecommerce	0.202 *** (0.046)	−0.047 *** (0.012)	0.209 *** (0.036)	−0.034 *** (0.009)	0.138 *** (0.046)	−0.019 (0.012)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Farmer FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	13,894	13,894	13,894	13,894	13,894	13,894
R ²	0.644	0.673	0.668	0.705	0.648	0.682

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Values in parentheses are standard errors.

5.1.2. Physical Capital

Household living consumption expenditure is used to denote the material capital of farm households, which are divided into two groups of high and low material capital based on the median. The order greater than the median is 1, and vice versa is 0. The results of the heterogeneity test of material capital are shown in columns (3) and (4) of Table 5, which show that E-commerce policy plays a greater role in promoting the income of farmers with low physical capital and has a stronger role in alleviating their income inequality. The possible reason is that traditional agricultural production is limited by physical capital endowment [72], and the scarcity of physical resources locks low-material-capital farmers into local inefficient markets, resulting in slow growth of their incomes. In addition, the shared infrastructure of digital platforms greatly reduces the cost threshold for accessing markets [73], which helps low physical capital farmers to access markets, thus alleviating the distributional imbalance caused by differences in resource endowments.

5.1.3. Financial Capital

The financial capital of farm households is measured using household end-of-year deposit balances, and farm households are categorized into two groups of high and low financial capital based on the median, which takes the value of 1 if it is greater than the median and zero otherwise. The results of the financial capital heterogeneity test, as shown in columns (5) and (6) of Table 5, indicate that the promotion effect of the e-commerce policy on the income of low-financial-capital farmers is greater, and the suppression of their income inequality is also stronger. This is because the data-driven credit assessment mechanism breaks through collateral dependence, making it possible for low-financial-capital farmers to access formal financial services. In contrast, high-financial-capital farmers already have traditional financing channels, and the incremental effect of the policy is limited. By reshaping the risk-pricing rules, the e-commerce platform allows the initial financial capital-poor group to obtain super-marginal returns [74], thereby dampening the Matthew effect of wealth accumulation.

5.2. Rural Characteristics

5.2.1. Agricultural Areas

Farmers are categorized according to whether their village belongs to an agricultural area, and if it does, it is assigned a value of 1, and vice versa, it is set to 0. The results of the heterogeneity test for agricultural areas are shown in columns (1) and (2) of Table 6, which show that the e-commerce policy has a greater role in promoting income and mitigating income inequality for farmers located in an agricultural area. As agricultural areas are limited by transportation isolation and information asymmetry and have long been at the low end of the value chain, the e-commerce policy enables decentralized agricultural producers to directly connect to the national market through digital platforms, significantly enhancing transaction efficiency [75]. The policy facilitates factor endowment convergence through improved market integration, generating more equitable income distribution patterns.

Table 6. Rural characteristics heterogeneity.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Totincome	Inequality	Totincome	Inequality	Totincome	Inequality
Ecommerce × Argiarea	−0.206 *** (0.068)	0.054 *** (0.018)				
Argiarea	0.103 *** (0.031)	−0.027 *** (0.008)				
Ecommerce × Conven			−0.185 *** (0.045)	0.048 *** (0.012)		
Conven			0.008 (0.031)	−0.009 (0.007)		
Ecommerce × Civili					−0.202 *** (0.041)	0.051 *** (0.011)
Civili					0.030 (0.029)	−0.009 (0.008)
Ecommerce	0.288 *** (0.062)	−0.070 *** (0.017)	0.164 *** (0.035)	−0.038 *** (0.008)	0.230 *** (0.035)	−0.053 *** (0.009)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Farmer FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	13,894	13,894	13,894	13,894	13,894	13,894
R ²	0.644	0.674	0.644	0.674	0.645	0.674

Notes: *** $p < 0.01$. Values in parentheses are standard errors.

5.2.2. Traditional Villages

Farmers are classified based on whether their village is designated as a traditional village (coded as 1) or not (coded as 0). The results of the heterogeneity test of traditional villages are shown in columns (3) and (4) of Table 6, which show that the e-commerce to the countryside policy has a greater role in promoting the income of farmers in traditional villages and mitigating their income inequality. The possible reason is that traditional villages retain unique products due to cultural heritage but lack commercialization channels, and the e-commerce policy transforms cultural capital into economic premiums through branding narratives and differentiated marketing [76]. Compared to other regions, their product scarcity brings higher value-added, and the collective property rights structure inhibits individual monopoly and superior earnings diffusion, thus reinforcing the dual role of policy on income growth and gap narrowing.

5.2.3. County-Level Civilized Villages

Farmers are categorized based on their village's designation as a county-level civilized village (assigned 1) or otherwise (assigned 0). The county-level civilized village heterogeneity analysis (Table 6, columns (5) and (6)) reveals the e-commerce to the countryside policy's dual efficacy: significantly enhancing farmer incomes and substantially mitigating wealth disparities in these villages. This dual impact arises primarily from (1) enhanced institutional infrastructure characterized by robust grassroots governance, well-developed public services, and streamlined policy execution [77]; (2) denser social networks coupled with elevated communal trust, which minimize transaction costs in digital collaboration. These institutional advantages generate scale economies that simultaneously augment household earnings while suppressing rent-seeking behaviors through community-based governance, achieving synergistic improvements in both economic efficiency and distributive equity.

5.3. Economic Development Level

Economic development and registered poor villages are used to represent the economic level. According to the economically developed degree of residence of farmers' villages in the county (city) level for classification, the samples in the lower middle and lower regions are assigned 1, and the others are assigned 0. According to whether the farmers' villages belong to the poor villages for classification, if they belong to them, then it takes the value of 1, or otherwise 0. The results of the test of heterogeneity of the economic level are shown in Table 7, which shows that the e-commerce to the countryside policy has a greater role in promoting the income of farmers in economically underdeveloped areas and poor villages and has a stronger role in alleviating their income inequality. The possible reason for this is that economically less developed regions and poor villages are limited by geographic location and infrastructure shortcomings, and have long faced the problems of market segmentation and information blockage, and factor mobility is seriously insufficient. The e-commerce to the countryside policy breaks down spatial barriers through digital connectivity, enabling regional products to be directly embedded in the unified national market, significantly reducing cross-regional transaction costs [78], thus promoting income enhancement and common prosperity for farmers.

Table 7. Economic development level heterogeneity.

Variable	(1)	(2)	(3)	(4)
	Totincome	Inequality	Totincome	Inequality
Ecommerce × Needy	0.232 *** (0.055)	−0.072 *** (0.014)		
Needy	−0.128 *** (0.030)	0.033 *** (0.006)		
Ecommerce × Undevel			0.438 *** (0.064)	−0.123 *** (0.017)
Undevel			−0.072 ** (0.031)	0.016 ** (0.006)
Ecommerce	−0.005 (0.052)	0.015 (0.013)	−0.206 *** (0.059)	0.069 *** (0.016)
Controls	Yes	Yes	Yes	Yes
Farmer FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	13,894	13,894	13,894	13,894
R ²	0.645	0.675	0.646	0.676

Notes: ** $p < 0.05$, *** $p < 0.01$. Values in parentheses are standard errors.

6. Mechanisms

According to the theoretical mechanism, the e-commerce to the countryside policy primarily promotes the optimization of industrial structure, the reorganization of factor allocation, and the market participation of rural households, thereby increasing the income of rural residents and alleviating income inequality. Next, we will further explore the path of e-commerce to the countryside in promoting rural household income growth and alleviating income inequality from the perspectives of industrial structure, factor allocation, and market participation.

6.1. Industrial Structure Optimization

6.1.1. Corporate Growth Driver

Enterprise growth is measured by the number of rural collective enterprises established, and the results of the test of the enterprise growth driving mechanism are shown in Column (1) of Table 8. The results show that the e-commerce policy to the countryside has significantly contributed to the growth of rural enterprises, which in turn has provided sufficient impetus for farmers to increase their income and reduce income inequality. The e-commerce to the countryside policy reduces market access thresholds and transaction costs, contributing to a significant increase in the number of rural enterprises. Digital platforms provide standardized access interfaces such as logistics and payment systems, weakening the monopoly power of traditional channels and stimulating local entrepreneurship. At the same time, the policy has guided the transfer of production factors to non-agricultural areas, and the cross-industry reallocation of labor and capital in the e-commerce ecosystem has created diversified non-agricultural employment opportunities for farmers, laying the micro foundation for income growth and distribution optimization.

Table 8. Industrial structure optimization mechanism.

Variable	(1)	(2)	(3)
	Enterprise Growth	Industrial Transformation	Service Upgrade
	Firm	Revshare	Indrate
Ecommerce	0.576 ** (0.243)	0.056 *** (0.010)	0.285 *** (0.084)
Controls	Yes	Yes	Yes
Village FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	224	224	224
R ²	0.388	0.445	0.302

Notes: ** $p < 0.05$, *** $p < 0.01$. Values in parentheses are standard errors.

6.1.2. Industrial Restructuring and Remodeling

Industrial transformation is expressed by the proportion of village collective income from secondary and tertiary industries to total income, and the larger the proportion, the higher the degree of industrial transformation in the village. The results of the industrial transformation reshaping mechanism test are shown in column (2) of Table 8, which shows that the e-commerce to the countryside policy significantly promotes industrial transformation. The e-commerce to the countryside policy promotes the transformation of the industrial structure from the domination of one industry to the synergy of the second and third industries and extends the length of the industrial chain by reconfiguring the agricultural value chain and embedding agricultural production in high-value-added segments, such as processing, logistics, and services. At the same time, the consumer side of the personalized demand forces the production side of the specialized division of

labor, giving rise to deep processing of agricultural products, e-commerce services, and other emerging industries. Changes in industrial structure have stimulated the income-generating potential of the non-agricultural sector and weakened the income gap within traditional agriculture through the homogenized distribution of employment opportunities, thus realizing the compatibility of growth and equity.

6.1.3. Service Upgrade Empowerment

Service upgrading is measured by the ratio of village collective tertiary industry income to secondary industry income, with higher values indicating stronger service-enabling effects from the e-commerce ecosystem. The service-upgrading mechanism analysis in column (3) of Table 8 demonstrates that the rural e-commerce policy significantly enhances service sector development. Digital platforms lower service industry entry barriers through technological spillovers, enabling manufacturing enterprises to expand into service-oriented activities like product design and brand marketing. Additionally, the growing demand for logistics, financial, and data services stimulates capital and labor migration to the tertiary sector. This service expansion both absorbs low-skilled labor for inclusive growth and reduces factor return disparities through knowledge diffusion, creating synergistic linkages between industrial advancement and equitable income distribution.

6.2. Factor Allocation Reorganization

6.2.1. Labor Force Activation

This study measures labor force activation through farm households' participation in nonfarm employment. The rural e-commerce policy facilitates workforce transition from agricultural to higher-productivity nonfarm sectors by reducing informational barriers and skill requirements in non-agricultural labor markets. The results of the labor activation mechanism test are shown in column (1) of Table 9, which shows that e-commerce to the countryside significantly promotes the nonfarm employment of rural laborers, and the diversification of the employment structure reduces the risk of fluctuating agricultural incomes, improves the ability of disadvantaged groups to resist risks, and reduces the degree of income inequality. On the one hand, the digital platform creates new types of jobs, and the precise push based on geo-tagging breaks the spatial restriction of traditional job search and widens the employment choices of farmers; on the other hand, it activates the potential productivity of agricultural laborers and realizes the Pareto improvement of the labor factor by lowering the search cost and the probability of skill mismatch.

Table 9. Factor allocation reorganization mechanism.

Variable	(1)	(2)	(3)	(4)
	Labor Force	Capital Remuneration	Property Rights Reform	
	Nonfarm	Nfarminc	Landout	Landin
Ecommerce	0.195 *** (0.020)	0.048 *** (0.010)	0.138 ** (0.060)	0.324 *** (0.125)
Controls	Yes	Yes	Yes	Yes
Farmer FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	13,894	13,894	13,894	13,894
R ²	0.545	0.421	0.218	0.267

Notes: ** $p < 0.05$, *** $p < 0.01$. Values in parentheses are standard errors.

6.2.2. Capital Remuneration Increased

Capital remuneration is measured by the proportion of non-agricultural income in farmers' total income. The e-commerce to the countryside policy drives structural income transformation through expanded nonfarm employment, optimizing factor income distribution by increasing non-agricultural revenue shares. The results of the test on the mechanism of capital compensation increase are shown in column (2) of Table 9, which shows that e-commerce to the countryside has significantly increased the capital compensation of farm households, and the diversification and stability of income sources have been enhanced, which not only raises the overall income level, but also reduces the income gap within the group by weakening the dependence on a single factor. The adsorption effect of the e-commerce ecosystem on low-skilled labor improves its bargaining power and drives the wage level closer to the market equilibrium value. At the same time, the elasticity of substitution of capital and labor in the non-agricultural sector is lower than that in agriculture, and the rate of return on human capital is relatively stable, weakening the income divergence caused by the difference in land endowment in traditional agriculture.

6.2.3. Property Rights Reform Deepening

Land property rights reform is assessed through the total area of cultivated land transfers (both outflows and inflows) among agricultural households. The larger the area of arable land transferred, the more effective the land property rights reform. The test results of the deepening mechanism of land property right reform are shown in columns (3) and (4) of Table 9. The e-commerce to the countryside policy has significantly contributed to the transfer of arable land out and into the countryside, the intensification of arable land management to improve total factor productivity in agriculture, the welfare of farmers who have transferred out of their land to achieve welfare improvement through the combination of land rent and wage income, and the improvement of land allocation efficiency to reduce the inequality of income due to differences in the scale of operation. The e-commerce policy changes the land factor allocation decision of farming households by raising the expectation of nonfarm income and promoting the transfer of arable land to business entities; the increase in nonfarm employment opportunities raises the opportunity cost of farming, and the transfer of arable land becomes a rational choice.

6.3. Farmers Market Participation

6.3.1. Information Accessibility

Information channel efficacy is assessed through farmers' communication expenditures, with higher expenditure levels indicating stronger information acquisition capacity. The results of the information channel through the mechanism test are shown in Column (1) of Table 10; the e-commerce to the countryside policy significantly broadens farmers' access to information, breaks the information monopoly of the traditional circulation hierarchy, and enables real-time data such as price and demand to reach the producers directly to optimize the accuracy of production decisions. Information transparency weakens the bargaining advantage of intermediaries, and farmers can directly participate in terminal pricing to increase their income share; enhanced information capital narrows the information endowment differences among farmers, eases income differentiation due to information asymmetry, and promotes equalization of market participation opportunities.

Table 10. Farmers market participation mechanism.

Variable	(1)	(2)	(3)
	Information Channel	Social Capital	Technology Adoption
	Inform	Social	Internet
Ecommerce	0.071 *** (0.020)	0.139 *** (0.051)	0.051 *** (0.017)
Controls	Yes	Yes	Yes
Farmer FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	13,894	13,894	13,894
R ²	0.618	0.750	0.594

Notes: *** $p < 0.01$. Values in parentheses are standard errors.

6.3.2. Social Capital Accumulation

Social capital is measured by the gifts and cash expenditures that farmers use to maintain their relationships, with more expenditures generally leading to higher social capital for farmers as well. The results of the social capital accumulation mechanism test are shown in column (2) of Table 10, e-commerce to the countryside significantly increases the social capital accumulation of farmers, and the network effect of social capital reduces the transaction risk and coordination cost so that marginalized farmers can break through the restriction of the traditional geographic relationship and share the economic benefits. The policy of e-commerce to the countryside has reshaped the social capital structure of farmers through the construction of digital transaction networks. The online evaluation system and mutual credit recognition mechanism strengthen the bond of trust and promote cross-regional cooperation in production and marketing, thereby increasing income; cross-regional cooperation in trading increases trading opportunities and enables small farmers to participate in the sale of high-value-added products, thereby narrowing the income gap.

6.3.3. Technology Adoption Acceleration

This study measures technology adoption through farmers' internet access status. The ability to connect enables participation in e-commerce platforms, digital tools, and online training, with this connectivity choice inherently reflecting a willingness to adapt technologically. The results of the technology adoption acceleration mechanism test are shown in Column (3) of Table 10, which shows that e-commerce to the countryside significantly promotes farmers' technology adoption. Technology adoption acceleration promotes farmers' income increases and alleviates income inequality through a dual path. On the one hand, smart tools optimize the efficiency of factor allocation, reduce production costs, and increase the added value of products, thus widening the space for income growth; on the other hand, knowledge sharing and skill diffusion facilitate disadvantaged farmers to realize market reversal through the emerging mode, narrowing the income gap with the monopoly dominant group.

7. Conclusions

Positioned at the intersection of digital transformation and sustainable rural revitalization, this study explores how the e-commerce to the countryside policy innovation can mediate the triple dilemmas faced by farmers in major food-producing provinces in developing countries—promoting rural economic prosperity, increasing farmers' income, and reducing income inequality among farmers. Leveraging longitudinal panel data (2009–2022) from fixed observation points across Henan's agricultural heartland, we employ a staggered difference-in-differences (DID) design to empirically assess the dual

impacts of China's Rural E-Commerce Promotion Policy on household income dynamics and wealth distribution patterns. The robust evidence reveals the following points: first, the e-commerce to the countryside policy significantly increases farmers' income and alleviates income inequality, which still holds after robustness tests such as instrumental variables, replacement of the dependent variable, exclusion of other policy factors, heterogeneity of the staggered DID, and placebo test.

Second, the policy operates through three primary pathways: industrial structure optimization, factor allocation restructuring, and enhanced farmer market engagement. Regarding industrial structure optimization, the policy stimulates rural enterprise growth, drives industrial transformation, and accelerates service upgrading, collectively contributing to household income growth while mitigating income disparity. Through factor allocation restructuring, it enhances labor mobility, optimizes capital returns, and institutionalizes property rights reforms, thereby improving income levels and reducing inequality. By facilitating farmer market participation, the initiative expands information access, strengthens social capital accumulation, and modernizes technology adoption, ultimately generating equitable income growth.

Third, capital endowment heterogeneity finds that the income-generating effect of the e-commerce to the countryside policy is greater for farm households with low human capital, low physical capital, and low financial capital, and the mitigating effect on their income inequality is stronger; regarding rural characteristics, the policy displays heightened efficacy in agricultural zones, traditional villages, and county-level civilized villages, where both income gains and inequality reduction are statistically more substantial. Concerning economic development levels, the policy's effectiveness peaks in economically disadvantaged regions and poverty-stricken villages, achieving dual outcomes of amplified income growth and intensified inequality mitigation.

Limited by data availability, we investigate the impact of rural e-commerce policy on farmers' income and income inequality, mainly for Henan Province. In addition, since the data used come from the rural survey, there may be problems such as response bias and measurement error, which may affect the regression results, and some data cannot be obtained due to the limitations of the questionnaire. In addition, the staggered DID approach relies on the parallel trend assumption, and the rural e-commerce policy is gradually implemented at different times and in different regions, which may lead to differences between the treatment and control groups at multiple points in time, thus affecting the accuracy of the estimation results.

The following policy implications are proposed in response to the findings of the study. First, deepen the integration of digital technology and traditional agriculture, and build a synergistic path to promote rural revitalization and common prosperity. According to the baseline regression results, the rural e-commerce policy can significantly increase farmers' income and alleviate income inequality. Therefore, we provide suggestions from the perspective of digital technology and agricultural integration. Through the construction of a big data platform for agricultural products in the whole region, the intelligent matching channel between land rights information, weather monitoring data, and e-commerce demand preferences has been opened, to realize the precise allocation of production factors and the value-added increasing of the industrial chain. Focus on supporting the "e-commerce plus cooperatives plus farmers" joint model, relying on digital platforms to integrate fragmented production capacity, and cultivate standardized, branded agricultural clusters with regional characteristics.

Second, focusing on three core mechanisms to build a synergistic driving framework of "industry-factors-market". The results of mechanism tests show that the rural e-commerce policy improves farmers' income and alleviates income inequality by promoting indus-

trial structure optimization, the reorganization of factor allocation, and farmers' market participation, so we provide suggestions from three aspects. About industrial structure optimization, the government should guide e-commerce enterprises to nest deeply with the rural industrial chain through tax incentives, and promote the "digital and real integration" to give rise to a new type of service industry; in the field of reorganization of factor allocation, innovate the mode of digitized pledge of land management rights, and establish a property rights trading platform for the two-way flow of factors in urban and rural areas. In the area of market participation mechanism construction, strengthen the function of village-level e-commerce service centers, and systematically break the multi-dimensional constraints of small farmers docking to the big market.

Third, implement differentiated support strategies to amplify the targeting effect of policy implementation. The results of the heterogeneity analysis show that the rural e-commerce policy has greater income-enhancing benefits and stronger disincentives to income inequality for low capital endowment farmers, those with distinct rural characteristics, and those in less developed regions; therefore, specific recommendations are made to address the heterogeneity, for low human capital groups to establish a "skills certification-job matching-revenue sharing" support mechanism, and for weak material capital farmers to provide standardized e-commerce equipment leasing services. In terms of spatial layout, priority is given to the construction of county e-commerce distribution centers in traditional agricultural areas, and the extension of the logistics network breaks the effect of geographic spatial division. The less economically developed regions will innovate the mode of industrial combination, transforming the digital dividend into a combination of ecological resources, cultural assets, and other endowment advantages.

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Appendix A

Table A1. Variable definitions.

Variables Type	Variable Meaning	Variable	Definition
Independent Variable	Rural	Ecommerce	Whether the farmer's county is an e-commerce demonstration county: yes = 1, no = 0
Dependent Variable	E-Commerce	Totincome	The logarithm of total annual household income plus one is taken
	Total Revenue	Inequality	The relative deprivation index of income calculated based on the Kakwani index
	Income Inequality		

Table A1. Cont.

Variables Type	Variable Meaning	Variable	Definition
Control Variable	Gender	Igender	Gender of farmer: 1. male, 2. female
	Age	Iage	Age of the farmer
	Profession	Ijob	The main industry of farmer: 1. agriculture, forestry, animal husbandry, and fishery, 2. mining, 3. manufacturing, 4. electricity, gas, and water production and supply, 5. construction, 6. transportation, storage, and postal services, 7. wholesale and retail trade, 8. accommodation and catering, 9. renting and business services, 10. residential and other services, 11. others
	Education	Ieduc	The number of years of education of farmer
	Health Status	Ihealth	Farmers' self-identified health status: 1. excellent, 2. good, 3. moderate, 4. poor, 5. incapacitated
	Automobile	Fcar	Whether the household owns a car: yes = 1, no = 0
	Cadre	Fcadre	Whether the family member is a village cadre: yes = 1, no = 0
	Cropland Area	Farea	Household cultivated area plus 1 to take the logarithm (acres)
	House Area	Fhouse	Logarithm of the living space of the family-owned house (square meters)
	Family Size	Flabor	Number of family labor force
	Per Capita Income	Aveinc	Logarithm of the village collective per capita disposable income (yuan)
	Total Population	Popular	Logarithm of the household registration population of the village collective at the end of the year
	Total Expenditure	Totexp	Logarithm of total village collective expenditures (yuan)
	Total Assets	Asset	Logarithm of total village collective assets (yuan)
	Total Liability	Debt	Logarithm of total village collective liabilities (yuan)
	Firm Number	Firm	Number of collective enterprises established in the village during the year
	Industrial Transformation	Revshare	Income from secondary and tertiary sectors as a proportion of total income
	Service Upgrade	Indrate	Ratio of tertiary to secondary sector income
	Nonfarm Employment	Nonfarm	Participation in nonfarm employment: yes = 1, no = 0
Mechanism Variable	Nonfarm Income	Nfarminc	Non-farm income as a proportion of total income
	Farmland Transferred Out	Landout	Cropland transferred out during the year plus 1 to take the logarithm (mu)
	Farmland Transferred In	Landin	Cropland transferred in during the year plus 1 to take the logarithm (mu)
	Information Capital	Inform	Communications expenditure plus 1 to take the logarithm
	Social Capital	Social	The gifts or cash expenditures used to maintain the relationship plus 1 to take the logarithm
	Technology Adoption	Internet	Internet access: yes = 1, no = 0

Table A1. Cont.

Variables Type	Variable Meaning	Variable	Definition
Heterogeneity Variable	Human Capital	Heduc	Whether the farmer has more than 6 years of education: yes = 1, no = 0
	Physical Capital	Hconsum	Whether the household living consumption expenditure is more than the median: yes = 1, no = 0
	Financial Capital	Hdepo	Whether the household's year-end savings balance is more than the median: yes = 1, no = 0
	Agricultural Area	Argiarea	Whether the village where the farmer is located belongs to the agricultural area: yes = 1, no = 0
	Traditional Village	Conven	Whether the village where the farmer is located belongs to a traditional village: yes = 1, no = 0
	Civilized Village	Civili	Whether the village where the farmer is located belongs to a civilized village at the county level or above: yes = 1, no = 0
	Poor Village	Needy	Whether the village where the farmer is located belongs to the registered poor village: yes = 1, no = 0
	Economic Level	Undevel	Whether the degree of economic development of the village is lower than the middle level of the county (city): yes = 1, no = 0

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