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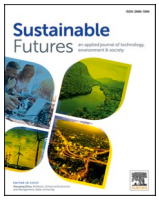

Digital divide, agricultural supply chain finance, and the urban-rural income gap in China

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ABSTRACT

The growing income disparity between urban and rural regions poses a major challenge to China's economic development. Addressing the persistent urban-rural income gap (URIG) is essential for sustaining the country's current economic momentum. This study investigates how agricultural supply chain finance (ASCF) shapes the distribution of income across urban and rural populations and examines the extent to which the digital divide, a prominent feature of the digital era, influences this interaction, thereby exacerbating income inequalities. This analysis is crucial for identifying barriers to rural revitalization and fostering equitable prosperity among Chinese farmers. Utilizing dynamic panel data collected from provincial-level observations between 2014 and 2020, the research finds that ASCF contributes to achieving a more balanced income distribution between urban and rural areas. However, the results indicate that the digital divide weakens ASCF's effectiveness in narrowing the URIG. A mediating analysis highlights that ASCF mitigates income inequality through two primary pathways: advancing urbanization and enhancing non-agricultural employment opportunities, thereby promoting integrated development across regions. This paper offers valuable theoretical insights and actionable policy recommendations for advancing urbanization, achieving inclusive digital growth, bridging the digital divide, revitalizing rural economies, and fostering shared prosperity for farmers.

1. Introduction

Achieving common prosperity is a fundamental element of socialism with Chinese characteristics, serving as both a guiding principle for establishing a moderately prosperous society and a critical milestone in advancing comprehensive socialist modernization. Ensuring balanced urban-rural development is vital to realizing this goal, as the significant disparity in income reflects the uneven progress between these areas [1]. Data from 2023 reveal that the per capital disposable income of urban residents was 51,821 yuan, in contrast to 21,691 yuan for rural residents, yielding an income ratio of 2.39. This figure represents a slight reduction of 0.06 compared to the previous year. These findings demonstrate that while the URIG is narrowing, it remains considerable. Equitable income distribution across urban and rural populations plays a pivotal role in achieving high-quality development and unlocking the potential of domestic demand, particularly as China's economy faces mounting downward pressure [2]. Consequently, addressing the urban-rural income gap (URIG) and advancing common prosperity has become both a pressing challenge and a critical social goal. Reducing this gap hinges on strengthening the agricultural sector and rural economy [3]. However, agricultural production is subject to numerous uncertainties, such as environmental variability, while small and micro agricultural enterprises encounter barriers including inadequate information, poor credit ratings, limited access to capital markets, and insufficient collateral assets [4]. As a result, financing difficulties have emerged as a significant bottleneck hampering agribusiness development, leading to mismatches in the supply and demand of rural financial services and their structural balance.

Agricultural supply chain finance (ASCF), a vital financial innovation within rural finance, has partially mitigated the financing constraints faced by agriculture-related SMEs. With advancements in agricultural modernization and digital transformation, ASCF has experienced rapid growth, encompassing various aspects of agricultural production, processing, and distribution [5]. By introducing diverse financial entities, such as commercial banks and cooperative financial institutions, ASCF has addressed deficiencies in the rural financial market, providing an

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array of tailored financial products and services to agriculture-related enterprises [6,7]. Additionally, financial support from ASCF has facilitated the adoption of advanced agricultural technologies and production equipment, enabling an increase in production scale and enhancing the quality of agricultural products [8]. This progress helps farmers achieve higher market prices and greater income. The integration of ASCF with the digital economy has become a critical approach to narrowing the URIG. However, while the digital economy serves as a key enabler for the growth of ASCF, the persistent digital divide has emerged as a significant obstacle to its further development [9]. Based on the Statistical Report on China's Internet Network Development, as of 2023, approximately 317 million individuals, accounting for 22.5 % of the country's population, were non-internet users, with the majority residing in rural areas. Limited resources and inadequate digital skills among these populations hinder the adoption of agricultural technology and financial services in rural regions, thereby constraining the overall progress of ASCF.

Existing research on the link between financial development and the URIG predominantly examines the mechanisms and dynamic interactions tied to digital inclusive finance. Zhang et al. [10] contend that the widespread implementation of digital inclusive finance can contribute to narrowing the URIG, though its effectiveness exhibits regional disparities and follows a trend of diminishing marginal returns [11,12]. ASCF shares similarities with inclusive finance and precision poverty alleviation, as participation in such financial systems enables poorer households to achieve higher incomes [13]. Nevertheless, the effectiveness of different ASCF types in alleviating poverty varies due to discrepancies in poverty classifications and the financial strategies designed for farmers [14]. Despite this, limited attention has been given to directly examining the role of ASCF in reducing the URIG. In particular, within the context of the digital era, further exploration is needed to understand how ASCF reduces this gap and the conditions under which it is most effective. Addressing this gap provides a meaningful foundation for the present study.

The contributions of this study are summarized as follows. Firstly, it examines the role of ASCF in addressing the URIG, expanding the theoretical framework of ASCF. Furthermore, it provides empirical evidence demonstrating its impact on poverty reduction, while deepening the understanding of factors shaping the URIG. Secondly, this research delves into the mechanisms through which ASCF affects the URIG, highlighting the pathways that connect supply chain finance to income disparities. This analysis clarifies previously ambiguous links between ASCF and income inequality, offering strategic insights into revitalizing rural economies and enhancing farmers' livelihoods. Thirdly, the study investigates the influence of the digital divide in shaping the relationship between ASCF and the URIG within the digital era. By systematically incorporating the digital divide into the governance framework of supply chain finance, the research broadens the scope of its implications. The findings offer actionable recommendations for policymakers to implement targeted measures aimed at reducing regional digital disparities and ensuring that ASCF effectively contributes to narrowing the URIG.

2. Theoretical analysis and proposal of hypotheses

2.1. The impact of ASCF on the URIG

ASCF refers to a framework that delivers capital support and financial services for agricultural production and operations through collaboration among financial institutions, agricultural enterprises, and related entities [15]. As an innovative model of agricultural finance, ASCF plays a pivotal role in promoting rural urbanization and creating non-farm employment opportunities, ultimately helping to narrow the income disparity between urban and rural areas.

Firstly, ASCF not only alleviates the financial constraints faced by agricultural enterprises but also accelerates rural infrastructure development, fostering rural urbanization. It offers diverse financing modes, including order financing, inventory financing, and accounts receivable financing [16], which flexibly address the varying financial requirements of agricultural stakeholders. For example, upstream suppliers utilize accounts receivable financing to ease financial burdens from credit sales, while core agribusinesses rely on inventory-based financing to meet low inventory and high liquidity needs. Downstream distributors, in contrast, apply prepayment or sales order financing to mitigate financial pressures related to prepayment [17,18]. By tightly linking the upstream and downstream segments of the agricultural value chain, ASCF fosters industrial connectivity and resource interoperability, optimizes resource allocation, enhances financial institutions' agricultural support, and drives agricultural industrialization and broader rural revitalization. However, the effectiveness of ASCF in mitigating rural financial constraints is fundamentally shaped by the local financial ecosystem. According to financial ecosystem theory, the institutional environment, including the credit system, regulatory framework, and market infrastructure, critically influences the accessibility and efficiency of financial services [19]. In rural China, underdeveloped credit information systems and decentralized financial regulation pose systemic barriers. For instance, the absence of a comprehensive rural credit registry exacerbates information asymmetries, compelling rural credit union participants to rely primarily on the creditworthiness of the core enterprise rather than standardized risk assessments [20]. Similarly, regulatory discrepancies between rural and urban areas, such as inconsistent collateral identification and loan approval procedures, increase transaction costs and constrain the scalability of ASCFs [21]. Furthermore, the infusion of significant capital enables farmers to acquire advanced agricultural equipment and technologies, improving production efficiency and advancing agricultural modernization [22,23]. However, due to the fragmented distribution of rural economic agents and the limited financial needs in these regions, the cost for formal financial institutions to serve rural areas often exceeds that of urban regions [24]. According to financial intermediation theory, reducing transaction costs is critical for the sustainable development of financial institutions [25]. Internal financing within ASCF provides loans to farmers, minimizes transaction costs, and fulfills the capital demands of rural production and operations [26]. This financing mechanism also boosts rural consumption and upgrades consumption patterns, laying a robust economic foundation for rural urbanization. Additionally, it enhances rural infrastructure, such as transportation and communication, significantly improving the quality of life in these areas [27]. As rural urbanization progresses, rural residents gain more opportunities to engage in urban economic activities, thereby raising their income and consumption levels [28]. The growing investment in rural social capital has emerged as a critical driver of rural economic development, providing both financial resources and momentum to reduce the URIG.

Secondly, ASCF has significantly contributed to extending and diversifying the agricultural value chain through a variety of tailored financial services, thereby creating more opportunities for rural non-farm employment. Drawing on transaction cost theory, ASCF offers financial assistance via the core enterprise's initiatives, which support less advantaged entities within the supply chain. This approach enhances these entities' creditworthiness and bargaining power, fosters equitable and reciprocal partnerships along the supply chain, and drives the overall positive development of the agricultural value chain [29]. Nevertheless, the fragmented rural financial ecosystem complicates value chain integration. Disparities in regional financial regulation, for example, may hinder cross-jurisdictional financing agreements, while inadequate digital infrastructure limits the adoption of fintech solutions critical for ASCF efficiency. Financial ecosystem theory underscores those systemic improvements, such as interoperable regulatory standards and investments in rural fintech, are vital to unlocking ASCF's full potential in value chain diversification and employment generation [30]. Consequently, ASCF facilitates financial backing for various actors

across the upstream and downstream segments of the agricultural value chain, encouraging diversified advancements in agricultural production, processing, transportation, sales, and related activities [31]. This, in turn, generates additional non-farming employment opportunities. Moreover, financial support enables agriculture-related enterprises and rural SMEs to enhance R&D capabilities, achieve cost reductions, improve efficiency across different segments [32], and elevate employee welfare. These developments attract more skilled workers to rural areas, further incentivizing farmers to engage in non-farm economic activities. This expansion increases the scale of rural non-farm employment while promoting the rural economy's diversified and sustainable growth. In the context of rural urbanization, the emergence of new industries and services creates additional employment opportunities and entrepreneurial platforms for farmers [33]. Non-farm employment absorbs a large share of surplus rural labor, alleviates employment pressures in rural areas [34], and facilitates the restructuring and diversification of rural economic activities, contributing to increased prosperity for rural communities and improved farmers' incomes. Furthermore, the growth of non-farm employment strengthens farmers' social security coverage, enhances their overall quality of life, and raises their social security standards [35], effectively narrowing the social security gap between urban and rural areas. The expansion of these employment opportunities plays a pivotal role in mitigating the URIG.

Finally, urbanization serves as a catalyst for non-agricultural employment by fostering industrial clustering and facilitating skill spillovers. For instance, ASCF-facilitated investments in rural infrastructure, such as agro-processing clusters and cold-chain logistics centers, contribute to the formation of localized economic ecosystems. Conversely, non-farm employment reinforces urbanization through income–consumption feedback loops and the return migration of human capital. Rising incomes from rural non-farm employment stimulate local consumption and generate demand for business services and urban amenities. Thus, urbanization establishes the structural conditions for non-farm employment, while non-farm income, in turn, sustains and reinforces the process of urbanization. Based on these findings, this paper proposes hypothesis 1:

H1: ASCF mitigates the URIG by fostering urbanization and facilitating non- agriculture employment.

2.2. The moderating role of the digital divide

The digital transformation of financial services has emerged as a crucial focus of recent research, with technological advancements bringing new innovations to supply chain finance (SCF) models. However, significant disparities persist in digital infrastructure across China's provinces, as Internet technology deployment varies asynchronously between regions [36]. The southeast coastal region of China, significantly shaped by the Internet boom, manifests a pattern of regional disparities aligned with industrialization trends since the 1980s [37]. Initially, regional disparities in digital infrastructure, such as unequal internet penetration and uneven access to smart devices, create asymmetric information flows between ASCF participants [38]. Rural farmers and SMEs lacking digital connectivity cannot contribute real-time data to blockchain-based ASCF platforms, forcing financial institutions to rely on outdated proxies like land ownership records for credit assessments. Furthermore, low digital adoption raises operational costs across the ASCF value chain. Manual processes increase administrative overheads, incentivizing lenders to prioritize urban clients. Meanwhile, inefficiencies and opacity in China's financial markets hinder regions from achieving Pareto efficiency in financial resource allocation [39]. According to the theory of equal opportunity, the digital divide not only creates unequal access to digital technologies for residents but also exacerbates income inequality, thereby destabilizing economic and societal development [40]. This issue is particularly acute in rural areas, where financial disincentives, driven by limited access to digital technology, reach up to 70.92 % [41]. Finally, even when rural actors gain digital access, disparities in usage skills and data quality trigger algorithmic bias and exclusion. This exclusion reduces data generation from marginalized groups, further eroding their visibility in ASCF system. These dynamics create a self-reinforcing cycle: information asymmetry and high transaction costs limit rural access to ASCF capital; algorithmic biases compound exclusion; and resource misallocation suppresses rural productivity. Consequently, digitally marginalized regions are less likely to be affected by ASCF, which in turn leads to a widening income gap between rural and urban areas. Accordingly, the following hypotheses are proposed:

H2: The digital divide weakens the effectiveness of ASCF in reducing the URIG.

3. Research design

3.1. Data source

Considering data availability and consistency, prefectures with missing data were excluded. Initially, 312 prefecture-level administrative units were identified from the National Bureau of Statistics' regional division codes. After applying exclusion criteria, removing regions with (1) incomplete ASCF participation records (>30 % missing years), (2) extreme outliers in urban-rural income ratios (>3 SD from mean), and (3) administrative boundary changes during 2011–2021, 42 prefectures (13.5 % of the initial sample) were excluded. The final dataset comprises 270 prefectures as empirical samples. To assess whether excluded prefectures systematically differed from the retained sample, we conducted *t*-tests comparing key variables. Results indicated no statistically significant differences. The primary data sources include the *China Statistical Yearbook, China Population and Employment Statistical Yearbook*, and *China Urban Statistical Yearbook* (2011–2021). These datasets were accessed through the China Economic and Social Development Statistical Database and the Wind Database, among other platforms. To address missing values, a linear interpolation method was primarily applied for non-critical variables with sporadic gaps. However, for key variables, multiple imputation methods were employed to ensure robustness. Following Stavseth et al. [42], we generated five imputed datasets using chained equations, incorporating auxiliary variables to preserve relationships among variables. The results from imputed datasets were pooled and compared with linear interpolation outcomes, confirming no statistically significant differences ($p > 0.10$), thereby validating data integrity. The final empirical sample spans the years 2011–2021, comprising a total of 2668 observations. Furthermore, to account for the effects of inflation in the regression analyses, all monetary indicators were adjusted using 2011 as the base year.

3.2. Model construction

To evaluate hypothesis H1, this study utilizes a panel linear regression model (1) for validation. To verify hypothesis 2, Model 2 is constructed

$$Gap_{it} = a_0 + a_1 sndk_{it} + \sum \text{Control} + \sum City + \sum Year + \varepsilon \quad (1)$$

$$Gap_{it} = b_0 + b_1 sndk_{it} + b_2 Digital + b_3 Digital * sndk_{it} + \sum \text{Control} + \sum City + \sum Year + \varepsilon \quad (2)$$

3.3. Variable definition

3.3.1. Dependent variable

Variation in URIG (Gap). Metrics for evaluating income disparities encompass the Gini coefficient, the Theil index, and the ratio of urban to rural disposable incomes. The urban-rural income ratio, while

straightforward, suffers from two critical limitations. First, it neglects population weighting. Second, it fails to capture inequality within urban or rural subgroups, potentially underestimating disparities in areas with heterogeneous intra-group income distribution. The Gini coefficient, though widely adopted, measures overall inequality across an entire population rather than specifically isolating urban-rural divergence. Its decomposition into between-group (urban-rural) and within-group components is mathematically feasible but requires restrictive assumptions about income distributions, often leading to unstable estimates in empirical applications. This obscures the distinction between general income inequality and URIG, particularly in developing economies where urban-rural disparities dominate national inequality profiles. While the Gini coefficient provides a broad measure of income inequality by categorizing the population into various income levels, it does not specifically address the URIG. Moreover, the distinction between general income inequality and the URIG often remains unclear. Therefore, this study selects the Theil index as the primary indicator to quantify the dependent variable of the URIG, using the following calculation formula.

$$GAP_{it} = \sum_{2}^{i=1} \left(\frac{Y_{it}}{Y_t}\right) * Ln\left[\left(\frac{Y_{it}}{Y_t}\right)\left(\frac{X_{it}}{X_t}\right)\right]$$

3.3.2. Core explanatory variable

ASCF (Sndk). Farmers' hesitation to engage with agricultural loans and various financial services stems primarily from informational asymmetries in formal financial institutions, compounded by their insufficient collateral and poor credit standing. In practice, most agricultural financing is routed through localized financial entities, including rural credit unions and small-scale rural banks. As a result, the volume of agricultural loan balances within financial institutions is widely regarded as a metric to evaluate the level of rural financial development in a specific region. Referencing Gelsomino et al. [6], this research utilizes agricultural loan balances as a representative proxy for assessing ASCF across different areas.

3.3.3. Adjusting variables

This paper draws on the study by Cruz-Jesus et al. [43], which uses the average years of education ratio between urban and rural labor forces as an indicator to reflect the digital skill usage gap between urban and rural regions. Theoretically, higher levels of educational attainment are associated with greater human capital, which enhances the likelihood of developing advanced internet skills. In China's labor market, specific preferences for academic qualifications and professional certifications play a crucial role in hiring practices, title evaluations, and labor allocation. Hence, the education level of employees is strongly linked to their professional expertise and technical capabilities.

3.3.4. Control variable

Drawing from Feng et al. [44], this research incorporates the following control variables:

Transportation Development (Traffic): Regions with advanced transportation systems typically achieve higher income levels due to enhanced economic integration. Conversely, areas lacking adequate transportation infrastructure tend to experience slower economic growth and lower income levels.

Government Support for Agriculture (Gov supports): Increased governmental investment in agriculture serves as a crucial driver for stimulating rural economic growth and promoting income equality between urban and rural populations.

Industrial Structure (Insratio): Improvements in industrial structure contribute significantly to overall economic development and are instrumental in mitigating income inequality between urban and rural areas.

Per Capita Real Gross Domestic Product (Gdp): Higher levels of economic development, as reflected in per capita income, are strongly associated with reduced urban-rural income disparities, underscoring the role of economic growth in income balancing.

Total Agricultural Machinery Power (Agriculture): This metric reflects the degree of rural productivity. Elevated values indicate more advanced agricultural development, which helps raise income levels for rural households while reducing income inequality. Furthermore, literature highlights that factors like economic openness [45] and government spending preferences (Gov bias) [46] can significantly affect the URIG.

The specific control variables are summarized in Table 1.

3.4. Descriptive statistics

Table 2 provides the descriptive statistical analysis. The Gini coefficient reveals significant disparities in the average, median, and maximum values of the URIG across China, highlighting pronounced income inequality in specific regions. Furthermore, a substantial disparity is observed in the development of ASCF among provinces.

4. Empirical validation and results analysis

4.1. Baseline return and adjustment effect

Table 3 provides a comprehensive summary of the core regression results and moderation effect tests. The analysis integrates Ordinary Least Squares (OLS) mixed regression, Random Effects (RE), and Fixed Effects (FE) models, presented in columns (1) to (3), with column (4) detailing findings from the moderation analysis.

In the FE specification (Column 3), a one-unit increase in ASCF development reduces the URIG (Gap) by 0.002 units. Translating this into economic terms: given the mean URIG value of 0.35 (Theil index), a standard deviation increase in ASCF would lower the income gap by 8.6 %, roughly equivalent to raising annual rural household income by ¥3840. The results demonstrate that ASCF substantially reduces the URIG, highlighting its efficiency in bridging income inequality between urban and rural areas. Furthermore, control variables consistently show a significant negative correlation between per capita real GDP and the

Table 1
Variable declaration.

Variable name	Symbol	Indicators and units	Unit
Rural-Urban Income Disparity	Gap	Theil index	%
Agricultural loan balance	Sndk	Balance of agricultural loans	Billion
Digital Divide	Digital	The ratio of average years of education for urban and rural labor force	%
Traffic	Traffic	Highway mileage per unit provincial area	Km
Total power of agricultural machinery	Agriculture	Total power of agricultural machinery	Kw
Per capita real GDP	Gdp	Per capita actual GDP per unit	Yuan
Open	Open	The proportion of foreign investment imports and exports to GDP	%
Government's lean towards expenditures	Gov bias	The proportion of regional fiscal expenditure to GDP	%
Rural financial support expenditure	Gov supports	The proportion of fiscal agricultural expenditure to total fiscal expenditure	%
Industrial structure	Insratio	The proportion of the output value of the tertiary industry to the total output value	%

Table 2
Descriptive statistics.

Variable	N	Mean	Median	Sd	Max	Min
Gap	2668	2.357	6.390	0.542	11.78	0.537
Sndk	2668	4.250	4.380	0.877	5.990	2.150
Digital	2668	1.340	1.310	0.108	1.680	1.170
Traffic	2668	1.050	0.978	0.726	3.890	0.068
Agriculture	2668	7.640	7.840	1.140	9.370	4.630
Gdp	2668	6.320	6.240	0.404	7.360	5.580
Open	2668	0.097	0.048	0.138	0.699	0.000
Gov bias	2668	0.290	0.239	0.210	1.330	0.121
Gov supports	2668	0.118	0.118	0.035	0.190	0.043
Insratio	2668	0.906	0.910	0.050	0.997	0.767

URIG across all columns, reflecting a stabilizing effect on income distribution during regional economic development. Similarly, the degree of foreign investment openness exhibits a notable negative correlation, suggesting that inflows of foreign capital do not exacerbate the existing URIG. Instead, foreign investment serves as a crucial source of funding for small and medium-sized enterprises, driving demand for rural labor and increasing non-farm employment opportunities. This progression enhances rural incomes by raising wages and reducing the share of low-income individuals. Additionally, the strong negative influence of government financial support for agriculture emphasizes its pivotal role in reducing the URIG, corroborating prior studies. However, the combined impact of agricultural mechanization, fiscal imbalances, and industrial structure adjustments on the income gap is minimal. This finding may stem from the ongoing shift from primary to secondary and tertiary sectors, alongside constraints in domestic agricultural output. Consequently, the validation of H1 is achieved.

This study also examines how the digital divide moderates the influence of ASCF on urban-rural income distribution, as detailed in column (4). The moderation analysis indicates that the impact of ASCF on URIG is consistent with the initial hypothesis, with a statistically significant coefficient of −0.191 at the 1 % level. The positive significance of the interaction term between ASCF and the digital divide. The interaction term Sndk*Digital reveals that the URIG-reducing effect of ASCF diminishes by 0.004 units for each incremental disparity in digital access. In practical terms: prefectures with internet penetration below 60 % experience 32 % weaker ASCF impacts compared to high-access regions. Closing this gap could amplify ASCF's annual poverty reduction effect by ¥2100 per rural household. It suggests that the digital divide undermines the effectiveness of ASCF in reducing the URIG. These findings validate hypothesis 2.

Moreover, the analysis of individual moderating factors shows a significant negative effect, with a coefficient of 0.006 at the 5 % significance level. This suggests that disparities in the use and transformation of internet resources into economic capital, across demographic and regional divides, intensify structural inequalities, referred to as "digital dividends." Such widening gaps negatively impact overall economic performance by exacerbating inefficiencies in resource allocation and creating financial anomalies, thereby deepening structural disparities in urban-rural economic development and expanding the URIG. Hence, this study highlights the urgent need to bridge the internet accessibility gap caused by regional differences in digital infrastructure, while simultaneously promoting ASCF and digitalization. Enhancing the infusion of internet capital in rural areas, converting digital resources into productive assets, and extending digital opportunities to rural communities are vital measures to achieve equitable income distribution and foster shared prosperity. These conclusions further reinforce the validity of hypothesis 2.

4.2. Robustness testing

The dynamic panel data model in this study addresses potential endogeneity concerns stemming from reverse causality. Specifically, reducing the URIG may stimulate regional economic expansion, which in turn enhances ASCF. To reinforce foundational regression findings, this paper employs a lagged variable approach, the two-stage least squares (2SLS) technique, and the one-step system generalized method of moments (GMM). Results are presented in Table 4. Guided by the Hausman test, the study employs the fixed effects (FE) model with a

Table 3
Benchmark regression and moderation effect results.

Variable	(1) OLS	(2) RE	(3) FE	(4) Moderating effect(*fe*)	(5) DID
Sndk	−0.004***	−0.003**	−0.002***	−0.002***	
	(−17.732)	(−16.845)	(−13.745)	(−4.826)	
Sndk(did)					−0.002***
					(−3.244)
Gdp	−0.364***	−0.218**	−0.241**	−0.258**	−0.236**
	(−4.473)	(−2.352)	(−2.164)	(−1.997)	(−1.972)
Open	−1.038***	−1.188***	−0.999***	−0.968***	−0.863***
	(−9.643)	(−6.739)	(−5.382)	(−4.322)	(−4.826)
Traffic	−0.064	−0.015	0.117	0.114	0.104
	(−1.424)	(−1.284)	(0.844)	(0.725)	(0.713)
Agriculture	0.077	0.043	−0.015	−0.026	−0.024
	(0.077)	(0.046)	(0.058)	(0.059)	(0.053)
Gov bias	0.331	0.758	0.131	0.096	0.104
	(0.523)	(0.534)	(0.550)	(0.525)	(0.516)
Gov supports	−1.706***	−1.504***	−1.784***	−1.861***	−1.846***
	(−9.251)	(−8.446)	(−7.833)	(−6.926)	(−6.519)
Insratio	0.678	0.257	−0.161	−0.119	−0.112
	(0.707)	(0.659)	(−0.823)	(−0.851)	(−0.827)
Digital				0.006**	0.005**
				(2.284)	(2.184)
Sndk*Digital				0.004**	0.003**
				(2.044)	(1.983)
Constant	3.841***	3.129***	4.366***	3.638***	3.518***
	(16.492)	(8.492)	(6.492)	(5.294)	(5.926)
Year	No	Yes	Yes	Yes	Yes
City	No	No	Yes	Yes	Yes
N	2668	2668	2668	2668	2668
R^2	0.307	0.219	0.258	0.229	0.265

Notes: The parentheses represent standard errors, the same below.

lagged variable approach, demonstrating consistency with foundational hypotheses. By lagging ASCF variables by one period, we mitigate contemporaneous feedback from URIG reduction to ASCF development. This design assumes that current URIG levels cannot retroactively influence past ASCF maturity: A plausible assumption given the institutional inertia of rural financial systems [47]. Additionally, the 2SLS strategy explicitly targets reverse causality by selecting instruments orthogonal to URIG. In selecting instrumental variables (IVs) for the two-stage least squares (2SLS) approach, following prior research [48], a two-category, five-dimensional indicator system was constructed by weighting "agricultural industrialization level" and "rural financial development level" (as detailed in Table 5). This composite system serves as the IV for ASCF in the empirical analysis. To further strengthen the exogeneity of instruments, we incorporate exogenous regional agricultural policy shocks into the IV framework. Drawing on quasi-experimental designs, we identify a policy reform: National Agricultural Financial Reform Pilot Zones (NAFRPZ). A 2016 policy designating several prefectures as experimental zones for ASCF-linked innovations (e.g., collateral expansion for agri-loans). We code this as a time-varying dummy (1 for pilot zones post-2016, 0 otherwise). This policy instruments satisfy exclusion restrictions, as their implementation timing and intensity were determined centrally or provincially, orthogonal to prefecture-level economic conditions. The augmented IV set significantly improves first-stage explanatory power. The one-step system GMM estimator accounts for dynamic endogeneity by using lagged differences as instruments for level equation. Re-Estimating the Baseline Model Using the 2011–2018 Sample Period: Addressing Potential Structural Shocks of the COVID-19 Pandemic on ASCF and URIG.

The methodology for index construction and the entropy method for calculating index weights are detailed in Table 5. The first-stage F value of 30.07 (Table 4, Column 2) confirms the instrument's robustness, meeting relevance and exogeneity criteria. Results exhibit a significantly negative correlation, aligning with initial hypotheses. The system GMM is preferred for addressing endogeneity due to reciprocal causality, with the one-step system GMM proving more efficient for smaller datasets compared to its two-step counterpart. Column (3) verifies primary hypotheses, with an R^2 value of 0.304 indicating no autocorrelation, thus confirming robustness. The coefficient of sndk in Column (4) is statistically significant at the 1 % level, suggesting that the pandemic shock has not systematically distorted the operational mechanism through which ASCF affects URIG.

Table 4
Robustness test results.

	(1) Lagging Indicator	(2) IV-2SLS	(3) SYS-GMM (one step)	(4) Excluding the COVID-19 Pandemic Period
L.sndk	−0.242*** (−4.853)		−0.266*** (−3.853)	
IV.sndk		−0.149** (−2.274)		
sndk				−0.143*** (−9.372)
NAFRPA		0.572* (1.872)		
Control variable	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
Constant	3.903*** (5.293)	4.721*** (4.162)	2.791** (2.548)	3.174*** (7.285)
F value	26.44	28.87(first stage)	—-	—
Control variable	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes
R^2	—	—	0.304	0.238
N	2668	2668	2668	1764

Notes: The parentheses represent standard errors.

4.3. Mediation effect test

To explore how ASCF impacts urban-rural income distribution, this study examines the mediating roles of urbanization (Urban) and non-agricultural employment (Fnjy), employing a conventional three-step analytical approach. The findings, detailed in Table 6, are summarized as follows:

Column (1) quantifies the overall effect of ASCF, with a coefficient of −0.285, statistically significant at the 1 % level. Column (2) assesses ASCF's direct influence on urbanization, reflected by a coefficient of 0.018 (significant at the 1 % level). Column (3) highlights the mediating role of urbanization, with a coefficient of −0.236 (also significant at the 1 % level), underscoring ASCF's role in promoting urbanization and narrowing the URIG. To verify these findings, the Sobel test was conducted, producing consistently significant outcomes. Additionally, the Goodman-1 (Aroian) test yielded a value of −0.049 (significant at the 1 % level), demonstrating partial mediation and revealing that 17.34 % of the total effect is mediated by urbanization. By lagging ASCF variables by one period, we mitigate contempora of transportation infrastructure upgrades (8–12 %) in similar contexts [49]. Such comparisons suggest that urbanization serves as a more potent channel for ASCF's income-equalizing effects than physical infrastructure. ASCF is tailored to alleviate the financial pressures of farmers and SMEs in agriculture, mitigating rural financial constraints. By enabling smoother capital flows within the supply chain, ASCF supports enterprise development, enhances the economic value of marginal land, accelerates urbanization, and improves farmers' income levels.

In Table 6, Column (5) presents the effect of ASCF on non-agricultural employment, with a coefficient of 0.068 (significant at the 1 % level). Column (6) highlights the mediating role of non-agricultural employment, confirming ASCF's role in boosting rural non-agricultural employment and its dampening effect on the URIG. The Sobel test supports this mediating role, consistent with urbanization-related findings. Non-agricultural employment is identified as a partial mediator, with a Goodman-1 (Aroian) value of −0.04 (significant at the 1 % level), contributing to 13.96 % of the total mediating effect. While this figure is slightly lower than the mediating effect of urbanization, it exceeds the impact of rural land reform (9–11 %) in Vietnam's post-Đổi Mới era [50]. This demonstrates that ASCF's employment effects are superior to those of traditional structural reforms. Job creation remains vital for sustaining livelihoods, as income from non-agricultural employment plays a critical role in narrowing the URIG. Therefore, it is imperative for the government to adopt measures that enhance rural non-agricultural employment opportunities while ensuring the efficient utilization of ASCF. This strategy should focus on providing additional startup credit to farmers and small rural businesses, thereby encouraging entrepreneurship. Such initiatives can effectively narrow the income divide and promote balanced economic growth between urban and rural areas.

5. Tests of policy effects

The implementation of ASCF is intrinsically linked to policy formulation and execution. ASCF establishes a financial supply network connecting core enterprises with upstream and downstream entities by integrating logistics, capital, and information flows. This aligns with inclusive financial policies aimed at supporting the real economy and achieving policy objectives. In 2018, China released the Public Notice on the Evaluation Results of National Supply Chain Innovation and Application Pilot Cities and Enterprises, marking the transition of supply chain finance policies into a substantive implementation phase. To further examine the impact of ASCF on the URIG, this study uses financial inclusion policy as a proxy variable for ASCF and applies the difference-in-differences (DID) model to test their relationship. Prior to

Table 5
Specific content of indicator construction.

Category	Dimension	Indicator construction	Unit	Nature
Agricultural industrialization level	Mechanization level	Per capita total power of agricul-tural machinery	KW	P
		Per capita electricity consumption in rural areas	KWH	P
	Intensification level	Per capita agricultural gross domestic product	Million	P
		Industrial agglomeration degree	%	P
	Scale level	Per capita crop sowing area	Hm^2	P
		Per capita fixed assets investment in agriculture	Million	P
Rural financial development level	Financing level	The ratio of loan balance of rural financial institutions to the output value of the primary industry	%	P
		Annual per capita loans of rural financial institutions	Million	P
	Penetration level	Number of business outlets of rural financial institutions per 10,000 hectares	—	P
		Number of rural financial institution branches per 10,000 people	—	P

Table 6
Testing the mediation effect of urbanization and non-agricultural employment.

	(1)Gap	(2)City	(3)Gap	(4)Gap	(5)Fnjy	(6)Gap
Sndk	−0.285***	0.018***	−0.236***	−0.285***	0.068***	−0.245***
	(−4.824)	(0.327)	(−3.448)	(−3.291)	(3.196)	(−2.944)
Urban			−0.799***			−0.587***
			(−4.408)			(−3.472)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes
City	Yes	Yes	Yes	Yes	Yes	Yes
Constant	3.064***	0.311***	3.932***	3.062***	0.527*	3.371***
	(5.483)	(4.274)	(4.193)	(3.271)	(1.792)	(3.194)
R^2	0.384	0.347	0.412	0.364	0.402	0.435
Sobel test			−0.049***			−0.040***
			(−3.722)			(−4.024)
(Goodman-1 Aroian)		Yes			Yes	
Is there a mediating effect		Partial			Complete	
Partial or complete Proportion		17.34 %			13.96 %	
N	2668	2668	2668	2668	2668	2668

Notes: The parentheses represent standard errors.

employing the DID model, a parallel trends test must be conducted to ensure that the intervention and control groups exhibit similar paths of change before and after policy implementation. To enhance the reliability of the findings, this paper constructs an econometric model by employing the event study approach for parallel trend testing and dynamic effect estimation [51,52].

$$Gap_{it} = a_0 + \sum_{k=-5}^{k=5} \alpha_k DID_{it}^k + \sum \text{Control} + \sum \text{City} + \sum Year + \varepsilon \quad (3)$$

Based on the results shown in Fig. 1, before the policy implementation, the regression coefficients are insignificant and near zero, indicating that the treatment and control groups satisfy the parallel trend assumption. After the policy implementation, initial effects are muted, likely due to institutional inertia in rural financial systems. The regression coefficients begin to show a downward trend starting from the second year and eventually become significantly negative. This indicates that ASCF positively influences the reduction of the URIG. Its effects demonstrating increasing marginal returns over time. It also suggests that ASCF's impact amplifies as rural financial ecosystems

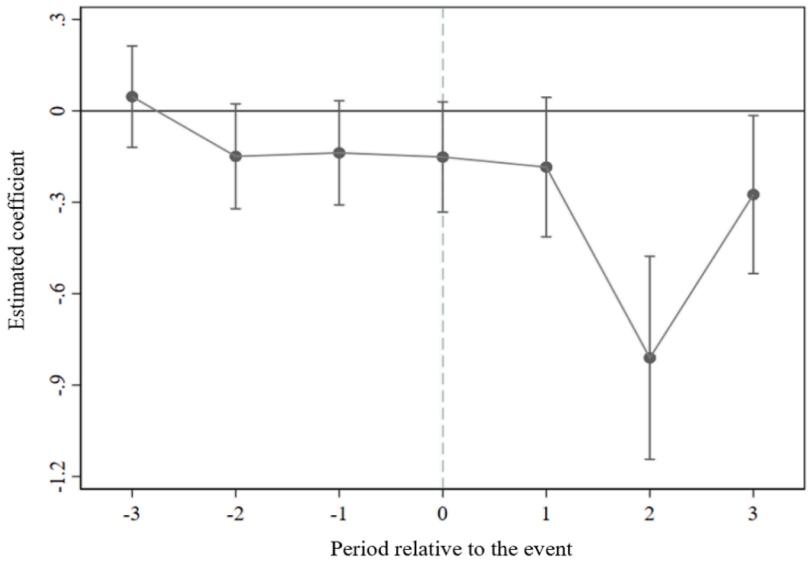

Fig. 1. Parallel trend test result.

mature. Having established the parallel trend assumption, this paper replaces Model 1′s explanatory variable with a dummy for inclusive finance policy and re-runs the regression. Baseline results are summarized in Table 5. Column 5 of Table 5 shows that, after controlling for year and city fixed effects, the estimated coefficient for ASCF is significantly positive at the 1 % level, further corroborating its positive role in reducing the URIG.

To verify the stability of the findings, this paper employs a randomization-based experiment following the methodology of Calderon et al. [53]. In this approach, the randomized allocation determines sample firms and the timing of policy implementation, forming the treatment group for the experiment. Subsequently, 500 regression analyses are conducted to compare the treatment and control groups, simulating the random effects of policy implementation, as illustrated in Fig. 2. The estimated coefficients of the spurious difference-in-differences term are largely centered around zero, exhibiting Gaussian distribution characteristics and indicating no significant omitted variable bias concerns. These results confirm that the narrowing of the URIG is indeed attributable to the implementation of SCF, and the core conclusion remains robust.

6. Research findings and insights

This study provides a comprehensive empirical analysis of how ASCF affects URIG, based on macro-dynamic panel data spanning 2014 to 2020. The findings are summarized as follows:

(1) Initial regression results indicate that ASCF significantly reduces the URIG, thereby promoting shared prosperity across these areas;
(2) Mediation analysis demonstrates that ASCF contributes to reducing the URIG by enhancing urbanization and facilitating the transition to non-agricultural employment;
(3) Interaction effect analyses show that regional disparities in internet access, manifesting as a digital divide, hinder ASCF's ability to equitably distribute income between urban and rural regions.

While this study advances understanding of ASCF-URIG linkages, two limitations warrant attention. First, despite employing 2SLS with instrumental variables, unobserved confounders, such as informal financial networks or cultural attitudes toward debt, may bias estimates. Second, the digital divide proxy (internet penetration) overlooks qualitative dimensions like data privacy concerns or algorithmic discrimination in rural fintech. Future research should prioritize two directions: (1) Integration of geospatial data and machine learning to map real-time interactions between digital infrastructure upgrades and URIG dynamics; (2) Cross-country comparative studies, particularly in Global South contexts, to assess the generalizability of China's ASCF model under divergent institutional regimes.

Based on these insights, several policy recommendations are proposed:

Firstly, sustained support is essential to advancing ASCF, especially considering significant regional disparities in its development across provinces and cities. In eastern regions, where industrial agglomerations are well-established, market-driven refinements should be prioritized through public-private partnerships (PPPs). For instance, corporate tax reductions and streamlined cross-provincial regulatory approvals could incentivize private sector participation. Conversely, in central-western regions, subsidy-driven growth mechanisms are critical. Tiered fiscal subsidies, such as 30 % interest rate subsidies for ASCF loans in low-industrialization prefectures versus 15 % in moderately developed areas, coupled with 5-year tax exemptions for rural SMEs participating in ASCF networks, would address systemic gaps. To mitigate financial risks, provincial ASCF guarantee funds should be established, alongside interregional coordination mandating eastern provinces to allocate 2 % of annual ASCF profits to cross-regional infrastructure projects in central-western regions, supervised by the Ministry of Agriculture. The complex nature of agricultural supply chains and diverse stakeholder interests underscores the necessity for integrating supply chain functions with financial services. Establishing a mutually beneficial ecosystem is paramount, requiring government interventions, financial incentives, and strategic actions to foster equitable regional development.

Secondly, accelerating the establishment of digital finance systems in underdeveloped areas is imperative. The current disparities in China's digital development widen the gap within the dual economic structure of urban and rural regions. Enhancing rural digital infrastructure and promoting the adoption of digital technology in financial services are critical. For example, in the eastern regions, allocate 30 % of provincial digital budgets to subsidize telecom firms (e.g., China Telecom) for last-mile fiber optic deployment in townships, targeting 95 % 5 G coverage by 2025. In the central-western regions, partner with China's LEO satellite program to provide subsidized broadband in remote areas, prioritizing 1000 townships by 2025.

Furthermore, Governments should prioritize improving rural

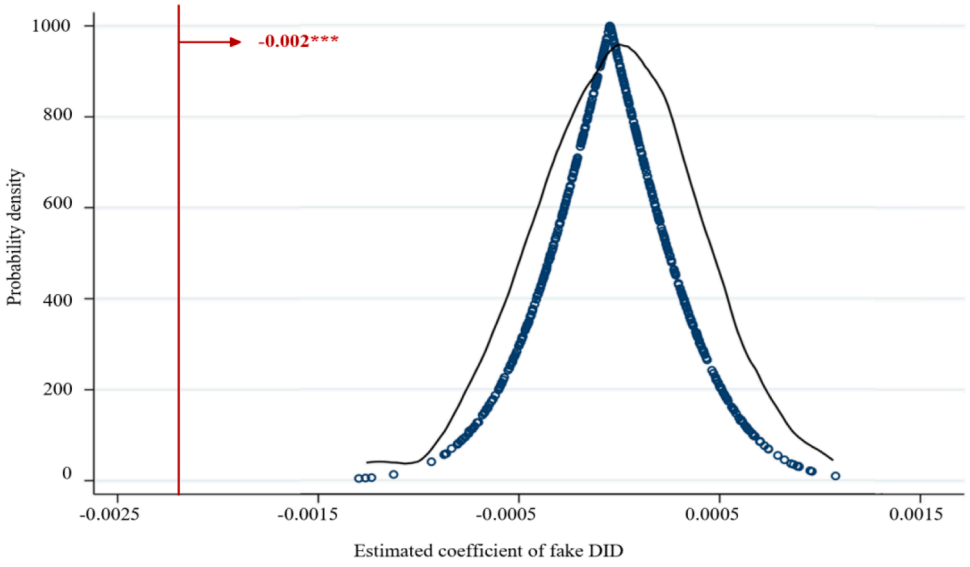

Fig. 2. Placebo test result.

residents' digital competencies, creating access to market information, and leveraging digital tools to stimulate inclusive financial growth and entrepreneurial opportunities in rural areas. For example, A structured three-tiered digital literacy framework should be implemented nationwide. Farmers could enroll in 6-month modular courses via mobile apps, covering e-commerce operations and digital payment tools, with completion certificates linked to microloan eligibility. Rural SME owners would benefit from mandatory annual fintech workshops on supply chain ERP systems and blockchain-based credit scoring, co-hosted local universities and tech firms. Concurrently, village cadres should undergo train-the-trainer programs focused on digital policy implementation and ASCF platform troubleshooting. Progress must be tracked through quantifiable KPIs, such as 45 % farmer participation in digital training by 2026 and a 35 % increase in rural online transactions, with annual third-party audits by institutions like the China Academy of Information and Communications Technology.

CRediT authorship contribution statement

Songqin Ye: Writing – original draft, Conceptualization. **Anpeng Tu:** Writing – original draft, Data curation. **Yongling Ye:** Writing – review & editing, Formal analysis. **Feimei Liao:** Methodology, Funding acquisition.

Declaration of competing interest

The authors declare that they have no conflict of interest. The research was conducted without any financial or personal relationships that could inappropriately influence or bias the work presented.

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Data availability

Data will be made available on request.

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