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Original Paper

Digital Infrastructure and Increasing Farmers' Income: A Quasi-Natural Experiment Based on the "Broadband China" Strategy

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Abstract
Digital infrastructure serves as a significant catalyst for economic advancement, capable of narrowing the digital gap that exists between urban, rural, and regional areas. And it enables more people to enjoy the convenience brought by digitalization, and promote social inclusion and equality. This study employs the "Broadband China" strategy as a quasi-natural experiment and employs a progressive Difference-in-Differences (DID) model to investigate the effects of digital infrastructure on increasing farmers' income. The findings of the study indicate that the development of digital infrastructure can assist in increasing farmers' income. The establishment of digital infrastructure has greatly facilitated industrial rationalization, non-agricultural employment and human capital improvement in rural areas, provided farmers with more business opportunities and employment options, and contributed to the realization of rural revitalization and common prosperity. This research provides empirical support to gain a more profound insight into the significance of digital advancement to rural economic growth, and also provides a useful reference for relevant policy formulation.

Keywords
digital infrastructure, farmers' income increase, digital economy, common prosperity

1. Introduction

Since the initiation of reform and opening-up policies, the rural economy in China has experienced growing continuously, and the quality of life of farmers has significantly improved. Farmers' income growth has achieved "double super" growth in eight years, outperforming both economic growth and urban residents' income growth. However, it should be noted that the issue of uneven and insufficient progress in rural areas is still prominent. According to data, in 2013, the per capita disposable income of households within the top 20% income bracket of rural residents was 7.41 times that of the low-income 20% group. In 2022, it will increase to 9.17 times, an expansion of 1.76 times.

The digital economy, as a novel economic model distinct from traditional ones, embodies traits such as high innovation, extensive penetration, and broad reach. It has the capacity to lower economic expenses, encompassing both production and transaction costs, while also fostering knowledge dissemination. The creation and spread of information and ideas play a significant role in amplifying rural surplus value, diluting regional characteristics, and promoting the flow of factors. The development of digital infrastructure has significantly facilitated the cross-regional movement of material resources, labor, and data, permitting individuals across various economic and social sectors and geographic locations to enjoy universal digital dividends, and has an important impact on residents' income.

This paper will empirically investigate the impact of digital infrastructure on increasing household income. This article focuses on rural areas, utilizes the external influence of the "Broadband China" policy as a surrogate indicator for the progress of digital infrastructure, uses CFPS data , and employs an advanced DID model to empirically examine the effect and mechanism of digital infrastructure on farmers' income.

The notable contribution of this article primarily lies in two aspects: From a research standpoint, it investigates the influence and mechanisms of digital infrastructure on farmers' income. The discussion on this issue stems from the present state of income disparity between rural areas in China, the development goal of common prosperity, and the economic background of the booming digital economy. This article tells the story of increasing farmers' income in the digital age, supplements the analysis of the influencing factors of increasing farmers' income based on the economic development characteristics of this stage, and broadens the scope of research regarding the economic ramifications of digital infrastructure, which holds crucial theoretical and practical relevance. At the policy level, this article provides strong theoretical and empirical support for the government and decision-making departments to further use digital infrastructure construction to increase farmers' income and achieve Chinese-style modernization and common prosperity.

2. Literature review

2.1 Factors Influencing Farmers' Income Increase

Agricultural operating income and wage income are important components of farmers' income. Scholars have explored the factors influencing farmers' income increase from the perspectives of finance, technology, industry, and policy. Specifically, Xiuping and his colleagues believe that digital inclusive finance can elevate farmers' income levels and exert a more pronounced effect on augmenting the income of low-income farmers. (Xiuping et al., 2023); Samuel and his colleagues believe that farmers engaged in collective marketing experienced advantages such as enhanced production and improved sales. (Samuel et al., 2023); Vincent utilizes the PSM method to investigate the causal relationship between improved dairy feed, milk income, and poverty rates. The findings indicate that the adoption of enhanced feed technology led to an income boost and a decrease in poverty among dairy farmers in the research area. (Vincent, 2024); Liangjun Peng and his colleagues have found that farmers can boost their earnings by vending agricultural products through live streaming sales platforms. (Liangjun et al., 2021); Ke Xu and his colleagues have explored the impact of participating in Ecological Public Welfare Positions (PEPWP) on the income structure of farmers' families, and the results show that PEPWP can significantly increase farmers' wages (Xu et al., 2023).

From the above research, it can be seen that most of the current literature mainly regards the rational allocation of factors and industrial integration as important factors affecting farmers' income, while studying the infrastructure that affects the economic and social environment, especially the digital infrastructure that represents the characteristics of the development stage, has an important impact on farmers' income. There is little literature on the impact of increasing income, which is not conducive to understanding the role of the overall economic and technological environment of society in increasing farmers' income. In the digital era, the digital economy has emerged as a fresh impetus for economic growth. Ignoring the effect of digital facilities on rural households is not conducive to scientific understanding of the characteristics and facts of the new development stage and its social welfare effects, which is not conducive to the formulation and implementation of targeted reform and development measures to achieve common prosperity and promote rural revitalization.

2.2 Economic Effects of Digital Infrastructure

The second category of literature comprises studies focuses on the economic effects of digital facilities. Judging from existing research, researching the economic impacts of the digital economy mainly focuses on the macro and micro levels. From a macro level, Czernich and his colleagues prove the promotion effect of Internet development on economic growth (Czernich et al., 2011). Qi Zhang and his colleagues found that in the digital media environment, the process of digital industrialization and industrial digitization notably enhances the economic growth efficiency of Chinese cities (Zhang et al., 2024). Xueqin Deng and his colleagues utilized a spatial panel model to examine the spatial spill-over impact on rural revitalization. The research results showed that this effect is very significant and has heterogeneous and nonlinear characteristics (Deng et al., 2024). Harris' research points out that the Internet can improve the efficiency of factor allocation by reducing economic costs such as production and transactions and promoting the generation and dissemination of knowledge and information (Harris, 1998). From a micro level, Jiaqi Han's research shows that digital applications can significantly improve the economic situation of households by enhancing the technical capabilities of family members. For every unit increase in digital application level, The household per capita net income is expected to rise by 0.427 units, while the relative poverty incidence rate is anticipated to decline by 0.421 units (Han et al., 2023). Changming Cheng and his colleagues used the instrumental variable method and PSM method to empirically investigate the causal link between the beneficial influence of digital skills on farmers' agricultural entrepreneurship. For each incremental enhancement in digital skills, there is an associated rise of 1.10 percentage points in the likelihood of farmers engaging in agricultural entrepreneurship (Changming et al., 2024). Using probit and IPWRA models, Monica and his colleagues found that agricultural digitalization improves smallholder farmers' livelihood assets (tangible, financial, human and natural capital) and livelihood outcomes (Monica et al., 2024) Zhongwei Chen and his colleagues empirically tested the influence of digital literacy on individual income levels and earnings gaps based on data from the 2018 China Family Panel Study (CFPS). The findings indicated that digital literacy can substantially enhance an individual's overall income level and mitigate internal disparities in personal income (Zhongwei et al., 2024).

It can be seen that existing literatures primarily concentrate on examining the influence of digital infrastructure on macroeconomic efficiency and farmers' livelihood levels, and there are few studies focusing on the effect of rural development and farmers' earnings levels. Therefore, this article enriches the analytical perspective of the study on farmers' income status from the micro level, and improves the depth of analysis of the study on agricultural and rural farmers' problems. Studying the this problem is important for understanding the impact of digital economy era on farmers' income, and furnishes a foundation for governmental to further develop digital infrastructure, promote rural revitalization, and promote common prosperity.

3. Introduction to Empirical Models and Data

3.1 Baseline Model

On August 17, 2013, Chinese Government unveiled the strategic implementation plan for "Broadband China" to outline objectives and strategies for broadband development. It aims to encourage the building and expansion of broadband network infrastructure to support the comprehensive development of the digital economy and society. The core goals of this policy are to expand broadband network coverage, improve network speed and service quality, promote the widespread application of IT, and promote the vigorous development of the digital economy (Hong et al., 2023). This policy has achieved certain results, further improving network speed and connection quality, improving network coverage in urban and rural settings, and accelerating the speed and efficiency of information transmission. It promotes the popularization and speed of broadband networks in rural areas and helps narrow the urban-rural digital divide (Niu et al., 2022). It provides a platform for industrial upgrading and innovation, facilitates the growth of emerging sectors like rural e-commerce. agricultural product sales, and rural tourism, and promotes the diversification and growth of the rural economy. It has promoted the upgrading and modernization of rural industries. The marketing and production management of agricultural products have been improved through Internet technology, improving agricultural production efficiency and product quality (Bosworth et al., 2023). Therefore, the "Broadband China" strategy has advanced the enhancement of rural digital infrastructure, and it serves as a quasi-natural experiment for examining the influence of digital infrastructure on increasing farmers' income.

Using the pilot cities designated under the "Broadband China" policy as the treatment group and the rest as the control group, we construct the following progressive DID model to ascertain the causal impact of digital infrastructure on boosting farmers' income:

$$\text{lnindinc\_net}_{it} = \alpha_1 + \beta_1 Broadband_{it} + \theta_{it}\beta + \delta_i + \tau_i + \varepsilon_{it}\# \quad (1)$$

The variable that depends on other factors is lnindinc_net_{it}, defined as the per capita net income of household in year t. is the DID item that this article focuses on. is a control variable at the household and city levels. δ_i and τ_i are household and time fixed effects respectively. is a random disturbance term. Since individuals may not actually use the Internet even if they are located in the pilot city, β_1 represents an intention-to-treat effect and will not overestimate the true effect.

3.2 Data Introduction

This article mainly uses data from both macro and micro aspects. See Table 1 for the statistical summaries of the primary variables.

Table 1. Descriptive Statistics of Main Variables

	Variable	Mean	Standard deviation	Minimum value	Maximum value	Observations
Explained variable	Household net income per capita (take the logarithm)	9.17	1.12	-0.18	15.24	115058
Core explanatory variables	"Broadband China" pilot (yes=1)	0.26	0.44	0	1	118110
Family level control variables	Family size	4.53	1.92	1	15	117900
	Family support burden	0.35	0.46	0	7	117900
City level control variables	GDP per capita (take the logarithm)	10.56	0.66	8.58	12.07	117712
	Regional GDP growth rate	7.56	21.20	-530	109	117861
	Local general public budget revenue	4357118	1.28e+07	13765	7.11e+07	117356
	Local general public budget	5398728	1.45e+07	24375	8.35e+07	117356

Macroscopic data mainly includes digital infrastructure development status, city-level control variables, etc. The data concerning the external influence of the "Broadband China" policy, acting as a proxy for digital infrastructure development, is sourced from the Ministry of Industry and Information Technology of China. The control variables at the provincial and municipal levels come from the China Urban Statistical Yearbook data. The individual-level data is obtained from the China Family Panel Studies (CFPS). The important variable relevant to this article is household net income per capita.

4. Digital Infrastructure and Increasing Farmers' Income

4.1 Baseline Regression

Table 2 presents the baseline regression outcomes utilizing model (1) for estimation. This study employs a multidimensional panel fixed effects model for regression analysis, with standard errors clustered at the city level. All regressions incorporate individual fixed effects and time fixed effects to eliminate factors that remain constant across individuals or time periods from influencing the coefficient estimates of the primary explanatory variables. In Column (1), the influence of digital infrastructure on farmers' income is depicted while solely accounting for individual and time fixed effects. It is evident that digital infrastructure has a significant impact on farmers' income at the 95 % level. Whether a city becomes a "Broadband China" pilot may be affected by the city's economic conditions and other characteristics, and family size and family support burden (proportion of family members aged 6 and under and 60 and over) significantly affect the earnings of rural households. Column (2) of Table 2 controls variables at the household level, and Column (3) of Table 2 controls variables at the municipal levels. From the regression findings in Column (2) of Table 2 and Column (3) of Table 2, it is evident that the DID coefficient, indicative of digital infrastructure development, continues to notably contribute to the rise in farmers' income. Digital infrastructure has increased the income of farmers in pilot areas by an average of 6.88 %. The findings of this article show that digital infrastructure can significantly promote farmers' income increase and highlight the importance of digital infrastructure in broadening farmers' income channels.

Table 2. Digital Infrastructure and Increasing Farmers' Income: Return to Baseline

Variable	lnindinc_net		
	(1)	(2)	(3)
Broadband	0.0821**	0.0837**	0.0688*
	(0.0393)	(0.0402)	(0.0403)
Household level control variables	no	yes	yes
Urban level control variables	no	no	yes
Household fixed effects	yes	yes	yes

Time fixed effects	yes	yes	yes
Observations	115058	115058	113894
Adj. R^2	0.5212	0.5228	0.5215

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.2 Endogeneity Analysis: Parallel Trend Test

To verify that the impact of digital infrastructure is not due to systematic disparities between the treatment and control groups prior to the policy implementation, Figure 1 conducts a parallel trend test. It can be seen that there is no systematic difference in the first five periods of policy implementation. However, in the current period and the last five periods of policy implementation, farmers in the treatment group have a higher probability of increasing their income, confirming the parallel trend hypothesis.

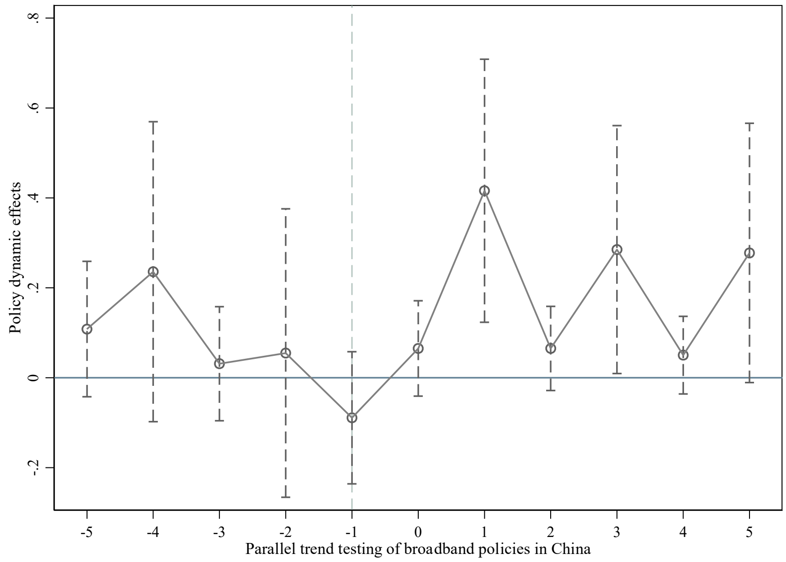

Figure 1. Parallel Trend Test

4.3 Placebo Test

4.3.1 Randomly Advance the Implementation Time of China's Broadband Policy

Assuming that the regions that implement the Broadband China policy remain unchanged, if in reality region *i* implements the Broadband China strategy in year *t* , then any year is randomly selected from the time range of [2010, t-1] as the time for region *i* to implement Broadband China. , based on which new samples are used to re-estimate the model (3) in Table 2 to obtain the estimated coefficient of the did item . Similarly, the above process is repeated 1,000 times. The estimation results show that the average coefficient of the logarithm of per capita net income of the explained variable is 0.04, which is approximately 41.86% lower than the estimation result of model (3) in Table 2. Therefore, randomly advancing the implementation time of China's broadband policy will lead to a significant decline in the promotion effect of digital infrastructure on farmers' income. This also confirms from a counterfactual perspective that digital infrastructure indeed promotes an increase in farmers' income.

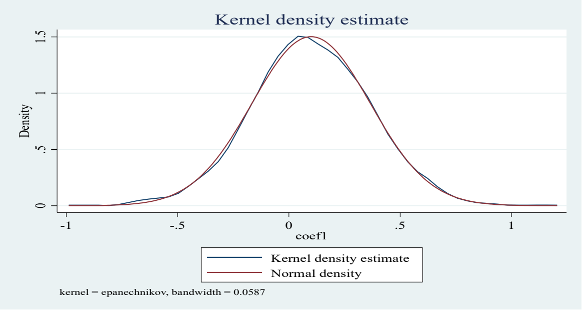

Figure 2. Placebo Test: Randomly Advancing the Implementation Time of China's Broadband Policy

4.3.2 Randomize Policy Time and Treatment Group Samples Simultaneously

In order to prevent any income disparities between the treatment group and the control group is caused by some non-observed characteristic factors. This paper randomly selects selects a sample period for each sample object as its policy time. Accordingly, to further validate the robustness of the estimation outcomes, this paper employs the following placebo test approach: To ascertain that digital infrastructure indeed has no real influence on farmers' income, a simulated broadband China policy is formulated, subjecting 108 sample cities to 500 random interventions. In each iteration, 45 cities are arbitrarily designated as the treatment group, with policy implementation times assigned randomly, generating 500 sets of dummy variables $Broadband^{random}$ (i.e., $treat^{random} \times policy^{random}$). The findings indicate that the potential factors do not significantly alter the baseline regression results of this study. The conclusion is robust.

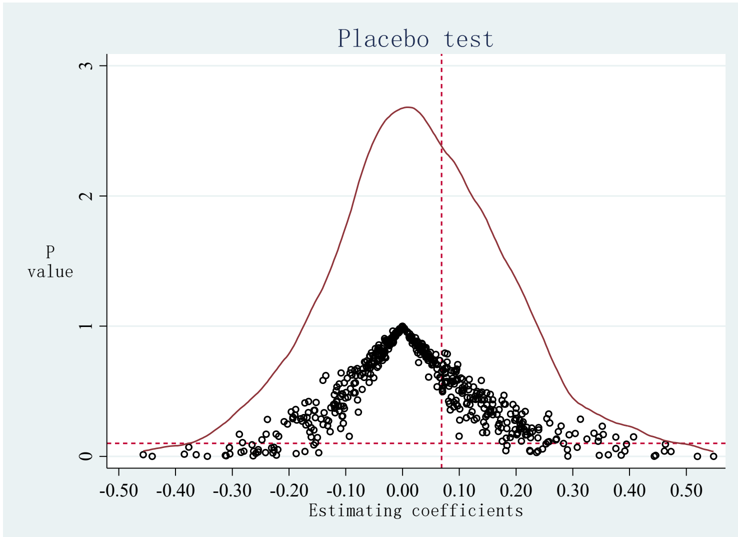

Figure 3. Placebo Test: Simultaneous Randomization of Policy Time and Treatment Group Samples

4.4 Robustness Test

The initial regression findings demonstrate that digital infrastructure has had a beneficial effect on farmers' income, and farmers have increased their income. However, to mitigate the influence of confounding variables on the research findings, several robustness tests are still necessary. This article analyzes multiple dimensions to ensure the reliability of the estimation outcomes.

4.4.1 Sample Data Screening

To mitigate the impact of outliers on the benchmark regression findings, the study samples were truncated at both the 5% and 10% levels based on the household per capita net income variable, and logarithmic transformation was applied to re-estimate Equation (1). The estimation outcomes reveal that the coefficient estimates remained statistically significant.

Table 3. Regression Results after Censoring 5% and 10 %

Variable	lnindinc_net truncated by 5%	lnindinc_net truncated by 10%
	(1)	(2)
Broadband	0.0575**	0.0663***
	(0.0255)	(0.0242)
Control variables	yes	yes
City and year fixed effects	yes	yes
Observations	102497	90907
Adj. R^2	0.5336	0.4750

4.4.2 Add Benchmark Variables to Mitigate the Impact of Selection

The optimal scenario for employing the progressive DID model is when pilot cities and non-pilot cities are chosen randomly. However, in reality, the selection of relevant policies is mostly not random. In order to avoid the impact of non-randomness in policy choices, including the interaction between urban benchmark variables and linear time trends in equation (1) , we get:

$$\text{lnindinc\_net}_{it} = \alpha_2 + \beta_2 Broadband_{it} + \theta_{it}\beta + \lambda_1 Q_i \times trend_t + \delta_i + \tau_i + \varepsilon_{it} \# \quad (2)$$

Among them, Q represents a set of dummy variables for urban benchmark factors. $trend_t$ is the time trend item. Upon inclusion of the interaction term, coefficient estimates for Broadband passed significance testing at the 10% level. This indicates that whether the interaction terms of urban benchmark factors and time trends are added individually or collectively, digital infrastructure notably fosters the augmentation of farmers' income, aligning with the benchmark outcomes. It shows that after taking into account the possible impact of inherent inter-city differences, the calculated outcomes are still steady.

Table 4. The Impact of Digital Infrastructure on Farmers' Income When Adding Baseline Variables

Variable	lnindinc_net				
	(1)	(2)	(3)	(4)	(5)
Broadband	0.0854* (0.0434)	0.0856* (0.0433)	0.0854* (0.0436)	0.0862** (0.0434)	0.0852* (0.0434)
Familysize	-0.0349*** (0.0081)	-0.0344*** (0.0081)	-0.0350*** (0.0080)	-0.0343*** (0.0081)	-0.0343*** (0.0081)
Fsburden	-0.0375* (0.0224)	-0.0382* (0.0225)	-0.0375* (0.0224)	-0.0379* (0.0225)	-0.0384* (0.0224)
Gdpgr	0.0035*** (0.0009)	0.0036*** (0.0009)	0.0035*** (0.0009)	0.0037*** (0.0009)	0.0036*** (0.0009)
Cityincome	1.29e-08* (6.92e-09)	1.25e-08* (6.81e-09)	1.30e-08* (6.76e-09)	1.22e-08* (6.84e-09)	1.31e-08* (6.73e-09)
Cityexpenditure	-9.58e-09 (6.02e-09)	-9.57e-09 (5.80e-09)	-9.62e-09 (5.93e-09)	-9.36e-09 (5.80e-09)	-9.95e-09* (5.75e-09)
Nnpgd	0.1129 (0.0882)	0.0944 (0.0884)	0.1154 (0.0878)	0.0913 (0.0881)	0.0938 (0.0891)

Two control areas× time trend	yes	no	no	no	yes
Provincial capital city× time trend	no	yes	no	no	yes
Special economic zone× time trend	no	no	yes	no	yes
East of Hu Huanyong Line× time trend	no	no	no	yes	yes
City and year fixed effects	yes	yes	yes	yes	yes
Observations	9 4880	9 4880	9 4880	9 4880	9 4880
Adj. R^2	0.4975	0.4976	0.4975	0.4976	0.4977

4.4.3 Exclude the Impact of Contemporaneous Policies

Considering that other policies during the sample period may also lead to changes in the employment structure and bias the baseline estimation results, it is important to eliminate the influence of important policies during the same period. This article selects two highly relevant policies for exclusionary testing, namely the "Notice of the General Office of the Ministry of Housing and Urban-Rural Development on Carrying out National Smart City Pilot Work" and the " Notice of the National Development and Reform Commission on Promoting National Innovative City Pilot Work", the regression outcomes are displayed in columns (1) to (2) of Table 5. The estimation findings reveal that after adjusting for the two policy types, the results remain consistent with the baseline regression outcomes, validating their robustness.

Table 5. Excludes the Impact of Contemporaneous Policies

Variable	(1)	(2)	(3)
Broadband	0.0694* (0.0393)	0.0857* (0.0442)	0.0862* (0.0437)

Familysize	-0.0432***	-0.0350***	-0.0351***
	(0.0069)	(0.0080)	(0.0081)
Fsburden	-0.0711***	-0.0374*	-0.0380*
	(0.0181)	(0.0223)	(0.0217)
Gdpgr	0.0005**	0.0035***	0.0035***
	(0.0002)	(0.0009)	(0.0009)
Cityincome	6.88e-09	1.30e-08*	1.35e-08*
	(8.65e-09)	(6.85e-09)	(7.18e-09)
Cityexpenditure	-3.67e-09	-9.68e-09	-9.96e-09
	(7.65e-09)	(6.00e-09)	(6.16e-09)
Nnpgd	0.1314***	0.1174	0.1199
	(0.0489)	(0.0881)	(0.0871)
Is it a smart city pilot?	yes	no	yes
Is it an innovative city pilot?	no	yes	yes
City and year fixed effects	yes	yes	yes
Observations	1 13894	9 4880	9 4880
$Adj.R^2$	0.5215	0.4975	0.4975

4.4.4 Propensity Score Matching DID Model

Although the asymptotic DID model isolates the average treatment effect of the policy, because the policy is not a natural experiment in the strict sense, there could be potential bias in the selection of both the treatment and control groups. To this end, this paper performs a robustness analysis using the multi-time point PSM-DID model. After using different matching methods respectively, Broadband 's coefficient estimate passed the significance test at different levels, which proves to a certain extent that digital infrastructure construction can promote farmers' income. The effect is robust.

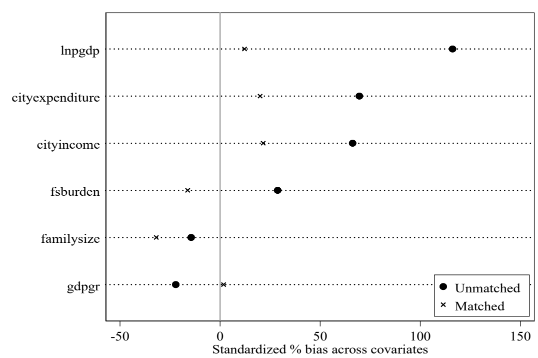

Figure 4. Cross-Sectional PSM Balance Test

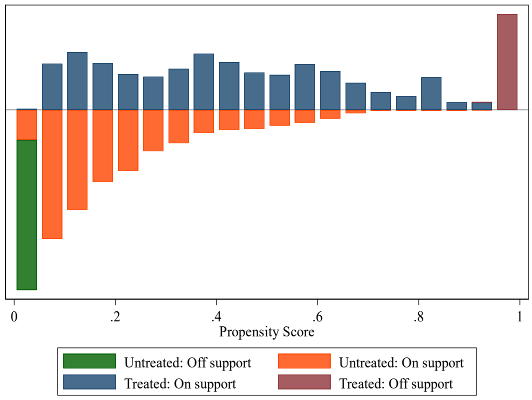

Figure 5. Distribution of Samples that Meet the Common Support Hypothesis

Table 6. PSM- DID Results

Variable	lnindinc_net			
	Kernel matching	Nearest neighbor matching	Radius match	Local linear regression matching
	(1)	(2)	(3)	(4)
Broadband	0.0688*	0.1044**	0.1045**	0.1044**
	(0.0403)	(0.0483)	(0.0483)	(0.0483)
Familysize	-0.0431***	-0.0379***	-0.0379***	-0.0379***
	(0.0069)	(0.0081)	(0.0081)	(0.0081)
Fsburden	-0.0708***	-0.0752***	-0.0753***	-0.0752***
	(0.0185)	(0.0232)	(0.0232)	(0.0232)
Gdpgr	0.0005**	0.0035	0.0035	0.0035
	(0.0002)	(0.0043)	(0.0043)	(0.0043)
Cityincome	6.61e-09	7.72e-09	7.62e-09	7.72e-09
	(8.45e-09)	(1.92e-08)	(1.93e-08)	(1.92e-08)
Cityexpenditure	-3.51e-09	-4.70e-09	-4.60e-09	-4.70e-09
	(7.56e-09)	(1.88e-08)	(1.89e-08)	(1.88e-08)
Nnpgd	0.1296***	0.1439**	0.1437**	0.1439**
	(0.0486)	(0.0681)	(0.0681)	(0.0681)
City and year fixed effects	yes	yes	yes	yes
Observations	113894	92184	9 2168	9 2184
Adj. R^2	0.5215	0.4809	0.4808	0.4809

4.5 Mechanism Analysis

4.5.1 Promoting Industrial Integration and Rationalization of Industrial Structure

Digital infrastructure has the potential to enhance industrial integration and streamline industrial structure, consequently boosting farmers' income. Industrial integration extends the agricultural industry chain by integrating relevant entities within the agricultural industry, relying on superior agricultural resources, adjusting the production structure of agriculture, forestry, animal husbandry and fishery, and achieving deep integration and cyclic development of various production departments within the agricultural industry, thereby improving agriculture. Industrial integration can break the original single production model of agriculture, promote the commercialization and diversification of agricultural production, and make the agricultural industry structure more rational while increasing agricultural output value (Kitole et al., 2024). At the same time, industrial integration can enable agricultural production to obtain more financial support, improve agricultural production conditions, improve agricultural production efficiency, transfer more labor forces from the planting industry to engage in production work in other departments, and further rationalize agriculture and industry structure, thereby facilitating the increase in farmers' earnings (Xu et al., 2024). Therefore, This study employs the industrial structure rationalization index as a mediator variable to investigate how digital infrastructure facilitates the increase in farmers' income.

$$Structure_{i,t} = \sum_{i=1}^{n} \frac{Y_i}{Y} \ln\left(\frac{\frac{Y_i}{L_i}}{\frac{Y}{L}}\right) = \sum_{i=1}^{n} \frac{Y_i}{Y} \ln\left(\frac{\frac{Y_i}{Y}}{\frac{L_i}{L}}\right) \# \tag{3}$$

Among them, Y_i/Y and L_i/L respectively represent the ratio of the output value contributed by the primary, secondary, and tertiary industries to the city's total output value and the ratio of the number of labor force employees in the primary, secondary and tertiary industries in the city's labor force.

Column (1) of Table 7 shows the estimated results. This shows that digital infrastructure construction has significantly improved the industrial structure. This study additionally examines the influence of industrial structure rationalization on the income level of farmers (see column (2) of Table 7). It shows that digital infrastructure construction can promote farmers' income increase by improving the industrial structure.

Table 7. Mechanisms for Digital Infrastructure Construction to Increase Farmers' Income: Promote the Rationalization of Industrial Structure

Variable	Industrial structure rationalization index	lnindinc_net
	(1)	(2)
Broadband	55.3314***	

	(3.9290)	
Industrial structure rationalization index		0.0000441***
		(0.000009)
Observations	96517	93757
$Adj. R^2$	0.0285	0.4956

4.5.2 Promoting the Transfer of Non-Agricultural Employment

Digital infrastructure has the potential to facilitate the transition to non-agricultural employment., thereby increasing the income of farmers. Digital infrastructure represents a new technological change and has a significant role in changing resource allocation methods, production methods, and consumption methods to facilitate the optimization and restructuring of industrial composition. It can promote the flow of rural labor in non-agricultural industries by promoting the advancement of consumer internet and industrial internet (Ren et al., 2023). Labor transfer to employment is an important way to effectively increase farmers' income. Non-agricultural employment in developing nations can spur economic growth, foster diversification of farmers' income, generate job opportunities, and alleviate poverty (Qiao et al., 2024). Therefore, this article uses farmers' non-agricultural employment decisions in the CFPS adult questionnaire to explore the mechanism by which digital infrastructure promotes farmers' income increase.

Column (1) of Table 8 presents the estimated outcomes regarding the influence of digital infrastructure on decisions related to non-agricultural employment. This indicates that digital infrastructure construction has significantly improved the possibility of non-agricultural employment for farmers. This article further tests the impact of non-agricultural employment on farm household income (see column (2) of Table 8). This indicates that by stimulating non-agricultural employment, the construction of digital infrastructure enhances the income of rural households.

Table 8. The Mechanism by Which Digital Infrastructure Promotes Farmers' Income Increase: Improving Non-Agricultural Employment Levels

Variable	Non-agricultural employment	lnindinc_net
	(1)	(2)
Broadband	0.0779***	
	(0.0283)	
Non-agricultural employment		0.1129***
		(0.0068)
Observations	3 6622	3 5977

Adj. R^2	0.0971	0.2079

4.5.3 Improving the Level of Human Capital

Building digital infrastructure can enhance the standard of human capital, thereby promoting an increase in farmers' income. The relative shortage of public services such as education is an important factor leading to the inadequate level of human capital among rural residents. The emergence of digital technology has transcended limitations of time and space., changed the supply pattern of public services, and enabled public services such as education to achieve wider dissemination and sharing at lower marginal costs (Osei et al., 2024). Improvements in public service conditions such as education can help rural residents improve their human capital levels and indirectly increase family income (Qin et al., 2016). This article uses the educational level of rural population as a substitute indicator for human capital.

Column (1) of Table 9 shows that digital infrastructure construction has significantly promoted the improvement of rural human capital levels. This paper further tests the impact of human capital on farmers' income (see column (2) of Table 9This shows that digital infrastructure improves rural household income by promoting the development of rural human capital.

Table 9. Mechanism of Low-Carbon City Pilot Policy to Optimize Employment Structure: Promote the Development of Digital Economy

Variable	Human capital	lnindinc_net
	(1)	(2)
Broadband	0.2095*** (0.0771)	
Human capital		0.1837*** (0.0051)
Observations	19783	19703
Adj. R^2	0.6688	0.2542

5. Heterogeneity Analysis

5.1 Differences in the Impact of Digital Infrastructure on Different Types of Income of Farmers

To precisely capture the influence of digital infrastructure on farmers' income, the logarithm of agricultural production income, wage income, non-agricultural business income, property income, and transfer income were employed as dependent variables in the regression analysis. The results are shown in Table 10. It can be seen that agricultural production income, wage income, and transfer income are significantly affected by digital infrastructure. By breaking down the income types, it can be seen that digital infrastructure has a negative impact on agricultural production income, but can promote the increase of wage income and transfer income. Among them, transfer income has the greatest promotion effect.

Table 10. Test for Different Types of Income Heterogeneity

Variable	Agricultural production income	Wage income	Non-agricultural business income	Property income	Transfer income
	(1)	(2)	(3)	(4)	(5)
Broadband	-0.0397** (0.0162)	0.0257** (0.0110)	0.0119 (0.0225)	0.0611 (0.0500)	0.0447** (0.0177)
Control variables	yes	yes	yes	yes	yes
City and year fixed effects	yes	yes	yes	yes	yes
Observations	5 5918	9 1922	4 7029	1 3239	7 2536
Adj. R^2	0.5358	0.4447	0.4686	0.6562	0.6685

5.2 The Difference in the Impact of Digital Infrastructure on the Income of Urban Farmers in Different Economic Geographical Locations

According to the economic geographical location of the city, this article conducts regression analysis on the sample data of western cities, central cities and eastern cities based on Equation (1). Columns (1)-(3) of Table 11 show the estimated results of the impact of digital infrastructure on the income of urban farmers in different regions. This shows that there is diversity in the influence of digital infrastructure on the income of farmers in different economic geographical locations. The development of digital infrastructure can notably boost farmers' income in the eastern region, but it does not lead to increased income for farmers in the central and western regions. The possible reason for this result is that the digital economy development environment in the eastern region is better, farmers with higher digital literacy and greater information utilization skills experience a more pronounced impact from the development of digital infrastructure.

Table 11. Heterogeneity Test in Different Economic Geographical Locations

Variable	lnindinc_net		
	East area	Central Region	Western Region

	(1)	(3)	(5)
Broadband	0.1282*** (0.0460)	0.0189 (0.0677)	0.0032 (0.1200)
Control variables	yes	yes	yes
City and year fixed effects	yes	yes	yes
Observations	47413	3 5631	3 0815
Adj. R^2	0.5606	0.4863	0.4424

5.3 Differences in the Impact of Digital Infrastructure on the Income of Farmers in High-and Low-Income Groups

Based on the average net income per capita of the household, farmers are divided into high-income groups and low-income groups, and regression analysis is performed based on equation (1). Table 12 shows that the influence of digital infrastructure on varies across different. Digital infrastructure construction can significantly increase the income of high-income farmers, but it cannot improve the earnings of farmers with lower incomes. The possible reason for this result is that farmers in the high-income group are less dependent on agricultural income, and their income is mainly obtained through non-agricultural employment. Non-agricultural employment is significantly influenced by the construction of digital infrastructure. Farmers can use e-commerce, Network anchors and other non-agricultural jobs earn high incomes. At the same time, low-income farmers mainly rely on agriculture to make a living, and the popularity of smart agriculture is low. Therefore, digital infrastructure construction exerts a lesser effect on the earnings of farmers with lower incomes.

Table 12. Heterogeneity Test of Farmers in High-Income Groups and Low-Income Groups

Variable	lnindinc_net	
	High-income group	Low-income group
	(1)	(2)
Broadband	0.0714* (0.0366)	0.0096 (0.0552)
Control variables	yes	yes
City and year fixed effects	yes	yes
Observations	5 9177	4 9043

Adj. R^2	0.4837	0.1599

6. Conclusion and Policy Implications

This study employs a progressive DID model to investigate the effect of digital infrastructure on augmenting farmers' income. The research in this article shows that digital infrastructure has significantly contributed to increasing farmers' income. Mechanism analysis shows that digital infrastructure can improve the degree of rationalization in the agricultural industrial structure by adjusting the production structure of agriculture, forestry, animal husbandry and fishery, thereby promoting the growth of farmers' income. Digital infrastructure can also facilitate the migration of rural labor into non-agricultural sectors through the advancement of consumer internet and industrial internet., helping farmers achieve income growth. Simultaneously, the construction of digital infrastructure can break the boundaries of time and space, enable education to be disseminated and shared on a wider scale at a lower marginal cost, enhance the human capital of rural residents, consequently raising the income of rural households indirectly. Heterogeneity analysis shows that digital infrastructure adversely affects agricultural production income, but can stimulate the growth of wage earnings and transfer income. Among them, the promotion effect on transfer income is the greatest. Digital infrastructure can significantly increase the income of farmers in the eastern region, but it cannot increase the income of farmers in the other regions. The development of digital infrastructure can markedly increase the income of high-income farmers, but it cannot improve the income of low-income farmers.

Therefore, the research in this article has the following policy implications:

First, since digital infrastructure is conducive to the increase in farmers' earnings, investment in Internet infrastructure in rural areas should be increased to ensure that farmers can easily access the Internet. At the same time, digital technology training is provided to rural residents, including basic Internet use, electronic payment and agricultural information management, to ensure that farmers can skillfully use digital tools. Financial innovation and policy support can also be used to promote the popularization of rural financial services.

Secondly, because digital infrastructure can increase the income of farmers by promoting industrial rationalization, non-agricultural employment and improving human capital levels, a digital agricultural product supply chain platform can be established to track and manage the production, distribution, and sale of agricultural goods through information technology, improving Transparency and efficiency of the industrial chain. Provide entrepreneurial support and encourage farmers to carry out entrepreneurial activities through digital channels, such as establishing online stores, digital agricultural service providers, etc. Governments can provide loans, training and market support to stimulate the advancement of digital entrepreneurship. Simultaneously, invest in digital education and training projects in rural areas to improve the overall quality of farmers so that they can better adapt to the growth of the digital economy.

Finally, since the role of digital infrastructure in increasing farmers' income also depends on the economic and social environment, on the one hand, it is also necessary to ensure the improvement of infrastructure construction and service coverage, such as improving roads, electricity and water supply, etc. Infrastructure to improve transport and storage conditions for agricultural products. On the other hand, it is also necessary to provide incentives, such as tax exemptions or subsidies, to encourage companies to invest in rural digital infrastructure to foster the expansion of the digital economy, while strengthening policy supervision to ensure fair competition and data privacy.

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