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Does digital technology service foster income gains in rural villages? Evidence from China's third agricultural census

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The application of digital technology service like rural e-commerce service centers (RESCs) has captured considerable attention in China, but existing literature has not yet provided solid empirical evidence regarding its potential to foster rural income gains. Utilizing large-scale survey data from the Third National Agricultural Census (TNAC) of China, this study attempts to investigate the impact and underlying mechanisms of RESCs on income gains across 49,135 villages. The results indicate that RESCs significantly increase village income gains in rural China, which confirm the theory of "space of flows." In addition, heterogeneity analysis reveals that this income increasing effect is significantly higher in eastern China, as well as in rural villages with migrant populations and college-graduate cadres. The conclusion remains robust even after conducting several robustness checks and instrumental variable estimation. Furthermore, mechanism analysis unveils that RESCs improve village income gains by promoting characteristic agricultural development, encouraging entrepreneurship, and enhancing government funding support. The findings shed light on policy implications for the design and implementation of rural digital technology policies in developing countries.

KEYWORDS

digital technology, e-commerce service centers, village income gains, third agricultural census, rural China

1 Introduction

Rural e-commerce is an application of digital technology that facilitates faster and richer online transactions, with the potential to enhance income gains in rural China. With the rapid expansion of logistics infrastructure and the continuous improvement of information technology, China is now at the forefront of the developing world in e-commerce (Li et al., 2021). According to the 51st Statistical Report on China's Internet Development, online e-commerce transactions in China have ranked first in the world for a decade. These transactions have surged from \$0.21 trillion in 2012 to \$2.05 trillion in 2022, with an average annual growth rate of 25.59%. Meanwhile, the Chinese government has initiated a national policy priority of expanding e-commerce into the countryside since 2014, which aims to accelerate rural economic development. One of the most eye-catching phenomena in China over the past decade has been the remarkable growth of rural residents engaging in online buying and selling activities (Ma et al., 2022b; Xia et al., 2023; Yang et al., 2023; Zhang et al.,

2023; Zhang, 2024). As reported by China's Ministry of Commerce, online retail sales in rural areas have reached \$0.32 trillion in 2022. And the Chinese government has supported 1,489 counties in building more than 2,700 county-level e-commerce logistics service stations and 158,000 village-level e-commerce service centers. The surge in rural e-commerce service centers (RESCs) and their potential for rural economic growth has not only captured extensive media attention, but has also been widely discussed within the academic community. In this study, we aim to answer the following questions: first, whether digital technology service can foster village income gains in rural China; second, whether there is heterogeneity or a digital divide when digital technology service affects village income gains; and third, how digital technology service influences village income gains.

A growing number of studies have investigated various factors driving rural economic development. These include, for example, rural industrial transformation (Liu et al., 2022), land transfer and labor outmigration (Nguyen et al., 2019; Peng et al., 2020; Qin et al., 2020; Leng et al., 2024), agricultural commercialization (Ogotu and Qaim, 2019; Zheng and Ma, 2023a), rural road construction (Asher and Novosad, 2020; Lu et al., 2023), non-farm employment and entrepreneurship (Gaddefors et al., 2020; Dong et al., 2021; Rajkhowa and Qaim, 2022; Ma et al., 2022a; Shao et al., 2023), and poverty alleviation policies (Chang et al., 2022; Tang J. et al., 2022; Cui et al., 2023; Liu and Liu, 2024; Zhao and Zhao, 2024). In recent years, the emergence and adoption of information and communication technologies (ICTs), such as Internet technology and mobile phone usage, have exhibited a pronounced impact on rural economic development (Ma et al., 2020, 2023b; Gu et al., 2023; Zheng and Ma, 2023b; Du et al., 2024). Specifically, e-commerce, as an important application of information technology, has been effectively improving the income of farmers and villages. Taobao village, agricultural inputs commerce, rural e-commerce industrial park, rural e-commerce service centers (RESCs), and various other innovative initiatives have successively emerged in rural China (Jin et al., 2020; Zang et al., 2023).

Although recent studies have indicated that e-commerce can increase consumer surplus primarily by reducing transaction costs and information search costs (Fan et al., 2018; Liu et al., 2021; Dolfen et al., 2023; Zhang et al., 2023), the effect of rural e-commerce expansion on village income gains is still controversial in China. On one hand, some studies show that the development of rural e-commerce has promoted the formation and agglomeration of Taobao villages (Li and Qin, 2022; Zhang Y. et al., 2022; Zang et al., 2023). Taobao villages have contributed to specialized division of labor and created a more favorable environment for employment and entrepreneurship. Thus, they can stimulate income growth among rural residents. On the other hand, research also indicates that e-commerce expansion may not be beneficial to rural residents according to household and local price surveys conducted at village level (Tang and Zhu, 2020; Couture et al., 2021). E-commerce expansion could be expensive and that typical policies may not be effective without complementary interventions, especially in rural areas of developing countries where there is limited transport logistics and weak digital infrastructure (Chen et al., 2023). Hence, it is imperative to conduct rigorous empirical studies that focus on the income effects of rural e-commerce expansion, including the role of RESCs. In particular, two questions are of paramount importance: that is, whether and how the RESCs can foster local income gains, and

what underlying mechanisms and complementary measures are required for program implementation. These hold significance for both the academic community and policymakers.

Based on the Third National Agricultural Census (TNAC), this paper provides some of the first empirical evidence in the field by leveraging the RESCs that provide public services in rural China. We evaluate the impact of RESCs on the collective income gains of 49,135 villages. Firstly, villages are the homes for the majority of rural residents and the economic engines of rural areas. The village-level collective income serves as a crucial financial resource for the delivery of public services in rural regions, thus playing a critical role in the rural revitalization. Secondly, compared with the indicators of household or individual income in the micro survey, the village collective income in the agricultural census is directly derived from the village collective accounting, and the error rate of the data is smaller. In micro survey, high-income groups are less willing to participate, and even if they do, they will often underreport their income level (Li and Sicular, 2014). This advantage underscores the strength of utilizing village-level collective economy data, as it provides more accurate and reliable information, particularly when dealing with issues related to income gains.

Our work primarily contributes to a branch of literature that investigates the socioeconomic implications of e-commerce expansion, with a particular focus on the Taobao villages. A growing body of research has been dedicated to examining the determinants and formation of Taobao villages through case studies and qualitative analyses (Qi et al., 2019; Zhou et al., 2021; Zhang Z. et al., 2022; Zang et al., 2023). As rural e-commerce develops, Taobao villages in rural China are gradually agglomerating and becoming large-scale, contributing to regional economic growth. It is found that villages experience an improvement in their overall income levels after they become Taobao Villages (Zeng et al., 2018; Li and Qin, 2022; Tang K. et al., 2022). However, the existing literature has not yet reached a consensus on whether rural e-commerce can effectively improve the regional welfare gains (Tang and Zhu, 2020). Couture et al. (2021) found that e-commerce expansion through the Alibaba's Rural Taobao Program has no significant influence on local income gains. It is worth noting that while Taobao Villages serve as typical examples, they may not be entirely representative when studying e-commerce expansion in rural China, as this approach overlooks the peculiarities of non-Taobao Villages. Consequently, we study this issue with the help of 49,135 administrative villages in the China's Third National Agricultural Census. The big sample data accounts for 7.45% of the total administrative villages in China, which is an effective representation of rural China's actual economic and e-commerce development status.

Our paper is also related to rural economic growth and how it is affected by rural e-commerce. The combination of information technology and rural economy has resulted in an explosion of rural e-commerce. It is becoming an important economic force not only in China, but also in Turkey (Yaşlak et al., 2021), France (Florez et al., 2022; Bellon-Maurel et al., 2023; Piot-Lepetit, 2023), Mexico (Martínez-Domínguez and Mora-Rivera, 2020), India (Angmo et al., 2023), BRICS countries (Karine, 2021), and other developing countries. In China, the growth of online consumption in rural areas has emerged as a new driving force behind regional economic development (Luo et al., 2019; Vatsa et al., 2023). The rapid and sustained development of rural e-commerce has given birth to various

new economic paradigms, promoting characteristic agricultural development, driving industrial upgrading, and creating employment opportunities (Mei et al., 2020; Zhang Y. et al., 2022; Qin et al., 2023; Zhong et al., 2023a). In addition, rural e-commerce provides farmers with a novel solution for achieving entrepreneurial transformation. A growing number of “new farmers,” primarily composed of skilled migrant workers and college graduates, are returning to their hometowns to initiate businesses because of the entrepreneurial opportunities brought by rural e-commerce. Furthermore, rural e-commerce actively cooperates with local governments by enhancing rural farmers with financial subsidies, and improving logistics and transportation infrastructure. Limited by a lack of extensive microdata at the village level, current studies focus mainly on household income from a micro perspective, ignoring the important role of village-level collective economy play in rural economic development. Despite the explosion of China’s rural e-commerce, it is still unclear whether and how RESCs can foster village collective income gains.

The subsequent sections of the paper are organized as follows. Section 2 introduces the background of RESCs and the theoretical framework of their impact on village income gains. Section 3 describes the data, methodology and variables selection, while Section 4 delves into the analysis of our empirical findings. Finally, conclusions and policy implications are presented in the Section 5.

2 Background and theoretical analysis

Previous studies provide the basis and ideas for the effect of rural e-commerce on regional economic development. However, there is still little literature on the income effect of rural e-commerce service centers (RESCs) in China, even though digital technology has transformed rural economies in recent years. In China, RESCs have been developed to harness the power of e-commerce to improve rural income growth. Therefore, we first provide a brief overview of the development background of RESCs in China. Then, we conduct a theoretical analysis of their impact on village income gains based on the mentioned background.

2.1 Background of rural e-commerce service centers

The rural e-commerce service centers (RESCs) aim to provide villagers with comprehensive e-commerce public services, focusing on the natural village serving as the fundamental unit. The development of the RESCs in China signifies a significant and transformative initiative aimed at bridging the digital divide, fostering the sales of agricultural products, and stimulating economic growth in rural areas. In June 2013, the first rural e-commerce service center was set up in Suichang County of Zhejiang Province, namely Ganjie service center. The center primarily provides services related to the sale of agricultural products and the purchase of consumer goods for local villagers. In October 2014, China’s Alibaba Group introduced the rural Taobao project and invested 10 billion yuan to establish the RESCs. Subsequently, in 2015, there was an outbreak phase as China Post Group, Jingdong Group, and Suning Group successively launched their rural e-commerce platforms: “Rural Tesco,” “Jindong Bang,” and “Suning Retail Cloud.” A notable aspect, however, emerged during this

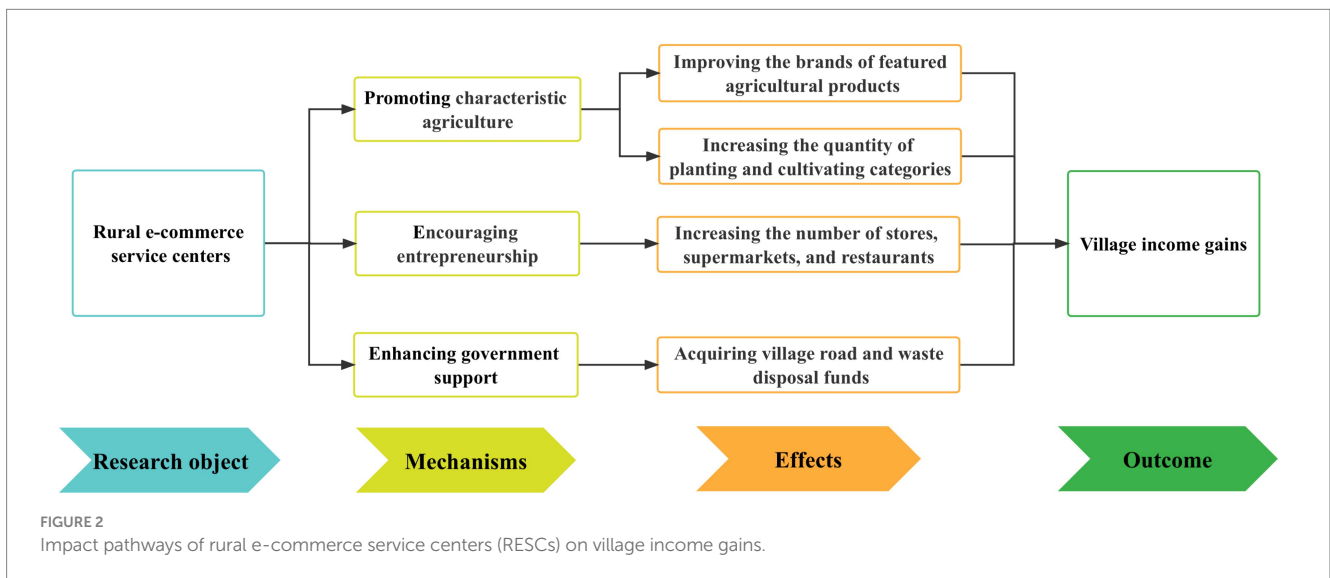
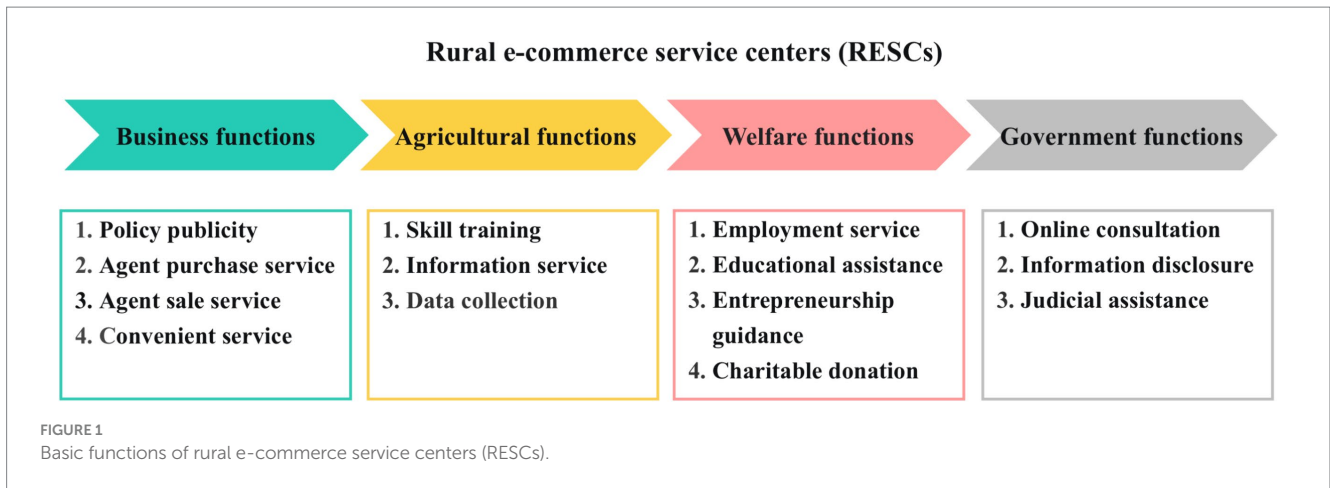
period in that most managers of the RESCs were convenience store owners. Due to a lack of structured training, these managers faced challenges in providing proficient and effective services. Consequently, the significant increase in the number of established RESCs did not fully reflect their genuine functional attributes. In response to these challenges, Alibaba pioneered a shift in the operational model of the RESCs by recruiting college graduates as full-time managers. These managers received comprehensive training and adequate remuneration. By the end of 2020, the network of the RESCs covered approximately 420,000 villages across over 1,500 counties in China (Jin et al., 2020).

In rural villages, RESCs play a multifaceted role with the goal of fostering digital connectivity, convenient life, economic empowerment, and social security. Specifically, the basic functions of RESCs can be categorized into four groups: business functions, agricultural functions, welfare functions, and government functions (Figure 1). The business functions involve collaborative efforts with governmental entities to disseminate policies and information on characteristic agricultural industries. They also facilitate online purchasing and price inquiries, provide sales guidance for characteristic agricultural products, and offer convenience services such as utility bill payments, express delivery, and reservations for travel and accommodations. The agricultural functions include skills training through various forms of farming expertise sessions, the dissemination of real-time agricultural information, and the compilation of a database related to agricultural equipment, pests, characteristic product production, and experts. The welfare functions are associated with an e-commerce platform that offers entrepreneurship and employment guidance, improves villagers’ education levels, and encourages charitable donations. The government functions embark on providing fiscal funds to support rural infrastructure construction, promptly disclosing village-related information, and assisting farmers with disputes in agriculture and daily life by offering judicial aid.

2.2 Theoretical analysis

The RESCs are an innovative initiative emerging from the broader “information technology plus rural public services” framework (Jin et al., 2020). This initiative aims to harness the power of the Internet and digital technologies to enhance public services in rural areas. The development of RESCs is a crucial component of this initiative, involving activities such as promoting the brand and sales of characteristic agricultural products, offering agent purchase and sale services, conducting e-commerce skills training courses, providing entrepreneurship guidance, and enhancing financial support for e-commerce operations. Drawing on the above background and previous relevant studies (Li et al., 2021; Chen et al., 2023), we present a concise framework to illustrate the potential pathways through which RESCs influence village collective income (Figure 2).

The first pathway is related to the fact that RESCs may promote the development of characteristic agriculture in rural areas. Characteristic agriculture refers to the specific planting and cultivating categories that thrive in a particular geographic condition and possess unique characteristics, whose farming area or cultivating quantity constitutes more than 10% of total category within a Chinese county. According to the “space of flows” theory (Castells, 2009; Zhang



Y. et al., 2022), RESCs have the potential to facilitate two-way elements flows of characteristic agricultural products to the city and technology inflows to the countryside. On one hand, RESCs serve as an effective solution for issues related to product circulation and marketing. It promotes the high-speed flow of production elements and the branding of characteristic agricultural products. On the other hand, technology inflows assist villages in developing large-scale industrial clusters in rural areas (Yin and Choi, 2022). This gives birth to the emergence of Taobao Villages dedicated to the production of various agricultural products such as tea, flowers, apples, hairy crabs, crawfish, eggs, etc (Zeng et al., 2019). Therefore, RESCs become integrated with local characteristic agricultural industries, optimizing the industrial structure and yielding positive outcomes for rural areas.

The second pathway indicates that RESCs can encourage entrepreneurship within the village. RESCs provide free skills training in e-commerce entrepreneurship to rural youth and farmers. Meanwhile, RESCs address information asymmetry and mitigate the fixed costs associated with market entry, creating a supportive entrepreneurial environment for female entrepreneurs, and generating opportunities for entrepreneurship (Fan et al., 2018; Moeini Gharagozloo et al., 2023).

These opportunities attract the return of rural elites, primarily composed of college graduates and skilled migrant workers, to engage in starting businesses (Wang et al., 2021). The guidance provided by these rural elites has emerged as a pivotal factor in activating entrepreneurial motivation among households, spreading gradually in rural villages through the ripple effect of rural social networks (Mei et al., 2020). E-commerce entrepreneurship may result in additional offline consumption, expanding the sales scope of offline retail stores or supermarkets (Luo et al., 2019). Thus, RESCs can foster local income gains in rural villages by promoting the e-commerce entrepreneurship.

The third pathway is associated with obtaining government funding support. Support for rural e-commerce from superior governments, such as township and county-level governments, plays a crucial role in fostering local economic growth. However, higher-level governments usually begin to get involved only after the scale of rural e-commerce has attained a certain threshold (Zhang Y. et al., 2022). Villages with RESCs are more inclined to improve essential infrastructure and logistics systems to offer e-commerce services in rural areas (Couture et al., 2021). As a result, these villages can receive more technical guidance and financial support from governments, striving to create more favorable

external conditions for village economic development. Moreover, RESCs enable the government to provide e-commerce-oriented credit support, alleviating farmers' financial constraints, increasing their e-commerce activities, and facilitating entrepreneurial transformation in rural areas (Yang et al., 2021; Ma et al., 2023a). In general, the RESCs enhances the government's support and involvement in rural e-commerce, which contribute to the improvement of village income gains. In summary, RESCs enhance government involvement and support in rural e-commerce, thereby contributing to the improvement of village income gains.

Overall, we expect that RESCs may foster local income gains through the above three channels at the village level. However, the urban leadership theory demonstrates that urban areas may benefit more from the provision of broadband Internet since rural regions tend to be much more expensive to provide facilities and resources (Forman et al., 2005). The RESCs project may not be able to effectively increase income gains in rural areas, where Internet infrastructure is weak and digital connectivity is low. Therefore, rigorous empirical research should be conducted to assess the income effect and underlying mechanisms of RESCs in such contexts.

3 Data and methodology

3.1 Data source

The data utilized in this study primarily originates from the administrative village census data derived from the Third National Agricultural Census (TNAC) of China conducted in 2017. Agricultural census is conducted every 10 years in China since 1997. It is designed to comprehensively collect information about rural areas, farmers, and agricultural development. This data serves as a foundation for understanding the dynamics of rural economies and social development, as well as policies for new rural construction. The TNAC employs a comprehensive investigation methodology. This involves direct visits to households and units, allowing for in-depth data collection on rural areas and agricultural production. The objects of TNAC mainly cover administrative villages, towns and townships (streets), agricultural corporate, large-scale agricultural households, and rural residential households with confirmed tenure of land.

This study focuses on the impact of RESCs on village income gains. We use administrative village census data for analysis. The dataset encompasses basic village statistics, demographics, rural industry statistics, basic social service statistics, village collective economic statistics, village cadre statistics, and other statistics. And there are a total of 49,135 sub-sample data of administrative villages randomly selected from the TNAC. The proportion of administrative villages with RESCs is 22.9% in our sample, which closely aligns with the 25.1% reported by the National Bureau of Statistics of China. Therefore, it indicates a strong representation of the sample data and enhances the reliability of the following study.

3.2 Model specification

3.2.1 Benchmark model

This study examines the impact of RESCs on village income gains through a baseline regression analysis. The ordinary least squares

(OLS) method is used to controls for the province fixed effects. At the village level, all standard errors are robust to take into account potential heteroscedasticity. The baseline regression model is as follows:

$$\begin{aligned} \ln(\text{Village Income})_i = & \beta_0 + \beta_1 \text{RESCs}_i + \beta_2 X_i \\ & + \text{Province}_i + \varepsilon_{1i} \end{aligned} \quad (1)$$

where the subscript i refers to an administrative village, β_0 is the constant term, and ε is a random disturbance term. The dependent variable (*Village Income*) represents the annual village collective income. The core explanatory variable (*RESCs*) is a dummy variable that equals 1 if a village has an e-commerce service center. The vector X denotes a series of control variables, including village characteristics and individual characteristics. The variable (*Province*) is the province fixed effects. In this study, β_1 is the key parameter of interest, which identifies the influence magnitude of RESCs on village income gains.

3.2.2 Mechanism model

According to the above theoretical analysis, we argue that RESCs can affect village income gains by promoting the development of characteristic agriculture, encouraging rural entrepreneurship, and enhancing the support of government funding. Therefore, we further adopt the mediation effect model to perform mechanism analyses (Zhong et al., 2022; Zhang J. et al., 2022). Specifically, the following two steps are constructed:

Step 1: Assessing the impact of RESCs on characteristic agriculture, rural entrepreneurship, and government support. It is specified as follows:

$$\text{Mechanism}_i = \alpha_0 + \alpha_1 \text{RESCs}_i + \alpha_2 X_i + \text{Province}_i + \varepsilon_{2i} \quad (2)$$

where the definition of *E_commerce*, X , and *Province* are the same as above. The main variable of interest is *Mechanism*, which represents the three potential pathways.

Step 2: If the parameter α_1 in Equation 2 is found to be statistically significant, we can proceed to include additional mechanism variables in the following model:

$$\begin{aligned} \ln(\text{Village Income})_i = & \gamma_0 + \gamma_1 \text{RESCs}_i + \gamma_2 \text{Mechanism}_i \\ & + \gamma_3 X_i + \text{Province}_i + \varepsilon_{3i} \end{aligned} \quad (3)$$

where it confirms that RESCs can affect village income gains through mechanism variables when γ_2 is statistically significant and γ_1 is smaller than β_1 in Equation 1.

3.3 Variable selection and descriptive statistics

3.3.1 The explained variable

The dependent variable of this study is the annual village collective income. In the administrative village census questionnaire, the corresponding item is "Village collectives' revenue of the year (unit: 10 thousand yuan)." Village collective income includes operating revenue, subsidies revenue, contract awarding, submittal revenue, and

TABLE 1 Definition and descriptive statistics of variables.

Variable	Definition	Obs.	Mean	S.D.
Ln(Village income)	The logarithmic of the annual village collective income	49,135	2.395	1.509
RESCs	Whether the village has an e-commerce service center: 1 = yes, 0 = no	49,135	0.229	0.420
Ln(Population)	The logarithmic of the number of permanent residents in the village	49,135	6.979	0.874
Ln(Village area)	The logarithmic of administrative area of the whole village	49,135	5.959	1.143
Village topography	The village topography: 1 = plain; 2 = hills; 3 = mountain	49,135	1.901	0.821
Road condition	The road conditions in the village: 1 = concrete; 2 = asphalt; 3 = gravel; 4 = slate; 5 = other	49,135	1.336	0.841
Tourism village	Is the village a national characteristic landscape tourism village: 1 = yes, 0 = no	49,135	0.004	0.065
Ln(Primary school)	The logarithmic of the number of primary schools in the village	49,135	0.367	0.490
Ln(Sports venue)	The logarithmic of the number of sports and fitness venues in the village	49,135	0.496	0.462
Ln(Library)	The logarithmic of the number of libraries and cultural stations in the village	49,135	0.486	0.349
Village cadre education	The education of the village branch secretary: 1 = illiteracy; 2 = primary school; 3 = middle school; 4 = high school; 5 = college and above	49,135	3.795	0.845
Concurrent positions	Whether the village branch secretary holds a director position on the village committee: 1 = yes, 0 = no	49,135	0.304	0.460
Agricultural category	Whether the village has a characteristic planting or breeding category: 1 = yes, 0 = no	49,135	0.133	0.339
Ln(Agricultural quantity)	The logarithmic of cultivating quantity of characteristic planting or breeding category	49,135	0.703	1.989
Ln(Store)	The logarithmic of the number of stores with a business area of more than 50 square meters	49,135	0.315	0.345
Ln(Restaurant)	The logarithmic of the number of licensed restaurants	49,135	0.185	0.307
Village road funds	Whether the main funding source for roads construction in the village comes from the government: 1 = yes, 0 = no	49,135	0.717	0.451
Waste disposal funds	Whether the main funding source for the centralized disposal of waste in the village comes from the government: 1 = yes, 0 = no	49,135	0.529	0.499

All indicators are derived from the Third National Agricultural Census (TNAC) of China; S.D. refers to the standard deviation.

other revenues. In micro income surveys, farmers often face challenges in accurately describing their income and consumption levels. Consequently, they tend to provide only a broad range, resulting in serious data deviations (Sicular et al., 2020). In comparison, the agricultural census derives village collective income directly from the village accounting. This data exhibits a lower error rate, which indicates higher accuracy in subsequent empirical analysis.

3.3.2 Core explanatory variable

The core explanatory variable is rural e-commerce service centers (RESCs), defined as a dummy variable. It takes the value of 1 if a village has established e-commerce distribution sites, otherwise the value of 0 is assigned. Within the entire sample, there are 11,275 villages have RESCs, accounting for 22.9% of the total. This indicates a significant growth and acceleration of e-commerce development in rural China.

3.3.3 Control variables

Referring to existing relevant studies (Luo and Niu, 2019; Li et al., 2021; Chen et al., 2023), we control two sets of characteristics variables that may affect village income gains. First, the village characteristics variables mainly include permanent population, administrative area, village topography, accessibility (roads to the village), national tourism village status, and the availability of basic social services such as primary schools, sports venues, and libraries. Second, the individual characteristics variables encompass the education level of the village branch secretary, and the number of positions he or she holds.

3.3.4 Mechanism variables

To identify potential mechanisms, six variables related to village characteristics are considered. To begin with, the development of characteristic agriculture is a crucial pathway for rural industry development in China, particularly given the relatively low level of rural economic development. This paper measures the development of characteristic agriculture by examining the category and quantity of characteristic planting or breeding industry. It indicates a highly competitive agricultural development if a village has a characteristic planting or breeding category. Secondly, two variables are selected to measure the entrepreneurial situation within villages: the logarithmic of the number of stores with a business area exceeding 50 square meters, and the logarithmic of the number of licensed restaurants. Thirdly, this study assesses the funding relationships between higher government and villages. If the main funding source for roads construction or the centralized disposal of waste comes from the government, it signifies that government funding support can effectively stimulate the development of village-level collective economy.

3.3.5 Statistical description

The descriptive statistics of the above variables are shown in Table 1. According to Table 1, the average village collective income is 39,866 yuan, indicating that rural China is experiencing an acceleration in economic development at the village level. Meanwhile, 22.9% of the sample villages have established RESCs, showing a significant advancement in China's rural e-commerce development.

This growth reflects the increasing integration of e-commerce into rural areas, likely contributing to their economic and social development. Moreover, the overall topography and road conditions of the surveyed villages are hills and concrete, respectively. National characteristic landscape tourism villages only make up 0.4% of the total sample, suggesting that these villages may not be primarily known for their tourist attractions. As for the village branch secretaries, the average education level is nearly high school. Additionally, around 30.4% of them hold director positions on the village committee. This suggests that a significant portion of village branch secretaries may have leadership roles within the village administration.

4 Empirical results and discussions

4.1 Baseline regression results

Table 2 presents the benchmark regression results for the effect of RESCs on village income gains. The estimation results are displayed in Column (1) without additional control variables. Following that, we sequentially add provincial fixed effects, village characteristics, and individual characteristics in Columns (2) to (4). The R-square value increases as the control variables are added, indicating the necessity to control these factors affecting village income. The estimated coefficients of RESCs in all regressions are significantly positive at the 1% level, implying that RESCs can significantly improve village income gains. Specially, the impact coefficient of RESCs is 0.116 in Columns (4). This indicates that compared with villages without RESCs, villages with RESCs have a higher income gains ratio by 11.6%. These findings are in line with previous studies emphasizing the benefits of adopting rural e-commerce (Liu et al., 2021; Li and Qin, 2022; Tang K. et al., 2022).

Table 2 also reports the results for the influence of control variables on village income gains. The village population and administrative area have a significant positive effect on village income gains. This may be attributed to the return of migrant workers or college graduates who return to their hometowns to initiate businesses, thereby increase village income. This result aligns with the findings of Chen and Wang (2019), who recognized the promotional effect of return migration on rural economic development. Moreover, a significant positive relationship is observed between village topography and road conditions and village income. This is consistent with the conclusions drawn by Chakraborty and Guha (2009) and Zhou et al. (2022), signifying that infrastructure development can contribute to economic growth and poverty alleviation. In addition, village sports facilities, libraries, and branch secretaries' education also exhibit a significant positive effect on village income. However, this study predicts no significant relationship between characteristic tourism village and income gains.

4.2 Heterogeneity analysis

The benchmark estimation results only capture the average effects of the entire sample. In this section, we further explore how RESCs influence village income gains by conducting a heterogeneity analysis

TABLE 2 The effect of RESCs on village income gains.

Variables	Dependent variable: Ln (village income)			
	(1)	(2)	(3)	(4)
RESCs	0.329*** (0.016)	0.309*** (0.015)	0.121*** (0.014)	0.116*** (0.014)
Ln(Population)			0.423*** (0.009)	0.404*** (0.009)
Ln(Village area)			0.028*** (0.007)	0.029*** (0.007)
Village topography			-0.066*** (0.010)	-0.066*** (0.010)
Road condition			-0.065*** (0.007)	-0.064*** (0.007)
Tourism village			0.145 (0.088)	0.143 (0.088)
Ln(Primary school)			-0.032** (0.014)	0.027** (0.014)
Ln(Sports venue)			0.305*** (0.014)	0.294*** (0.014)
Ln(Library)			0.104*** (0.018)	0.094*** (0.018)
Village cadre education				0.119*** (0.007)
Concurrent positions				-0.041*** (0.015)
Province fixed effects	No	Yes	Yes	Yes
Constant	2.319*** (0.008)	4.778*** (0.069)	1.855*** (0.092)	1.480*** (0.095)
Observations	49,135	49,135	49,135	49,135
R-squared	0.008	0.236	0.305	0.309

Provincial fixed effects include 31 provinces in China; Robust standard errors in parentheses; ***and **indicate significance at the 1 and 5% levels, respectively.

based on regional and individual characteristics. Our estimation strategy is to separately add interactive variables with RESCs based on Columns (4) in Table 1. The estimation results of the heterogeneous effect test are presented in Table 3.

First, the impact of RESCs on local income gains may vary significantly due to the imbalanced regional development in China. Referring to Qiu et al. (2021) and Zhong et al. (2023b), we divide the surveyed villages according to whether they are located in the economically developed eastern regions of China. As shown in Columns (1) of Table 3, the coefficients of RESCs and its interaction terms with the eastern region are both significantly positive. It turns out that RESCs tend to foster village income gains mainly in eastern China. Compared to the eastern region, the central and western regions of China suffer from inadequate transportation condition and a significant deficiency in technological accessibility. This significantly limits the expansion of effective RESCs to increase village income in

these areas. Moreover, digital literacy is an important means in spreading digital technology service in rural villages. A digital divide in terms of technological knowledge and experience has hindered the central and western regions of China from achieving income gains and common prosperity.

Second, the effect of RESCs on local income gains may be different in villages with external residents. Rural e-commerce has been shown to attract migrant workers, and promote economic development in rural areas (Cai et al., 2019). In this way, the impact of RESCs on village income gains may be moderated by the presence of external workers in the village. We involve the interaction term of e-commerce with migration in the regression. In Columns (2) of Table 3, the coefficient of this interaction term is significantly positive at the 1% level, illustrating that RESCs contribute to more local income gains in villages with migrant populations. The majority of the migrant population consists of skilled workers and college graduates. They engage in starting businesses and broaden avenues for employment and income growth in rural villages.

Third, the influence of RESCs on local income gains may also differ depending on whether the village has college-graduate cadre. As shown in Columns (3) of Table 3, the coefficients of RESCs and its interaction term with college-graduate cadre are both significantly positive at the 1% level. The estimation results show that RESCs can improve village income gains, especially in villages with college-graduate cadres. The possible reason is that college-graduate cadres can be capable of contributing to poverty alleviation in rural China, and this aligns with the study of He and Wang (2017). College-graduate cadres tend to have a higher education level, and possess strong abilities in utilizing online e-commerce. They can effectively collect commodity market information and promote the development of rural digital technology service and village-level collective economy.

4.3 Robustness test

4.3.1 Choosing alternative independent variable

We further employ the substitution variable method to verify the reliability of the baseline regression results. Considering the fact that rural e-commerce is one of the Internet applications, we construct an indicator of the Internet to replace the dependent variable. In the agricultural census questionnaire, it inquires whether a village is connected to the Internet: Yes = 1, otherwise = 0. As shown in Columns (1) of Table 4, a significant positive relationship still exists between RESCs and village income gains, which further strengthens the reliability of our conclusion.

4.3.2 Changing estimation method

As the core explanatory variable of this study is a dummy variable, we also utilize the probit model for a robustness check. In Columns (2) of Table 4, the coefficient of RESCs remain positive and significant at the 1% level. The results reveal that when the setting estimation method is changed, there is still a significant positive relationship between RESCs and village income gains.

4.3.3 Removing the top and bottom 1% of village income

To address the potential impact of outliers and non-randomness, we conduct a sensitivity analysis by excluding the

TABLE 3 Heterogeneous impact of RESCs on village income gains.

Variables	Dependent variable: Ln (village income)		
	(4)	(5)	(6)
RESCs	0.083*** (0.019)	0.055*** (0.020)	0.075*** (0.015)
RESCs × Eastern region	0.079*** (0.029)		
RESCs × Migration		0.076*** (0.027)	
RESCs × College-graduate cadre			0.221*** (0.030)
Control variables	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes
Constant	0.303*** (0.086)	1.450*** (0.094)	1.477*** (0.095)
Observations	49,135	49,135	49,135
R-squared	0.309	0.318	0.310

Eastern region denotes whether the village locates in China's eastern region: 1 = yes, 0 = no; Migration refers to whether the village has external residents: 1 = yes, 0 = no; College-graduate village cadre represents whether the village has college-graduate cadre: 1 = yes, 0 = no; The control variables are listed in Table 1; Provincial fixed effects include 31 provinces in China; Robust standard errors in parentheses; ***indicates significance at the 1% level.

top and bottom 1% of village collective income data. The re-regression results are presented in Columns (3) of Table 4. Notably, even after accounting for outliers and non-randomness, the RESCs continue to exhibit a significant positive impact on village income gains. This further reinforces the robustness and consistency of our findings.

4.4 Endogeneity discussion

The results presented above suggest that RESCs can foster village income gains. However, this conclusion may face challenges related to endogeneity. On one hand, there may be a reverse causal relationship between RESCs and village income gains. The establishment of RESCs might be influenced by existing village income levels. For instance, higher income villages are more inclined to exploit rural e-commerce to further boost their economic development. On the other hand, despite controlling for several factors that affect village income, the issue of omitted variables still persists in the cross-sectional data. For example, there are unobservable village characteristics that can influence both RESCs and village income. Therefore, this paper employs the instrumental variable (IV) method to address the endogeneity of RESCs (Angrist and Pischke, 2009).

Following the relevant literature by Li and Qin (2022) and Qiu et al. (2021), this paper selects the number of rural fixed broadband interfaces per 100 people in 2006 as the IV for the construction of RESCs. First, rural e-commerce infrastructure relies on traditional fixed broadband interfaces and broadband Internet network. Thus, the chosen IV satisfies the requirement of being correlated with rural

TABLE 4 Robustness tests of the effect of RESCs on village income gains.

Variables	Dependent variable: Ln (village income)		
	Alternative variable	Probit model	Truncated treatment
	(4)	(5)	(6)
RESCs	0.062*** (0.022)	0.043*** (0.013)	0.105*** (0.014)
Control variables	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes
Constant	1.432*** (0.097)	1.770*** (0.374)	1.641*** (0.093)
Observations	49,135	49,135	48,320
R-squared/ Pseudo R-squared	0.308	0.098	0.305

The control variables are listed in Table 1; Provincial fixed effects include 31 provinces in China; Robust standard errors in parentheses; ***indicates significance at the 1% level.

e-commerce. Second, the IV is a historical variable, and the earliest year for which we can obtain the data is 2006. This historical nature ensures minimal influence from current rural e-commerce development, adhering to the assumption of the externality of IV. Recognizing that the core explanatory variable in this study is binary and discrete, the conventional two-stage least squares (2SLS) method might not be the effective approach. As a general practice in the academic community (Roodman, 2011), scholars generally prefer employing the conditional mixed process (CMP) method for analysis.

As shown in Table 5, the first-stage estimation results unveil a statistically significant positive correlation between fixed broadband interface penetration rate and rural e-commerce infrastructure at the 1% level. This alignment supports the correlation condition essential for IV. In addition, the endogeneity test parameter $atanhrho_{12}$ is significant at the 1% level, signifying that RESCs is an endogenous explanatory variable within the model. In the subsequent second-stage regression, the regression results reveal that after considering the possible endogeneity of the model, RESCs still have a significant positive effect on village income gains.

4.5 Mechanism analysis

We further investigate the potential mechanisms through which RESCs may impact village income gains. As delineated in the theoretical analysis section, RESCs possess the capacity to increase village income gains by fostering the development of characteristic agriculture, encouraging rural entrepreneurship, and enhancing the support of government funding. Thus, we validate these three pathways through the implementation of two-step mechanism models.

4.5.1 Mechanism I: promoting the development of characteristic agriculture

Table 6 provides the estimation results of how RESCs increase village income gains by promoting the development of characteristic

agriculture. Columns (1) and (3) present the results for Equation 2, while Columns (2) and (4) provide the results for Equation 3. First, the findings from Columns (1) and (3) indicate that the expansion of RESCs within villages can significantly foster both the category and quantity of characteristic planting or breeding industries. Second, the results presented in Columns (2) and (4) demonstrate a statistically significant and positive association between characteristic agricultural industries (both in terms of category and quantity) and village income. Hence, these results provide empirical support for Mechanism I, indicating that the expansion of RESCs can increase village income gains by promoting the development of characteristic agriculture. Our finding is largely consistent with the outcomes of related studies (Yan and Liu, 2022; Liu et al., 2023), who have demonstrated that the adoption of e-commerce presents significant advantages in selling agricultural products directly to consumers and improving agricultural production efficiency. On one hand, the development of RESCs has emerged as a crucial channel for the sale of agricultural products in rural villages by cutting out intermediaries. These centers significantly broaden the sales channels for characteristic agricultural products and enhance the visibility of featured agricultural goods. On the other hand, RESCs provide valuable publicity for local characteristic agriculture and offer training on advanced planting techniques for rural farmers.

4.5.2 Mechanism II: encouraging entrepreneurship within the village

Table 6 provides the estimation results of how RESCs increase village income gains by promoting the development of Table 7 presents the results targeted at verifying the mechanism through which RESCs foster rural income by encouraging entrepreneurship within the villages. The outcomes exhibited in Column (1) and (3) unveil that villages with RESCs experience a significant increase in both the number of stores and the quantity of licensed restaurants. Meanwhile, these two variables in Column (2) and (4) regarding to village entrepreneurial situation are all significantly positive at the 1% level. Accordingly, the data affirm the validity of Mechanism II, asserting that RESCs play a pivotal role in amplifying village income gains by encouraging entrepreneurship within the village. These results are in line with the theoretical analysis presented in this study. The development of RESCs has significantly expanded local sales in retail stores and supermarkets by driving offline consumption. These centers also drive the dissemination of local village characteristic resources, promoting the development of the local tourism industry, and expanding the establishment of affiliated characteristic restaurants. Therefore, it can improve village income gains by creating job opportunities and promoting non-agricultural employment.

4.5.3 Mechanism III: enhancing villages with the support of government funding

Table 8 reports the results concerning the mediation effect of government funding support in RESCs and village income gains. As illustrated in Columns (1) and (3), RESCs significantly enhance villages with the government support for roads construction and waste disposal. The results in Column (2) and (4) highlight that RESCs and government funding support for villages are all significantly and positively correlated with village income gains. Therefore, this finding supports the theoretical analysis of Mechanism III articulated in this paper. Specifically, it illustrates that RESCs play a pivotal role in

facilitating the development of villages through government funding, thereby indirectly leading to an increase of village income gains.

5 Conclusion and policy implications

This study takes advantage of large-scale administrative village survey data from the Third National Agricultural Census of China,

and provides fresh empirical insights into the income effects of rural e-commerce service centers (RESCs). The results reveal a significant increase in village income gains associated with RESCs. Villages with RESCs exhibit a higher income gains ratio of 11.6% compared to those without such centers. Moreover, the positive impact of the RESCs on village income gains is heterogeneous by regional and individual characteristics. RESCs are inclined to foster local income gains primarily in eastern China, as well as in villages with migrant populations and college-graduate cadres. These conclusions remain robust after conducting several robustness checks and handling endogeneity concerns through instrumental variable estimation. Furthermore, mechanism analyses verify that RESCs stimulate local income gains by promoting characteristic agricultural development, encouraging entrepreneurship, and enhancing government funding support.

Based on the above findings, there are significant policy implications as follows:

To begin with, our research demonstrates that RESCs can contribute substantially to the village income gains in rural areas. Thus, policies aimed at constructing e-commerce service centers should be encouraged, especially in developing countries. The policy designs should seek to improve the construction of rural public digital facilities, such as internet access, logistics networks, warehouses, and rural roads. Digital technology investment in rural areas has become critical in recent years for alleviating poverty and increasing income. By introducing digital technology services and business platforms into rural areas, e-commerce is expected to alleviate poverty in the future.

Secondly, the heterogeneous impact of RESCs on village income gains suggests that policymakers should tailor rural e-commerce practices to the distinct socioeconomic development levels of each region in China. In addition, the roles of migrant workers and college-graduate cadre in increasing village income gains should be acknowledged, with complementary interventions such as training in e-commerce skills. Policymakers need to consider regional

TABLE 5 The effect of RESCs on village income gains: IV estimation results.

Variables	CMP method	
	First stage	Second stage
	(1)	(2)
RESCs		0.045*** (0.010)
Fixed broadband interface penetration rate in 2006	0.508*** (0.070)	
atanrho_12	-2.997*** (0.162)	
Control variables	Yes	Yes
Province fixed effects	No	Yes
Constant	0.181*** (0.020)	0.455*** (0.051)
Observations	49,135	49,135

This table presents the estimation results of IV regression using fixed broadband interface penetration rate; CMP refers to the conditional mixed process method because the core explanatory variable is binary and discrete in this study; The atanrho_12 represents the endogeneity test parameter; The control variables are listed in Table 1. Provincial fixed effects include 31 provinces in China; Robust standard errors in parentheses; ***indicates significance at the 1% level.

TABLE 6 Impact of RESCs on characteristic agriculture.

Variables	Agricultural category	Ln (village income)	Ln (agricultural quantity)	Ln (village income)
	(1)	(2)	(3)	(4)
RESCs	0.019*** (0.004)	0.115*** (0.014)	0.109*** (0.022)	0.116*** (0.013)
Agricultural category		0.042** (0.017)		
Ln(Agricultural quantity)				0.006** (0.003)
Control variables	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Constant	0.142*** (0.025)	1.474*** (0.095)	1.172*** (0.146)	1.473*** (0.095)
Observations	49,135	49,135	49,135	49,135
R-squared	0.055	0.309	0.054	0.308

Agricultural category refers to whether the village has a characteristic planting or breeding category: 1 = yes, 0 = no; Agricultural quantity denotes cultivating quantity of characteristic planting or breeding category; The control variables are listed in Table 1; Provincial fixed effects include 31 provinces in China; Robust standard errors in parentheses; ***and **indicate significance at the 1 and 5% levels, respectively.

TABLE 7 Impact of RESCs on inner village entrepreneurship.

Variables	Ln (Store)	Ln (village income)	Ln (Restaurant)	Ln (village income)
	(1)	(2)	(3)	(4)
RESCs	0.060*** (0.003)	0.108*** (0.014)	0.094*** (0.003)	0.076*** (0.014)
Ln(Store)		0.143*** (0.019)		
Ln(Restaurant)				0.432*** (0.020)
Control variables	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Constant	0.332*** (0.023)	1.528*** (0.095)	0.372*** (0.021)	1.641*** (0.095)
Observations	49,135	49,135	49,135	49,135
R-squared	0.243	0.310	0.170	0.315

Store refers to the number of stores with a business area of more than 50 square meters within the village; Restaurant denotes the number of licensed restaurants within the village; The control variables are listed in Table 1; Provincial fixed effects include 31 provinces in China; Robust standard errors in parentheses; ***indicates significance at the 1% level.

TABLE 8 Impact of RESCs on government funding support.

Variables	Village Road Funds	Ln(Village Income)	Waste Disposal Funds	Ln(Village Income)
	(1)	(2)	(3)	(4)
RESCs	0.014*** (0.005)	0.102*** (0.011)	0.059*** (0.005)	0.115*** (0.014)
Village road funds		0.169*** (0.013)		
Waste disposal funds				0.022* (0.012)
Control variables	Yes	Yes	Yes	Yes
Province fixed effects	Yes	Yes	Yes	Yes
Constant	0.924*** (0.032)	1.729*** (0.095)	0.924*** (0.032)	1.729*** (0.095)
Observations	49,135	49,135	49,135	49,135
R-squared	0.120	0.315	0.125	0.309

Village road funds refer to whether the main funding source for roads construction in the village comes from the government: 1 = yes, 0 = no; Waste disposal funds denote whether the main funding source for the centralized disposal of waste in the village comes from the government: 1 = yes, 0 = no; The control variables are listed in Table 1; Provincial fixed effects include 31 provinces in China; Robust standard errors in parentheses; ***and *indicate significance at the 1 and 10% levels, respectively.

differences, with special attention being paid to assisting vulnerable rural villages with digital assistance. The policy should promote the establishment of more service points for e-commerce platforms in the central and western regions of China. And the widening digital divide in rural areas indicates a need to improve digital literacy in vulnerable villages.

Lastly, the mechanism analysis underscores the responsibility of local governments in leading the planning and implementation of rural e-commerce construction projects. This involves promoting the brands of characteristic agricultural products, providing entrepreneurial skills training, and expanding financial support for rural e-commerce operations. Local governments support the establishment of RESCs distribution points to help rural producers

build recognizable agricultural brands, and ensure a high quality of characteristic products. Additionally, local governments and e-commerce firms should provide high-quality skills training and financial incentives to enhance the employment potential of affiliated industries in rural villages.

This study still has some limitations that need further exploration. First, the cross-sectional nature of the third agricultural census data made it impossible to capture the dynamic income increasing effect of RESCs. Thus, future studies should gather data from a longer period to verify the representativeness of the findings in this paper. Second, this study mainly measures the digital technology services from the perspective of RESCs. Future research could incorporate other indicators to obtain a more comprehensive measure of digital

technology services. Third, this study did not investigate other related income effects of digital technology services in rural areas. Future studies can consider the happiness and health effects of digital technology services on rural residents.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

SZ: Conceptualization, Formal analysis, Funding acquisition, Writing – original draft. WS: Funding acquisition, Supervision, Writing – review & editing. PY: Methodology, Software, Writing – review & editing.

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Conflict of interest

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