Received 27 December 2020
Revised 26 March 2021
21 May 2021
10 July 2021
Accepted 16 July 2021

Does broadband infrastructure really affect consumption of rural households? – A quasi-natural experiment evidence from China

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Abstract

Purpose – As an important public infrastructure, broadband has absorbed a large amount of investment in China. However, how and to what extent these investments affect economic and social development is largely unknown. The purpose of this paper is to analyze the impact of broadband infrastructure construction on consumption of rural households, using an exogenous policy shock introduced by the China's "Broadband Countryside" pilot project.

Design/methodology/approach – Using the tracking sample data of China Household Financial Survey in 2013 and 2015, this study estimates the effect of broadband construction on rural household consumption and draws causality between them relying on a quasi-natural experiment based on an exogenous policy shock.

Findings – The difference-in-difference estimates show that broadband construction has significantly increased rural household consumption by 16.69%. This positive promotion effect is mainly achieved through mobile phone access to the Internet, while penetration of computer crowds out rural household consumption. Further research find that broadband construction has increased rural household consumption related to daily life and high-quality household consumption, but not statistically significant for the latter, and it has not helped to promote the consumption upgrading of rural households.

Originality/value – This study contributes to the understanding of the positive status of broadband infrastructure in economic and social development by analyzing the impact of broadband infrastructure construction on rural household consumption. This study expands the content of consumption to rural households, especially high-quality consumption and consumption upgrading in rural areas, which provides the possibility to further tap the consumption potential of rural market. The study is the first to explore how broadband infrastructure construction affects consumption of rural households using a quasi-natural experiment.

Keywords Rural household consumption, "Broadband countryside" pilot policy, Difference-in-differences model, Quasi-natural experiment

Paper type Research paper

China Agricultural Economic Review
Vol. 13 No. 4, 2021
pp. 832-850

1756-137X
DOI 10.1108/CAER-12-2020-0303

This research is financially supported by the following programs: National Natural Science Foundation of China (Grant No. 71774073, 71964014), Key Project supported by the Social Science Foundation of Jiangxi Province, China (Grant No. 20YJ02), and Youth Project supported by the Social Science Foundation of Fujian Province, China (Grant No. FJ2019C031). The authors thank two anonymous reviewers for their helpful comments and suggestions. All remaining errors belong to the authors.

1. Introduction

Concomitant with the development of information communication technology (ICT), China is entering the digital economy era in recent years. In order to provide basis for the advancement of digital economy and adapt to the "new era", China initiated lots of new program, such as "Digital Infrastructure" and "New Infrastructure" strategy, both are based on broadband infrastructure. Then what is the role of the broadband infrastructure in socio-economic development is of great significance for government's following investment plan as well as provides invaluable experience and lessons. In August 2013, China's State Council issued the "Broadband China" strategy, then broadband has become a national strategic public infrastructure for the first time. Subsequently, a large amount of capital has been invested into broadband construction, but there is not enough research on its actual effect on China's economic activity and social benefit, especially the real acquisition of rural residents.

On the other hand, all over the world, including China, are facing the dilemma of slowing economic growth, especially the impact of the COVID-19 has overshadowed haze over the economic situation. Since 2015, China has entered a "New Normal" with the marginal contribution of exports and investment to economic growth declining, meaning that two of the troika are failing. Then how to stimulate consumption and expand domestic demand has become the top priority to maintain China's sustainable economic development. Due to China's unique "dual" structure, the rural consumer market which involves more than half of China's population, has long been "asleep" as well as facing the dilemma of insufficient consumption. This not only restricts the development of rural economy seriously, but also becomes one of the "shackles" affecting the overall economic advancement of the country. Rural market has huge online consumption potential in China, yet restricted by the relative backwardness of rural basic communication as well as Internet facilities construction. Broadband, as the foundation of the Internet and a momentous national infrastructure project, continues to increase coverage in rural areas. Hence, does the large-scale broadband construction really play a crucial role in boosting household consumption? This is exactly the problem to be studied in this paper.

Based on the above considerations, this article combines Chinese Household Financial Survey (CHFS) data, relies on a quasi-natural experiment based on an exogenous policy shock of the "Broadband Countryside" pilot project which was implemented by the Chinese government in the western region, to examine the impact of broadband infrastructure construction on rural household consumption. Specifically, we took Sichuan province and Yunnan province as experimental groups, while Chongqing Municipality and Guizhou province as control groups, then constructed a difference-in-differences model in line with the time difference of "Broadband Countryside" construction in provinces. The results show that broadband infrastructure construction has a significant positive impact on the consumption level of rural households. To ensure the reliability of the empirical results, we also discuss the possible endogenous problems of "Broadband Countryside" policy, and carry out counterfactual tests through various methods.

The remainder of this paper is arranged as follows: Section 2 briefly summarizes the existing literature on broadband and consumption as well as dealing with the relationship between them. Section 3 provides a detailed description of the "Broadband Countryside" pilot policy. Section 4 introduces the data used and make clear the quasi-natural experiment research design. Section 5 sets out the main results on the causal effect of broadband construction on rural household consumption as well as tests for robustness. Section 6 mainly focuses on the heterogeneity of consumption types and the main online tools for rural household consumption. Finally, Section 7 concludes and highlights the policy implications from the study.

2. Literature review

There are two key streams of research that are particularly relevant to the present analysis: studies investigating relationships between infrastructure and household consumption or personal behavior, and studies about how information technology affects rural households'

consumption, production or consumption behavior. These strands are then combined to provide theoretical support for studying the impact of broadband infrastructure on rural households' consumption.

2.1 Interactions between infrastructure and household consumption or personal behavior

Infrastructure can be defined in many ways. Generally speaking, it refers to large, capital-intensive natural monopolies such as transportation, water and sewers, power facilities, information and communication technologies (Gramlich, 1994). Infrastructure construction has always been regarded as one of the nontrivial factors to promote economic growth and development (Donaldson and Hornbeck, 2016). In order to better analyze the mechanism of infrastructure affecting economic and social development, scholars have carried out research from many specific angles, such as exploring the relationship between infrastructure and residents' consumption or personal behavior. After Barro's (1981) pioneering research, mainstream economics believes that government spending on infrastructure will have a crowding-out effect on residents' consumption in the long run, that is to say, there is a negative correlation between the two. However, subsequent research found that infrastructure expenditure does not necessarily squeeze out personal consumption (Olivier and Roberto, 2002). Moreover, infrastructure expenditure is also helpful to reduce the level of household and individual poverty (Medeiros *et al.*, 2021).

At the same time, many scholars have carried out research on specific infrastructures in order to more clearly analyze the impact of various infrastructures on economic and social development. Transportation is one of the hottest branches of infrastructure research, and researchers have documented the effect of various types of transportation on household consumption and personal behavior, which provides a reference for exploring the status of other infrastructure. Khandker *et al.* (2009) found that by reducing transportation costs, building rural road infrastructure can significantly improve the consumption level of high-income residents. Similarly, Donaldson (2010) showed that farmers' consumption is higher in areas with railway connections than in areas without in India. In addition to household consumption**,** scholars have also studied the impact of transportation infrastructure on individual entrepreneurship and wages. Audretsch *et al.* (2015) compared the impact of highways, railways, schools, broadband, etc. on entrepreneurship by German county-level data, it is found that railways and broadband played a greater role. Recently, Ma *et al.* (2021) used the difference-in-difference approach and find that China's high-speed railway construction greatly reduces the cost of inter-regional travel and increases the probability of residents' entrepreneurship.

2.2 Interactions between information technology and rural households' consumption, production or consumption behavior

Information technology has the advantages of increasing the productivity of existing factors, reducing transaction costs and information asymmetry, as well as allowing more people and organizations to participate in the market (Aker, 2011; Deichmann *et al.*, 2016), then scholars began to study the impact of information technology on economic and social development (Rogers, 2000). First, for household consumption and expenditure. Hou *et al.* (2019) believed that computers would have an impact on farmers' consumption, mainly reflected in stimulating the per capita expenditure on transportation, housing, clothing and insurance. Based on a cross-sectional data set of 33 countries, Bris *et al.* (2017) used a log-log framework and found that information technology has a negative impact on average household transportation expenditure, with an elasticity of −0.394. Secondly, for rural household production and market. Lio and Liu (2006) used panel data from 81 countries to study the impact of information and communication technology on agricultural productivity, and showed the benefits of using low-cost tools to increase the efficiency of obtaining household agricultural production advice.

Coincidentally, Jin and Deininger (2009) also found that information technology helps to improve the production efficiency of rural households mainly because of its key role in reducing the information asymmetry between supply and demand of land transfer. The third main line of research on the impact of information technology on rural households or farmers is mobile information technology. Research has confirmed that mobile phones are indeed improving farmers' production methods and encourage them to adopt new practices (Tadesse and Bahiigwa, 2015). Specifically, the reasons why rural households widely use mobile phones to access information networks and engage in production activities are: First, mobile phones are not only cheaper than computers, but also easier to carry, so they are widely used to improve the efficiency of rural markets (Jensen, 2007). Secondly, mobile phones technology could simplify the process of searching for farmer's market information at a lower cost (Jensen, 2010), allowing them to obtain more market prices information (Tack and Aker, 2014), thereby increasing rural household consumption (Bahia *et al.*, 2020). For example, new research by Hartje and Hubler (2017) found that accessing the Internet platform through smartphones further expanded the functions of traditional mobile phones, enhance information flow, and provide guidance for farmers on weather, employment, finance, agricultural technology, product and service purchase.

Another strand of literature focuses on the relationship between e-commerce and rural households or farmers. The advantages of e-commerce platforms are reflected in the ability to provide consumers with a wider variety of products, including products that are not available offline (Brynjolfsson *et al.*, 2003), and the introduction of e-commerce will improve the quality of matching between consumers and products (Ellison and Ellison, 2018) as well as lower the price of products on sale (Brown and Goolsbee, 2002). Above all, e-commerce is beneficial to rural households' production. Baorakis *et al.* (2002) showed that e-commerce platform breaks the limitations of time and space, significantly strengthens the ability of online businesses to collect, sort as well as use information, which is beneficial for farmers to pay close attention to market demand and product dynamics, then effectively guide farmers' production and sales. Furthermore, e-commerce can expand the sales market of rural products. Alavion and Taghdisi (2021) analyzed data collected from approximately 1,000 villages in Iran with ICT offices and found that e-commerce helps farmers sell agricultural products and handicrafts online. Liu *et al.* (2021) collected 2027 observations from 480 apple farmers and found that the adoption of e-commerce increased the sales prices of their products, thereby enhancing the total revenue from agricultural products sales, but with the increase in marketing costs. Last but not least, e-commerce promotes rural households' consumption growth. Couture *et al.* (2018) researched the first national e-commerce expansion project in China and found that the promotion of e-commerce expanded the network market to rural areas, enriched the consumption choices of rural residents as well as changed their consumption behavior, then promoted rural households' consumption expenditure. Luo *et al.* (2019) matched Chinese county-level e-commerce information with the CFPS survey data, and found that e-commerce promoted consumption growth and contributed more to rural, inland and poor households, which helps reduce spatial inequality in consumption.

To sum up, we find that the existing research on the relationship between infrastructure and household consumption is mainly concentrated in the field of transportation infrastructure. Some literature discusses the impact of information technology (including the Internet, computers, mobile phones, and e-commerce) on rural households and farmers, mainly focusing on its impact on household production, online marketing, and personal behavior. Study on the effects of broadband infrastructure on rural household consumption is scant, however. Furthermore, potential endogenous selection problems may play a non-negligible role in the process of accessing broadband Internet and making consumption choices. In addition to different behaviors in the investigation process, individuals will also make choices to use broadband based on some unobservable factors. Besides that, there may be a reciprocal

causation between broadband construction and household consumption. Because of the above-mentioned intractable endogeneity, causal empirical evidence between broadband construction and consumption is generally extremely rare. The possible contributions of this paper are mainly reflected in: First, this paper studies the impact of broadband infrastructure on household consumption, enriching and expanding the influencing factors of consumption in the context of the digital economy. Second, this article employs a quasi-natural experiment based on an exogenous policy shock of "Broadband Countryside" strategy to better draw causal inference between broadband infrastructure and consumption of rural households, provides rigorous and reliable empirical evidence, and tests the effectiveness of national policy. Third, most of the previous researches have focused on the consumption of all residents or urban residents, we take rural residents as a research subject. And using the micro rural household survey data to explore the impact of broadband construction on consumption of rural households to deepen the understanding of rural residents' consumption behavior.

3. Background on "Broadband Countryside" policy

As early as 1994, China started the construction of public computer Internet. After more than 20 years of development, China's network infrastructure construction has made a great breakthrough, one of the most significant milestones is, in August 2013, the State Council issued "'Broadband China' Strategy and Implementation Plan" in accordance with the requirements of the "National Informatization Development Strategy for 2006 and 2020". It marks the rise of broadband construction from a sectoral action to a national strategy, and for the first time it has become a national public infrastructure with equal status with water, electricity and roads. However, imbalance of regional development and other shortcomings are still relatively obvious, which brings obstacles to the economic and social development of the country. Especially in rural areas, due to scattered housing and relatively low household affordability, the investment cost of broadband construction is huge, but with low return rate, so rural broadband construction lags behind urban areas for a long time. For the purpose of solving this problem, in June 2014, the National Development and Reform Commission (NDRC), the Ministry of Finance and the MIIT jointly organized the implementation of the "Broadband Countryside" pilot project, aims to achieve the corresponding rural broadband development goal under the overall goal of "Broadband China" strategy. The "Broadband Countryside" pilot project has the following three characteristics: First, the broadband penetration rate of administrative villages has increased. Second, the speed of residents' access to the network through broadband has increased, and the velocity of data transmission has been upgraded. Third, develop wired broadband and wireless broadband at the same time, promote the evolution of 3G/4G networks, and facilitate rural residents to utilize lower-cost mobile phones to access the Internet.

With regard to the specific implementation of the "Broadband Countryside" policy, in June 2014, the relevant departments of Inner Mongolia Autonomous Region, Sichuan Province, Guizhou Province, Yunnan Province, Shaanxi Province and Gansu Province received a joint document from the NDRC, the Ministry of Finance and the MIIT, which mentioned that in order to implement the "Broadband China" strategy and implementation plan and accelerate the promotion of broadband development and popularization in rural areas, the three government departments will jointly organize the implementation of the "Broadband Countryside" pilot project (phase I) in 2014. Through an expert review of the "Broadband Countryside" construction plan reported by six provinces (autonomous regions), Sichuan and Yunnan provinces were selected as the first phase pilot areas of the "Broadband Countryside" project, which was undertaken by Sichuan Telecom and Yunnan Mobile respectively in July 2014. The other two provinces (Guizhou and Chongqing) in the south-west mentioned in government documents started relatively late, they launched the "Broadband Countryside" project in June and September 2015, respectively. In this paper, the causal identification is

based on the difference in the start time of the construction of the "Broadband Countryside" in the above four provinces.

4. Research design

4.1 Model design

This paper identifies the impact of broadband construction on rural household consumption by constructing a Difference-in-Differences Model (DID). In order to ensure the reliability of the DID model analysis results, we carefully take the rural areas of Sichuan and Yunnan Province as the experimental group, both of which started "Broadband Countryside" construction in 2014. For the sake of comparing with the experimental group provinces, this paper finally chooses Chongqing municipality and Guizhou province as the control group after considering the economic development level and geographical location factors. Specifically, Chongqing municipality and Sichuan province were originally one province in the administrative division, so the two regions have similar climate, language and customs. Moreover, Yunnan and Guizhou Province belong to the "Yunnan-Kweichow Plateau", which are similar in topography, geomorphology, climate and folklore. On the other hand, Sichuan province and Chongqing municipality are geographically adjacent, as are Guizhou and Yunnan provinces. Therefore, each pair has strong comparability in rural household income and industrial development level, as shown in Table 1. The per capita net income of rural residents in Sichuan and Chongqing is extremely close, while Yunnan and Guizhou are relatively close. In terms of industrial structure, overall, the industrial structure of the four provinces is relatively close.

On the strength of aforementioned analysis on the selection of the experimental group and the control group, the model setting of this paper is as follows:

$$y_{i,t} = \alpha_0 + \alpha_1 \text{Treat*Post} + \sum \text{Controls}_{i,t} + v_t + e_i + \in_{it} \quad (1)$$

Among them, $y_{i,t}$ represents the dependent variable of the model, which is the consumption level of family i at time t. v_t is year dummy variable, e_i is province dummy variable and $\in_{it}$ is the error term. Treat*Post is the product of the dummy variable of the experimental group and the dummy variable of the year, and its coefficient α_1 is the average treatment effect, which reflects the difference in consumption changes between the families in the provinces of the experimental group and those in the provinces of the control group before and after the

Province	GDP per capita	Per capita net income of rural residents	Proportion of primary industry	Proportion of secondary industry	Proportion of tertiary industry	Group	"Broadband countryside" starting year
Sichuan	32,454	7895.3	13.04%	51.71%	35.25%	Experimental group	2014
Chongqing	42,795	8332.0	8.03%	50.55%	41.42%	Control group	2015
Yunnan	25,088	6141.3	16.17%	42.04%	41.79%	Experimental group	2014
Guizhou	22,922	5434.0	12.85%	40.51%	46.64%	Control group	2015

Note(s): The data are from China Statistical Yearbook. The quantitative units of GDP per capita and per capita net income of rural residents are both Chinese yuan

Table 1. Comparison of macroeconomic variables between experimental and control groups (2013)

implementation of the policy. $\sum Controls_{i,t}$ are the control variables, including characteristic variables of household and head of household.

4.2 Data sources and descriptive statistics

4.2.1 Data sources. The data used in this paper comes from the China Household Finance Survey (CHFS) project conducted by Southwestern University of Finance and Economics (SWUFE) in 2013 and 2015, which was initiated by the China Family Finance Survey and Research Center of SWUFE in 2011 and is the only family tracking survey in China with the theme of family finance. The CHFS not only has a low rejection rate (about 10.9%, minimum level in similar surveys), but also with its demographic characteristics very close to the national census data. Meanwhile, the survey sample is well-represented nationwide as well as with high quality data.

We retained the rural samples of Sichuan Province, Yunnan Province, Chongqing City and Guizhou Province in the 2013 and 2015 CHFS survey data, in terms of data selection, the family-consistent tracking survey data is selected, and then formed a panel data spanning 2 years. There are two reasons for this decision: Firstly, data from both periods are collected before and after the policy, and consistent household tracking survey data are more helpful in evaluating the impact of the policy. Secondly, by combining multiple observations at different points in time, the sample size can be further increased to obtain more accurate estimates and more effective test statistics.

4.2.2 Variable descriptions and descriptive statistics. The data in this article is balanced panel data, with a total of 2,208 valid samples. Table 2 reports the variable descriptions and descriptive statistical results of the main variables in this paper.

From the perspective of the most commonly used network access equipment, the construction of "Broadband Countryside" has a significant impact on the proportion of

Table 2. Variable descriptions and Descriptive statistics

Variables	Variable description	*N*	Mean	Std Dev
Household characteristic variables				
lnTcons	Natural logarithm of household total consumption in the past year	2,208	9.718	1.006
Av_age	Average age of all family members	2,208	43.41	14.649
C_ratio	The proportion of children aged 0–15 in the total family population	2,208	0.156	0.174
E_ratio	The proportion of the elderly population over 65 years old in the total family population	2,208	0.197	0.307
Av_educ	Average years of education for all family members	2,208	2.056	0.858
H_prop	Proportion of healthy family members to total family population	2,208	0.516	0.332
Hou_num	The total population of the family	2,208	4.088	1.811
Work_num	The total number of working people in the family	2,208	2.294	1.291
A_sub	Whether family receives a subsidy for agricultural operations, 1 = Yes, 0 = No	2,208	0.489	0.5
lnGinco	Natural logarithm of general income of the family in the past year	2,208	9.539	1.459
lnTasset	Natural logarithm of total household assets	2,208	11.436	1.422
Household head characteristics variables				
Male	Gender of head of household, 1 = Yes, 0 = No	2,208	0.856	0.352
Married	Whether the head of household is married, 1 = Yes, 0 = No	2,208	0.875	0.33
Work	Whether the head of household has a job, 1 = Yes, 0 = No	2,208	0.813	0.39
Insurance	Whether the head of household has social health insurance, 1 = Yes, 0 = No	2,208	0.922	0.268
Deposit	Whether the head of household has a fixed term deposit, 1 = Yes, 0 = No	2,208	0.114	0.318

households with computers and mobile phones. As shown in Figure 1(a), after the "Broadband Countryside" pilot policy took place, the range of improvement in the experimental group was greater than that in the control group (6.81 vs 3.57%). Figure 1(b) shows that for cellphone, the experimental group's improvement was 3.91% points higher than the control group. Table 4 shows the univariate analysis of household consumption before and after the "Broadband Countryside" pilot policy. In addition, it can be seen from Table 3 that the increase in household consumption in the experimental group was greater than that in the control group (about ¥10,856 vs ¥6420), while the consumption of the two groups in 2013 was very close (¥17,642.86 VS ¥17,853.37). The aforementioned analysis shows that before and after the "Broadband Countryside" pilot policy, the computer and mobile phone ownership rates and consumption levels of families in the experimental group and the control group have increased, and the increase in the experimental group is greater than that of the control group, but whether the "Broadband Countryside" pilot policy really affects the household consumption in the experimental group needs further analysis.

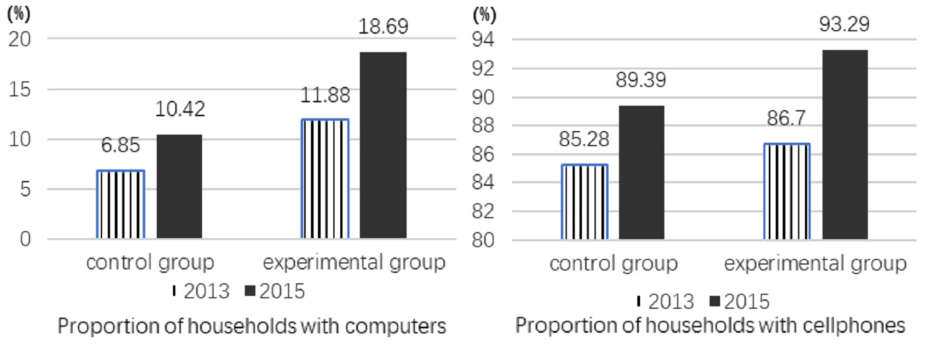
5. Estimated results and analysis

5.1 Estimated results of DID

The following Model (1) to Model (3) in Table 4 is used to estimate the impact of the "Broadband Countryside" pilot policy on rural household consumption by gradually adding the household characteristic and the household head individual characteristic variables. According to the results, the estimated coefficient of Treat*Post is 0.1568, 0.1624 and 0.1669, respectively, and all of them are statistically significant. Specifically, Model (3) shows that broadband construction has increased the consumption of rural households by about 16.69%, and is significant at the level of 5%.

5.2 Estimated results of PSM-DID

The DID method must meet strict prerequisites, one is the randomness of sample selection assumption, and the other is the common trend assumption. In order to obtain more reliable results, this paper uses the method of PSM-DID to make full use of the respective advantages of the DID method and the propensity score matching (PSM) method, while overcoming the influence of unobservable variables and observable variables on sample selection (Heckman *et al.*, 1998).



Source(s): Calculated based on the 2013 and 2015 China Household Financial Survey conducted by the SWUFE

Figure 1. Reflection of broadband construction

In order to make the control group as close as possible to the state of the experimental group's families not affected by the "Broadband Countryside" pilot policy, we used the nearest neighbor matching method to find a similar control group for the treatment group. Due to the family samples of the experimental group and the control group are closer, we use a 1:1 ratio for matching. Finally, DID test is carried out again according to the Model (1) to Model (3). Results are shown in Table 5 [1], the coefficients of Treat*Post in Column 2 to Column 4 are all significantly positive at least 10% level, and their direction and significance level are consistent with the results in Table 4, indicating that the above DID model estimated results are reliable.

5.3 Estimated results of itemized consumption

In this section, according to the classification standards of China National Bureau of Statistics, the CHFS's household consumption expenditure items are divided into seven

Table 3.
Changes in household consumption before and after the impact of policies

Index	Time	*N*	Mean	Mean test *T* Value
Experimental group				
Total household consumption	Before policy	664	17642.86	5.7341***
	After policy	549	28499.62	
Control group				
Total household consumption	Before policy	592	17853.37	5.3577***
	After policy	525	24273.91	

Note(s): ***$p < 0.01$

Table 4.
Effects of "Broadband Countryside" construction on rural household consumption (DID)

	Rural household consumption		
	Model (1)	Model (2)	Model (3)
Treat*Post	0.1568* (0.0845)	0.1624** (0.0681)	0.1669** (0.0683)
Av_age		−0.0160*** (0.0029)	−0.0167*** (0.0029)
Av_educ		0.1124*** (0.0264)	0.1064*** (0.0263)
C_ratio		−0.2195 (0.1964)	−0.2942 (0.1958)
E_ratio		0.0503 (0.0878)	0.0958 (0.0881)
H_prop		0.2583*** (0.0711)	0.2084*** (0.0717)
Hou_num		0.1284*** (0.0160)	0.1212*** (0.0171)
Work_num		−0.1111*** (0.0198)	−0.1285*** (0.0226)
A_sub		−0.0328 (0.0359)	−0.0443 (0.0359)
lnGinco		0.1007*** (0.0155)	0.1041*** (0.0154)
lnTasset		0.2193*** (0.0161)	0.2151*** (0.0160)
Male			0.0193 (0.0498)
Married			0.2838*** (0.0588)
Work			0.0345 (0.0538)
Insurance			0.0817 (0.0698)
Deposit			−0.0634 (0.0503)
Year dummy variables	control	control	control
Province dummy variables	control	control	control
Constant	9.4214*** (0.0569)	6.2944*** (0.2770)	6.0965*** (0.2883)
N	2,208	2,208	2,208
Adj-R^2	0.0432	0.3870	0.3964

Note(s): Standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

categories [2], namely, housing expenditure (House_cons), daily necessities and service expenditures (Daily_cons), transportation and communication expenditures (Trans_cons), education, culture and entertainment expenditures (Educ_cons), food expenditure (Food_cons), Clothing expenditure (Cloth_cons), medical care expenditure (Medical_cons). All the itemized consumption enters the regression in the form of logarithm.

From the regression results in Table 6, broadband construction has significantly increased rural households' consumption of daily necessities and services as well as clothing. It also promotes an increment in consumption of housing products, transportation and communication products, food as well as education, culture and entertainment products, but the corresponding estimated coefficients are not statistically significant. In addition, the construction of broadband squeezes out consumption of medical care products. Based on the estimated size and direction of the effect of broadband construction on rural households' itemized consumption, we find that rural households pay much attention to the consumption of practical products, such as daily necessities, household durables, and clothing, which means that broadband construction is gradually improving and facilitating the living conditions of rural households.

5.4 Other robust discussions

In this section, we further use diversified methods to analyze and discuss the robustness of the conclusion.

5.4.1 Endogenous discussion. Several characteristics of the policy itself can ensure that it is exogenous to some extent, such as the project is established only based on the plan submitted by the province, the time from document issuance to the start of the project is short, and the project is province-level policy. Therefore, this paper believes that the construction of "Broadband Countryside" can be approximated as a quasi-natural experiment, but reasonable analysis is still needed to obtain further support.

First, we discuss the exogeneity of the construction of "Broadband Countryside". If the "Broadband Countryside" pilot project has a strong exogeneity, household consumption decisions should not be related to the division of the experimental group and the control group. Therefore, we verify the exogeneity of the "Broadband Countryside" policy by estimating the impact of whether it is the experimental group on household consumption. The results are shown in Table 7. Column 3 shows that the estimated coefficient of Treat is −0.0027 and is not significant at the level of 10%. Therefore, there is no significant correlation between household consumption decisions and whether to enter the experimental group, which enhances our confidence in the construction of "Broadband Countryside" with strong exogeneity.

Furthermore, in order to better deal with unobservable region effects or time effects, we also use panel fixed effects to estimate. And column 4 of Table 7 reports the estimation

	Rural household consumption		
Treat*Post	0.1512* (0.0846)	0.1514** (0.0682)	0.1549** (0.0684)
Household characteristics variables	No control	control	control
Household head characteristics variables	No control	No control	control
Year dummy variables	control	control	control
Province dummy variables	control	control	control
Constant	9.4222*** (0.0569)	6.2474*** (0.2762)	6.0311*** (0.2879)
N	2,200	2,200	2,200
Adj-R^2	0.0420	0.3875	0.3972

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 5. Effects of "Broadband Countryside" construction on rural household consumption (PSM-DID model)

Table 6.
Effects of "Broadband Countryside" construction on itemized consumption

	Rural household itemized consumption						
	House_cons	Daily_cons	Trans_cons	Educ_cons	Food_cons	Cloth_cons	Medical_cons
Treat*Post	0.0466 (0.1618)	0.4262*** (0.1474)	0.1290 (0.1013)	0.0622 (0.2901)	0.0807 (0.1170)	0.5152*** (0.1952)	−0.0759 (0.1956)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	−0.8246 (0.6282)	−0.7197 (0.5723)	−0.0018 (0.4216)	−1.7879 (1.1057)	2.5506*** (0.4613)	0.3934 (0.7303)	−2.9669*** (0.7527)
N	2,208	2,208	2,208	2,208	2,208	2,208	2,208
Adj-R^2	0.1600	0.1514	0.3441	0.2417	0.1531	0.2684	0.6699

Note(s): Controls include Household characteristics variables, Household head characteristics variables, year dummy variables and province dummy variables; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

results. From the results, the estimated coefficient of Treat*Post is 0.1759, which is the same as the estimated result in Table 4, indicating that the DID results are robust.

5.4.2 Counterfactual tests. In order to investigate whether the effect of the "Broadband Countryside" pilot policy on families of the experimental group was caused by some unobservable variables or random factors, we further tested by constructing counterfactual methods. Based on the method of Bharadwaj *et al.* (2014) we randomly divided the samples into experimental group or control group, and assumed that the experimental group suffered a policy shock in 2014, and then estimated the effect of the virtual policy. As shown in column 2 of Table 8, the estimation results indicate that the virtual policy has no significant impact on household consumption. Furthermore, for the control group sample, the results in Column 3 show that the conclusion has not changed. Estimated results from these counterfactual regressions enhance the reliability of the DID model used in this paper.

In addition, this paper uses the random test of the implementation time of the "Broadband Countryside" policy to ensure the rationality of the DID design. We add 2011 data on the basis of the original data to estimate, and assume that the implementation time of the broadband policy is 2012. Since the amount of data in 2011 is very small, so here we use mixed cross-section data for regression, and does not include the total asset variable. Column 4 of Table 8 reports the corresponding estimation results, and the fictitious policy has no significant impact on household consumption decisions. In a way, it can also explain that household consumption decisions have not violated the parallel trend assumption.

Furthermore, in order to show the robust results of the counterfactual test more intuitively, we randomly change the value of Treat*Post for each family, and keep other variables and unobservable missing variables (assuming existence) unchanged, and then the analysis is re-analyzed using this set of virtual data. This paper has done 500 simulations to obtain the Treat*Post regression coefficients and corresponding t values, as shown in Figure A1.

	Rural household consumption		
	OLS	OLS	FE
Treat	0.0003 (0.0511)	−0.0027 (0.0511)	
Post			
Treat*Post			0.1759*** (0.0667)
Household characteristics variables	control	control	control
Household head characteristics variables	No control	control	control
Year dummy variables			control
Province dummy variables			control
Constant	6.2774*** (0.2778)	6.0624*** (0.2893)	6.3952*** (0.9011)
N	1,141	1,141	2,208
Adj-R^2	0.3797	0.3883	0.2230

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 7. Estimates of household consumption differences before policy implementation and fixed effect models

	Rural household consumption		
	All samples	Control group sample	Add 2011 data
Treat*Post	−0.0206 (0.0689)	0.0172 (0.0945)	0.1311 (0.1187)
Controls	Yes	Yes	Yes
Constant	6.0629*** (0.2873)	5.8219*** (1.6607)	8.3200*** (0.6858)
N	2,208	1,067	2,550
Adj-R^2	0.3893	0.4452	0.3551

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 8. Counterfactual test (DID model)

6. Further discussion

6.1 Role of network access facilities

At present, the mainstream Internet access equipment mainly includes computer and mobile phone, so which one will play a critical role in raising the consumption level of rural households in broadband construction? Further analysis is required.

Considering that the network access devices such as computer and mobile phone will not directly affect the household consumption of farmers, but can only play a role through broadband construction, it does not add computer or mobile phone variables to the model independently, but appears in the form of interaction items with Treat*Post. Table 9 shows the estimated results. As shown in Column 2, the coefficient of the interaction item of Treat*Post and the computer is negative but not significant at the 10% level. In Column 3, the coefficient of the interaction item is 0.4092, and it is significant at the 1% level. Column 4 refers to regression results of adding the interaction items of Treat*Post with computer and mobile phone to the model at the same time. The interaction items of Treat*Post with computer are negative and significant, while the interaction term of Treat*Post with mobile phone is significant at the 1% level, with an estimated coefficient of 0.4153. Through the above series of results, it can be found that the possession of computers in rural households has a crowding-out effect on household consumption, and the promotion of broadband construction on rural household consumption is mainly achieved by means of mobile phones. The possible explanation is that the price of the computer is relatively high compared to the income of the rural family. After the family buys a computer, it will reduce other expenditures accordingly. However, the popularity of low-cost smartphones has provided opportunities for rural residents to access the Internet, and mobile phones have become the main online tool for rural residents.

6.2 Heterogeneity of consumption

As China is gradually entering the stage of high-quality development, the pursuit of high-quality consumption has also become the integral component of development, and is also an inevitable requirement to meet people's yearning for a better life. Although we have confirmed the positive impact of broadband construction on rural household consumption, whether the "broadband rural" policy has improved the consumption structure of rural households in addition to promoting the consumption needed for daily life needs further elaboration.

According to the classification of consumption by the Bureau of Statistics of China, this paper will represent the improvement of consumption quality by increasing consumption related to transportation, communication, culture and entertainment, luxury goods expenditure, education and training, tourism, family visit, and name it as "high-quality consumption" synthetically. At the same time, we will denote the consumption other than

Table 9.
Impact of broadband construction on rural household consumption (the role of network access facilities, DID model)

	Rural household consumption		
	Computer	Cellphone	Both
Treat*Post	0.1884*** (0.0708)	−0.2155 (0.1243)	−0.1919 (0.1193)
Treat*Post*Computer	−0.1775 (0.1138)		−0.2137* (0.1145)
Treat*Post*Cellphone		0.4092*** (0.1167)	0.4153*** (0.1176)
Controls	Yes	Yes	Yes
Constant	6.2275*** (0.2903)	6.1109*** (0.2872)	6.2446*** (0.2889)
N	2,208	2,208	2,208
Adj-R^2	0.4025	0.3986	0.4050

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

high-quality consumption as "consumption of daily life". In addition, we also use the proportion of high-quality consumption in total consumption to measure the consumption structure, which is also a manifestation of whether consumption is upgraded. From the estimated results in Table 10, the coefficient of Treat*Post in Column 2 is 0.2099, which is significant at the level of 1%, indicating that broadband construction has indeed promoted consumption related to daily life significantly. The estimated coefficient of Treat*Post in Column 3 is 0.1201, which is positive but not significant at the 10% level, meaning that broadband construction has not significantly increased the demand for high-quality consumption by rural households. In addition, the results in Column 4 show that the estimated coefficient of Treat*Post is −0.0314, and is not significant at the 10% level, indicating that broadband construction has not improved the consumption structure of rural households, which also means that it has not promoted rural household consumption upgrading.

6.3 How broadband stimulates consumption for rural households

According to the previous discussion, the benefits of information technology for rural families and farmers are mainly reflected in the convenience and enrichment of information acquisition (Jin and Deininger, 2009; Gao *et al.*, 2018).Therefore, the role of broadband construction in promoting consumption of rural households may be because farmers can more easily obtain rich information, which reduces the search cost of information and the asymmetry of information, then increasing rural household willingness to consume. Therefore, we construct a mediating effect model to test whether broadband construction promotes the increase of rural household consumption by reducing information search costs and information asymmetry. We choose the degree of information attention as a mediated variable (the questionnaire in CHFS asks "how much do you usually pay attention to economic and financial information?"), and we also pay attention to the information brought about by the expansion of social network. Studies have found that social network plays an important role in information transmission and communication, and can also reduce transaction costs (Bloch *et al.*, 2008). We take the household social spending (logarithmic form) as a measurement variable of the social network.

As shown in Table 11, Columns 2 and 4 are the impact of broadband construction on information attention and social network, respectively. The estimated results show that broadband construction has promoted information attention and social network, and they are significant at the levels of 5 and 1%, respectively. In Columns 3 and 5, information attention and social network are used as control variables and their effects on rural household consumption are estimated, respectively. The estimated results show that both of them significantly increase the consumption of rural households. Based on the above analysis, the role of broadband in promoting rural household consumption through information attention and social network is supported by empirical evidence, which means that rural households

	Rural household consumption		
	Consumption of daily life	High-quality consumption	Consumption structure
Treat*Post	0.2099*** (0.0696)	0.1201 (0.1440)	−0.0314 (0.0183)
Controls	Yes	Yes	Yes
Constant	5.6306*** (0.2943)	2.3298** (0.5803)	0.1953*** (0.0719)
N	2,208	2,208	2,208
Adj-R^2	0.3499	0.3493	0.1770

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 10. Impact of broadband construction on heterogeneous consumption

Table 11.
"Broadband Countryside" construction unblocked information channels (DID)

	Information attention	Household consumption	Social spending	Household consumption
Treat*Post	0.0878** (0.0396)	0.1540** (0.0683)	0.7510*** (0.2848)	0.1331** (0.0672)
Information attention		0.1473*** (0.0358)		
Social spending				0.0451*** (0.0051)
Controls	Yes	Yes	Yes	Yes
Constant	−0.3985 (0.1489)	6.1552*** (0.2868)	−4.0220*** (1.0673)	6.2779*** (0.2815)
N	2,208	2,208	2,208	2,208
Adj-R^2	0.0610	0.4010	0.1606	0.4181

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

rely on broadband to reduce information search cost and information asymmetry, and then promote the growth of their own consumption.

7. Conclusions

Compared with transportation infrastructure, the important role of broadband infrastructure has not attracted enough attention. This article applies a quasi-natural experiment to draw causal inference based on the exogenous policy shock of the "Broadband Countryside" pilot project. Specifically, this paper divides the sample into experimental groups and control groups according to whether the location of rural households is selected as the pilot province of "Broadband Countryside", and uses the difference-in-differences model (DID) to estimate the impact of broadband construction on rural household consumption. The empirical study found that compared with the control group (rural households in Chongqing Municipality and Guizhou), broadband construction increased the consumption of rural households in the pilot provinces (Sichuan and Yunnan) by 16.69%, indicating that broadband construction has significantly promoted consumption of rural households. From the perspective of broadband network access facilities, the promotion of broadband on rural household consumption is mainly achieved through mobile phones, while computers have a crowding out effect on rural household consumption due to high price. Furthermore, from the perspective of consumption heterogeneity, broadband construction has a significant role in promoting the daily life consumption of rural households, and it also promotes high-quality consumption without statistically significant, but has no effect on the improvement of rural household consumption structure.

This research has reference significance for policy making. In the context of "the new normal", "rural revitalization" and "the contradiction between the growing needs of the people for a better life and the unbalanced and inadequate development", the potential of rural consumption needs to be activated, especially high-quality and high-grade consumption. The research results of this paper help to understand the role of broadband in promoting rural household consumption, and also provide a policy evaluation basis for vigorously carrying out broadband infrastructure construction in rural areas and the subsequent "new infrastructure" planning.

Notes

1. The estimated results of the control variables from Tables 5 to 11 can be requested from the authors.
2. In addition to the seven categories of consumption explained in the main text, there is an "other consumption" (the luxury expenditure in CHFS). Since the survey data is almost all 0, it is not considered in this paper.

References

Aker, J.C. (2011), "Dial 'a' for agriculture: a review of information and communication technologies for agricultural extension in developing countries", *Agricultural Economics*, Vol. 42 No. 6, pp. 631-647.

Alavion, S.J. and Taghdisi, A. (2021), "Rural e-marketing in Iran; modeling villagers' intention and clustering rural regions", *Information Processing in Agriculture*, Vol. 8 No. 1, pp. 105-133.

Audretsch, D.B., Heger, D. and Veith, T. (2015), "Infrastructure and entrepreneurship", *Small Business Economics*, Vol. 44 No. 2, pp. 219-230.

Bahia, K., Castells, P., Cruz, G., Masaki, T., Pedrós, X., Pfutze, T. and Winkler, H. (2020), *The Welfare Effects of Mobile Broadband Internet: Evidence from Nigeria*, IZA Discussion Papers, Institute of Labor Economics (IZA), Bonn.

Baorakis, G., Kourgiantakis, M. and Migdalas, A. (2002), "The impact of e-commerce on agro-food marketing: the case of agricultural cooperatives, firms and consumers in Crete", *British Food Journal*, Vol. 104 No. 8, pp. 580-590.

Barro, R.J. (1981), "Output effects of government purchase", *Journal of Political Economy*, Vol. 89 No. 6, pp. 1086-1121.

Bharadwaj, P., Johnsen, J.V. and Loken, K.V. (2014), "Smoking bans, maternal smoking and birth outcomes", *Journal of Public Economic*, Vol. 115, pp. 72-93.

Bloch, F., Genicot, G. and Ray, D. (2008), "Informal insurance in social networks", *Journal of Economic Theory*, Vol. 143, pp. 36-58.

Bris, M., Pawlak, J. and Polak, J.W. (2017), "How is ICT use linked to household transport expenditure? A cross-national macro analysis of the influence of home broadband access", *Journal of Transport Geography*, Vol. 60, pp. 231-242.

Brown, J.R. and Goolsbee, A. (2002), "Does the Internet make markets more competitive? Evidence from the life insurance industry", *Journal of Political Economy*, Vol. 110 No. 3, pp. 481-507.

Brynjolfsson, E., Hu, Y. and Smith, M.D. (2003), "Consumer surplus in the digital economy: estimating the value of increased product variety at online booksellers", *Management Science*, Vol. 49 No. 11, pp. 1580-1596.

Couture, V., Faber, B., Gu, Y. and Liu, L. (2018), *E-commerce Integration and Economic Development: Evidence from China*, NBER working paper [No. w24383], NBER, Cambridge, Massachusetts.

Deichmann, U., Goyal, A. and Mishra, D. (2016), "Will digital technologies transform agriculture in developing countries?", *Agricultural Economics*, Vol. 47 S1, pp. 21-33.

Donaldson, D. (2010), "Railroads of the Raj: estimating the impact of transportation infrastructure", *American Economic Review*, Vol. 108 No. 4, pp. 899-934.

Donaldson, D. and Hornbeck, R. (2016), "Railroads and American economic growth: a 'market access' approach", *The Quarterly Journal of Economics*, Vol. 131, pp. 799-858.

Ellison, G. and Ellison, S.F. (2018), *Match Quality, Search, and the Internet Market for Used Books*, NBER working paper [No. w24197], NBER, Cambridge, Massachusetts.

Gao, Y., Zang, L. and Sun, J. (2018), "Does computer penetration increase farmers' income? An empirical study from China", *Telecommunications Policy*, Vol. 42 No. 5, pp. 345-360.

Gramlich, E. (1994), "Infrastructure investment: a review essay", *Journal of Economic Literature*, Vol. 32, pp. 1176-1196.

Hartje, R. and Hübler, M. (2017), "Smartphones support smart labour", *Applied Economics Letters*, Vol. 24 No. 7, pp. 467-471.

Heckman, J.J., Ichimura, H. and Todd, P.E. (1998), "Matching as an econometric evaluation estimator", *Review of Economic Studies*, Vol. 65 No. 2, pp. 261-294.

Hou, J., Huo, X. and Yin, R. (2019), "Does computer usage change farmers' production and consumption? Evidence from China", *China Agricultural Economic Revie*, Vol. 11 No. 2, pp. 387-410.

Jensen, R. (2007), "The digital provide: information (technology), market performance and welfare in the South Indian fishers sector", *Quarterly Journal of Economics*, Vol. 122 No. 3, pp. 879-924.

Jensen, R. (2010), "Information, efficiency and welfare in agricultural markets", *Agricultural Economics*, Vol. 41 No. S1, pp. 203-216.

Jin, S. and Deininger, K. (2009), "Land rental markets in the process of rural structural transformation: productivity and equity impacts from China", *Journal of Comparative Economics*, Vol. 37 No. 4, pp. 629-646.

Khandker, S.R., Bakht, Z. and Koolwal, G.B. (2009), "The poverty impact of rural roads: evidence from Bangladesh", *Economic Development and Cultural Change*, Vol. 57 No. 4, pp. 685-722.

Lio, M. and Liu, M.C. (2006), "ICT and agricultural productivity: evidence from cross-country data", *Agricultural Economics*, Vol. 34 No. 3, pp. 221-228.

Liu, M., Min, S., Ma, W. and Liu, T. (2021), "The adoption and impact of E-commerce in rural China: application of an endogenous switching regression model", *Journal of Rural Studies*, Vol. 83, pp. 106-116.

Luo, X., Wang, Y. and Zhang, X. (2019), *E-Commerce Development and Household Consumption Growth in China*, World Bank Policy Research Working Paper [No. 8810], The World Bank, Washington DC.

Ma, L., Niu, D. and Sun, W. (2021), "Transportation infrastructure and entrepreneurship: evidence from high-speed railway in China", *China Economic Review*, Vol. 65 No. 101577, doi: 10.1016/j.chieco.2020.101577.

Medeiros, V., Ribeiro, R.S.M. and Amaral, P.V.M.D. (2021), "Infrastructure and household poverty in Brazil: a regional approach using multilevel models", *World Development*, Vol. 137 No. 105118, doi: 10.1016/j.worlddev.2020.105118.

Olivier, B. and Roberto, P. (2002), "An empirical characterization of the dynamic effects of changes in government spending and taxes on output", *Quarterly Journal of Economics*, Vol. 117, pp. 1329-1368.

Rogers, E.M. (2000), "Informatization, globalization, and privatization in the new millennium", *Asian Journal of Communication*, Vol. 10 No. 2, pp. 71-92.

Tack, J. and Aker, J.C. (2014), "Information, mobile telephony, and traders' search behavior in Niger", *American Journal of Agricultural Economics*, Vol. 96 No. 5, pp. 1439-1454.

Tadesse, G. and Bahiigwa, G. (2015), "Mobile phones and farmers' marketing decisions in Ethiopia", *World Development*, Vol. 68, pp. 296-307.

Appendix

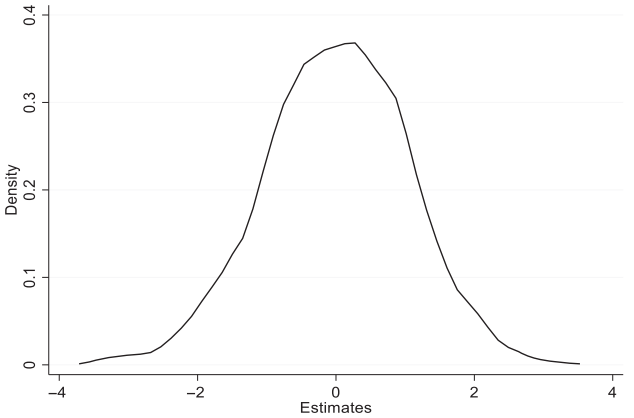


Figure A1.
Distribution of *t* value of Treat*Post coefficient

Note(s): Figure A1 shows that almost all *t*-values are smaller than the *t*-value of the true regression's coefficient ($t = 2.44$) in the benchmark model (Column 4 in Table 4), indicating that rural household consumption is indeed affected by broadband construction

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