Rural Infrastructure and Poverty in China

by Xiaodi Qin and Haitao Wu

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The study develops a framework of how irrigation and drainage infrastructure and rural transportation infrastructure influence poverty. Using panel data on 31 provinces in China from 2002 to 2017, this paper estimates basic and continuous difference-in-differences (DID) models to investigate the preliminary impact of irrigation and drainage infrastructure and rural transportation infrastructure on poverty and further explores the influence mechanisms of these rural infrastructures on poverty by using the mediating effect model. The results show that irrigation and drainage facilities infrastructure can directly reduce poverty. On the one hand, rural transportation infrastructure directly leads to rural hollowing out and aggravates rural poverty; on the other hand, it indirectly promotes poverty reduction by stimulating economic growth. Overall, the positive and negative effects of rural transportation infrastructure on poverty offset each other.

Keywords: Irrigation and drainage infrastructure; Rural Transportation Infrastructure; Poverty; DID model;

Mediating Effect Model

JEL classification codes: I32, I38.

Ⅰ. Introduction

Poverty reduction has always been a core component of the Sustainable Development Goals of the United Nations, which are deeply important for promoting the sustainable development of the world. On November 23rd 2020, China announced that it had eliminated absolute poverty nationwide by uplifting all its citizens beyond its set ￥2,300 (CNY) per year, or around $1.52 per day poverty line. Over the past 40 years, China has pursued many stimuluses to achieve this goal and more than 700 million people has been lifted out of poverty. One of the stimuluses is to promote a variety of infrastructure projects (X Shenxiang et al., 2018). In fact, infrastructure plays a fundamental role in promoting growth and alleviating poverty in China, especially in rural areas. As one of the most important documents in China, the No. 1 central document of the Central Committee of the Communist Party of China in 2010 proposed to substantially increase investment to rural infrastructure, especially for irrigation and drainage and transportation infrastructure. About 86.2 billion CNY was invested to small-sized irrigation projects and 132.3 CNY to rural roads and other public transport infrastructures. It is revealed that transportation infrastructure usually attracts more investment than irrigation and drainage infrastructure. That is because transportation infrastructure has the characteristics of high profits and quick return and consequently promote economic growth. However, rural transportation infrastructure may not have social benefits and succeed in reducing poverty if rural laborers choose to transfer to urban areas due to the lack of agglomeration of local economies. On the contrary, rural poverty may be deepened because of the loss of young and middle-aged rural labor force and the decline of abandoned villages (Donaldson, D. ,2018). Moreover, irrigation and drainage infrastructure may also fail to count in that case. Given this background, what is the role of rural infrastructure of irrigation and drainage and rural transportation infrastructure in reducing poverty in China? How much can they count and is there any difference between the two kinds of rural infrastructure? What is the mechanism behind the impact? Clarifying these problems will help China reasonably adjust investment structure in rural infrastructure and further consolidate its existing achievements in poverty alleviation, as well as provide useful information to other developing countries troubled by poverty.

Many empirical studies have suggested a positive role for rural infrastructure in allowing improvements to the quality of life of those living in poverty and alleviating poverty. Most of these studies highlight the impact of rural infrastructure on economic growth and thus indirectly on poverty, which is called a trickle-down effect (Barro, 1990; McKay, 1990; Fernald, 1999; Fan and Zhang, 2004; Hulten; 2006; Calderón, 2014). The research by these authors illustrates that rural infrastructure such as rural transportation infrastructure can stimulate economic growth through gains in productivity, which in turn leads to increases in income and poverty alleviation. Sasmal, R., and Sasmal, J. (2016) and Chotia and Rao (2017) examine the connection between economic growth and poverty alleviation as well as how the two are connected to public infrastructure. The results reveal that economic growth may drive poverty reduction, and infrastructure features largely in both growing the economy and reducing poverty.

Some seminal works also pay attention to how rural infrastructure directly affects poverty. Most of the authors believe that rural infrastructure construction can directly reduce farmers' production costs and improve productivity, thereby increasing their income and reducing poverty (Wondemu, 2011; Lenz et al., 2017). Fan et al. (2005) reveal that investment in rural infrastructure can increase household income and promote poverty reduction, with road infrastructure playing the most important role. More recently, some scholars have pointed out that the improvement of rural infrastructure, especially rural transportation infrastructure, may promote urbanization. However, it may also lead to less productive capital and skilled labor in rural areas. In such "hollow villages", the rural poor may fall into greater poverty (Banerjee et al., 2020). This increase in poverty may offset the poverty reduction effect of rural infrastructure, which is called the masking effect of rural infrastructure. Other studies also explore the relationship between irrigation and drainage infrastructure and rural incomes or rural poverty (Li, J. et al., 2020).

Overall, previous studies have emphasized the importance of rural infrastructure for poverty reduction. Most studies focus on the rural transportation infrastructure and usually conclude that is can reduce poverty. However, few literatures mange to figure out the mechanisms of how the irrigation and drainage infrastructure influence poverty. The specific poverty reduction mechanism behind the irrigation and drainage infrastructure needs to be further determined. In addition, it is important to discuss the potential negative impact of rural transportation infrastructure on poverty reduction and make a comparison with the irrigation and drainage infrastructure. Therefore, this paper contributes to a growing but inconclusive body of literature by theoretically clarifying how irrigation and drainage infrastructure and rural transportation can affect poverty. In addition, this paper uses the basic and continuous DID approach to study the preliminary impact of different rural infrastructures on poverty. This continuous DID approach can solve certain endogeneity problems in the model. The two-stage least squares method and a change in the dependent variables are also used as tests of the robustness of the conclusion. Third, this paper uses the mediating effect model to further explore the mechanisms behind the effects of irrigation and drainage infrastructure and transportation infrastructure on poverty. Different from most existing studies, this study finds that rural transportation infrastructure both aggravates rural poverty and reduces poverty by promoting economic growth. Given the current policy situation and this realistic background, it is necessary to pay more attention to the irrigation and drainage infrastructure, which is related to agriculture production and peasants' life. This consideration will further consolidate the gains in poverty alleviation and prevent future increases in poverty.

The rest of this paper is structured as follows. The next section reviews the background of No. 1 Central Document and rural infrastructure in China. Section Ⅲ analyzes the influence mechanisms of the three kinds of rural infrastructure on poverty. Section Ⅳ describes the data, methods and models. Section Ⅴ presents the empirical test and discusses the results. The last section concludes with policy suggestions.

Ⅱ Background: No. 1 Central Document and Rural Infrastructure in China

Agriculture, rural areas and farmers' issues have always been China's top priorities since 2004 and there have been 17 No. 1 central documents, made by the government of China, prioritizing development of agriculture and rural areas with different key themes each year. In 2010, China’s No. 1 central document proposed to strengthen construction of rural infrastructure, especially for rural irrigation and drainage and transportation infrastructure, to reduce poverty. The central and local government funds as well as national debt funds needed to be invested to the construction and management of rural infrastructure. More specifically, the government arranged 818.3 billion CNY for agriculture, peasants, and rural areas in 2010. Among them, 86.2 billion CNY was allocated for small-sized irrigation projects and 132.3 CNY for rural roads and other public transport infrastructures, beyond the previous investment.

After 2010, China’s No. 1 central document still attaches great importance to rural infrastructure of irrigation and transportation and keep investing to rural infrastructure. In fact, the irrigation and transportation infrastructure are two of the most important infrastructures in rural areas, with irrigation and drainage infrastructure closely related to peasants’ production and transportation infrastructure closely related to non-agriculture employment. The construction of rural infrastructure of irrigation and transportation in China lays a solid foundation for future great achievements in poverty alleviation. Therefore, in this article, the rural infrastructures refer to the irrigation and drainage and rural transportation infrastructure.

Ⅲ Framework and Hypotheses

Ⅲ.1. Irrigation and drainage infrastructure and poverty

On the one hand, irrigation and drainage infrastructure can directly reduce poverty. As one of the most basic public goods in rural areas, irrigation and drainage infrastructure can improve agricultural production conditions and grain yield by improving irrigation capacity. Farmers are able to adjust their crop structure, develop large-scale breeding programs and engage in processing and nonagricultural industries to eliminate poverty. At the same time, the improvement of irrigation and drainage infrastructure can enhance farmers’ ability to deal with disasters and reduce risks. Therefore, production efficiency will rise with lower agricultural production costs, thereby reducing poverty. In addition, irrigation and drainage infrastructure can release part of the rural labor force from farm work and optimize the work-time structure. This saved labor and time can be used for higher income activities. Thus, poverty can be reduced. On the other hand, irrigation and drainage infrastructure can indirectly reduce poverty by promoting the growth of agriculture, forestry, animal husbandry and fisheries (Zhang Xun and Zhang Rui, 2017). According to the Cobb-Douglas production function, the elasticity of capital and labor may directly determine growth. Irrigation and drainage infrastructure can increase the output from a unit of capital and labor by reducing the impact of floods and other disasters on them. The growth in agriculture, forestry, animal husbandry and fisheries can continue, thus indirectly affecting poverty.

Based on the literature review, we have the following hypotheses:

Hypothesis 1a. Irrigation and drainage infrastructure can directly reduce poverty.

Hypothesis 1b. Irrigation and drainage infrastructure can indirectly reduce poverty through increasing the growth in local agriculture, forestry, animal husbandry and fisheries.

Ⅲ.2. Rural transportation infrastructure and poverty

The relationship between rural transportation infrastructure and poverty remains complex. In terms of its direct impact, improvements in rural transportation infrastructure can reduce the transportation costs of farmers and expand the market opportunities for local agricultural products (Chotia et al., 2018). However, due to the remote location of and the lack of talent and capital concentration in rural areas, new roads transfer a large amount of labor to the city. This directly leads to the loss of local talent and the hollowing out of rural areas, which aggravates rural poverty (Qin, 2017; Asher and Novosad, 2020).

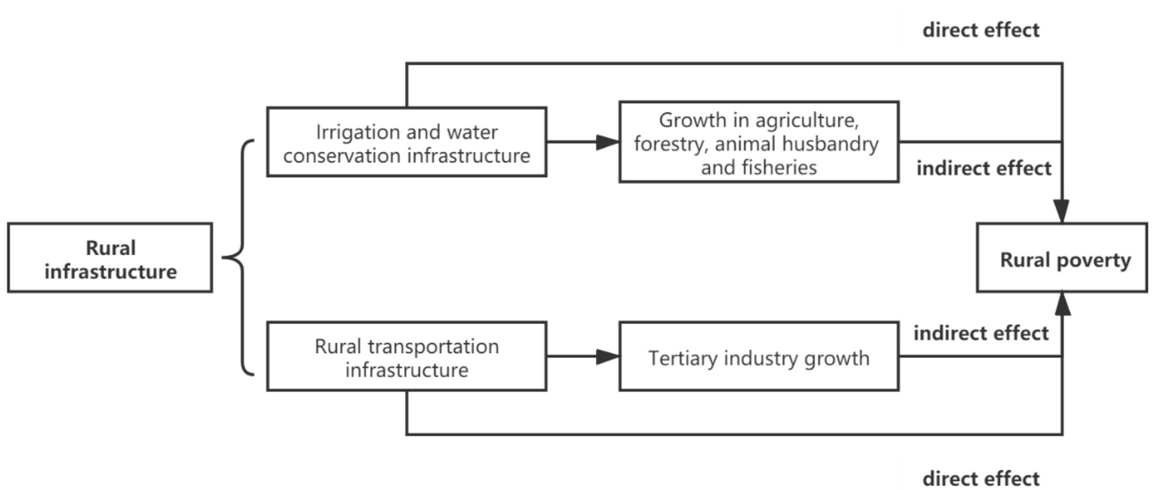
On the other hand, rural transportation infrastructure can reduce poverty indirectly by promoting tertiary industry and stimulating economic growth. The trickle-down effects from economic growth contribute to poverty alleviation. As one of the factors of production, investment in rural transportation infrastructure can promote the division of labor, improve production efficiency, and directly promote economic growth. The multiplier effect produced by investment can further stimulate the vitality of economic growth. In addition, as a public good, rural transportation infrastructure has externalities. This means that investment in rural transportation infrastructure can cause farmers to accumulate human capital and can promote manufacturing production. Additionally, transportation costs can consequently decrease, which can improve the overall investment structure to allow for additional investments and bring about economic growth (Lewis, 1998; Zou et al, 2008; R. P Pradhan et al., 2015; Liu Shenglong et al., 2011; Zhang Xueliang, 2012; Wu Qinghua et al., 2015). Economic growth can reduce poverty by increasing employment opportunities and improving transfer payments, which are both trickle-down effects.

Therefore, we have hypotheses presented as below:

Hypothesis 2a. Rural transportation infrastructure may directly aggravate rural poverty.

Hypothesis 2b. Rural transportation infrastructure can promote tertiary industry growth and thus indirectly reduce poverty.

Figure 1 shows the impact on poverty of 3 kinds of rural infrastructure



Ⅳ. Data and methodology

Ⅳ.1. Data

Due to limited data availability, this paper uses panel data on 26 provinces in China from 2002 to 2017. The data are collected mainly from the 2003-2018 China Rural Statistical Yearbook, China Statistical Yearbook, and the National Bureau of Statistics. The ethnic regions in this paper are eight ethnic provinces in China, referring to the Inner Mongolia Autonomous Region, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region, Tibet Autonomous Region and Guangxi Zhuang Autonomous Region, as well as Guizhou, Yunnan and Qinghai provinces. Poverty is more serious in these areas for environmental and historical reasons. Additionally, due to a lack of data, we do not consider Beijing, Shanghai, Hainan, or Tibet.

Ⅳ.2. Definition of variables

Dependent variables: rural poverty incidence rate (Poverty_ rate) and the size of the rural poor population (Poverty_num). We define people in rural China whose income falls below the minimum income required by the government as the rural poor. The proportion of these people to the total rural population is the rural poverty incidence rate. With the targeted poverty alleviation program in China, those who receive basic living allowances account for an increasing proportion of the impoverished population. They are good representatives for those who live in extreme poverty.

Core independent variables: Referring to the definition of Peng Daiyan (2002), rural infrastructure is different from traditional public services. It caters to farmers' production, life and development with a long service life and two of the most important are irrigation and drainage and rural transportation infrastructure. Irrigation and drainage infrastructure is closely related to peasants' production and may help them increase family business income. While rural transportation infrastructure is closely related to non-agriculture employment and may help them increase wage income. Both irrigation and drainage and rural transportation infrastructure are crucial to poor peasants' income and poverty reduction. We choose effective irrigation area to represent the construction of irrigation and drainage infrastructure as it can reflect the actual irrigation effect on cultivated land. And for rural transportation infrastructure, we choose rural road mileage to represent its construction.

Intermediary variable: According to the previous theoretical analysis, irrigation and drainage infrastructure can indirectly reduce poverty by promoting the growth of agriculture, forestry, animal husbandry and fisheries. Rural transportation infrastructure can indirectly reduce poverty by influencing the growth of the service industry. Therefore, for irrigation and drainage infrastructure, we choose the added value of agriculture, forestry, animal husbandry and fisheries as the intermediary variable (Strobl， E. et al, 2011; Huang, Q. et al, 2006). While for rural transportation infrastructure, we choose and the added value of tertiary industries as intermediary variable (Zou, W. et al, 2008).

Control variables: To increase the robustness of the model, this paper refers to previous studies (Xie, S.X et al., 2018; Lenz et al.,2017) and selects control variables from the three dimensions of economy, society and environment. The development of economy, society and environment may have influences on poverty through many ways. For example, the development of economy may reduce poverty through increasing consumption and expanding the channels of employment. And the development of society may affect the social welfare of the peasants and then pose impact on poverty. While the development of environment may directly influence the agricultural production and then affect welfare of the peasants and poverty. And referring to Sasmal et al.(2016), Lenz et al.(2017) and Zhang(2012), the control variables at the economic level include per capita GDP, per capita industrial output, industrial structure, government expenditures, and rural residents' consumption levels. From the social dimension, the control variables are population density, human capital, population urbanization rate, land urbanization rate, urban-rural income gap, rural electricity consumption, mechanization level, and level of financial support for agriculture. From the environmental dimension, the control variables are land area available for crop planting, reservoir capacity, soil erosion control, and grain yield. The proxy indicators for each control variable are shown in Table 1.

Table 1 Definition of the variables in the model

Variable type	Dimension	Variable	Symbol	Description
Dependent variable	Poverty	The size of the rural poor population	Poverty_num	The number of the rural poor population
		Rural poverty incidence rate	Poverty_rate	Rural minimum living guarantee population / Total rural population
Independent variable	Rural infrastructure	Irrigation and drainage infrastructure	Irrigation	Effective irrigation area (1000 HA)
		Rural transportation infrastructure	Road	Rural road mileage (km)
Intermediary variable	Industrial added value	The added value of agriculture, forestry, animal husbandry and fisheries	Primary industry	Added value of agriculture, forestry, animal husbandry and fishery (100 million CNY)
		The added value of tertiary industries	Tertiary industry	The added value of tertiary industries (100 million CNY)
Control variable	Economy	Per capita GDP	Pgdp	Per capita GDP (CNY/person)
		Per capita industrial output	Pindustrialization	Industrialization level (10000 CNY / person)
		Industrial structure	Industrial structure	The ratio of the sum of the primary industry and the secondary and tertiary industries

		Government expenditures	Government expenditures	Reflecting government expenditure (100 million CNY)
		Rural residents' consumption levels	Consumption	Reflect the expenditure of rural residents (CNY / person)
	Society	Population density	Population	Number of people per unit land area (person / km²)
		Human capital	Human capital	Years of education per capita (years)
		Population urbanization rate	Popu_urban	Proportion of urban population
		Land urbanization rate	Land_urban	Built up area (10000 square kilometers)
		Urban-rural income gap	Urban-rural_gap	Income of urban residents / Rural residents
		Rural electricity consumption	Electricity	Rural electricity consumption (100 million kwh)
		Mechanization level	Mechanization	Total power of agricultural machinery (10000 kW)
		Level of financial support for agriculture	Afinance	Local expenditure on agriculture, forestry and water affairs (100 million CNY)
	Environment	Land area available for crop planting	Seed	Sown area of crops (1000 HA)
		Reservoir capacity	Reservoir	Total reservoir capacity (100 million cubic meters)
		Soil erosion control	Erosin	Soil erosion control area (1000 HA)

		Grain yield	Grain	Grain yield per unit area (kg / HA)

The descriptive statistics for the main variables are shown in Table 2. To further ensure the stability of the data and reduce problems such as collinearity and heteroscedasticity in the model, this paper conducts logarithmic transformation on the variables in the data except for the share of the population receiving the rural minimum living guarantee, industrial structure, human capital, population urbanization rate, and urban-rural gap. “ln” before a variable name indicates that logarithmic transformation has been carried out.

Table 2 Descriptive of the variables in the model.

Variable	Obs	Mean	Std. Dev.	Min	Max
ln_Poverty_num	399	1.408657	0.425755	-1.35972	1.837654
Poverty_rate	407	0.061637	0.050879	7.28E-05	0.235325
ln_Irrigation	416	7.486912	0.760957	5.1723	8.704663
ln_Road	324	7.411814	1.061345	3.941776	9.309233
ln_Primary industry	416	6.986169	0.943963	3.856722	8.55312
ln_Tertiary industry	416	8.231568	1.09169	5.002805	10.78074
ln_Pgdp	416	10.06023	0.72028	8.088562	11.58199
ln_Pindustrialization	416	-0.07355	0.781023	-2.27242	1.443663
ln_ Industrial structure	416	0.142803	0.059551	0.038807	0.313253
ln_ Gconsume	416	7.192041	0.920773	4.368054	9.317255
ln_ Rconsume	416	8.437778	0.673429	7.037906	10.19448
ln_ Population	416	5.191411	1.148958	1.993566	6.688268
Human_capital	416	8.414243	0.781646	6.040471	10.10491
Popu_urban	409	0.474366	0.104505	0.242927	0.786396
Land_urban	416	7.018347	0.780466	4.088997	8.684587
Urban-rural_gap	416	2.994952	0.58042	2.03	5.53

ln_ Electricity	416	4.604345	1.324577	0.81093	7.543268
ln_ Mechanization	416	7.78932	0.786424	5.639741	9.499497
ln_ Afinance	416	5.146046	1.13552	2.013342	6.930622
ln_ Seed	416	8.500647	0.727268	6.145901	9.609299
ln_ Reservoir	416	5.273126	0.839136	2.923162	7.14195
ln_ Erosin	416	8.034497	0.794122	4.72473	9.514219
ln_ Grain	416	8.487088	0.21631	7.992971	8.972838

IV.3. Model Specification

IV.3.1. Difference-in-differences

In 2010, to improve peasants' income and reduce poverty, the Chinese government issued No. 1 central document to strengthen investment to rural infrastructure especially irrigation and drainage infrastructure and rural transportation infrastructure. Therefore, this paper will use a difference-in-differences (DID) model and use the investment as a quasi-natural experiment. The impact of rural infrastructure on poverty will be evaluated in this way. This paper selects nonethnic areas as the experimental group and ethnic areas as the control group. The reasons are as follows. Due to natural resource endowments and historical developments, ethnic areas fall far behind nonethnic areas in economic and social terms. According to that situation in China and the theory of Development Poles, the investments in rural infrastructure in China is also developed-region-oriented. Referring to Q Mao et al. (2016), DID applies to this case if the policy in 2010 has relatively larger effects on nonethnic areas than ethnic areas. Theoretically, the parallel trend assumption of DID is satisfied. We will test the assumption in Section 4. The model is as follows:

Basic Difference-in-difference Model

$$y_{it} = \alpha_0 + \alpha_1 du \cdot dt + \sum \alpha_j Z_{it} + \lambda_i + \nu_t + \varepsilon_{it} \qquad (1)$$

where (1) represents the basic DID model. y_{it} is rural poverty incidence rate. du is a group dummy variable. If individual i belongs to the experimental group affected by the policy, we let du=1; otherwise, it is 0. dt is a time dummy variable. dt equals 1 if the observation is from after the policy; otherwise, it is 0. The policy under study was implemented in 2010, which is the treatment period. du·dt is the interaction between the group and time dummy variables; its coefficient denotes the net effect of policy implementation, which is of great importance. $\boldsymbol{\lambda_i}$and $\boldsymbol{\nu_t}$ represent the province fixed effects and the time fixed effects, respectively.

Continuous Difference-in-difference Model

$$y_{it} = \alpha_0 + \sum \alpha_m X_{it} \cdot dt + \sum \alpha_j Z_{it} + \lambda_i + \nu_t + \varepsilon_{it} \qquad (2)$$

In equation (2), the time dummy variable dt is replaced by the continuous variable X_{it}, which represents the different types of infrastructure construction in this article. That is called continuous DID because α_m represents the net effect of the change in each rural infrastructure on poverty (Qian N,2008).

Model of Parallel Trends

$$y_{it} = \beta_0 + \beta_1 D_{it}^{-3} + \beta_2 D_{it}^{-2} + \beta_3 D_{it}^{-1} + \beta_4 D_{it}^{0} + \beta_5 D_{it}^{1} + \beta_6 D_{it}^{2} + \beta_7 D_{it}^{3} + \sum \alpha_j Z_{it} + \varepsilon_{it} \qquad (3)$$

where the dummy variables of "D's," equal zero, except for the following: D~j equals 1 for experimental groups in the jth year before policy, while D+j equals 1 for experimental groups in the jth year after policy. We examine the trends of poverty rates before and after 3 years of the policy. Also, we add the year of the policy and estimate the dynamic effect of policy on poverty rates relative to the year of policy. More importantly, we can test the parallel trend of DID.If β_k (k=1,2,3) before the policy is not significant, then the parallel trend assumption is satisfied. This means that the experimental group and the control group have similar trends before the policy. Similarly, if β_k (k=4,5,6,7) after the policy is significant, it means that differences arise between the experimental group and the control group after the policy implementation.

IV.3.2. Mediating effect model

To test the influence mechanisms of different types of rural infrastructure on poverty, this paper further uses the mediating effect model. Equations (4) - (6) are the regression equations set by the intermediary effect test procedure.

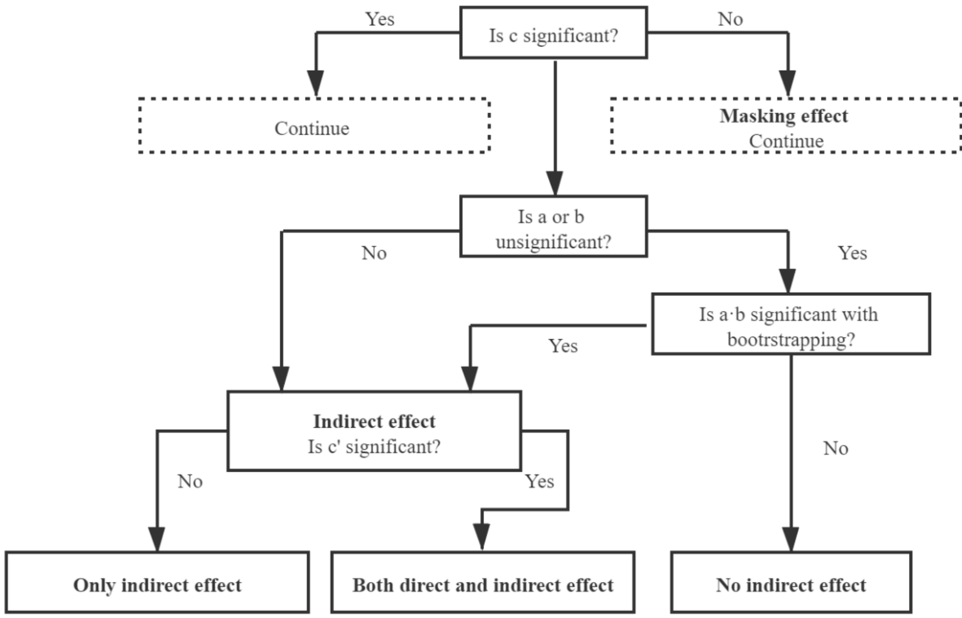
$$y_{it} = \beta + cX_{it} + \alpha \sum Z_{it} + \vartheta_t + \mu_t + \varepsilon_{it} \qquad (4)$$

$$M_{it} = \beta + aX_{it} + \alpha \sum Z_{it} + \vartheta_t + \mu_t + \varepsilon_{it} \qquad (5)$$

$$y_{it} = \beta + c'X_{it} + bM_{it} + \alpha \sum Z_{it} + \vartheta_t + \mu_t + \varepsilon_{it} \qquad (6)$$

where the first step is to regress the dependent variable y_{it} on the independent variable X_{it} to confirm that X_{it} is a significant predictor of y_{it} in Equation (4). Then regress the mediator M_{it} on X_{it} to confirm that X_{it} is a significant predictor of M_{it} in Equation (5).. Finally, regress Y_{it} on both X_{it} and M_{it} to confirm that the $M_{it}$is a significant predictor of Y_{it} in Equation (6). The test procedure of mediating effect test is shown in Figure 1 (preacher and Hayes, 2008; Wen Zhonglin, 2014). The masking effect indicates X_{it} may show no effect on y_{it} on the whole, as positive and negative offsets each other.

Figure 2. Test procedure of mediating effect



Ⅴ. Results and Discussion

Ⅴ.1. Benchmark

In this section, we examine the actual effects of rural infrastructure investment and the different types of rural infrastructure construction on poverty after the 2010 stimulus policy was implemented. Using equation (1), we test the effect of rural infrastructure investment on poverty reduction and control for the fixed effects of provinces and years, as well as the control variables at the provincial level. First, following the benchmark from the DID model shown in equation (1), the poverty incidence rate is taken as the explanatory variable. The effect is estimated by a multiway fixed effect model. Since the investment plan was promoted in 2010, this paper selects 2010 as the treatment period. The estimated results are shown in Table 3. In Table 3, Column (1) does not include control variables, while Column (2) does. The coefficient on the interaction between the time dummy variable and group dummy variable is the focus of our attention and reflects whether rural infrastructure affects poverty. In Column (2), the interaction between the group dummy variable and the dummy variable for 2010 is significantly negative. This result suggests that rural infrastructure construction in 2010 effectively helped alleviate poverty in China.

Table 3 Result of benchmark model of DID

	(1) Poverty_rate	(2) Poverty_rate
$duxdt_{2010}$	-0.0485***	-0.0436***
	(-4.71)	(-5.46)

Control for Year	Yes	Yes
Control for Province	Yes	Yes
Control Variables	No	Yes
Constant	0.077***	1.62*
	(23.01)	(2.05)
Observations	407	400
R-squared	0.8203	0.8791

Note:t statistics in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

However, this conclusion does not reveal irrigation and drainage infrastructure and rural transportation infrastructure can influence rural poverty. To address these questions, this article will further use the continuous DID model to investigate the effects of irrigation and water conservancy infrastructure and rural transportation infrastructure on poverty reduction. The test results based on equation (2) are shown in Table 4.

Table 4 Result of continuous model of DID

	(1)	(2)	(3)	(4)
	Poverty_rate	Poverty_rate	Poverty_rate	Poverty_rate
ln_Irrigation×t2010	-0.00999	-0.0177**		
	(-1.66)	(-2.75)		
ln_Rroad×t2010			0.0075**	-0.0031
			(2.21)	(-0.75)
Control for Year	Yes	Yes	Yes	Yes
Control for Province	Yes	Yes	Yes	Yes
Control Variables		Yes		Yes

Constant	0.0954***	0.968	0.0456***	0.574
	(4.69)	(0.96)	(3.05)	(0.54)
Observations	407	400	311	311
R-squared	0.7818	0.8690	0.8367	0.8588

Note:t statistics in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

As shown in this table, Columns (2) and (4) are based on the estimation results from the continuous DID model from equation (3) and verify the impact of irrigation and drainage infrastructure and rural transportation infrastructure on poverty, respectively. Columns (2) and (4) added control variables to the analyses from (1) and (3), respectively. Column (2) shows that the interaction term between irrigation and drainage infrastructure and the year 2010 is negative and has a significance level of 5%. The results prove that irrigation and drainage infrastructure can effectively reduce poverty. In Column (4), the interaction coefficient between rural transportation infrastructure and the year 2010 is not statistically significant. This result indicates that unlike the other two types of rural infrastructure, rural transportation has no overall significant impact on poverty. We assume that the alleviation effect and aggravation effect of rural transportation infrastructure on poverty are offset, which creates an "illusion" of no impact. To test this assumption, we make use of a mediating effect model to conduct further analysis on influence mechanisms of rural transportation infrastructure on poverty.

Ⅴ.2. Robustness checks

Ⅴ.2.1. Parallel trend test

The parallel trend test results are shown in Table 5. Referring to L Yue et al. (2019), we choose the period three years before and after the implementation of the policy (2010) to test for common trends. As shown in Table 7, control variables are not used in Columns (1) and (2) to ensure the robustness of the regression results. Column (2) shows that the regression coefficients on the interaction terms between the time dummy variables and group dummy variables are not significant in 2007, 2008 or 2009. This finding shows that before the implementation of rural infrastructure construction in 2010, the incidence of poverty in ethnic areas and nonethnic areas experienced the same trend. The fluctuations in the two measures are not significantly different. The experimental group and the control group conform to the DID common trend assumption. Moreover, after 2010, the regression coefficients on the interaction terms between the time dummy variables and group dummy variables are significantly negative in 2011, 2012 and 2013. This result indicates that the trends in poverty in the experimental group and the control group were different after the implementation of the policy in 2010. Therefore, the result passes the parallel trend test required by the DID method.

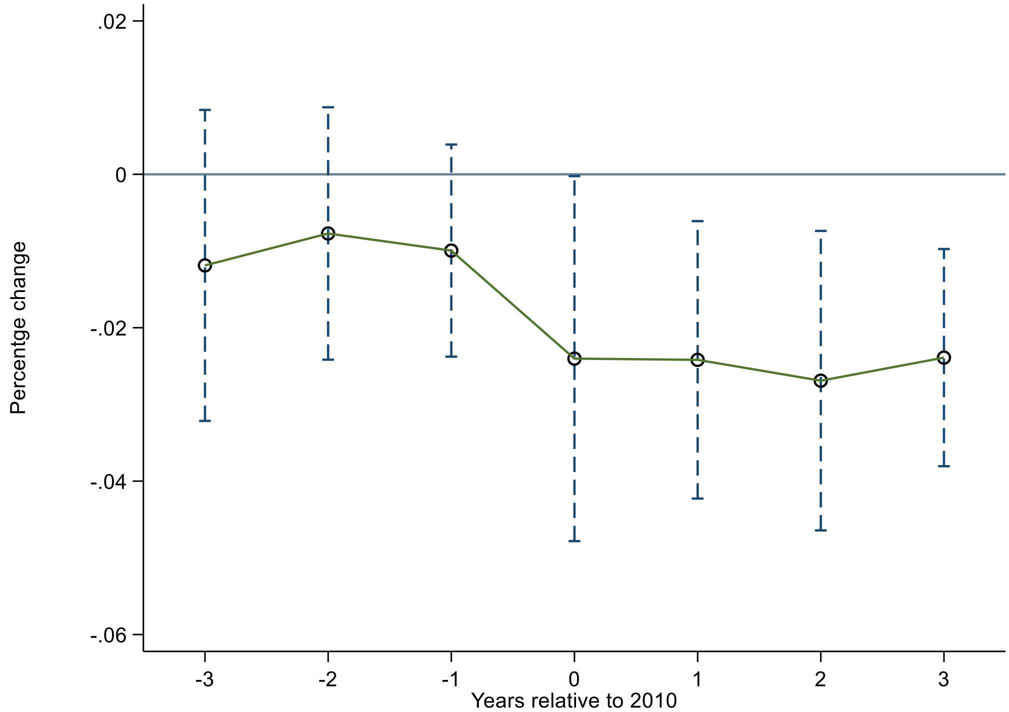
Table 5 Parallel trend test

	(1)	(2)
Pre3	-0.00679	-0.0119

	(-0.97)	(-1.00)
Pre2	-0.00649	-0.00771
	(-0.83)	(-0.80)
Pre1	-0.0108*	-0.00995
	(-1.75)	(-1.23)
Current	-0.0291	-0.0240*
	(-1.69)	(-1.72)
Aft1	-0.0344**	-0.0242**
	(-2.12)	(-2.28)
Aft2	-0.0371**	-0.0269**
	(-2.33)	(-2.35)
Aft3	-0.0384**	-0.0239***
	(-2.67)	(-2.88)
Control for Year	YES	YES
Control for Province	YES	YES
Control Variables	NO	YES
Constant	0.0693***	0.441
	(20.01)	(0.45)
Observations	407	400
R-squared	0.7656	0.8395

Note:t statistics in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

Figure 3. The dynamic impact of rural infrastructure on poverty.



The figure plots the impact of implementation of the policy on rural poverty rates. We consider a 6-year window, spanning from 3 years before the until 3 years after deregulation. The dashed lines represent 95% confidence intervals. Specifically, we report estimated coefficients from the following regression:

$$y_{it} = \beta_0 + \beta_1 D_{it}{}^{-3} + \beta_2 D_{it}{}^{-2} + \beta_3 D_{it}{}^{-1} + \beta_4 D_{it}{}^{0} + \beta_5 D_{it}{}^{1} + \beta_6 D_{it}{}^{2} + \beta_7 D_{it}{}^{3} + \sum \alpha_j Z_{it} + \mathcal{E}_{it}$$

Figure 3 illustrates the same key points as Table 5: there is no trend in poverty rates in two groups prior to the policy. Next, note that poverty rates fall immediately after policy, such that D^{+1} is negative and significant at the 5% level. Thus, the mechanisms and channels connecting rural infrastructure with the infrastructure must be fast acting.

V.2.2. Instrumental variable estimation

To further circumvent the potential endogeneity of the continuous policy variables in equation (3) and test the robustness of the research findings, this section estimates equation (3) using the two-stage least squares method. Equation (3) evaluates the impact of various types of rural infrastructure on poverty. The instrumental variables are lagged irrigation and drainage infrastructure, and lagged rural transportation infrastructure. The results are shown in Table 6. Columns (1), (3) and (5) do not include the control variables and reflect the impact of irrigation and drainage infrastructure and rural transportation infrastructure on poverty, respectively. Columns (2), (4), and (6) include the control variables to the models from Columns (1), (3), and (5), respectively. In Columns (2) and (4), the coefficients on the interaction terms are significantly negative, which is consistent with the above results. In Column (6), the coefficient on the interaction term with 2010 is not significant, which is also consistent with the previous results. Once again, irrigation and drainage infrastructure can promote poverty reduction. However, the effect of rural transportation infrastructure on poverty reduction is not clear. These results show that the findings from the above analysis are robust.

Table 6 Result of two stage least square method

	(1) Poverty_rate	(2) Poverty_rate	(3) Poverty_rate	(4) Poverty_rate	(5) Poverty_rate	(6) Poverty_rate
ln_Irrigation×t2010	-0.00984***	-0.0166***				
	(-2.94)	(-4.89)				
lnMedi×t2010			-0.00342	-0.0160***		
			(-0.71)	(-3.41)		
ln_Road×t2010					0.00714***	0.00270
					(3.61)	(1.26)
Control for Year	YES	YES	YES	YES	YES	YES
Control for Province	YES	YES	YES	YES	YES	YES
Control Variables		YES		YES		YES
Constant	0.00385	0.771	0.00397	1.055*	0.0577***	0.262
	(0.77)	(1.46)	(0.78)	(1.84)	(19.01)	(0.46)
Observations	382	378	382	378	286	286
R-squared	0.6715	0.8032	0.6635	0.7953	0.3844	0.5273

Note:t statistics in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

V.2.3. Change in the dependent variable

The above regression results show that the implementation of rural infrastructure construction in 2010 promoted rural poverty reduction. Among the two types of rural infrastructure, irrigation and drainage infrastructure reduced poverty. However, the effect of rural transportation infrastructure was not clear. To further verify the robustness of the above conclusions and reduce endogeneity in the model, we replace the dependent variable as a robustness test. Specifically, the dependent variable in equation (1) and equation (3) is replaced by the size of the rural poor population.

To enhance robustness, the logarithm of the rural poor population is taken. The regression results are shown in Table 7. Column (1) shows the estimation results based on equation (1). Column (2) includes control variables in the model from Column (1). Columns (3) and (5) are the estimation results from equation (3), showing the impact of irrigation and drainage and rural transportation infrastructure on the size of the rural poor population, respectively. Columns (4) and (6) include control variables in the models from (3) and (5). As shown in Columns (2), (4) and (6) in Table 6, the dependent variable is replaced by the size of the rural poor population. After running the regression, the interaction term coefficients are consistent with the previous regression results. This result shows once again that rural infrastructure construction can help reduce poverty, especially the irrigation and drainage. Overall, the rural transportation infrastructure has no obvious effect.

Table 7 Result of changing the dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)
	ln_poverty_num	ln_poverty_num	ln_poverty_num	ln_poverty_num	ln_poverty_num	ln_poverty_num
du×t2010	-0.354^{***}	-0.168^{***}				
	(-4.86)	(-2.92)				
ln_Irrigation×t2010			-0.0309	-0.0579^{*}		
			(-0.63)	(-1.89)		
ln_Road×t2010					0.0189	0.0119
					(1.03)	(0.94)
Control for Year			YES	YES	YES	YES
Control for Province			YES	YES	YES	YES

Control Variables				YES		YES
constant	1.527***	-3.353	1.515***	-6.417	1.483***	-15.27**
	(62.85)	(-0.29)	(9.00)	(-0.60)	(18.41)	(-2.57)
Observations	399	392	399	392	311	311
R-squared	0.6887	0.7559	0.6569	0.7532	0.7601	0.8589

Note:t statistics in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

Ⅴ.3. Test of mechanisms

From the above regressions, we can see that irrigation and drainage infrastructure can promote poverty reduction, but their poverty reduction mechanisms need to be verified. Although rural transportation infrastructure has no significant impact on poverty, it remains to be seen whether it has a "masking effect" on poverty. Using the mediating effect test model proposed by Preacher and Hayes (2008) and Wen and Ye (2014), this section explores the internal influence mechanisms of the two types of rural infrastructure on poverty. The results are shown in Table 8.

In Table 8, Columns (1) - (3) examine the poverty reduction mechanisms behind irrigation and water conservancy infrastructure. As discussed in the theoretical analysis, irrigation and drainage infrastructure can not only directly reduce poverty but also indirectly reduce poverty by promoting the growth of agriculture, forestry, animal husbandry and fisheries. Therefore, the growth of agriculture, forestry, animal husbandry and fisheries is selected as the intermediate variable for irrigation and water conservancy infrastructure. The mediating effect test procedure is shown in Figure 1. As shown in Column (1) of Table 8, the construction of irrigation and drainage infrastructure has a significant negative impact on poverty, so we continue to carry out the intermediary effect test. In Column (2), the coefficient on irrigation and drainage infrastructure, which estimates the infrastructure's effect on the intermediary variable of rural economic growth, is not significant. In Column (3), the coefficient on irrigation and drainage infrastructure is significantly negative, while that on the growth of agriculture, forestry, animal husbandry and fisheries is significantly positive. Therefore, further bootstrap tests are needed, and the results are shown in Table 9. The coefficients on both the direct and indirect effects of irrigation and drainage infrastructure are negative. However, the confidence interval for the indirect effect after correction is [-.0016786, .001194]. The value 0 is included in the interval, indicating that the indirect effect is not significant. The confidence interval for the direct effect after correction is [-.0300072, -.0099262], which excludes 0. This means that the direct effect is significant. Therefore, H1a is proved, and there is on evidence to support H1b. Irrigation and drainage infrastructure can directly reduce poverty, but its indirect effect on poverty reduction is not clear.

In Table 8, Columns (4) - (6) are used to test the impact of rural transportation infrastructure on poverty. According to the regression results in Table 4, the overall impact of rural transportation infrastructure on poverty is not significant. However, how rural transportation infrastructure influences poverty has not been confirmed. Therefore, this section tests whether the transportation infrastructure has both indirect and direct impacts on poverty that create a masking effect. Due to the convenience brought by rural transportation infrastructure, on the one hand, the loss of the rural population leads to the hollowing out of rural areas and aggravates poverty. At the same time, the rural population mostly flows to the labor-intensive tertiary industry in cities and towns. This situation will lead to increases in wages and remittances to rural areas, reducing poverty. Therefore, this section selects the growth of the tertiary industry as the intermediary variable explaining how rural transportation infrastructure affects poverty. The results are shown in Table 8.

The coefficient on rural transportation infrastructure in Column (4) is not significant. According to Figure 1, the impact of rural infrastructure on poverty may be masked. In Column (5), the coefficient on rural transportation infrastructure, which estimates its effect on the tertiary industry, is significantly positive. In Column (6), the impact coefficient of the growth of the tertiary industry on rural poverty is significantly negative, and the impact of rural transportation infrastructure on rural poverty is significantly positive. This finding indicates that rural transportation infrastructure directly leads to rural hollowing out and aggravates rural poverty. In addition, rural transportation infrastructure promotes the growth of the tertiary industry, therefore indirectly promoting rural poverty reduction. Accordingly, the positive and negative effects offset each other, resulting in these effects being masked overall. Table 9 displays the bootstrapping test results for rural transportation infrastructure. The results show that the corrected direct effect is significantly positive at the 95% level. The indirect effect is significantly negative at the 95% level. This result further indicates that rural transportation infrastructure may not only directly aggravate poverty but also reduce poverty by promoting the growth of the tertiary industry. Therefore, H2a and H2b are proved.

Table 8 Result of mediating effect

	Irrigation and drainage infrastructure			Rural transportation infrastructure		
	(1)	(2)	(3)	(4)	(5)	(6)
	Poverty_rate	Ln_Primary industry	Poverty_rate	Poverty_rate	ln_Tertiary industry	Poverty_rate
ln_Irrigation×t2010	-0.0177^{***}	-0.0061	-0.0171^{***}			
	(-5.45)	(-0.87)	(-5.37)			
ln_Primary industry			0.0927^{***}			
			(3.84)			
ln_Road×t2010				0.0023	0.0142^{***}	0.0056^{**}
				(0.96)	(3.77)	(2.40)
ln_Tertiary industry						-0.2309^{***}
						(-6.13)
Control for Year	YES	YES	YES	YES	YES	YES

Control for Province	YES	YES	YES	YES	YES	YES
Control Variables	YES	YES	YES	YES	YES	YES
constant	1.128**	1.89***	0.9534*	-0.495	-9.265***	-2.635***
	(2.12)	(1.61)	(1.82)	(-0.69)	(-8.32)	(-3.48)
Observations	400	400	400	311	311	311
R-squared	0.8690	0.9980	0.8724	0.8840	0.9994	0.8989

Note:t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9 Result for bootstrapping.

		Observed Coef.	Bias	Bootstrap Std. Err.	Normal-based [95% Conf. Interval]
ln_Irrigation×t2010	Indirect effect	-.00057362	-.0001354	.00082755	[-.0021794, .0010257] (P) [-.0016786, .001194] (BC)
	Direct effect	-.0171468	.0004506	.00400739	[-.0248126, -.009654] (P) [-.0300072,.-.0099262] (BC)
ln_Road×t2010	Indirect effect	-0.0032976	0.0000615	0.00103574	[.0053486, .0013547] (P) [.0056422,.0015639] (BC)
	Direct effect	-6.71096	0.0003991	0.00227134	[.0015815, 0.0104943] (P) [.0003989, .0098849] (BC)

(P) percentile confidence interval; (BC) bias-corrected confidence interval

VI. Conclusions and suggestions

Along with provincial panel data on China from 2002 to 2017, this paper uses a basic DID model to examine how investment policy on rural infrastructure influences poverty in rural China. Then a continuous DID model is used to investigate how two of the most important rural infrastructures, irrigation and drainage infrastructure and rural transportation infrastructure, influence rural poverty in China. Instrumental variable estimation and a change in the independent variable are used to enhance the robustness of the results. In addition, the mediating effect model is used to investigate the influence mechanisms of irrigation and drainage infrastructure and rural transportation infrastructure on rural poverty in China. The final conclusions are as follows: First, irrigation and drainage infrastructure can effectively reduce rural poverty in China, and rural transportation infrastructure has no clear impact on poverty on the whole. Second, irrigation and drainage infrastructure can reduce poverty directly, and no evidence of indirect influence mechanisms has been found. Third, for rural transportation infrastructure, it can directly aggravates rural poverty in China on the one hand. On the other hand, it can promote economic growth by driving the development of the tertiary industry and indirectly promotes poverty reduction in rural China through the trickle-down effects of economic growth. However, the two effects offset each other, and rural transportation infrastructure has no obvious impact on poverty overall.

Under the background of achieving the Sustainable Development Goals and realizing the aim of no poverty, this paper have clear policy significance for the global government on how to further strengthen the current poverty reduction effects of various rural infrastructure, consolidate the existing achievements in poverty alleviation and prevent poverty levels from increasing. In the context of urbanization, developing countries, represented by China, mostly focus on rural transportation to achieve poverty reduction. However, this paper finds that although rural transportation infrastructure can promote economic growth and achieve poverty reduction, it can also promote the decline of rural areas, and the poorest people are abandoned in rural areas. Moreover, the lack of irrigation and drainage infrastructure has a significant direct effect on poverty. In addition, under the background that COVID-19 may exist for a long time around the world, some migrant workers have chosen to return to their hometown to engage in agricultural production and entrepreneurship and . even participate in the industrialization of agriculture. In this situation, the government is required to pay more attention to the construction of irrigation and drainage infrastructures which is of great importance to people's livelihood in rural areas. In addition, the government needs to increase financial input to poor rural communities to consolidate the achievements in poverty alleviation. Second, the reason why rural transportation infrastructure may aggravate poverty is that it can accelerate the outflow of the rural population. This means that although such infrastructure can promote urbanization, it may lead to rural hollowing out. However, urbanization is an inevitable trend in economic development worldwide. The government should, in combination with this trend, reposition rural functions, support local development projects with comparative advantages, and provide equal public services for the poorest rural populations.

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